FINAL REPORT

REGIONAL STORMWATER MANAGEMENT PLAN

County of Fairfax
Department of Public Works

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CAMP DRESSER & McKEE
Annandale, Virginia

CDM
environmental engineers, scientists
planners, and management consultants

FINAL REPORT

REGIONAL STORMWATER MANAGEMENT PLAN

Prepared for

County of Fairfax
Department of Public Works
Fairfax, Virginia

Prepared by

Camp Dresser & McKee
7535 Little River Turnpike
Suite 200
Annandale, Virginia

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EXECUTIVE SUMMARY

The Regional Stormwater Management Plan consists of a regional detention basin network which will provide water quality and erosion/flood control benefits. The total county cost considering both capital costs and maintenance costs would be less than the projected County maintenance cost of on-site detention systems to serve the same area.

A study area of 122 square miles in the rapidly developing areas of the County was chosen for regional consideration. This study area includes portions of the following seven watersheds: Cub Run, Little Rocky Run, Difficult Run, Horsepen Creek, Sugarland Run, Pohick Creek (upstream of Burke Lake) and Long Branch (tributary to Accotink Creek). The facilities plan consists of a network of 134 detention basins that will directly control 35 square miles of drainage area. Of these regional basins, 32 are proposed to have permanent pools (wet basins) and the remaining 102 are proposed to be "extended-dry" basins.

The recommended regional detention basin network for the plan was delineated through a multi-step planning process. Initially, the criteria for the location and design of regional facilities were developed and approved by the County. Peak flow reduction benefits were analyzed immediately downstream from the regional detention basin site and at critical locations in each watershed. Because of various siting constraints, particularly existing or committed development that precluded the establishment of a regional detention facility, portions of each watershed could not be served by the plan. In order to compensate for areas which could not be served by the regional detention basin network, investigations were performed to develop detention basin designs which could release less than the predevelopment peak flows. Where adequate storage was available at a particular site, these "maximum efficiency" detention basins were sized to achieve a peak release rate set as low as 33 percent of the predevelopment peak flow. Where storage was limited, "conventional" detention basins were sized to achieve a peak release rate set at the predevelopment peak flow.

In addition to evaluating the benefits of maximum efficiency detention basins, detention basin releases and downstream hydrograph timing were analyzed to determine the watershed areas of greatest impact from upstream groups or clusters of regional detention basins. For those areas within the watershed which could not be controlled by regional detention basins due to siting constraints, the need for on-site detention was also evaluated.

The plan also considered the feasibility of designing the regional detention basins to serve as "best management practices" (BMP's) for water quality improvement. Because wet detention basins achieve greater pollutant removal efficiencies than extended dry detention basins, wet detention basins were the preferred BMP for the Occoquan Basin which drains into the Occoquan Reservoir water supply. Conformance with the County's nonpoint pollution loading goals for the Occoquan Basin were achieved for the two Occoquan watershed study areas: Cub Run and Little Rocky Run. Extended dry detention basins were considered for the remaining watersheds.

In addition to the recommendations for the water quality improvement, stream bank erosion control and flood protection; financing mechanisms to implement the Regional Stormwater Management Plan were investigated. The plan recommends County funding for implementation be obtained through a combination of General Funds, future Storm Bond Funds, Pro-Rata Share contributions, developer participation and possible future establishment of a storm water utility to generate funds for design, construction and maintenance.

1.0 INTRODUCTION

1.1 PURPOSE AND SCOPE

The purpose of this study is to enhance the efficiency and cost-effectiveness of stormwater management in Fairfax County through the development of a Regional Stormwater Management Plan. As an initial step to achieve this goal, it was considered desirable that regional stormwater detention facilities be implemented in selected areas of the County undergoing rapid development. There were seven watersheds selected for the Regional Plan, with a total area of 122 sq mi:

- Cub Run
- Little Rocky Run
- Difficult Run
- Horsepen Creek
- Sugarland Run
- Pohick Creek (drainage area above Burke Lake)
- Long Branch (tributary to Accotink Creek)

Figure 1-1 presents a map of the seven watershed boundaries and the shaded study area within each watershed.

The concept of regional stormwater management has previously been pursued by the County on a limited basis and, in some cases, was achieved through developer cooperation, rezoning proffers, and joint County/developer projects. To improve this process, it was necessary to develop an overall plan that identified the most appropriate locations for regional detention facilities and provided information on the size and function of the regional detention facilities. In addition to "peak-shaving benefits" (i.e., flood protection and stream bank erosion control), the plan also considered the feasibility of designing the regional detention basins to serve as "best management practices" (BMP's) for water quality control.

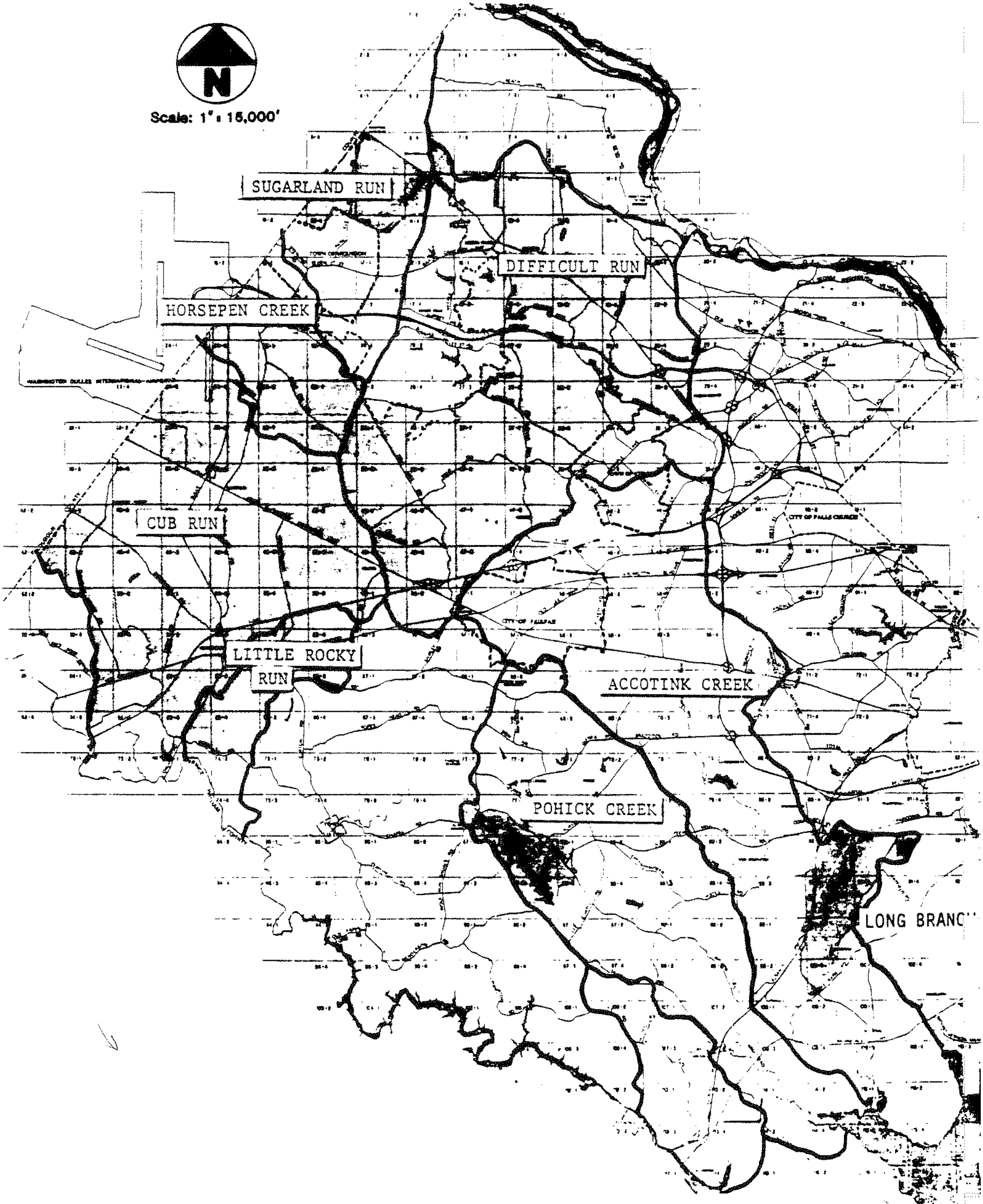


Figure 1-1. Study Area for Regional Stormwater Management

This was initiated due to the continual local, State, and Federal movement toward requiring the improvement of urban runoff water quality as evidenced by the Chesapeake Bay Program, annual recommendations made by the County's Environmental Quality Assurance Committee (EQAC) and the upcoming expansion of the National Pollution Discharge Elimination System (NPDES) permit program by USEPA to include permits for urban storm sewer discharge points. In addition, BMP's are an important component of the County's overall water quality management program for the Occoquan Basin which drains into the Occoquan Reservoir water supply.

The recommended regional detention basin network for the County Stormwater Management Plan was delineated through a multi-step planning process. Initially, the criteria for the location and design of regional facilities were developed by CDM and approved by the County. Candidate sites for regional detention basins were then determined based on the land availability, topography and available storage. A storage capacity check (required storage vs. available storage) was performed for each candidate site through a simplified screening approach which determined management objectives (e.g. water quality protection, streambank erosion control and flood protection) which could be achieved at the site.

Two types of detention basins were evaluated for water quality control. They included wet detention basins and extended dry detention basins. Because wet detention basins have a permanent pool, they require more storage than extended dry detention basins in which the stored runoff waters are released over an extended period of time. The detention storage requirements for each type of basin are based on the percent imperviousness of the upstream land use. Because they achieve greater pollutant removal effectiveness than extended dry detention basins, wet detention basins were the preferred BMP for the critical Occoquan watershed. Extended dry detention basins were considered for the remaining watersheds.

In addition to BMP design criteria, the regional detention basins were also designed to meet existing County performance standards for post-development erosion control and flood control. Erosion control criteria were considered for detention basins which could protect against the 2-year frequency storm, that is the peak flow released from the detention basin for future land use conditions is equal to or less than the predevelopment peak flow at the site. Flood protection for a 10-year frequency storm was also considered, with the performance standard involving the restriction of the peak flow for future land use conditions to the 10-year predevelopment peak flow at the site. Assuming that sufficient storage capacity was available, the regional detention basin was sized to achieve both the 2-year and 10-year performance standards in addition to the BMP requirement. If available storage was insufficient for 10-year control, the regional detention facility was sized to achieve the erosion control (2-year) performance standard.

Hydrologic and hydraulic computer models were used to route the design storms (2-year and 10-year) through the selected detention basins and throughout the stream channels of the study area watersheds. Peak flow reduction benefits were analyzed immediately downstream from the regional detention basin site and at critical locations in each watershed. Because of various siting constraints, particularly existing or committed development that precluded the establishment of a regional detention facility, portions of each watershed could not be served by regional detention basins. In order to compensate for areas which could not be served by the regional detention basin network, investigations were performed to develop detention basin designs which could release less than the predevelopment peak flows. Where adequate storage was available at a particular site, these "maximum efficiency" detention basins were sized to achieve a peak release rate set as low as of 33 percent of the predevelopment peak flow. Where storage was limited, "conventional" detention basins were sized to achieve a peak release rate set at the predevelopment peak flow. (i.e., as much as three times the "maximum efficiency" release rate.)

In addition to evaluating the benefits of maximum efficiency detention basins, detention basin releases and downstream hydrograph timing were analyzed to determine the watershed areas of greatest impact from upstream groups or clusters of regional detention basins. For those areas within the watershed which could not be controlled by regional detention basins due to siting constraints, the need for onsite detention was evaluated.

Water quality benefits of regional detention basins were evaluated in terms of the reductions in annual nonpoint source pollution loads from the watersheds. Conformance with the County's nonpoint source pollution loading goals for the Occoquan Basin were evaluated for the two Occoquan watershed study areas: Cub Run and Little Rocky Run.

The Regional Stormwater Management Plan consists of a recommended regional detention basin network which will provide water quality and erosion/flood control benefits for the seven watershed study areas at a total cost which is less than the total cost of onsite detention systems to serve the same area. Stormwater management planning is an ongoing process and, in order to meet the County's needs, working maps, screening evaluation information for detention basin sites and initial storage check analyses have been provided to the County for their continual use. Other deliverables produced by this project include the transfer of the hydrologic and hydraulic models to the County's computer system and training in model applications for County staff.

1.2 BACKGROUND: BENEFITS OF REGIONAL PLANNING

Regional stormwater detention basin systems for each of the seven watershed study areas were developed as a cost-effective approach to stormwater management. Regional detention systems offer benefits which are equal to or greater than onsite control benefits at a lower cost. Most of the advantages of the regional planning approach over the onsite approach can be attributed to the need for fewer structural facilities which are strategically located within the watershed. The specific advantages of the regional planning approach are summarized below.

- Reduction in capital costs for structural runoff controls: The use of a single stormwater detention facility to control runoff from 10 to 20 development sites within a 100-300 acre subwatershed permits the local government to take advantage of economies-of-scale in designing and constructing the watershedwide facility. In other words, the total capital cost (e.g., construction, land acquisition, engineering design) of several small onsite detention basins is greater than the cost of a single detention basin which provides the same total storage volume.

- <u>Reduction in maintenance costs</u>: Since there are fewer stormwater detention facilities to maintain, the annual cost of maintenance programs are significantly lower. Moreover, since the regional detention facility recommended in the master plan can be designed to facilitate maintenance activities, annual maintenance costs are further reduced in comparison with onsite facilities. Examples of design features that are typically only feasible at regional master plan facilities to reduce maintenance costs include: access roads that facilitate the movement of equipment and work crews onto the site (by comparison, detention facilities implemented under the onsite approach are often located in residential backyards); additional storage capacity to permit an increase in the time interval between facility clean-out operations; and onsite containment areas for sediment and debris removed during clean-out. Regional detention basins provide opportunities for higher levels of maintenance. Since fewer basins require maintenance, more time can be expended at each facility for such items as grass mowing, fertilization and debris removal.

- <u>Greatest downstream benefits</u>: The regional master plan results in a relatively small number of strategically located detention facilities which offer the greatest downstream benefits. Thus, the risks of adverse downstream impacts due to the combined effects of randomly located detention facilities can be minimized.

- <u>Opportunities to manage existing stormwater problems</u>: Stormwater flows from existing developed areas can be affordably controlled at the same regional facilities which are sited to control future urban development. This is because the provision of additional storage capacity to control runoff from existing development in the facility's drainage area should be relatively inexpensive due to economies-of-scale. By comparison, the costs of retrofitting existing development sites with onsite detention measures to control existing stormwater problems would probably be prohibitively expensive.

- Acceptance among land developers: Land developers recognize that economies-of-scale available at a single regional detention facility should produce lower capital costs in comparison with several onsite detention facilities. They also tend to prefer the regional plan approach because it eliminates the need to set aside acreage for an onsite detention facility.

- Benefits to homeowners: Properly planned and located regional detention basins will provide safe and aesthetically pleasing detention facilities. Regional basins will also remove the burden of maintaining many smaller detention basins by the homeowners associations.

1.3 CONTENTS OF REPORT

Section 2.0 presents the criteria used to locate and size regional detention basins in the area watersheds. Locational criteria include: upstream drainage areas, topography, soils, sensitive environmental areas, property access, adjoining land use, and land development level. Sizing criteria include: type of facility, design storms, performance standards, storage requirements, and dimensions.

Section 3.0 summarizes the procedures for initial and final screening of regional detention basin sites. The characteristics of the regional detention basins recommended for each of the seven watersheds are also summarized. A total of 134 regional detention basins are recommended in this plan.

Section 4.0 describes the hydrologic and hydraulic models used to evaluate the watershedwide benefits of the regional detention basin network.

Section 5.0 summarizes the benefits of the regional detention basin system, including projected reductions in peak flow (localized and areawide) and water quality benefits.

Section 6.0 summarizes the recommended regional plan. Recommended regional detention basins are prioritized, and suggested guidelines for onsite detention are presented.

2.0 CRITERIA FOR LOCATION AND DESIGN OF REGIONAL FACILITIES

The first task of this study was to develop criteria for siting and sizing regional detention basins within Fairfax County. The intent was not to present detailed design specifications but to develop procedures and guidelines for laying out a cost-effective regional detention basin system in seven major watersheds within the County. The regional detention basin system should minimize environmental and land use conflicts while providing sufficient detention storage at the most desirable watershed locations for downstream protection. To achieve these objectives, several tasks were performed.

The first task involved a review of information compiled by County staff and literature from other sources which present criteria on the location and design of regional stormwater detention facilities. Data sources included:

- County policies as specified in the Public Facilities Manual (Fairfax County, VA, 1985) and the Draft Design Report for Designing BMP Facilities developed by the Department of Environmental Management (Fairfax County, VA, 1980);

- Criteria of other federal, state, and municipal agencies; and

- Studies presented in technical journals and the general literature documenting regional approaches to stormwater management.

The second task involved finalizing and adopting specific criteria for this study. The third task involved a trial application of the recommended locational and design criteria to a selected study area.

The following section presents the criteria for the location and design of the regional stormwater detention basins. The literature review and trial application are presented in Appendix A, (bound separately) which represents the interim report was previously submitted to the County and approved for the criteria task.

2.1 GENERAL GUIDELINES

The following guidelines should be considered in determining the location and formulating the design of a regional stormwater detention facility:

1. Selections of BMP's should reflect the water quality management needs of each watershed, with the most effective BMP's (wet detention basin) to be used in the areas with the most critical water quality problems.

2. Environmental constraints and other site compatibility issues should be considered in siting and sizing.

3. Locations and facility sizes which minimize State and federal permitting requirements should receive top priority, although sites requiring permits should still be considered.

4. Maximize the use of natural topography in order to minimize facility costs.

5. Supplemental control measures may be required to protect areas upstream of a regional detention basin site (e.g., onsite detention for highly impervious land uses such as commercial, office, or industrial development).

The criteria are subdivided into two major categories: locational and design factors. In each category, the criteria are listed in bullet format for ease of reference.

2.2 LOCATIONAL CRITERIA

2.2.1 UPSTREAM DRAINAGE AREAS

- Ideally 100 to 300 acres

- Smaller drainage areas (less than 100 acres) may be considered on a case-by-case basis for highly impervious areas

- Larger drainage areas (greater than 300 acres) may be considered for certain situations where further upstream sites are not feasible or to take advantage of other particularly good locations

2.2.2 TOPOGRAPHY

- Conform to existing topography where possible

- Minimize required dam length

- Avoid excavation where feasible (excavation may be required in some cases to achieve the required permanent pool storage for wet detention basins)

2.2.3 SOILS

- Avoid soils which are structurally prohibitive (e.g., "shrink-swell" clays)

2.2.4 NONTIDAL WETLANDS AND CRITICAL ENVIRONMENTAL AREAS

- Avoid these areas where feasible

- Minimize intrusion of stormwater management facilities in County Environmental Quality Corridor (EQC) systems

- o Minimize impacts on high priority wetlands identified by Fairfax County

- o Minimize area of wetlands disturbance where it is not feasible to avoid them entirely

  - Assign highest priority to detention basin locations which impact no more than 10 acres of wetlands, preferably less than 1 acre (i.e., 404 Nationwide permit)

  - Assign lowest priority to detention basin locations which impact more than 10 acres of wetlands

- o Emphasize the use of dry detention basins where wetlands impacts would otherwise be significant

2.2.5 PROPERTY ACCESS

- o Minimize easement area

- o Ensure that sufficient area is available for maintenance vehicle access roads: 10 ft minimum width

- o Slope for access road: less than 10% preferred, 15% maximum

- o Minimum easement width: 15 ft

2.2.6 ADJOINING LAND USE

- o Buffer zone to minimize encroachment: consider on a case-by-case basis

  - Property impacts: 100-year high water for detention basins should not inundate lots of 1 acre or less

  - Utilities: avoid encroachment on major utilities

- Roads: the use of State road embankments as detention basin dams is discouraged where future county maintenance will be required

- Historical/archaeological areas: solicit review of regional detention basin site map by the Environmental and Cultural Heritage Resources Branch of Fairfax County Office of Comprehensive Planning (OCP)

2.2.7 LAND DEVELOPMENT LEVEL

- Priority systems for required detention basin locations:

  - Future vs. existing development

    #1 Priority: Facilities which serve proposed development

    #2 Priority: Retrofit of existing development

- Special policies for regional detention

  - Drainage area of regional detention basin should exhibit sufficient ultimate urban development to justify structural stormwater controls: address on a case-by-case basis

  - Regional detention basins may not be required to serve drainage areas that are covered primarily by single family residential development with lot sizes of 5-acre or greater

2.2.8 LOCATIONAL DIFFERENCES IN DETENTION BASIN EFFECTIVENESS

- o Consider general guidelines for locational differences in effectiveness when screening alternative regional detention basin sites: base guidelines on watershed modeling studies

- o Consider available information on the locations of key problem areas in siting regional detention basins (e.g., undersized stream crossings, floodprone areas, eroded or erodable areas)

2.2.9 SPECIAL CONSIDERATIONS

- o Require trickle channels for dry detention basins

- o Require clearing of standing timber that will be subject to water damage following site specific review by County Arborist (for determination of non-hydric species)

2.3 DESIGN CRITERIA

2.3.1 TYPE OF FACILITY

The following order of preference for a particular type of detention facility is recommended:

Drainage Basins with Critical Receiving Waters	Other Drainage Basins
1. Wet detention + 2-yr erosion control + 10-yr flood control	1. Extended dry detention + 2-yr erosion control + 10-yr flood control
2. Wet detention + 2-yr erosion control	2. Extended dry detention + 2-yr erosion control
3. Extended dry detention + 2-yr erosion control	

The principal drainage basin with critical receiving waters (from a water quality management standpoint) is the Occoquan Basin. These areas merit more stringent water quality controls (i.e., wet detention basins) than other drainage basins in the County.

2.3.2 DESIGN STORMS (LEVEL OF PROTECTION)

- Erosion control: 2-year storm
- Flood protection: 10-year storm
- Emergency spillway design:
  - Less than 25 acre-ft of storage and less than 15-ft dam height: 100-yr storm
  - Between 25 and 35 acre-ft of storage and between 15 and 20 ft dam height: 1.5 x 100-yr storm
  - Between 35 and 50 acre-ft of storage and between 20 and 25 ft dam height: 2 x 100-yr storm up to 2.5 x 100-yr storm
  - Greater than 50 acre-ft of storage or greater than 25 ft dam height: 2.5 x 100-yr storm up to 5.0 x 100-yr storm (based on State Water Control Board regulations)
- Water Quality Management
  - Extended dry detention basin: Public Facilities Manual design curve (see Figure 2-1)
  - Wet detention basin: 2-week average hydraulic residence time for permanent pool (see Table 2-1)

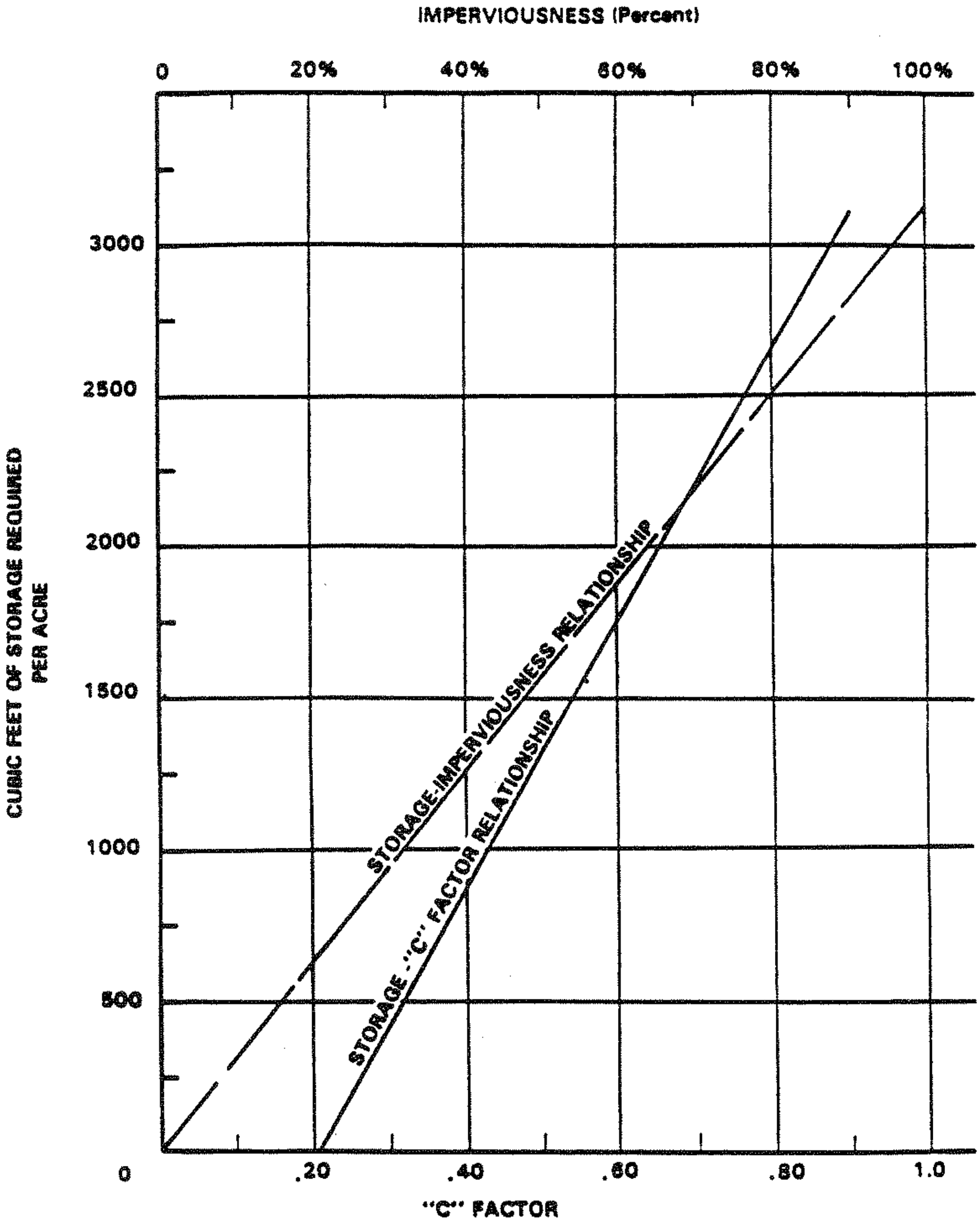


FIGURE 2-1. Extended Detention Storage Requirements

Source: Public Facilities Manual

TABLE 2-1

COMPARISON OF DETENTION STORAGE REQUIREMENTS:
PERMANENT POOL OF WET DETENTION BASIN
VS. EXTENDED DRY DETENTION

Land Use	% Impervious	Wet Detention[a] (in)	Extended Detention[a] (Dry) (in)
Forest/Undeveloped	0%	0.5	0.0
Low Density Single Family[b]	20%	0.7	0.1
Medium Density Single Family[c]	35%	0.8	0.2
Multi-family Residential	50%	1.0	0.4
Industrial/Office	70%	1.2	0.5
Commercial	80% - 90%[d]	1.3	0.8

[a] Storage capacity is in units of "inches per acre of drainage area".

[b] Percent imperviousness which is directly connected to a drainageway is assumed to be 12%.

[c] Percent imperviousness which is directly connected to a drainageway is assumed to be 25%.

[d] For drainage areas where the majority of the land area is covered with commercial development, an imperviousness of 80% is assumed. An imperviousness of 90% is assumed for all other situations.

2.3.3 PERFORMANCE STANDARDS (TO ASSESS WATERSHEDWIDE PROTECTION)

- o Stream crossings:
  - Primary roads: 25-year storm
  - Secondary roads: 10-year storm
- o Streambank erosion: 2-year storm
  - Minimize the increase in peak flow beyond predeveloped conditions
  - Maintain permissible maximum velocity for channel lining
- o Structures: 100-year protection
  - No more than a 0.2 ft increase in 100-year flood as a result of the regional detention system
- o Occoquan Basin Plan: Provide sufficient coverage of BMP's in the County's portion of the Occoquan Basin to maintain annual total phosphorus loadings from future development at the 1980 existing/commmitted loading levels (25,100 lbs/year of total P) specified as a water quality goal in the County's 1982 Occoquan Basin Study and as found in the Comprehensive Plan.

2.3.4 STORAGE REQUIREMENTS

A. Peak Flow Control (Erosion and Flood Control)

- o Initially base "storage-release rate" combinations on predevelopment peak discharge releases for appropriate design storm (i.e., 2-year and/or 10-year) at site. It may be necessary to reduce the initial detention basin release rates (i.e., increase required storage) to achieve watershedwide performance standards.

B. Water Quality Management

- Storage requirements for wet detention and extended dry detention basins are given in Table 2-1 for six land use categories

C. Land Use Assumption for Facility Drainage Area

- Postdevelopment land use assumptions for storage calculations:

  - Compare zoning map and comprehensive plan for the facility drainage area: select most intensive land use

  - Postdevelopment land use should be based on total potential amount of urban development in the facility drainage area (i.e., rather than on the incremental new development alone): this is a conservative approach which will maximize the benefits of the regional detention basin

- Predevelopment land use assumptions for storage calculations:

  - Assume predevelopment land use is 100% undeveloped (wooded) even if there is some existing urban development in the facility drainage area: this is a conservative approach which will maximize the benefits of the regional detention basin

- o Land uses designated as "mixed use" in the County Comprehensive Plan will be further defined by the County (e.g., percent imperviousness) on a case-by-case basis

D. Effectiveness of Existing Upstream Detention Basins

- o Ignore any existing onsite detention basins located upstream of the regional detention basin site (except for major "regional-type" detention basins located on individual development sites): this is a conservative approach which will maximize the benefits of the regional detention basin

E. Freeboard

- o Accepted engineering criteria will be used to establish freeboard requirements for the regional detention basins

- o For preliminary screening of alternate detention basin sites, a freeboard of 1.0 ft above the design flow depth in the emergency spillway should be acceptable

2.3.5 DIMENSIONS OF REGIONAL DETENTION BASINS

A. Length-Width Ratio

- o Maximize L/W ratios: preferably 2:1 or greater

- o Minimize short-circuiting potential

B. Side Slopes Along Shoreline: preferably 5H:1V or flatter

- o Reduce erosion potential

- o Promote wetland vegetation: this will minimize free-floating algae

- Minimize safety hazards
- Improve aesthetics
- Facilitate maintenance activities

C. Permanent Pool: Wet Detention Basin

- Surface Area: preferably no less than 5 acres (to facilitate maintenance), although basins with surface areas down to about 3 acres will be considered on a case-by-case basis
- Mean Depth (storage volume divided by surface area): 3 to 10 feet
    - Shallow enough to prevent vertical thermal stratification
    - Deep enough to minimize algal blooms
- Maximum Depth: ideally 15 feet, but no greater than 20 feet

3.0 REGIONAL DETENTION BASIN SITE SELECTION

3.1 GENERAL PROCEDURES

The criteria for location of regional detention basins were further developed, as discussed in Section 2.0, and were used to screen candidate sites for the regional detention basins in each of the seven study area watersheds. Two major factors were involved in site selection. The first factor was the general characteristics at the site, such as the topography, land use and any site constraints. The second factor was the actual storage available at the detention site compared to the required storage for the given management objective for water quality and peak flow control.

3.1.1 LOCATION OF CANDIDATE SITES

Sites for regional detention basins were selected based on a review of County maps and reports. Maps included topographic, flood plain, wet land, property ID, zoning, aerials, comprehensive plans and sanitary sewer maps. Reports included the comprehensive land use plan and Master Drainage Plan reports. Candidate sites were located on 1" = 500′ scale contour maps and on 1" = 500′ scale property ID maps as the analysis proceeded. These two working maps were provided to the county. [See submittals No. 1 and No. 2 presented in Section 3.1.4.]

The candidate sites were screened based on the established criteria. Initially the major factors for site location included a site which: controlled 100-300 acres, maximized the available storage, minimized the length of the dam, was located in the undeveloped portion of the watershed, and did not encroach upon existing or future development. Consideration was also given to the size of the detention basin. Detention basins were initially chosen with maximum dam depths less than 25 feet and maximum storage less than 50 ac-ft, thus allowing them to be exempt from the permitting requirements of the State Dam Safety Program. Additional checks were made to prevent detention basins from being located in the floodplain of the main stem and in presently identified wetland areas.

As part of the locational analysis, pending and approved development plans were reviewed with the County's Department of Environmental Management. These plans were used not only to check the location of a regional detention basin in relationship to new development, but also to determine which developments had proposed stormwater detention systems which might be incorporated into the regional detention basin network. This information was applied in detail during the final site screening stages.

Site screening was performed with the aid of information sheets which have been compiled into 3-ring notebooks for each of the seven watersheds. These notebooks were submitted to the County as backup material for use in the County's continuing planning program [see submittal No. 4 presented in Section 3.1.4].

3.1.2 STORAGE CAPACITY CHECK

A storage capacity check was performed to determine if the candidate site was adequate to control the desired water quality and flooding goals for the upstream drainage area under future land use conditions. Based on the best location of the dam for a regional detention basin, the available storage was calculated by developing an elevation-storage relationship for the site. These calculations relied upon the 1" = 200' scale topographic maps which have 5 ft contour intervals.

The required storage was a function of the controlled drainage area and its percent imperviousness, type of detention basin and emergency spillway design storm with freeboard. The types of detention basins considered for this study include, in order of preference, the following:

Occoquan Watershed (Cub Run and Little Rocky Run)	All Other Watersheds
1. Wet detention + 2-yr erosion control + 10-yr flood control	1. Extended dry detention + 2-yr erosion control + 10-yr flood control
2. Wet detention + 2-yr erosion control	2. Extended dry detention + 2-yr erosion control

3. Extended dry detention +
   2-yr erosion control

Two-year erosion control and 10-year flood control means that the detention basin's peak release rates for the future land use flow hydrographs are equal to or less than the predevelopment peak flows at the site for the 2-year and 10-year design storms, respectively.

At each site, the maximum level of protection was checked first to see if the available storage was sufficient for the required storage, if not, then the next level of protection was tested. For example, if an extended dry detention basin which achieved both 2- and 10-year protection could not fit at a particular site, then an extended dry detention basin with 2-year protection only was evaluated. The amount of storage required for wet detention, extended dry detention, and 2-year and 10-year peak flow protection was determined from the drainage area to the site and the percent imperviousness based on future land use.

The evaluation of required storage not only included the storage for the types of detention basins as described above, but also included the storage required for the passage of the emergency spillway design storm. The design storm, as given in the Fairfax County Public Facilities Manual, is a function of the storage and height of the dam. Larger detention basins are required to have an emergency spillway which will pass larger storms. The design storms are multiples of the 100-year storm. Storage is also required to provide a one-foot freeboard between the pool elevation of the emergency spillway design storm to the top of dam elevation.

In order to facilitate the storage checks for some 200 sites (initially) an inhouse computer program which compares required and available storage was applied to determine the type of detention basin that could be located at a given site. The computer program was based on the storage curves reported in the Criteria Report (Appendix A). This program was used to produce an initial evaluation of all candidate sites. Detailed flow routing was performed with the STORMLINK hydrologic model presented in Section 4.0, to determine the final detention basin sizes for the most promising sites.

An example of the analysis provided by the preliminary screening model is shown in Table 3-1. The first block of numbers give the elevation-surface area-storage available at the site. The total drainage area and percent imperviousness are also given. The second block of numbers provides an initial evaluation of the various elevations, surface areas and storages that are associated with the different levels of control. In this example, the pool levels include: water quality permanent pool (which is the water surface elevation of the wet detention pond); 2-year peak shaving pool (which is the maximum elevation the water would reach during a 2-year storm); 10-year peak shaving pool (which is the maximum elevation the water would reach during a 10-year storm and which is also the invert elevation of the emergency spillway); emergency spillway pool (which is the maximum elevation the water would reach during the spillway design storm); and top of dam (which is one foot greater than the emergency spillway pond, providing a foot of freeboard).

The storage check printout for the final network of regional detention basins has been provided to the County. [See Submittal No. 7 in Section 3.1.4.]

3.1.3 FINAL SITE SELECTION

The final selection of detention basin sites was made following a series of meetings and other communications with County staff. Site selection meetings included County staff from the Department of Public Works, Department of Environmental Management, Office of Comprehensive Planning and County Park Authority. The County played a major role in determining which detention basins should be kept or deleted based on the combined knowledge of the staff participating in the selection. In some instances candidate detention basins were deleted based on the most recent development plans and overall comprehensive planning where rezoning cases were considered. In other cases, proposed detention basins sites were relocated to provide the maximum benefit as suggested by the County staff. In general, detention basin storage was limited to a maximum of 50 ac-ft. However, the County indicated which detention basins they would consider to

TABLE 3-1

EXAMPLE OUTPUT FOR PRELIMINARY SCREENING MODEL

SITE C12

STORAGE-AREA-ELEVATION

Elevation (ft MSL)	Stage (ft)	Area (sq-ft)	Increm. Volume (cu-ft)	Increm. Storage (ac-ft)	Cumul. Storage (ac-ft)	Cuml. Storage (ac-ft/ac)
243.0	0.0	0.	0.	0.0	0.0	0.000
244.0	1.0	3400.	1700.	0.0	0.0	0.001
245.0	2.0	6800.	5100.	0.1	0.2	0.002
247.5	4.5	17600.	30500.	0.7	0.9	0.012
250.0	7.0	28400.	57500.	1.3	2.2	0.032
252.5	9.5	47600.	95000.	2.2	4.4	0.063
255.0	12.0	66800.	143000.	3.3	7.6	0.111
257.5	14.5	95600.	203000.	4.7	12.3	0.178
260.0	17.0	124400.	275000.	6.3	18.6	0.270
262.5	19.5	164800.	361500.	8.3	26.9	0.390
265.0	22.0	205200.	462500.	10.6	37.5	0.544

Location	Elevation (ft MSL)	Stage (ft)	Surface Area (acres)	Storage (acre-ft)
Bottom of Dam	243.0	0.0	0.0	0.0
Permanent Pool	254.2	11.2	1.4	6.6
2-Year Peak Shaving Pool	258.9	15.9	2.6	15.8
10-Year Peak Shaving Pool	260.9	17.9	3.2	21.6
Emergency Spillway Pool (51 ft weir, 2.0 * 100-YR flow)	263.4	20.4	4.1	30.7
Top of Dam	264.4	21.4	4.5	35.0

exceed the 50 ac-ft limit as a special case due to the need for control in a given area of a watershed.

Several recent development projects in the County have recently constructed major stormwater detention basins or have obtained County approval of a stormwater detention plan. These areas were reviewed with the County, and the County indicated which areas they wanted analyzed with the existing or approved detention basins.

Specific regional detention basins in each watershed were selected by the County as top priority sites. For each of these sites a more detailed site location than previously given on the 1" = 500' scale topographic maps was determined. The selected regional detention basins were located on 1" = 200' scale topographic working maps and show the location of the dam, emergency spillway, outfall, riser, trickle ditch, work area and access to dam and upstream area of the detention basin. These working maps were given to the County for use in final design of these facilities (see Submittal No. 3, Section 3.1.4). For these priority sites, a field reconnaissance was performed to obtain more detailed information. A notebook was prepared which includes site visit notes. Table 3-2 is an example of the forms that were filled out for each site. The notebook has also been submitted to the County (see Submittal No. 5, in Section 3.1.4). Photographs were also taken at each site as indicated on the form in Table 3-2. A photographic album of the priority sites was also given to the County (see Submittal No. 6, in Section 3.1.4). A list of the priority sites for each watershed is given in Section 3.2.

3.1.4 WORKING MAPS AND FILES PROVIDED TO THE COUNTY

A considerable amount of information concerning the regional detention basin site selection which was developed as part of this project has been transmitted under separate cover to the County. This information not only serves as back-up for the project but as useful working maps and data forms that can be updated as the County proceeds with final design of the recommended regional detention basins and with supplementary stormwater management plans.

TABLE 3-2

EXAMPLE SITE VISIT FORM FOR
PRIORITY REGIONAL DETENTION BASINS

FAIRFAX COUNTY REGIONAL STORMWATER MANAGEMENT PLAN

SITE VISIT

GENERAL

Date: ____________

Watershed: ____________________ Crew: ____________

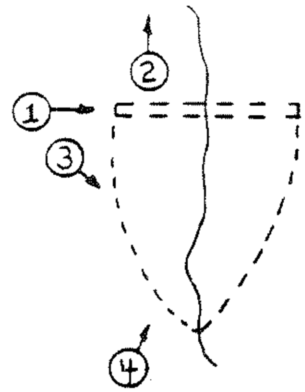
Site ID: ____________________

Location: ______________________________

Road Map ID: __________

Map Grid ID: __________

PHOTOGRAPHS



____ -1. Across Dam Site

____ -2. Downstream From Dam Site

____ -3. Upstream From Dam Site

____ -4. Downstream from Upper Limit of Pond Site

NOTES

o Access (from where through what)

- To Dam Site: ______________________________

- To Limit of Pond Site: ______________________________

o Ground Cover (grass, brush, tree; percent of each)

- At Dam Site: ______________________________

- Pond Site Area: ______________________________

o Downstream Land Use (open space, residential, commercial, stream crossing):

____

o Suitability (X)

- Large open area: _____

- Development adjacent to pond site: _____

- Other: ______________________________

o Comments:

____

____

The following is a list of the data provided to the County:

- Submittal No. 1

  1"=500' five-foot contour topographic maps with regional detention basin locations

- Submittal No. 2

  1"=500' property I.D. maps with regional detention basin locations

- Submittal No. 3

  1"=200' five foot contour topographic maps with detailed plan view of priority regional detention basins

- Submittal No. 4

  Three-ring notebooks for each of the seven watersheds which include: preliminary screening forms, secondary screening forms, DEM screening forms, hydrologic parameter forms, crossing forms and channel forms

- Submittal No. 5

  Three-ring notebook with site visit notes for priority regional detention basins

- Submittal No. 6

  Photographic album for site visit to priority regional detention basins

- o Submittal No. 7

  Computer printout folder with output from initial storage check analysis

- o Submittal No. 8

  1"=200' five-foot contour topographic maps with regional detention basin locations.

3.2 REGIONAL DETENTION BASIN SYSTEM FOR EACH WATERSHED

The regional detention basin site selections and storage checks provided the maximum areal coverage possible in each watershed for a regional detention basin system. The final regional detention basin network recommended for each of the seven watersheds are summarized below.

Summary tables 3-3 through 3-9 present the following information for each regional detention basin: basin identification number, basin type, County map grid number, top of dam storage, drainage area, percent imperviousness and future land use. The basin type refers to the level of water quality and erosion/flood control provided by the detention basin. "WET" refers to a wet detention basin with a permanent pool and "EXTDRY" refers to an extended dry detention basin. For basins that provide 2-year erosion control and 10-year flood control, the "WET" or "EXTDRY" is followed by a "10." For basins that only provide for 2-year erosion control, a "2" is indicated in the basin type abbreviation. The top of dam storage given in the summary tables 3-3 through 3-9 represents the storage for the maximum efficiency detention basins. The development and analysis of the maximum efficiency detention basins will be summarized in detail in Sections 4.0 and 5.0.

For each proposed regional detention basin, comprehensive 2-page tables which describe the characteristics of the site were developed and are included in Appendix B (bound separately). These tables include a description of detention basin location, future land use, elevation-surface area-storage relationshps, elevation storage requirements, embankment characteristics and comments concerning property ownership, maintenance easement and nearby utilities.

Summarized below are the characteristics of the regional detention basin network for each watershed. A total of 134 regional detention basins are recommended in this plan, including 32 wet detention basins in the Occoquan Watershed and 102 extended dry detention basins.

3.2.1 CUB RUN

The 31 recommended regional detention basins for the Cub Run watershed are listed in Table 3-3. For Cub Run, wet detention basins are preferred over extended dry detention basins in order to provide greater water quality benefits within the Occoquan Reservoir Watershed. Based on the available storage at the selected sites, the regional detention basin network includes 21 wet detention basins 12 of which provide control for both the 2- and 10-year storms and 9 of which provided control for only the 2-year storm. There are 10 extended dry basin sites which could not support wet basins. The extended dry detention basins provide control for the 2-year storm.

Within Cub Run watershed, the County selected three regional detention basins which can exceed the maximum 50 ac-ft total storage originally set for all the detention basins. These facilities include C-18 with a storage of 104.1 ac-ft for a drainage area of 442 areas, C-19 with a storage of 53.7 ac-ft for a drainage area of 226 acres, and C-37 with a storage of 85.8 ac-ft for a drainage area of 438 acres.

The regional detention basin locations within the Cub Run watershed are shown in Figure 3-1. The general locations are shown with the detention basin number presented within a diamond. Of these 31 basins, the County has identified the following 10 basins for the priority list: C-5, C-19, C-20, C-22, C-28, C-35, C-37, C-49, C-54 and C-57. Additional information on the priority detention basins concerning site location, and field visit notes and photographs were provided to the County as discussed in Section

TABLE 3-3

CUB RUN
SUMMARY OF REGIONAL DETENTION BASIN SITES

BASIN ID	BASIN TYPE	MAP GRID #	TOP OF DAM STORAGE Max-Efficiency (ac-ft)	DRAINAGE AREA (ac)	% IMP	FUTURE LAND USE: FOREST (ac)	FOREST (%)	LLSF (ac)	LLSF (%)	LDSF (ac)	LDSF (%)	MDSF (ac)	MDSF (%)	INSTIT (ac)	INSTIT (%)	HD RESID (ac)	HD RESID (%)	IND/OFF (ac)	IND/OFF (%)	COMM<50% (ac)	COMM<50% (%)	COMM>50% (ac)	COMM>50% (%)
C03	EXTDRY-2	54-3	27.1	133.3	68.2%		0%		0%	21.2	16%	0.6	0%	2	2%		0%	1.6	1%		0%	107.9	81%
C04	WET-10	65-1	24.3	97	11.9%		0%	2	2%	95	98%		0%		0%		0%		0%		0%		0%
C05	WET-10	65-3	47.6	165	13.3%		0%		0%	150	91%	14	8%		0%	1	1%		0%		0%		0%
C11	WET-2	44-3	29.5	90	68.5%		0%		0%		0%	3	3%		0%	0	0%	87	97%		0%		0%
C12	WET-10	44-1	35.4	69	70.0%		0%		0%		0%		0%		0%		0%	69	100%		0%		0%
C18	WET-2	34-2	104.1	442	21.3%	144	33%		0%	133	30%	90	20%		0%		0%	59	13%	16	4%		0%
C19	WET-10	44-3	53.7	226	19.8%	104	46%	5	2%	12	5%	68	30%		0%		0%	37	16%		0%		0%
C20	WET-2	35-3	18.8	107.8	12.0%		0%		0%	107.8	100%		0%		0%		0%		0%		0%		0%
C21	WET-2	53-4	12.7	135	5.7%	6	4%	129	96%		0%		0%		0%		0%		0%		0%		0%
C22	EXTDRY-2	53-2	16.4	95	31.9%		0%		0%	17.3	18%	39.7	42%	7.1	7%	30.9	33%		0%		0%		0%
C23	WET-10	43-3	19.2	103	6.0%		0%	103	100%		0%		0%		0%		0%		0%		0%		0%
C24	WET-2	43-3	18.0	107.6	6.0%		0%	107.6	100%		0%		0%		0%		0%		0%		0%		0%
C25	EXTDRY-2	34-1	40.2	166.4	37.2%		0%		0%	94.1	57%		0%		0%		0%	72.3	43%		0%		0%
C28	WET-2	64-2	36.5	181	12.6%		0%	166.7	92%		0%		0%		0%		0%		0%	14.3	8%		0%
C30	WET-10	55-1	51.3	144	19.0%		0%		0%	131	91%		0%		0%		0%		0%	13	9%		0%
C35	WET-10	64-2	23.3	109	9.1%		0%	105	96%		0%		0%		0%		0%		0%	4	4%		0%
C37	WET-10	43-1	85.8	438	4.2%	135	31%	303	69%		0%		0%		0%		0%		0%		0%		0%
C39	EXTDRY-2	35-3	8.0	118	15.0%	8	7%		0%	75	64%	35	30%		0%		0%		0%		0%		0%
C40	EXTDRY-2	34-4	13.2	132	20.7%	1	1%		0%	42	32%	89	67%		0%		0%		0%		0%		0%
C41	WET-2	34-3	31.1	96	37.6%		0%		0%	55	57%		0%		0%		0%	37	39%	4	4%		0%
C43	WET-10	45-1	24.7	95	18.4%	1	1%		0%	46	48%	48	51%		0%		0%		0%		0%		0%
C44	EXTDRY-2	45-2	17.1	132.9	24.4%		0%		0%	55.9	42%	67	50%		0%		0%		0%	10	8%		0%
C46	WET-10	44-3	37.9	95	59.7%	14	15%		0%		0%		0%		0%		0%	81	85%		0%		0%
C47	WET-10	43-4	35.9	70	68.1%		0%		0%		0%	3	4%		0%		0%	67	96%		0%		0%
C49	WET-2	65-3	16.2	97	13.9%		0%	4	4%	77	79%	16	16%		0%		0%		0%		0%		0%
C50	WET-10	44-3	36.5	163	29.2%	95	58%		0%		0%		0%		0%		0%	68	42%		0%		0%
C53	EXTDRY-2	44-2	7.3	98	16.8%	4	4%	0	0%	54	55%	40	41%		0%		0%		0%		0%		0%
C54	EXTDRY-2	35-4	33.4	328	12.0%		0%		0%	328	100%		0%		0%		0%		0%		0%		0%
C57	EXTDRY-2	35-1	8.7	120	12.0%		0%		0%	120	100%		0%		0%		0%		0%		0%		0%
C62	WET-2	43-3	7.9	77	6.0%		0%	77	100%		0%		0%		0%		0%		0%		0%		0%
C63	EXTDRY-2	54-1	36.5	248.8	23.3%	8.5	3%		0%	27.5	11%	210.7	85%		0%		0%		0%	2.1	1%		0%

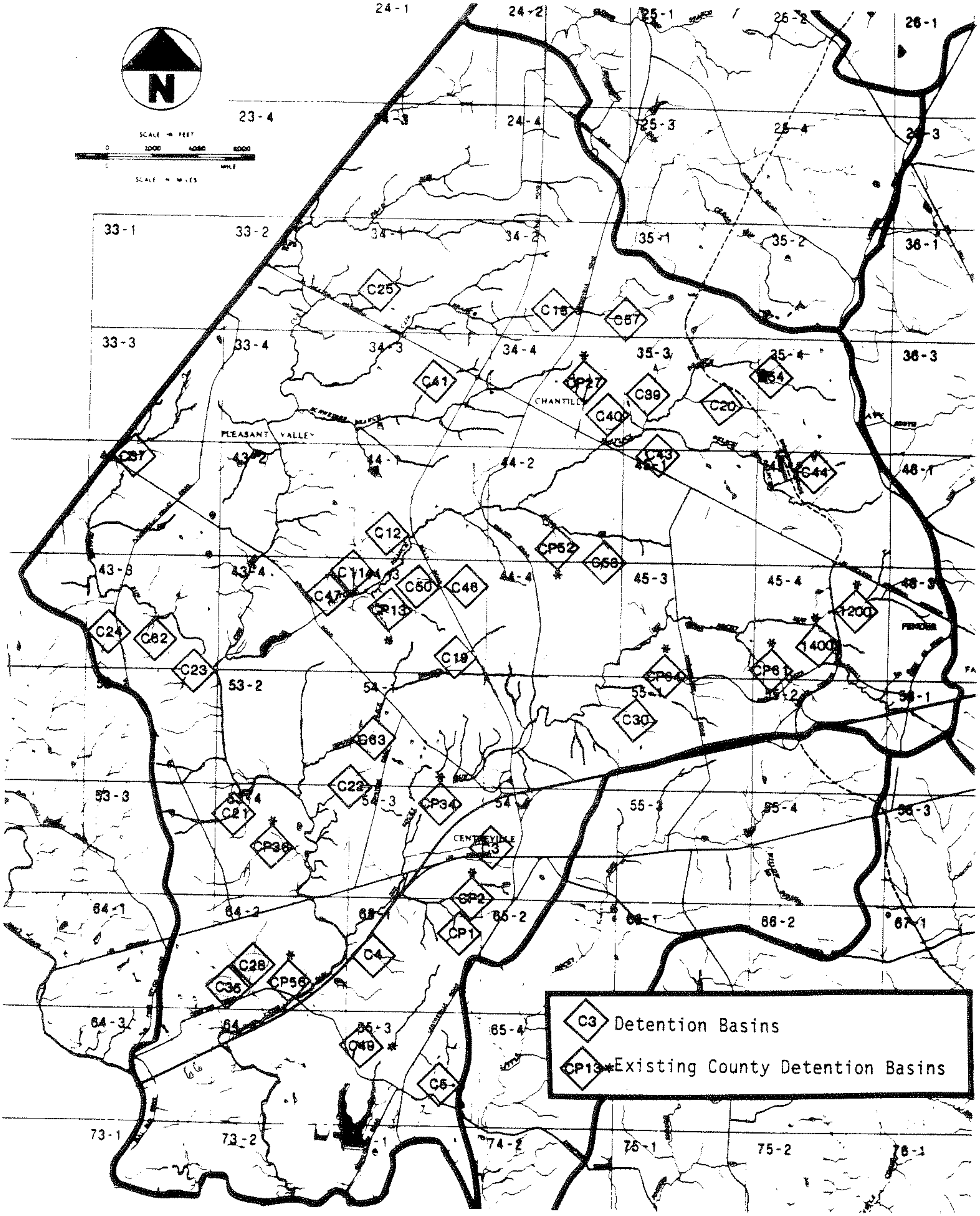


Figure 3-1. Cub Run: Regional Detention Basin Sites

3.1.3 (Submittals 3, 5 and 6). Several regional detention basins have been put into place for developed areas. These existing County detention basins, shown in Figure 3-1 and identified by an asterisk "*", were included in the regional analysis and are discussed in Section 4.1, Hydrologic Model.

3.2.2 LITTLE ROCKY RUN

The 13 recommended regional detention basins for the Little Rocky Run watershed are summarized in Table 3-4. Wet detention basins are the preferred BMP for the Little Rocky Run watershed, as they were for the Cub Run watershed, because both of these study areas are in the Occoquan Watershed. There are 11 wet detention basins of which four provided control for the 2- and 10-year storms and seven provided only 2-year control. The remaining two regional detention basins were extended dry detention basins with 2-year storm control. The extended dry detention basins were selected for those sites which did not have adequate storage to support a wet detention basin. Of these 13 basins, the County selected five as priority detention basins: R-2, R-8, R-11, R-13, and R-17. Additional information on the priority basins was provided to the County as described in Section 3.1.3.

Figure 3-2 shows the location of the detention basins given in Table 3-3. This figure also identifies the County detention basins that were included in the analysis. These basins will be discussed in Section 4.1.

3.2.3 DIFFICULT RUN

For the Difficult Run watershed and the remaining watersheds of the study, only extended dry detention basins were considered. These BMP's provide water quality benefits, but not to the extent provided by the wet detention basins which are designated for the critical Occoquan Watershed. Table 3-5 presents a summary of the 63 detention basins which includes information on storage, drainage area and future land use. There are 40 extended dry detention basin which provide both 2-year and 10-year control and 23 basins which provide 2-year control. All but five of the recommended regional

TABLE 3-4

LITTLE ROCKY RUN
SUMMARY OF REGIONAL DETENTION BASIN SITES

BASIN ID	BASIN TYPE	MAP GRID #	TOP OF DAM STORAGE Max-Efficiency (ac-ft)	DRAINAGE AREA (ac)	% IMP	FUTURE LAND USE: FOREST (ac)	FOREST (%)	LLSF (ac)	LLSF (%)	LDSF (ac)	LDSF (%)	MDSF (ac)	MDSF (%)	INSTIT (ac)	INSTIT (%)	HD RESID (ac)	HD RESID (%)	IND/OFF (ac)	IND/OFF (%)	COMM<50% (ac)	COMM<50% (%)	COMM>50% (ac)	COMM>50% (%)
R2	WET-2	65-4	41.5	194	19.6%		0%		0%	89	46%	101	52%		0%	4	2%		0%		0%		0%
R5	WET-10	65-2	23.7	55.4	44.5%		0%	0	0%	1.4	3%	10	18%		0%	44	79%		0%		0%		0%
R6	WET-2	55-4	50.1	285.6	5.6%	147	51%	11.7	4%	126.9	44%		0%		0%		0%		0%		0%		0%
R7	WET-10	55-3	13.0	47	12.0%		0%		0%	47	100%		0%		0%		0%		0%		0%		0%
R8	WET-10	55-4	35.1	137	12.4%	2	1%		0%	134	98%		0%		0%		0%		0%	1	1%		0%
R9	WET-2	55-2	7.3	56	18.0%		0%		0%	51.7	92%		0%		0%		0%		0%	4.3	8%		0%
R10	WET-2	55-4	17.7	102	12.0%		0%		0%	102	100%		0%		0%		0%		0%		0%		0%
R11	WET-2	66-1	9.9	54	12.0%		0%		0%	54	100%		0%		0%		0%		0%		0%		0%
R12	WET-10	55-2	15.4	65	26.7%	11.5	18%		0%	39.5	61%		0%		0%		0%		0%	14	22%		0%
R13	WET-2	66-1	24.7	172	10.3%	54	31%		0%	91	53%	27	16%		0%		0%		0%		0%		0%
R16	EXTDRY-2	55-3	4.9	115	12.0%		0%		0%	115	100%		0%		0%		0%		0%		0%		0%
R17	EXTDRY-2	55-3	34.7	623	6.0%	337	54%		0%	282	45%		0%		0%		0%		0%	4	1%		0%
R19	WET-2	55-4	18.5	162.4	4.5%	102	63%		0%	60.4	37%		0%		0%		0%		0%		0%		0%

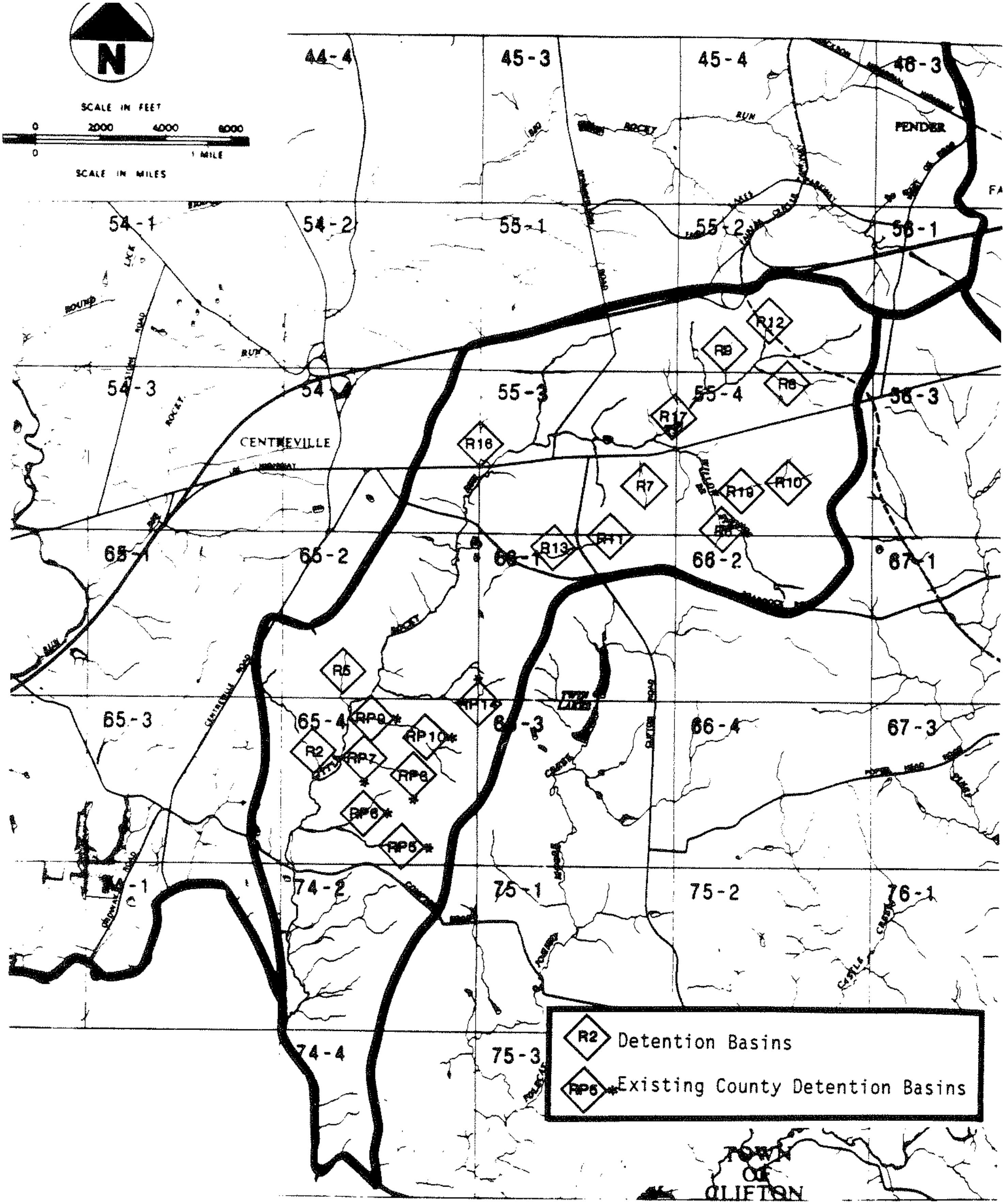


Figure 3-2. Little Rocky Run: Regional Detention Basin Sites

TABLE 3-5

DIFFICULT RUN
SUMMARY OF REGIONAL DETENTION BASIN SITES

BASIN ID	BASIN TYPE	MAP GRID #	TOP OF DAM STORAGE Max-Efficiency (ac-ft)	DRAINAGE AREA (ac)	% IMP	FUTURE LAND USE: FOREST (ac)	FOREST (%)	LLSF (ac)	LLSF (%)	LDSF (ac)	LDSF (%)	MDSF (ac)	MDSF (%)	INSTIT (ac)	INSTIT (%)	HD RESID (ac)	HD RESID (%)	IND/OFF (ac)	IND/OFF (%)	COMM<50% (ac)	COMM<50% (%)	COMM>50% (ac)	COMM>50% (%)
D01	EXTDRY-2	12-1	40.3	228	11.0%	1	0%	37	16%	190	83%		0%		0%		0%		0%		0%		0%
D02	EXTDRY-2	12-1	18.2	246	11.7%	10	4%		0%	232	94%	4	2%		0%		0%		0%		0%		0%
D03	EXTDRY-10	12-3	20.4	86	37.3%		0%	15	17%	28	33%	5	6%		0%		0%	38	44%		0%		0%
D04	EXTDRY-10	11-2	33.9	205	7.6%		0%	201	98%		0%		0%		0%		0%		0%	4	2%		0%
D05	EXTDRY-2	12-2	29.2	376	9.1%	28	7%	124	33%	224	60%		0%		0%		0%		0%		0%		0%
D06	EXTDRY-10	13-3	10.4	83	6.0%		0%	83	100%		0%		0%		0%		0%		0%		0%		0%
D07	EXTDRY-2	13-1	50.5	277	16.8%	5	2%	120	43%	125	45%		0%		0%		0%		0%	27	10%		0%
D09	EXTDRY-10	19-2	40.0	307	9.1%	5	2%	153	50%	146	48%		0%	3	1%		0%		0%		0%		0%
D10	EXTDRY-10	19-1	15.5	134	10.7%	9	7%	10	7%	115	86%		0%		0%		0%		0%		0%		0%
D11	EXTDRY-10	18-4	6.4	69	6.0%		0%	69	100%		0%		0%		0%		0%		0%		0%		0%
D12	EXTDRY-10	18-2	22.5	165	5.9%	3	2%	162	98%		0%		0%		0%		0%		0%		0%		0%
D13	EXTDRY-10	18-3	38.1	184	20.6%		0%	119	65%		0%		0%		0%		0%	65	35%		0%		0%
D14	EXTDRY-10	18-2	22.1	153	6.5%		0%	152	99%		0%		0%		0%		0%		0%	1	1%		0%
D15	EXTDRY-10	18-2	15.1	93	12.0%		0%		0%	93	100%		0%		0%		0%		0%		0%		0%
D16	EXTDRY-10	18-1	8.2	91	3.0%	46	51%	45	49%		0%		0%		0%		0%		0%		0%		0%
D17	EXTDRY-10	19-3	7.9	76	9.8%	1	1%	26	34%	49	64%		0%		0%		0%		0%		0%		0%
D18	EXTDRY-10	20-3	8.8	70	9.7%	1	1%	25	36%	44	63%		0%		0%		0%		0%		0%		0%
D19	EXTDRY-10	20-3	10.7	100	7.6%	1	1%	72	72%	27	27%		0%		0%		0%		0%		0%		0%
D20	EXTDRY-10	19-2	43.3	357	7.1%	6	2%	282	79%	69	19%		0%		0%		0%		0%		0%		0%
D21	EXTDRY-10	20-1	9.8	97	6.0%	2	2%	93	96%	2	2%		0%		0%		0%		0%		0%		0%
D23	EXTDRY-10	27-3	4.4	54	4.8%	10.6	20%	43.4	80%		0%		0%		0%		0%		0%		0%		0%
D24	EXTDRY-2	27-2	13.3	114	26.0%	4	4%	11.2	10%	69.2	61%		0%		0%		0%	29.6	26%		0%		0%
D25	EXTDRY-2	18-4	9.8	73	22.9%	1	1%	47	64%	11	15%		0%		0%		0%		0%	14	19%		0%
D26	EXTDRY-10	28-1	27.5	244	8.5%	72	30%		0%	172	70%		0%		0%		0%		0%		0%		0%
D27	EXTDRY-10	28-3	9.8	84	5.9%	1	1%	83	99%		0%		0%		0%		0%		0%		0%		0%
D28	EXTDRY-10	28-4	13.1	93	13.6%		0%	5	5%	78	84%	7	8%	3	3%		0%		0%		0%		0%
D29	EXTDRY-2	38-1	46.1	285	21.8%	11	4%		0%	188	66%	5	2%	22	8%	59	21%		0%		0%		0%
D30	EXTDRY-2	37-4	24.1	549	11.9%	29	5%		0%	507	92%	11	2%		0%		0%		0%	2	0%		0%
D31	EXTDRY-2	37-4	30.0	295	19.3%	22	7%		0%	228	77%	17	6%		0%		0%		0%	28	9%		0%
D32	EXTDRY-2	47-1	5.8	109	8.8%	29	27%		0%	80	73%		0%		0%		0%		0%		0%		0%
D33	EXTDRY-2	47-1	5.5	52	11.3%	3	6%		0%	49	94%		0%		0%		0%		0%		0%		0%
D34	EXTDRY-10	47-1	6.6	55	11.1%	4	7%		0%	51	93%		0%		0%		0%		0%		0%		0%
D35	EXTDRY-10	37-3	12.0	100	11.5%	3	3%	2	2%	95	95%		0%		0%		0%		0%		0%		0%
D36	EXTDRY-10	47-1	31.3	231	11.2%	15	6%		0%	216	94%		0%		0%		0%		0%		0%		0%
D37	EXTDRY-10	36-2	32.0	111	48.7%		0%	37	33%		0%		0%		0%		0%	74	67%		0%		0%
D38	EXTDRY-2	36-2	8.5	116	9.1%	28	24%		0%	88	76%		0%		0%		0%		0%		0%		0%
D39	EXTDRY-2	36-1	28.9	250	9.2%	64.5	26%		0%	184.5	74%		0%		0%		0%		0%	1	0%		0%

TABLE 3-5
CONTINUED

DIFFICULT RUN
SUMMARY OF REGIONAL DETENTION BASIN SITES

BASIN ID	BASIN TYPE	MAP GRID #	TOP OF DAM STORAGE Max-Efficiency (ac-ft)	DRAINAGE AREA (ac)	% IMP	FUTURE LAND USE: FOREST (ac)	FOREST (%)	LLSF (ac)	LLSF (%)	LDSF (ac)	LDSF (%)	MDSF (ac)	MDSF (%)	INSTIT (ac)	INSTIT (%)	HD RESID (ac)	HD RESID (%)	IND/OFF (ac)	IND/OFF (%)	COMM<50% (ac)	COMM<50% (%)	COMM>50% (ac)	COMM>50% (%)
D40	EXTDRY-2	36-3	77.6	305	11.6%	10	3%		0%	295	97%		0%		0%		0%		0%		0%		0%
D41	EXTDRY-2	36-3	30.5	314	9.4%	67	21%		0%	247	79%		0%		0%		0%		0%		0%		0%
D43	EXTDRY-10	36-1	7.3	92	5.0%	54	59%		0%	38	41%		0%		0%		0%		0%		0%		0%
D45	EXTDRY-2	46-2	24.6	309	12.2%	32	10%		0%	265	86%		0%		0%	12	4%		0%		0%		0%
D46	EXTDRY-2	47-3	45.8	277	31.3%		0%		0%	195	70%		0%		0%		0%	52	19%	30	11%		0%
D47	EXTDRY-10	56-2	29.0	111	67.1%	1	1%	0	0%	14	13%		0%		0%		0%	40	36%		0%	56	50%
D49	EXTDRY-2	56-2	51.3	102	26.5%	0	0%		0%	52.6	29%	90.9	50%		0%	38.5	21%		0%	0	0%		0%
D51	EXTDRY-2	27-4	42.0	482.5	6.4%	7	1%	435.5	90%	40	8%		0%		0%		0%		0%		0%		0%
D52	EXTDRY-2	27-2	67.6	375	25.5%	16	4%	103	27%	173	46%		0%		0%		0%	31	8%	52	14%		0%
D54	EXTDRY-10	19-3	16.4	97	24.6%	2	2%		0%	79	81%		0%		0%		0%		0%	16	16%		0%
D56	EXTDRY-10	37-1	10.7	82	12.6%		0%	66	80%		0%		0%	16	20%		0%		0%		0%		0%
D58	EXTDRY-10	36-1	10.9	78	12.0%		0%		0%	78	100%		0%		0%		0%		0%		0%		0%
D59	EXTDRY-10	37-3	9.3	80	11.3%	5	6%		0%	75	94%		0%		0%		0%		0%		0%		0%
D61	EXTDRY-10	36-2	32.2	153	39.6%	25	16%	1	1%	49	32%		0%		0%		0%	78	51%		0%		0%
D64	EXTDRY-10	12-4	14.6	114	11.3%	7	6%		0%	107	94%		0%		0%		0%		0%		0%		0%
D65	EXTDRY-10	19-1	6.4	59	9.2%		0%	28	47%	31	53%		0%		0%		0%		0%		0%		0%
D66	EXTDRY-10	20-3	19.8	130	10.8%	13	10%		0%	117	90%		0%		0%		0%		0%		0%		0%
D67	EXTDRY-2	29-1	31.1	263	58.8%		0%		0%	48	18%		0%		0%	40	15%	112	43%		0%	63	24%
D69	EXTDRY-10	36-1	21.9	101	40.3%	31	31%	3	3%	11	11%		0%		0%		0%	56	55%		0%		0%
D71	EXTDRY-10	35-2	35.7	209	11.9%	14	7%		0%	193	92%		0%		0%		0%		0%	2	1%		0%
D72	EXTDRY-10	37-1	9.1	83	6.1%	1	1%	80	96%	2	2%		0%		0%		0%		0%		0%		0%
D73	EXTDRY-2	38-3	8.4	142	15.8%	3	2%		0%	100	70%	36	25%		0%	3	2%		0%		0%		0%
D74	EXTDRY-10	38-1	16.8	121	13.3%	12	10%		0%	86	71%	23	19%		0%		0%		0%		0%		0%
D76	EXTDRY-2	13-4	15.3	302	6.0%		0%	302	100%		0%		0%		0%		0%		0%		0%		0%
D77	EXTDRY-10	56-2	58.6	210	31.8%		0%		0%	118	56%	35	17%		0%		0%	37	18%	20	10%		0%
D79	EXTDRY-10	36-4	31.1	215	10.9%	19	9%		0%	196	91%		0%		0%		0%		0%		0%		0%

detention basins have top of dam storages which are less than 50 ac-ft. Those basins with storages exceeding 50 ac-ft are as follows: D-7, D-40, D-49, D-52 and D-77. Figure 3-3 shows the locations of the proposed detention basins for Difficult Run. Two County detention basins (DP-70 and DP-75) are also located on Figure 3-3. The County detention basins and the existing lakes that were considered in this study are presented in Section 4.1, Hydrologic Model.

The County selected priority detention basins for which additional information on the sites was provided to the County as described in Section 3.1.3. Within the Difficult Run watershed, 12 priority sites were chosen: D-1, D-3, D-4, D-5, D-31, D-36, D-37, D-40, D-46, D-47, D-51 and D-71.

3.2.4 HORSEPEN CREEK

Table 3-6 presents a summary of the seven proposed maximum efficiency detention basins for Horsepen Creek. Four extended dry detention basins include control of the 2-year and 10-year storms and the remaining three detention basins included control of the 2-year storm. The County has designated four of the detention basins as priority basins: H-1, H-2, H-9 and H-18. Additional information concerning these sites was provided to the County on maps and forms from the site visits.

The seven detention basin locations within the Horsepen Run watershed are shown on Figure 3-4. One County detention basin was considered within the watershed and it is shown on the figure as HP-15. The analysis of this basin is discussed in Section 4.1, Hydrologic Model.

3.2.5 SUGARLAND RUN

Five maximum efficiency detention basins were selected in the Sugarland Run watershed. The proposed basins are given in Table 3-7. Two of the five basins provide control for the 2-year and 10-year storms and three provide control for the 2-year storm. Figure 3-5 shows the locations of the regional detention basins. No existing County regional detention basins

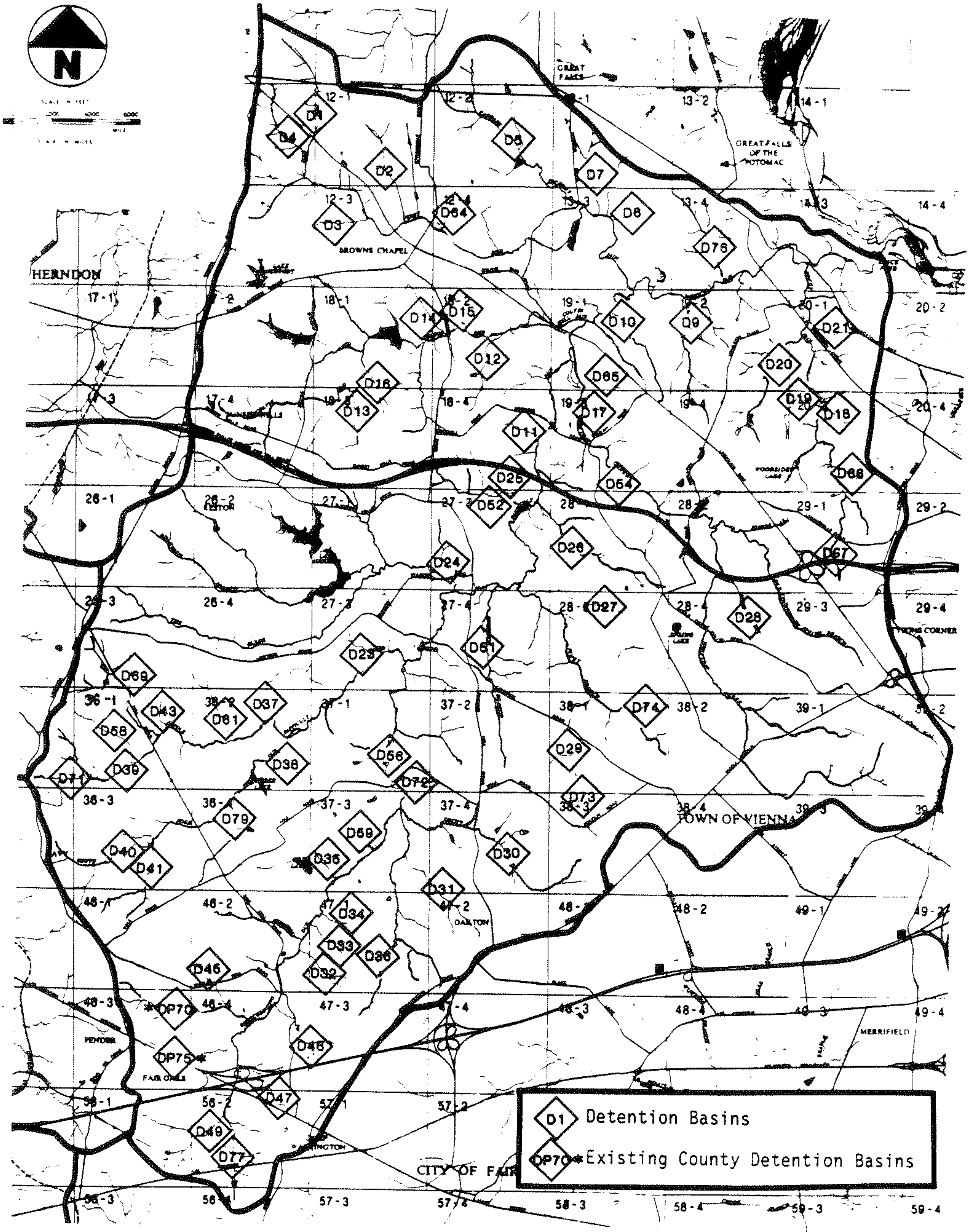


Figure 3-3. Difficult Run: Regional Detention Basin Sites

TABLE 3-6

HORSEPEN CREEK
SUMMARY OF REGIONAL DETENTION BASIN SITES

BASIN ID	BASIN TYPE	MAP GRID #	TOP OF DAM STORAGE Max-Efficiency (ac-ft)	DRAINAGE AREA (ac)	% IMP	FUTURE LAND USE: FOREST (ac)	FOREST (%)	LLSF (ac)	LLSF (%)	LDSF (ac)	LDSF (%)	MDSF (ac)	MDSF (%)	INSTIT (ac)	INSTIT (%)	HD RESID (ac)	HD RESID (%)	IND/OFF (ac)	IND/OFF (%)	COMM<50% (ac)	COMM<50% (%)	COMM>50% (ac)	COMM>50% (%)
H01	EXTDRY-10	16-3	21.2	76	19.0%		0%		0%	35	46%	41	54%		0%		0%		0%		0%		0%
H02	EXTDRY-10	24-4	36.8	101	70.0%		0%		0%		0%		0%		0%		0%	101	100%		0%		0%
H07	EXTDRY-10	25-3	15.9	78	22.7%		0%		0%	14	18%	64	82%		0%		0%		0%		0%		0%
H09	EXTDRY-10	15-4	35.4	100	70.0%		0%		0%		0%		0%		0%		0%	100	100%		0%		0%
H13	EXTDRY-2	35-2	24.0	291	12.0%		0%		0%	291	100%		0%		0%		0%		0%		0%		0%
H16	EXTDRY-2	25-4	6.2	80	11.6%	3	4%		0%	77	96%		0%		0%		0%		0%		0%		0%
H18	EXTDRY-2	25-2	17.3	152.5	22.3%	16.7	11%		0%		0%	135.8	89%		0%		0%		0%		0%		0%

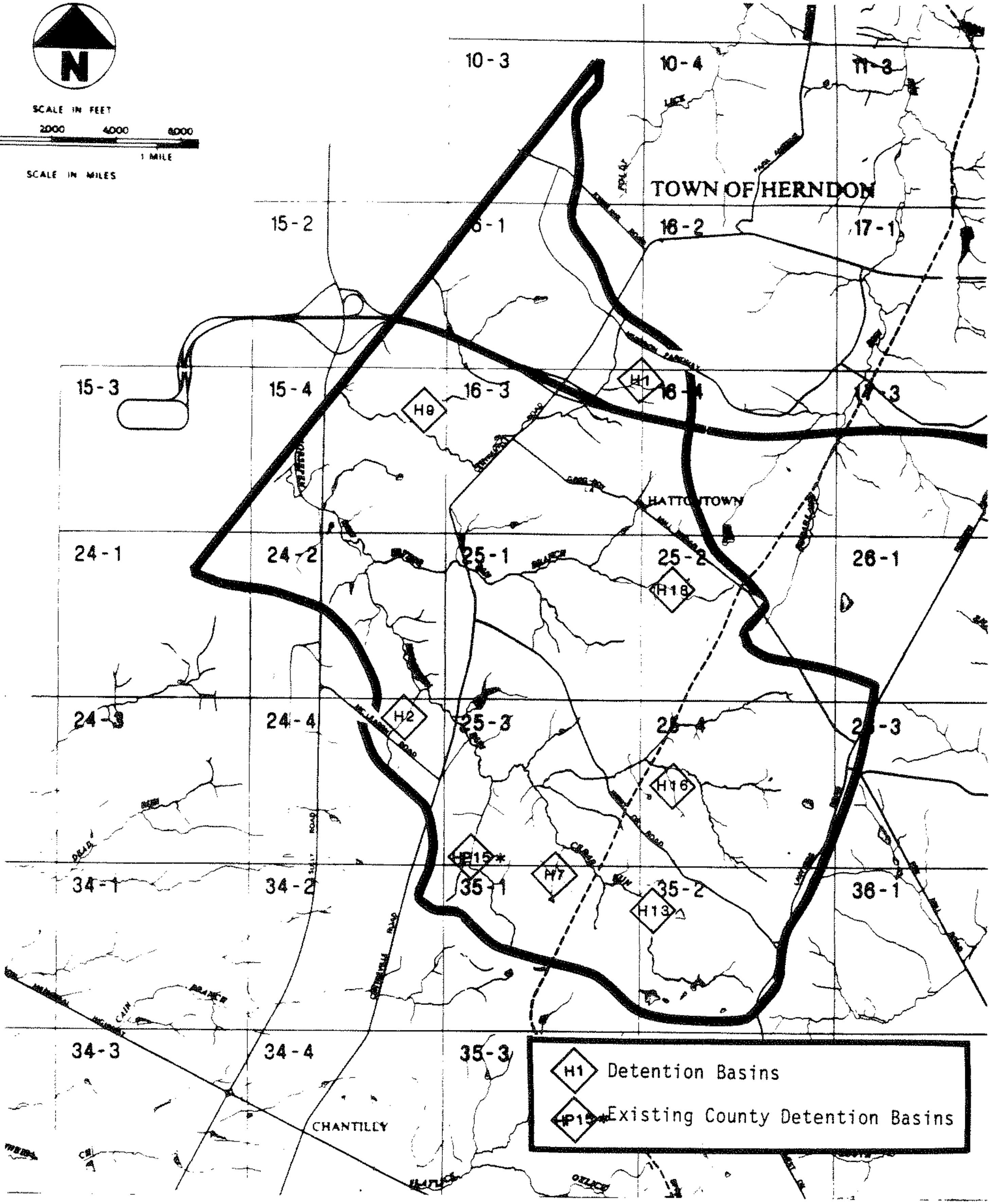


Figure 3-4. Horsepen Creek: Regional Detention Basin Sites

TABLE 3-7

SUGARLAND RUN
SUMMARY OF REGIONAL DETENTION BASIN SITES

BASIN ID	BASIN TYPE	MAP GRID #	TOP OF DAM STORAGE Max-Efficiency (ac-ft)	DRAINAGE AREA (ac)	% IMP	FOREST (ac)	FOREST (%)	LLSF (ac)	LLSF (%)	LDSF (ac)	LDSF (%)	MDSF (ac)	MDSF (%)	INSTIT (ac)	INSTIT (%)	HD RESID (ac)	HD RESID (%)	IND/OFF (ac)	IND/OFF (%)	COMM<50% (ac)	COMM<50% (%)	COMM>50% (ac)	COMM>50% (%)
S01	EXTDRY-2	11-1	15.6	77	12.0%	0	0%		0%	77	100%		0%		0%		0%		0%		0%		0%
S02	EXTDRY-10	11-1	29.9	142	21.8%		0%		0%	118	83%		0%		0%		0%	24	17%		0%		0%
S04	EXTDRY-10	10-2	9.9	55	28.6%		0%		0%	0	0%	47	85%		0%	8	15%		0%		0%		0%
S05	EXTDRY-2	6-3	23.9	264	16.2%	18	7%	5.8	2%	222	84%		0%	1.1	0%		0%		0%	17.1	6%		0%
S07	EXTDRY-2	11-1	33.5	453.3	16.8%	15.4	3%		0%	355.8	78%	52.5	12%	12.2	3%		0%		0%	17.4	4%		0%

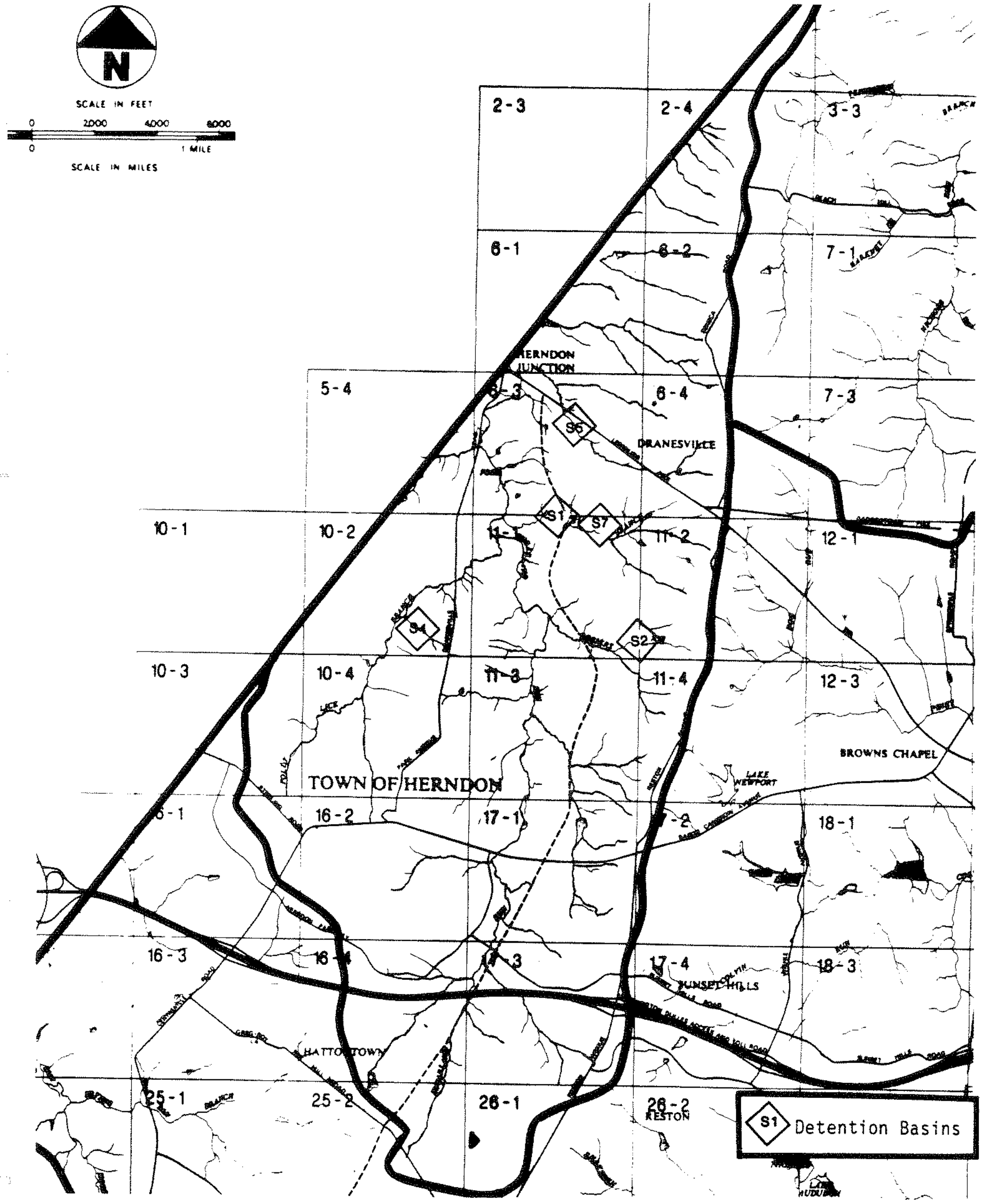


Figure 3-5. Sugarland Run: Regional Detention Basin Sites

are located within the watershed. The County has been supplied additional information on their selected priority detention basins: S-1, S-4 and S-7.

3.2.6 POHICK CREEK

The Pohick Creek watershed includes the area upstream of Burke Lake. Table 3-8 presents summary information for each of the maximum efficiency detention basins. Figure 3-6 shows the study area watershed boundary and the location of the eight selected regional detention basins. All regional detention basins except one (P-6) are extended dry basins with control for both the 2-year and 10-year storms. Basin P-6 only controls the 2-year storm. For Pohick Creek watershed, the County has selected P-3 and P-7 to be included on their priority list. More detailed information concerning these sites is given in submittals to the County as described in Section 3.1.4. There are no existing County regional detention basins in the area above Burke Lake included in this study.

3.2.7 LONG BRANCH

The Long Branch watershed which drains to Accotink Creek, was also included in this study. In addition to the Long Branch main stem, an additional detention basin site was selected on Fieldlark Branch which drains to Accotink Creek just west of the main stem of Long Branch. Table 3-9 presents a summary of the seven proposed regional detention basins and Figure 3-7 shows their locations. Four of the maximum efficiency basins provide 2-year and 10-year storm control and three of the maximum efficiency detention basins provide 2-year storm control. The County has approved one of the Long Branch regional detention basins to have a top of dam storage greater than the normal 50 ac-ft maximum. Basin L-10 has a total storage of 95.8 ac-ft which controls a 449-acre watershed area above the basin site.

Four of the seven regional detention basins were chosen by the County for the priority list: L-1, L-2, L-7 and L-9. Additional data for these basins was submitted to the County as Submittals 3, 5 and 6. There are no existing County regional detention basins in Long Branch to be considered as part of the regional analysis.

TABLE 3-8

POHICK CREEK
SUMMARY OF REGIONAL DETENTION BASIN SITES

BASIN ID	BASIN TYPE	MAP GRID #	TOP OF DAM STORAGE Max-Efficiency (ac-ft)	DRAINAGE AREA (ac)	% IMP	FUTURE LAND USE: FOREST (ac)	FOREST (%)	LLSF (ac)	LLSF (%)	LDSF (ac)	LDSF (%)	MDSF (ac)	MDSF (%)	INSTIT (ac)	INSTIT (%)	HD RESID (ac)	HD RESID (%)	IND/OFF (ac)	IND/OFF (%)	COMM<50% (ac)	COMM<50% (%)	COMM>50% (ac)	COMM>50% (%)
P01	EXTDRY-10	77-4	22.5	137	13.6%	11	8%		0%	120	88%		0%		0%		0%	6	4%		0%		0%
P02	EXTDRY-10	77-3	29.6	205	12.0%		0%		0%	205	100%		0%		0%		0%		0%		0%		0%
P03	EXTDRY-10	87-2	9.4	72	13.4%		0%		0%	64	89%	8	11%		0%		0%		0%		0%		0%
P04	EXTDRY-10	87-2	42.7	226	12.0%		0%		0%	226	100%		0%		0%		0%		0%		0%		0%
P05	EXTDRY-10	88-1	7.1	51	16.3%		0%		0%	34	67%	17	33%		0%		0%		0%		0%		0%
P06	EXTDRY-2	87-2	14.0	184	11.7%	5	3%		0%	179	97%		0%		0%		0%		0%		0%		0%
P07	EXTDRY-10	87-2	18.7	122	9.9%	21	17%		0%	101	83%		0%		0%		0%		0%		0%		0%
P08	EXTDRY-10	77-3	16.2	110	11.7%		0%	5.3	5%	104.7	95%		0%		0%		0%		0%		0%		0%

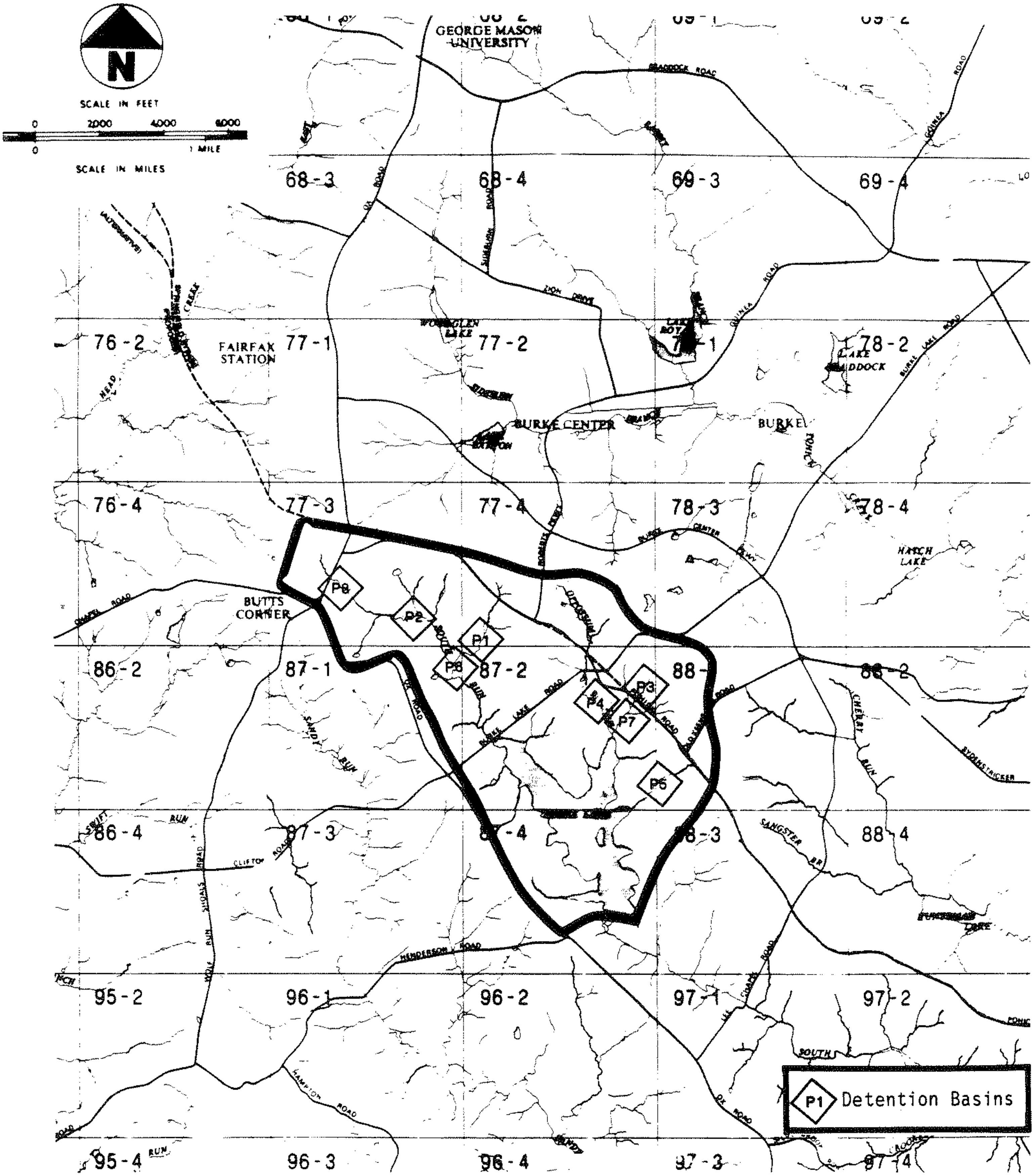


Figure 3-6. Pohick Creek: Regional Detention Basin Sites

TABLE 3-9

LONG BRANCH
SUMMARY OF REGIONAL DETENTION BASIN SITES

BASIN ID	BASIN TYPE	MAP GRID #	TOP OF DAM STORAGE Max-Efficiency (ac-ft)	DRAINAGE AREA (ac)	% IMP	FOREST (ac)	FOREST (%)	LLSF (ac)	LLSF (%)	LDSF (ac)	LDSF (%)	MDSF (ac)	MDSF (%)	INSTIT (ac)	INSTIT (%)	HD RESID (ac)	HD RESID (%)	IND/OFF (ac)	IND/OFF (%)	COMM<50% (ac)	COMM<50% (%)	COMM>50% (ac)	COMM>50% (%)
						FUTURE LAND USE																	
L01	EXTDRY-10	90-4	17.9	90	25.0%		0%		0%	0	0%	90	100%		0%		0%		0%		0%		0%
L02	EXTDRY-10	90-4	16.8	94	20.2%	18	19%		0%	0	0%	76	81%		0%		0%		0%		0%		0%
L05	EXTDRY-2	90-2	17.3	136	35.3%		0%		0%	80	59%	15	11%	0	0%		0%	11	8%	30	22%		0%
L06	EXTDRY-10	90-4	29.0	102	47.1%		0%		0%	23	23%	33	32%		0%		0%	22	22%	24	24%		0%
L07	EXTDRY-10	99-2	23.4	128	30.5%		0%		0%	60	47%	35	27%		0%		0%	33	26%		0%		0%
L09	EXTDRY-2	99-1	38.0	197.6	52.2%		0%		0%	12.6	6%		0%	113	57%		0%	42	21%	30	15%		0%
L10	EXTDRY-2	90-2	95.8	449	55.2%	50	11%		0%	33	7%	96	21%		0%		0%	116	26%	154	34%		0%

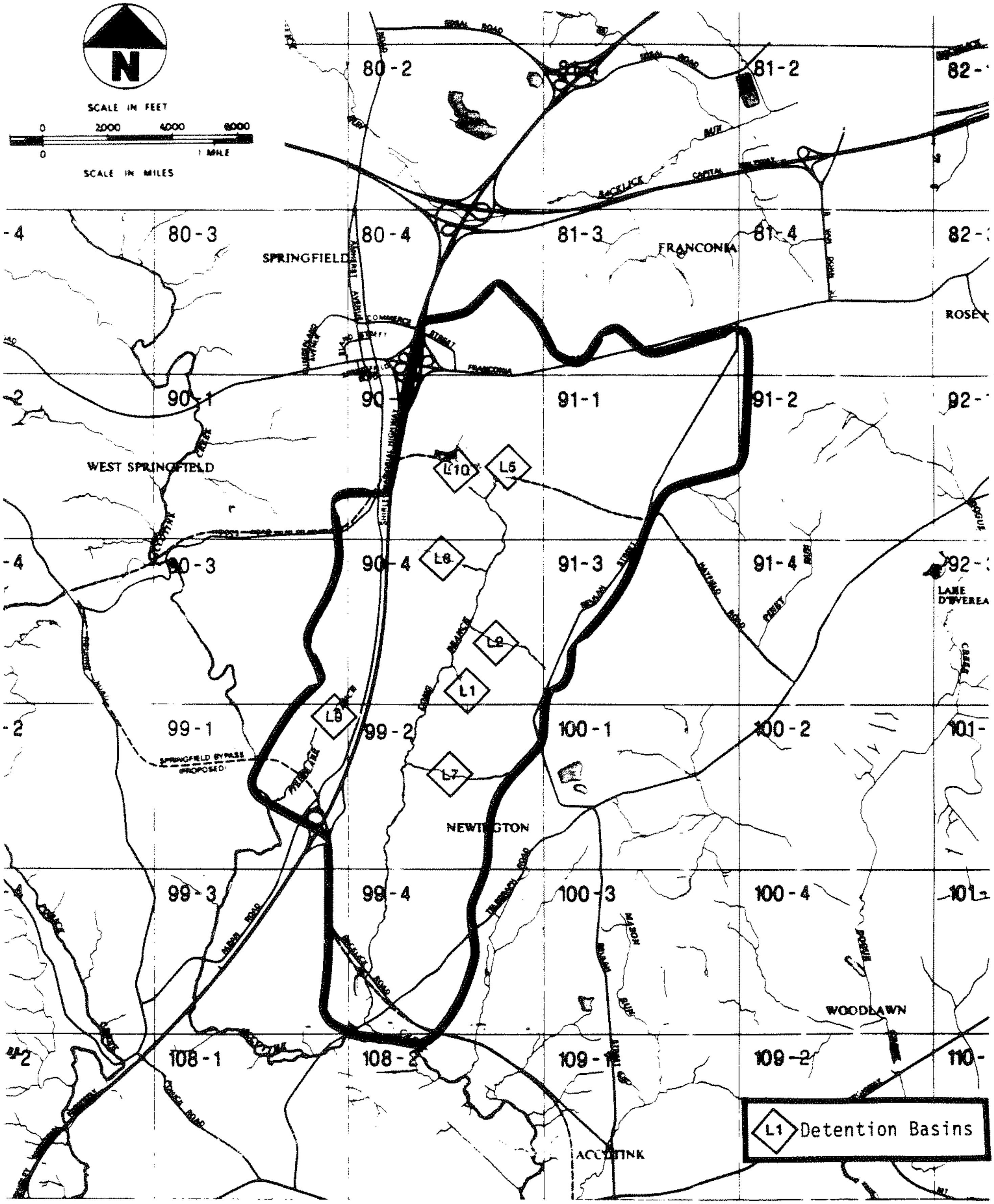


Figure 3-7. Long Branch: Regional Detention Basin Sites

4.0 STORMWATER MODELS

Stormwater models were developed and applied to analyze the watershedwide impacts of regional detention basins. The stormwater models used to evaluate changes in flow for erosion and flooding control included a hydrologic model and a hydraulic model. The hydrologic model, STORMLINK, was applied to simulate the runoff hydrographs from subbasins and route the hydrographs through the regional detention basins. The hydrographs from the hydrologic model were input into the hydraulic model, SWMM/EXTRAN, for evaluations of watershedwide impacts. EXTRAN routes the hydrographs throughout the watershed stream channel system.

4.1 HYDROLOGIC MODEL

The STORMLINK hydrologic model uses the SCS curve number method which was selected to simulate the overland flow component of the rainfall-runoff cycle. The "curve number" represents the runoff potential of an area and is based on the land use breakdown, soil distribution, and antecedent moisture condition of a subbasin. The greatest curve numbers have the greatest potential for runoff. The STORMLINK model can also simulate routing through detention basins and other impoundments.

4.1.1 RUNOFF HYDROGRAPHS

Runoff hydrographs were computed for watershed subbasins using: the design rainfall events; weighted curve numbers based on land use, soil type, times of concentration, and antecedent moisture conditions; and the SCS dimensionless hydrograph following the procedures given in Section 4, Chapter 16, of the Soil Conservation Service National Engineering Handbook (Mockus, 1969).

Design Storms

Fairfax County has adopted the 2-year and 10-year design storms for the design of stormwater detention basins (Fairfax County, 1985). Conventional approaches to stormwater management studies involve peak flow estimates from design storms based on rainfall intensity-duration-frequency curves. These curves represent statistically defined average rainfall intensities for storms of different durations having different probabilities of occurrence. Currently, the most recognized sources published by the National Weather Service (NWS) for the eastern United States are TP40 (U.S. Weather Bureau, 1963) for durations between 1 and 24 hours and HYDRO 35 (National Weather Service, 1977) for durations less than 1 hour.

The logical approach in examining drainage impacts at a particular location would be to use the design storm having a duration that gives the maximum peak discharge at the location. This approach is difficult to apply to a regional study because different locations in the basin have different times of concentration, thereby resulting in different critical durations. To standardize the rainfall distribution in the master plan, the SCS Type II 24-hour distribution was selected for all watersheds. The Type II rainfall distribution was designed by SCS to contain the intensity of any duration of rainfall for the frequency event being analyzed (SCS, 1986). In other words, the 10-year/6-hour rainfall is contained within the 10-year/24-year distribution, and so on. In addition, the SCS distribution is universally accepted and used by local engineers throughout the State of Virginia.

In summary, the design storms adopted for this study were based on TP-40 intensity-duration-frequency relationships for Fairfax County and the SCS Type II distribution. Return periods of 2-years and 10-years were used. Total rainfall volumes for these events are 3.2 and 5.0 inches, respectively. Table 4-1 presents the rainfall intensity in inches per hour for 15-minute increments for the 2-year and 10-year design storms.

Subbasin Hydrologic Characteristics

Within each of the seven watershed study areas, subbasins were delineated for the area above a proposed detention basin site. In addition, subbasins were delineated for watershed areas that did not have detention basins to complete the subbasin model for the watershed. The hydrologic model (SCS

TABLE 4-1

RAINFALL DESIGN STORMS (SCS TYPE II)

Storm Time (hours)	2-Year (in/hr)	10-Year (in/hr)	Storm Time (hours)	2-Year (in/hr)	10-Year (in/hr)
0.25	0.03	0.04	12.25	0.56	0.88
0.50	0.04	0.06	12.50	0.36	0.56
0.75	0.04	0.06	12.75	0.29	0.46
1.00	0.04	0.06	13.00	0.23	0.36
1.25	0.04	0.06	13.25	0.19	0.30
1.50	0.04	0.06	13.50	0.17	0.26
1.75	0.04	0.06	13.75	0.14	0.22
2.00	0.04	0.06	14.00	0.13	0.20
2.25	0.04	0.06	14.25	0.12	0.18
2.50	0.04	0.06	14.50	0.10	0.16
2.75	0.04	0.06	14.75	0.09	0.14
3.00	0.04	0.06	15.00	0.09	0.14
3.25	0.04	0.06	15.25	0.09	0.14
3.50	0.04	0.06	15.50	0.08	0.12
3.75	0.04	0.06	15.75	0.08	0.12
4.00	0.05	0.08	16.00	0.08	0.12
4.25	0.05	0.08	16.25	0.08	0.12
4.50	0.05	0.08	16.50	0.08	0.12
4.75	0.05	0.08	16.75	0.06	0.10
5.00	0.05	0.08	17.00	0.06	0.10
5.25	0.05	0.08	17.25	0.06	0.10
5.50	0.05	0.08	17.50	0.06	0.10
5.75	0.05	0.08	17.75	0.06	0.10
6.00	0.05	0.08	18.00	0.05	0.08
6.25	0.06	0.10	18.25	0.05	0.08
6.50	0.06	0.10	18.50	0.05	0.08
6.75	0.06	0.10	18.75	0.05	0.08
7.00	0.06	0.10	19.00	0.05	0.08
7.25	0.06	0.10	19.25	0.05	0.08
7.50	0.06	0.10	19.50	0.05	0.08
7.75	0.06	0.10	19.75	0.05	0.08
8.00	0.06	0.10	20.00	0.04	0.06
8.25	0.08	0.12	20.25	0.04	0.06
8.50	0.09	0.14	20.50	0.04	0.06
8.75	0.09	0.14	20.75	0.04	0.06
9.00	0.09	0.14	21.00	0.04	0.06
9.25	0.10	0.16	21.25	0.04	0.06
9.50	0.10	0.16	21.50	0.04	0.06
9.75	0.12	0.18	21.75	0.04	0.06
10.00	0.12	0.18	22.00	0.04	0.06
10.25	0.13	0.20	22.25	0.04	0.06
10.50	0.15	0.24	22.50	0.04	0.06
10.75	0.19	0.30	22.75	0.04	0.06
11.00	0.23	0.36	23.00	0.04	0.06
11.25	0.27	0.42	23.22	0.04	0.06
11.50	0.33	0.52	23.50	0.04	0.06
11.75	1.33	2.08	23.75	0.04	0.06
12.00	3.53	5.52	24.00	0.03	0.04

method) requires three subbasin parameters to transform rainfall into runoff. They include: subbasin drainage area, curve number, and time of concentration. The curve number was based on the land use and hydrologic soil groups.

Land Use. For this study, databases on predevelopment and future land use conditions were developed. The predevelopment land use was assumed to be forest and open land. This land use was used to generate hydrographs at detention basin sites for use as the performance standard for detention basin design (i.e., for the future land use condition inflow hydrograph, a detention basin was designed to release a peak discharge equal to or less than the predevelopment peak flow).

The future land use conditions were determined from the Comprehensive Land Use Plan and the zoning map of the County. Where a difference in land use was given by the two sources, the more dense land use (i.e., larger percent imperviousness) was chosen for the study.

Nine land use categories were selected for the study. They are listed in Table 4-2 with the corresponding classifications given by the Comprehensive Land Use Plan and the zoning maps. Table 4-2 also includes the SCS curve number and percent imperviousness associated with each land use category. The percent impervious was used in the initial evaluation of site suitability to determine the required storage at the detention basin site. The curve numbers are used as input into the STORMLINK hydrologic model.

For each subbasin the drainage area of each land use category was planimetered from the zoning maps and spreadsheets were developed to calculate a composite curve number for the subbasin based on land use and soils characteristics.

Soils. Curve numbers are also a function of the four hydrologic soil groups A, B, C and D. For each subbasin, the breakdown of the total area by hydrologic soil group was used to determine the composite curve number. The hydrologic soil groups assigned to the subbasins in each watershed were

TABLE 4-2

CURVE NUMBERS AND PERCENT IMPERVIOUSNESS
FOR LAND USE CATEGORIES

Land Use Category	Curve Number A	B	C	D	Percent Imperv.	Corresponding Categories: Land Use Plan	Zoning District
Forest/open, Floodplain (FOR/OP)	30	55	70	77	0%	Public parks	See map designation
Large lot Single Family (LLSF)	43	63	76	81	6%	0.1-0.2 DU/Ac 0.5-0.1 DU/Ac	RA - RE PDH
Low Density (LDSF)	46	65	77	82	12%	1-2 DU/Ac	R1 - R2 PDH1-PDH2
Medium Density Residential/Schools (MDSF)	54	70	80	85	25%	> 2-5 DU/Ac MH	R3-R5 R-MHP PDH3-PDH5
Institutional/Churches (INSTIT)	62	76	84	87	40%	Public Facilities, Government, and Institutional	II
High Density Residential (HDR)	68	80	86	89	50%	5-8 DU/Ac 20+ DU/Ac	R8-R30 PDH8-PDH30
Industrial/Office (IND/OFF)	80	87	90	93	70%	Office, Industrial	I1-I5, C1-C2 PDC-PRC
Commercial/Office >50% (COMM > 50%)	86	90	93	94	80%	Retail, Highways and Other	C3-C8, I6
Commercial < 50%) (COMM < 50%)	92	94	95	96	90%	Retail, Highways and Other	C3-C8, I6

determined from the Fairfax County Soil Survey (SCS, 1963). An average hydrologic soil group (A, B, C or D) was assigned to each soil association based on the soil series within the association and the hydrologic soil group the SCS has assigned to each soil series. The soils in the study area are dominated by Piedmont upland and Piedmont lowland soils which are predominantly B and C with some D hydrologic soil groups.

Curve Numbers. The curve number is a factor in the SCS runoff method which determines the amount of runoff which results from a given amount of rainfall. The curve numbers given in Table 4-2 were developed from the methods described in TR-55 (SCS, 1986). The impervious areas were assigned a curve number of 98 and the pervious areas were considered equivalent to open space in good hydrologic condition for each of the four hydrologic soil groups. The composite curve numbers for each hydrologic soil group were based on the percent imperviousness assigned to a given land use.

Time of Concentration. In addition to the subbasin drainage area and the curve number, the time of concentration for each subbasin is also required for the SCS method. The time of concentration is the time required for water to travel from the most distant point in the subbasin to the subbasin outlet. The method used to develop the time of concentration is described in TR-55. For each subbasin the longest drainage path was divided into three reaches representing sheet flow, shallow concentrated flow and open channel flows. The time of travel for sheet flow was based on a sheet flow Manning "n"; for shallow concentrated flow, a paved or unpaved condition; and for channel flow, on a channel Mannings "n." The sum of the three times of travel yields the total time of concentration. The sheet flow "n" varied with land use as did the paved or unpaved conditions.

Summary of Subbasin Characteristics for Hydrologic Modeling. For each subbasin the drainage area, curve number, and time of concentration are input into the hydrologic model to compute the runoff from the design rainfall event. For each of the seven watersheds under future land use conditions, Tables 4-3 through 4-9 give the basic STORMLINK model parameters and also the breakdown of land use and hydrologic soil groups for each subbasin. The table also lists the hydraulic model (EXTRAN) node number which receives the subbasin hydrograph from the hydrologic model (STORMLINK).

4.1.2 HYDROGRAPH ROUTING

The STORMLINK model was used not only to simulate the runoff hydrograph from each subbasin but also to route the flows through existing impoundments and proposed detention basins. The model can route flows through an impoundment by specifying a storage-discharge relationship or by providing direct representation of outflow structure geometry. Hydrographs that were routed through existing ponds and lakes or proposed detention basins were then input into the hydraulic model EXTRAN which received all hydrographs from the hydrologic model.

In some cases the hydrologic model combined subbasin hydrographs prior to input into the hydraulic model. For example, given two proposed detention basins in series, the model would compute the runoff hydrograph for the upstream subbasin and route the hydrograph through the upstream detention basin, then it would combine the routed hydrograph with the incremental area hydrograph between the two basins and then route the combined hydrograph through the downstream detention basin. The final outflow hydrograph from the downstream detention basin would be input into the hydraulic model.

Existing County Detention Basins and Lakes

Several existing County detention basins and lakes were modeled in STORMLINK with storage-discharge routing. Small farm ponds and other small impoundments were not modeled. These ponds were incorporated into individual subbasin areas where hydrograph were input into the hydraulic model.

TABLE 4-3

CUB RUN
SUBBASIN CHARACTERISTICS FOR HYDROLOGIC MODELING FUTURE LAND USE

Subbasin Id.	Area (acres)	Percent Land Use Category: FOR/OPEN 1	LLSF 2	LDSF 3	HDSF 4	INSTIT 5	HDR 6	IND/OFF 7	COMM>50 8	COMM<50 9	% Hyd. Soil Group: A	B	C	D	Tc (Hours)	Curve No.	EXTRAN Node
1	216.00	0.0	0.0	66.2	0.0	0.0	27.3	0.0	0.0	6.5	0	20	80	0	0.77	78.7	20060
2	138.00	5.7	0.0	71.7	0.0	3.4	3.9	0.0	15.3	0.0	0	20	80	0	0.51	77.6	20060
3	133.30	0.0	0.0	15.9	0.5	1.5	0.0	1.2	80.9	0.0	0	20	80	0	0.23	89.3	20140
4	97.00	0.0	2.1	97.3	0.0	0.0	0.0	0.0	0.0	0.0	0	20	80	0	0.36	74.6	20000
5	165.00	0.0	0.0	90.9	8.5	0.0	0.6	0.0	0.0	0.0	0	20	80	0	0.72	75.0	0
9	133.00	88.0	0.0	12.0	0.0	0.0	0.0	0.0	0.0	0.0	0	20	80	0	0.54	67.9	20380
10	161.00	55.3	0.0	40.4	0.0	0.0	0.0	0.0	4.3	0.0	0	20	80	0	0.86	71.2	20380
11	30.00	0.0	0.0	0.0	3.3	0.0	0.0	96.7	0.0	0.0	0	20	80	0	0.37	89.0	50120
12	69.00	0.0	0.0	0.0	0.0	0.0	0.0	100.0	0.0	0.0	0	20	80	0	0.32	89.4	50180
13	86.20	15.0	0.0	7.9	68.7	0.0	0.0	6.8	0.0	1.6	0	20	80	0	0.56	77.1	50120
57	120.00	0.0	0.0	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0	20	80	0	0.91	74.6	70200
18	322.00	7.5	0.0	41.3	28.0	0.0	0.0	18.3	5.0	0.0	0	20	80	0	0.88	78.6	70200
20	107.80	0.0	0.0	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0	20	80	0	0.67	74.6	50580
21	135.00	4.4	95.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	20	80	0	1.03	73.1	33000
22	95.00	0.0	0.0	18.4	41.8	7.4	32.4	0.0	0.0	0.0	0	20	80	0	0.47	79.9	30000
23	103.00	0.0	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	20	80	0	0.97	73.4	40000
24	107.60	0.0	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	20	80	0	0.66	73.4	40120
25	166.40	0.0	0.0	56.6	0.0	0.0	0.0	43.4	0.0	0.0	0	20	80	0	0.93	81.0	74000
27	91.00	0.0	0.0	47.3	3.3	0.0	0.0	0.0	49.5	0.0	0	20	80	0	0.68	83.5	50400
28	181.00	0.0	92.1	0.0	0.0	0.0	0.0	0.0	0.0	7.9	0	20	80	0	0.75	75.1	10000
29	91.00	0.0	0.0	74.7	25.3	0.0	0.0	0.0	0.0	0.0	0	20	80	0	0.51	75.5	20460
30	144.00	0.0	0.0	91.0	0.0	0.0	0.0	0.0	9.0	0.0	0	20	80	0	0.77	76.2	20520
34	41.00	3.7	0.0	0.0	0.0	0.0	96.3	0.0	0.0	0.0	0	20	80	0	0.27	84.1	20140
35	139.30	0.0	96.3	0.0	0.0	0.0	0.0	0.0	0.0	3.7	0	20	80	0	0.90	74.0	10000
36	351.00	0.0	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	20	80	0	0.73	73.4	25000
37	438.00	30.8	69.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	20	80	0	0.80	71.4	40220
39	113.00	6.8	0.0	63.6	29.7	0.0	0.0	0.0	0.0	0.0	0	20	80	0	0.56	75.1	50520
40	132.00	0.8	0.0	31.8	67.4	0.0	0.0	0.0	0.0	0.0	0	20	80	0	0.66	76.3	50460
41	36.00	0.0	0.0	57.3	0.0	0.0	0.0	38.5	4.2	0.0	0	20	80	0	0.73	81.0	60100
43	95.00	1.1	0.0	48.4	50.5	0.0	0.0	0.0	0.0	0.0	0	20	80	0	0.51	76.2	50500
44	132.30	0.0	0.0	42.1	50.4	0.0	0.0	0.0	7.5	0.0	0	20	80	0	0.48	77.6	50680

TABLE 4-3
CONTINUED

CUB RUN
SUBBASIN CHARACTERISTICS FOR HYDROLOGIC MODELING FUTURE LAND USE

Subbasin Id.	Area (acres)	Percent Land Use Category FOR/OPEN 1	LLSF 2	LDSF 3	MDSF 4	INSTIT 5	HDR 6	IND/OFF 7	COMM>50 8	COMM<50 9	% Hyd. Soil Group A	B	C	D	Tc (HRS)	Curve No.	EXTRAN Node (HRS)
46	95.00	14.7	0.0	0.0	0.0	0.0	0.0	85.3	0.0	0.0	0	20	80	0	0.32	86.1	50180
47	70.00	0.0	0.0	0.0	4.3	0.0	0.0	95.7	0.0	0.0	0	20	80	0	0.34	88.9	50080
49	97.00	0.0	4.1	79.4	16.5	0.0	0.0	0.0	0.0	0.0	0	20	80	0	0.60	75.1	0
50	68.00	0.0	0.0	0.0	0.0	0.0	0.0	100.0	0.0	0.0	0	20	80	0	0.46	89.4	50180
52	94.00	0.0	0.0	78.7	5.3	16.0	0.0	0.0	0.0	0.0	0	20	80	0	0.72	76.0	50300
53	98.00	4.1	0.0	55.1	40.8	0.0	0.0	0.0	0.0	0.0	0	20	80	0	0.60	75.7	50350
54	328.00	0.0	0.0	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0	20	80	0	0.61	74.6	50600
56	68.00	0.0	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	20	80	0	0.54	73.4	10000
61	201.00	0.0	0.0	0.0	0.0	0.0	0.0	100.0	0.0	0.0	0	20	80	0	0.31	89.4	20660
62	77.00	0.0	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	20	80	0	0.91	73.4	40060
19	226.00	46.0	2.2	5.3	30.1	0.0	0.0	16.4	0.0	0.0	0	20	80	0	0.82	74.5	30200
63	248.80	3.4	0.0	11.1	84.7	0.0	0.0	0.8	0.0	0.0	0	20	80	0	1.39	77.3	30200
64	427.40	9.2	0.0	44.7	6.0	0.0	0.0	35.0	0.0	5.1	0	20	80	0	0.78	80.3	20520
1200	515.00	2.0	0.0	30.9	27.9	2.3	6.3	25.0	0.0	5.6	0	20	80	0	0.59	81.0	20700

TABLE 4-3
CONTINUED

CUB RUN
SUBBASIN CHARACTERISTICS FOR HYDROLOGIC MODELING FUTURE LAND USE

Subbasin Id.	Area (acres)	Percent Land Use Category: FOR/OPEN 1	LLSF 2	LDSF 3	MDSF 4	INSTIT 5	HDR 6	IND/OFF 7	COMM>50 8	COMM<50 9	% Hyd. Soil Group: A	B	C	D	Tc (HRS)	Curve No.	EXTRAN Node
110	97.88	22.6	77.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	20	80	0	0.56	72.0	15000
120	190.00	7.5	58.0	21.0	3.2	0.0	0.0	0.0	0.0	10.3	0	20	80	0	0.55	75.5	15000
130	108.00	35.1	36.9	5.3	0.0	1.6	21.1	0.0	0.0	0.0	0	20	80	0	0.42	73.8	20000
140	223.00	0.0	0.0	78.9	0.0	0.0	20.6	0.5	0.0	0.0	0	20	80	0	0.33	76.7	20060
150	170.00	0.0	0.0	31.2	4.6	0.0	37.0	20.2	0.0	7.0	0	20	80	0	0.44	82.9	20060
165	335.00	3.2	0.0	44.0	0.2	2.5	3.7	8.6	0.0	37.8	0	20	80	0	0.59	83.8	20140
185	169.00	76.0	0.0	1.1	22.0	0.0	0.9	0.0	0.0	0.0	0	20	80	0	1.41	69.7	23000
200	199.70	2.7	41.1	12.0	9.8	0.0	34.4	0.0	0.0	0.0	0	20	80	0	0.46	77.7	25000
210	84.90	83.7	16.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	20	80	0	1.01	68.0	30000
220	90.60	2.5	97.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	20	80	0	0.65	73.2	33000
245	180.58	11.1	0.0	12.4	45.8	0.0	30.7	0.0	0.0	0.0	0	20	80	0	0.42	78.4	20200
250	132.00	37.9	0.0	10.8	0.0	6.8	5.0	0.0	11.4	28.1	0	20	80	0	0.76	80.5	20260
260	165.00	35.6	0.0	18.4	30.6	0.0	5.2	0.0	0.0	10.2	0	20	80	0	0.71	75.5	20340
270	102.00	97.7	0.0	0.0	2.3	0.0	0.0	0.0	0.0	0.0	0	20	80	0	0.62	67.3	20280
285	185.00	70.6	0.0	24.3	0.0	0.0	5.1	0.0	0.0	0.0	0	20	80	0	0.62	69.8	20200
305	108.60	1.9	0.0	1.9	96.2	0.0	0.0	0.0	0.0	0.0	0	20	80	0	0.55	77.7	30200
325	312.61	4.6	18.0	36.3	41.1	0.0	0.0	0.0	0.0	0.0	0	20	80	0	1.59	75.4	30000
330	182.40	53.1	4.4	17.1	25.4	0.0	0.0	0.0	0.0	0.0	0	20	80	0	0.82	71.4	30000
340	206.70	47.6	0.0	51.2	1.2	0.0	0.0	0.0	0.0	0.0	0	20	80	0	0.46	71.0	20400
350	285.00	6.3	93.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	20	80	0	1.02	73.0	33000
365	179.00	15.9	84.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	20	80	0	0.81	72.4	35000
380	171.00	39.8	28.6	31.6	0.0	0.0	0.0	0.0	0.0	0.0	0	20	80	0	0.47	71.2	35000
390	96.00	0.0	71.0	0.0	29.0	0.0	0.0	0.0	0.0	0.0	0	20	80	0	0.50	74.7	50040
405	313.00	0.0	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	20	80	0	0.69	73.4	40060
420	155.00	50.3	49.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	20	80	0	0.60	70.2	51500
440	215.00	0.0	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	20	80	0	0.83	73.4	40120
450	223.00	19.0	81.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	20	80	0	0.98	72.2	40180
463	290.00	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	20	80	0	1.03	67.0	40220
465	5050.00	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	20	80	0	2.99	67.0	40180
485	308.00	17.9	0.0	78.3	0.0	3.8	0.0	0.0	0.0	0.0	0	20	80	0	0.56	73.5	20560
505	541.00	3.8	0.0	63.8	23.4	0.0	2.7	0.0	0.0	6.3	0	20	90	0	0.12	76.7	50620
555	343.00	12.2	0.0	15.2	55.7	0.3	0.0	10.8	0.0	5.8	0	20	80	0	0.63	78.4	20700
575	647.00	14.7	0.0	10.5	56.8	4.3	3.6	5.6	0.0	4.5	0	20	80	0	0.43	77.9	20660
590	133.00	14.3	0.0	4.5	81.2	0.0	0.0	0.0	0.0	0.0	0	20	80	0	0.42	76.3	50350
600	151.00	0.0	0.0	14.6	11.9	0.0	49.0	0.0	0.0	24.5	0	20	80	0	0.56	85.0	50420
620	502.00	16.1	83.7	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0	20	80	0	1.12	72.4	40180
640	150.00	21.3	78.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	20	80	0	1.04	72.0	51500
650	191.00	0.0	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	20	80	0	0.64	73.4	57000
660	180.00	5.0	84.4	0.0	0.0	0.0	0.0	10.6	0.0	0.0	0	20	80	0	0.88	74.8	60000
670	137.20	23.6	76.0	0.0	0.0	0.0	0.0	0.4	0.0	0.0	0	20	80	0	0.50	72.0	70000
675	785.00	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	20	80	0	1.48	67.0	75000
685	393.20	42.0	0.0	0.0	0.0	0.0	0.0	55.2	0.0	2.8	0	20	80	0	1.23	80.1	74000
700	2350.00	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	20	80	0	1.87	67.0	75000
710	801.00	81.7	0.0	0.0	0.0	0.0	0.0	18.3	0.0	0.0	0	20	80	0	1.16	71.1	75000
725	227.50	0.0	0.0	0.0	0.0	0.0	0.0	99.5	0.0	0.5	0	20	80	0	0.85	89.4	74000
740	122.00	28.7	0.0	0.0	0.0	0.0	0.0	61.5	0.0	9.8	0	20	80	0	0.74	83.5	74000
770	81.00	0.0	0.0	0.0	0.0	0.0	0.0	100.0	0.0	0.0	0	20	80	0	0.60	89.4	60000
775	472.00	22.9	0.0	0.0	0.0	0.0	0.0	53.2	0.0	23.9	0	20	80	0	0.80	85.6	70040
780	208.60	1.1	0.0	0.0	0.0	0.0	0.0	98.9	0.0	0.0	0	20	80	0	0.47	89.2	60060

TABLE 4-3
CONTINUED

CUB RUN
SUBBASIN CHARACTERISTICS FOR HYDROLOGIC MODELING FUTURE LAND USE

Subbasin Id.	Area (acres)	Percent Land Use Category FOR/OPEN 1	LLSF 2	LDSF 3	HDSF 4	INSTIT 5	HDR 6	IND/OFF 7	COMM>50 8	COMM<50 9	% Hyd. Soil Group A	B	C	D	Tc (HRS)	Curve No.	EXTRAN Node
790	192.00	0.0	28.1	0.0	0.0	0.0	0.0	71.9	0.0	0.0	0	20	80	0	0.32	84.9	57000
800	111.00	0.0	89.2	0.0	0.0	0.0	0.0	10.8	0.0	0.0	0	20	80	0	0.54	75.1	53500
810	187.00	0.0	1.1	0.0	0.0	0.0	0.0	98.9	0.0	0.0	0	20	80	0	0.24	89.2	55000
815	111.90	12.0	86.7	0.0	0.0	0.0	0.0	1.3	0.0	0.0	0	20	80	0	0.72	72.8	53000
820	152.00	8.3	59.8	0.0	5.2	2.6	0.0	24.1	0.0	0.0	0	20	80	0	0.43	77.2	50060
830	125.00	0.0	0.0	0.0	100.0	0.0	0.0	0.0	0.0	0.0	0	20	80	0	0.55	78.0	50120
845	185.10	0.0	0.0	0.0	77.4	0.0	0.0	22.6	0.0	0.0	0	20	80	0	0.31	80.6	50120
865	252.00	0.0	0.0	0.0	0.0	0.4	0.0	99.6	0.0	0.0	0	20	80	0	0.40	89.4	50220
885	148.80	1.7	0.0	0.0	0.0	0.0	0.0	95.6	2.7	0.0	0	20	80	0	0.39	89.1	60060
920	487.60	0.6	2.2	11.6	0.2	0.0	0.0	63.8	1.6	20.0	0	20	80	0	0.93	88.3	60100
930	134.00	0.0	0.0	18.6	0.0	4.5	15.6	60.5	0.0	0.8	0	20	80	0	0.19	85.7	50460
935	85.00	0.0	0.0	0.0	0.0	0.0	0.0	100.0	0.0	0.0	0	20	80	0	0.35	89.4	50290
940	128.00	1.6	0.0	75.0	19.5	0.0	0.0	3.9	0.0	0.0	0	20	80	0	0.45	75.7	50300
950	104.00	5.8	0.0	31.7	28.8	0.0	33.7	0.0	0.0	0.0	0	20	80	0	0.56	78.6	50400
960	234.00	1.3	0.0	2.1	0.0	0.0	0.0	96.6	0.0	0.0	0	20	80	0	0.72	88.8	70140
965	241.00	16.2	0.0	0.0	0.0	0.0	0.0	83.8	0.0	0.0	0	20	80	0	0.37	85.8	70200
970	53.00	0.0	0.0	9.4	90.6	0.0	0.0	0.0	0.0	0.0	0	20	80	0	0.37	77.7	50500
980	119.09	0.0	0.0	60.9	39.1	0.0	0.0	0.0	0.0	0.0	0	20	80	0	0.50	75.9	50580
1000	114.00	0.0	0.0	75.5	24.5	0.0	0.0	0.0	0.0	0.0	0	20	80	0	0.32	75.4	50580
1005	160.00	0.0	0.0	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0	20	80	0	0.65	74.6	50600
1010	73.90	0.0	0.0	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0	20	80	0	0.65	74.6	50600
1070	121.00	14.0	0.0	81.0	0.0	0.0	5.0	0.0	0.0	0.0	0	20	80	0	0.51	74.0	20340
1080	65.00	0.0	0.0	0.0	0.0	0.0	0.0	100.0	0.0	0.0	0	20	80	0	0.25	89.4	50280
1090	53.00	1.9	0.0	0.0	98.1	0.0	0.0	0.0	0.0	0.0	0	20	80	0	0.57	77.8	20460
1100	102.00	2.5	0.0	40.9	0.0	0.0	3.4	53.2	0.0	0.0	0	20	80	0	0.34	82.6	20700
1110	174.00	7.1	21.3	0.0	3.3	0.0	22.9	45.4	0.0	0.0	0	20	80	0	0.46	83.0	20700
1140	186.00	0.0	0.0	72.6	1.6	0.0	25.8	0.0	0.0	0.0	0	20	80	0	0.82	77.3	0
1400	149.00	4.6	0.0	29.3	0.0	0.0	0.0	56.2	0.0	9.9	0	20	80	0	0.45	84.6	20700
2030	513.00	24.5	0.0	1.8	3.1	0.0	0.0	70.6	0.0	0.0	0	20	80	0	0.91	83.3	75000
2040	674.60	75.1	16.9	0.0	0.0	0.0	0.0	8.0	0.0	0.0	0	20	80	0	1.33	69.9	74000
2050	153.40	0.3	0.0	0.0	0.0	0.0	0.0	99.7	0.0	0.0	0	20	80	0	0.54	89.3	60060
2060	214.70	2.8	0.0	9.5	79.2	0.0	8.0	0.0	0.0	0.5	0	20	80	0	0.48	78.0	50350
2070	240.10	0.0	0.0	55.4	32.5	0.0	0.0	0.0	12.1	0.0	0	20	80	0	0.48	77.9	50680
2080	213.00	0.0	7.5	17.4	0.0	0.0	0.0	75.1	0.0	0.0	0	20	80	0	0.70	85.6	50280
33	258.00	34.3	0.0	39.7	0.0	7.0	0.0	7.8	0.0	11.2	0	20	80	0	0.90	76.0	20700

TABLE 4-4

LITTLE ROCKY RUN
SUBBASIN CHARACTERISTICS FOR HYDROLOGIC MODELING FUTURE LAND USE

Subbasin Id.	Area (acres)	Percent Land Use Category FOR/OPEN 1	LLSF 2	LDSF 3	MDSF 4	INSTIT 5	HDR 6	IND/OFF 7	COMM>50 8	COMM<50 9	% Hyd. Soil Group A	B	C	D	Tc (HRS)	Curve Number	EXTRAN Node
2	194.0	0.0	0.0	46.0	52.0	0.0	2.1	0.0	0.0	0.0	0	0	25	75	0.72	82.5	13000
5	55.0	0.0	1.8	0.0	18.2	0.0	80.0	0.0	0.0	0.0	0	0	25	75	0.39	87.3	20000
6	285.6	0.0	6.9	93.1	0.0	0.0	0.0	0.0	0.0	0.0	0	0	25	75	0.55	80.7	33200
7	47.0	0.0	0.0	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0	25	75	0.66	80.8	31000
8	137.0	1.5	0.0	97.8	0.0	0.0	0.0	0.0	0.0	0.7	0	75	25	0	0.47	68.0	33000
9	56.0	0.0	92.3	0.0	0.0	0.0	0.0	0.0	0.0	7.7	0	75	25	0	0.38	68.4	33000
10	102.0	0.0	0.0	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0	25	75	0.49	80.8	33200
11	54.0	0.0	0.0	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0	25	75	0.67	80.8	23300
12	65.0	17.7	0.0	60.8	0.0	0.0	0.0	0.0	0.0	21.5	0	75	25	0	0.26	72.0	33000
13	118.0	0.0	0.0	77.1	22.9	0.0	0.0	0.0	0.0	0.0	0	0	25	75	0.56	81.4	23300
15	179.0	6.9	0.0	80.2	0.0	0.0	0.0	0.0	0.0	12.9	0	75	25	0	0.57	70.7	29000
16	115.0	0.0	0.0	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0	75	25	0	0.72	68.0	27000
17	365.0	21.7	0.0	77.3	0.0	0.0	0.0	0.0	0.0	1.0	0	75	25	0	0.69	66.3	33000
19	60.4	0.0	0.0	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0	25	75	0.46	80.8	33200
110	247.0	11.2	8.8	26.6	53.4	0.0	0.0	0.0	0.0	0.0	0	0	25	75	0.36	81.6	12000
120	78.0	16.7	2.6	0.0	76.9	0.0	3.8	0.0	0.0	0.0	0	0	25	75	0.34	82.4	20000
210	165.0	4.9	5.5	0.6	89.0	0.0	0.0	0.0	0.0	0.0	0	0	25	75	0.55	83.1	21000
220	121.0	5.0	0.8	0.0	7.4	0.0	86.8	0.0	0.0	0.0	0	0	25	75	0.33	87.2	21000
230	156.0	10.3	14.1	0.6	71.8	0.0	3.2	0.0	0.0	0.0	0	0	25	75	0.44	82.4	23000
240	251.0	42.6	2.4	29.5	25.5	0.0	0.0	0.0	0.0	0.0	0	0	25	75	0.76	79.1	23000
310	133.0	12.8	82.7	3.0	0.0	0.0	0.0	0.0	0.0	1.5	0	75	25	0	0.46	65.8	30500
320	233.0	21.5	0.0	75.1	0.0	0.0	0.0	0.0	0.0	3.4	0	75	25	0	0.44	66.9	25000
330	109.0	10.1	89.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	75	25	0	0.42	65.5	31000
350	139.0	13.7	23.7	5.8	55.4	0.0	0.0	0.0	0.0	1.4	0	75	25	0	0.38	69.2	26000
380	157.0	1.9	0.0	97.5	0.0	0.0	0.0	0.0	0.0	0.6	0	75	25	0	0.52	68.0	33200
1005	55.0	0.0	0.0	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0	25	75	0.43	80.8	12000
1006	79.0	0.0	0.0	53.9	46.1	0.0	0.0	0.0	0.0	0.0	0	0	25	75	0.48	82.1	12000
1007	26.0	0.0	0.0	1.2	98.8	0.0	0.0	0.0	0.0	0.0	0	0	25	75	0.49	83.7	13000
1008	24.0	0.0	0.0	0.0	100.0	0.0	0.0	0.0	0.0	0.0	0	0	25	75	0.38	83.8	13000
1009	32.0	0.0	0.0	0.0	100.0	0.0	0.0	0.0	0.0	0.0	0	0	25	75	0.41	83.8	20000
1010	99.0	0.0	0.0	24.6	75.4	0.0	0.0	0.0	0.0	0.0	0	0	25	75	0.50	83.0	20000
1014	50.0	0.0	7.2	8.8	84.0	0.0	0.0	0.0	0.0	0.0	0	0	25	75	0.71	83.2	21000

TABLE 4-5

DIFFICULT RUN
SUBBASIN CHARACTERISTICS FOR HYDROLOGIC MODELING FUTURE LAND USE

Subbasin Id.	Area (acres)	Percent Land Use Category: FOR/OPEN 1	LLSF 2	LDSF 3	MDSF 4	INSTIT 5	HDR 6	IND/OFF 7	COMM>50 8	COMM<50 9	% Hyd. Soil Group: A	B	C	D	Tc (HRS)	Curve Number	EXTRAN Node
1	228.0	0.5	16.2	83.3	0.0	0.0	0.0	0.0	0.0	0.0		50	50		0.85	70.7	20760
2	246.0	4.1	0.0	94.3	1.6	0.0	0.0	0.0	0.0	0.0		50	50		0.58	70.7	20620
3	86.0	0.0	17.4	32.6	5.8	0.0	0.0	44.2	0.0	0.0		50	50		0.29	78.7	20620
4	205.0	0.0	98.0	0.0	0.0	0.0	0.0	0.0	0.0	2.0		50	50		0.60	70.0	20740
5	376.0	7.4	33.0	59.6	0.0	0.0	0.0	0.0	0.0	0.0		50	50		0.68	69.9	20900
6	83.0	0.0	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0		50	50		0.38	69.5	20150
7	277.0	1.8	43.3	45.1	0.0	0.0	0.0	0.0	0.0	9.8		50	50		0.66	72.5	20800
9	307.0	1.7	49.8	47.5	0.0	1.0	0.0	0.0	0.0	0.0		80	20		0.57	66.4	17000
10	134.0	6.7	7.5	85.8	0.0	0.0	0.0	0.0	0.0	0.0		80	20		0.48	66.6	22000
11	69.0	0.0	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0		80	20		0.40	65.6	32000
12	165.0	1.8	98.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0		50	50		0.56	69.4	25300
13	184.0	0.0	64.7	0.0	0.0	0.0	0.0	35.3	0.0	0.0		80	20		0.41	73.4	25900
14	153.0	0.0	99.3	0.0	0.0	0.0	0.0	0.0	0.0	0.7		50	50		0.81	69.7	25700
15	93.0	0.0	0.0	100.0	0.0	0.0	0.0	0.0	0.0	0.0		50	50		0.86	71.0	25700
16	91.0	50.5	49.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0		80	20		0.78	61.8	25900
17	76.0	1.3	34.2	64.5	0.0	0.0	0.0	0.0	0.0	0.0		80	20		0.40	66.7	30100
18	70.0	1.1	34.5	64.4	0.0	0.0	0.0	0.0	0.0	0.0		80	20		0.57	66.7	10400
19	100.0	1.0	72.0	27.0	0.0	0.0	0.0	0.0	0.0	0.0		80	20		0.34	66.0	10350
20	357.0	1.7	79.0	19.3	0.0	0.0	0.0	0.0	0.0	0.0		80	20		0.68	65.8	10200
21	97.0	2.1	95.8	2.1	0.0	0.0	0.0	0.0	0.0	0.0		80	20		0.46	65.5	10200
23	54.0	19.6	80.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0		80	20		0.35	64.1	50000
24	114.0	3.5	9.8	60.7	0.0	0.0	0.0	26.0	0.0	0.0		80	20		0.24	72.1	43500
25	73.0	1.4	64.4	15.0	0.0	0.0	0.0	0.0	0.0	19.2		80	20		0.66	71.3	35000
26	244.0	29.5	0.0	70.5	0.0	0.0	0.0	0.0	0.0	0.0		80	20		0.39	64.6	35500
27	84.0	1.2	98.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0		80	20		0.40	65.5	40000
28	93.0	0.0	5.4	83.9	7.5	3.2	0.0	0.0	0.0	0.0		80	20		0.58	68.0	30880
29	285.0	3.5	0.0	67.2	2.1	8.2	19.0	0.0	0.0	0.0		80	20		0.61	70.6	40250
30	549.0	5.3	0.0	92.3	1.9	0.0	0.0	0.0	0.0	0.0		80	20		0.67	66.7	60400
31	295.0	7.5	0.0	77.3	5.8	0.0	0.0	0.0	0.0	9.4		80	20		0.40	69.5	61100
32	109.0	26.6	0.0	73.4	0.0	0.0	0.0	0.0	0.0	0.0		90	10		0.51	63.6	70000
33	52.0	5.8	0.0	94.2	0.0	0.0	0.0	0.0	0.0	0.0		90	10		0.43	65.6	70000
34	55.0	7.3	0.0	92.7	0.0	0.0	0.0	0.0	0.0	0.0		80	20		0.50	66.7	66000
35	100.0	3.0	2.0	95.0	0.0	0.0	0.0	0.0	0.0	0.0		80	20		0.47	67.1	66000
36	231.0	6.5	0.0	93.5	0.0	0.0	0.0	0.0	0.0	0.0		90	10		0.61	65.6	61550
37	111.0	0.0	33.3	0.0	0.0	0.0	0.0	66.7	0.0	0.0		80	20		0.27	80.3	50160
38	116.0	24.4	0.0	75.6	0.0	0.0	0.0	0.0	0.0	0.0		80	20		0.51	65.1	50140
39	250.0	25.9	0.0	74.1	0.0	0.0	0.0	0.0	0.0	0.0		80	20		0.64	65.0	50410

TABLE 4-5
(CONTINUED)

DIFFICULT RUN
SUBBASIN CHARACTERISTICS FOR HYDROLOGIC MODELING FUTURE LAND USE

Subbasin Id.	Area (acres)	Percent Land Use Category: FOR/OPEN 1	LLSF 2	LDSF 3	MDSF 4	INSTIT 5	HDR 6	IND/OFF 7	COMM>50 8	COMM<50 9	% Hyd. Soil Group: A	B	C	D	Tc (HRS)	Curve Number	HYTRAN Node
40	305.0	3.3	0.0	96.7	0.0	0.0	0.0	0.0	0.0	0.0		80	20		0.49	67.1	50660
41	314.0	21.3	0.0	78.7	0.0	0.0	0.0	0.0	0.0	0.0		80	20		0.48	65.4	50660
43	92.0	58.7	0.0	41.3	0.0	0.0	0.0	0.0	0.0	0.0		80	20		0.41	61.9	50280
45	309.0	10.4	0.0	85.8	0.0	0.0	3.9	0.0	0.0	0.0		90	10		0.62	65.8	76100
46	277.0	0.0	0.0	70.4	0.0	0.0	0.0	18.8	0.0	10.8		90	10		1.13	73.2	74000
47	111.0	0.9	0.0	12.6	0.0	0.0	0.0	36.0	50.5	0.0		90	10		0.31	85.9	80000
49	182.0	0.0	0.0	29.0	50.0	0.0	21.0	0.0	0.0	0.0		90	10		0.34	71.6	80000
51	482.5	1.5	89.9	8.6	0.0	0.0	0.0	0.0	0.0	0.0		80	20		0.64	65.6	43000
52	375.0	4.3	27.5	46.1	0.0	0.0	0.0	8.2	0.0	13.9		80	20		0.86	71.9	35000
54	97.0	2.1	0.0	81.4	0.0	0.0	0.0	0.0	0.0	16.5		80	20		0.40	71.6	30350
56	92.0	0.0	80.7	0.0	0.0	19.3	0.0	0.0	0.0	0.0		80	20		0.55	67.9	55000
58	78.0	0.0	0.0	100.0	0.0	0.0	0.0	0.0	0.0	0.0		80	20		0.47	67.4	50410
59	80.0	6.0	0.0	94.0	0.0	0.0	0.0	0.0	0.0	0.0		80	20		0.64	56.8	63000
61	153.0	16.0	1.0	32.0	0.0	0.0	0.0	51.0	0.0	0.0		80	20		0.48	76.2	50220
64	114.0	6.1	0.0	93.9	0.0	0.0	0.0	0.0	0.0	0.0		50	50		0.57	70.5	20560
65	59.0	0.0	47.5	52.5	0.0	0.0	0.0	0.0	0.0	0.0		80	20		0.52	66.5	30100
66	130.0	10.0	0.0	90.0	0.0	0.0	0.0	0.0	0.0	0.0		80	20		0.63	66.5	10700
68	80.0	0.0	0.0	100.0	0.0	0.0	0.0	0.0	0.0	0.0		80	20		0.42	67.4	50280
69	101.0	30.7	3.0	10.9	0.0	0.0	0.0	55.4	0.0	0.0		80	20		0.20	75.7	50280
70	195.0	0.0	0.0	14.9	0.0	0.0	85.1	0.0	0.0	0.0		90	10		0.50	78.5	76100
71	209.0	6.7	0.0	92.3	0.0	0.0	0.0	0.0	0.0	1.0		80	20		0.45	67.3	50410
72	83.0	1.2	96.4	2.4	0.0	0.0	0.0	0.0	0.0	0.0		80	20		0.54	65.6	56000
73	142.0	2.1	0.0	70.4	25.4	0.0	2.1	0.0	0.0	0.0		80	20		0.35	68.7	40250
74	121.0	9.9	0.0	71.1	19.0	0.0	0.0	0.0	0.0	0.0		80	20		0.55	67.3	40400
75	196.0	0.0	0.0	27.0	0.0	0.0	18.8	10.8	35.4	8.0		90	10		0.42	81.9	77000
76	302.0	0.0	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0		50	50		0.53	69.5	15000
77	210.0	0.0	0.0	56.2	16.7	0.0	0.0	17.6	0.0	9.5		90	10		0.61	73.4	80000
79	215.0	8.8	0.0	91.2	0.0	0.0	0.0	0.0	0.0	0.0		80	20		0.52	66.6	50560
104	146.0	8.1	0.0	91.2	0.0	0.0	0.0	0.0	0.0	0.0		80	20		0.49	66.2	10600
110	107.0	21.9	0.0	78.1	0.0	0.0	0.0	0.0	0.0	0.0		80	20		0.59	66.3	66000
118	312.0	11.9	0.0	88.1	0.0	0.0	0.0	0.0	0.0	0.0		80	20		0.47	66.3	73000
120	1880.6	14.6	2.4	1.6	2.5	0.0	0.0	75.7	3.2	0.0		80	20		1.11	82.1	25900
121	614.3	9.0	0.0	0.0	0.0	0.0	0.0	91.0	0.0	0.0		80	20		1.32	84.9	25900
123	445.4	0.0	0.0	0.0	0.0	0.0	0.0	100.0	0.0	0.0		80	20		0.57	87.5	43500
124	1290.0	2.0	10.0	0.0	0.0	0.0	2.2	85.8	0.0	0.0		80	20		1.37	84.7	43500

TABLE 4-5
(CONTINUED)

DIFFICULT RUN
SUBBASIN CHARACTERISTICS FOR HYDROLOGIC MODELING FUTURE LAND USE

Subbasin Id.	Area (acres)	Percent Land Use Category: FOR/OPEN 1	LLSF 2	LDSF 3	MDSF 4	INSTIT 5	HDR 6	IND/OFF 7	COMM>50 8	COMM<50 9	% Hyd. Soil Group: A	B	C	D	Tc (HRS)	Curve Number	EXTRAN Node
142	249.0	17.9	1.9	55.6	0.0	0.0	0.0	24.6	0.0	0.0		80	20		0.61	70.7	50280
148	154.0	0.6	0.0	19.5	9.7	0.0	7.1	0.0	0.0	63.0		90	10		0.27	85.1	80000
153	251.0	6.8	0.0	7.2	1.2	0.0	6.4	2.4	0.0	76.1		80	20		0.23	88.6	30780
163	240.0	4.7	91.0	4.3	0.0	0.0	0.0	0.0	0.0	0.0		80	20		0.52	65.3	52000
167	263.0	18.3	0.0	18.3	0.0	0.0	15.2	42.6	0.0	24.0		80	20		0.48	95.2	10950
800	377.0	35.6	41.1	0.0	23.3	0.0	0.0	0.0	0.0	0.0		50	50		0.55	68.3	8000
1020	249.0	13.3	85.5	1.2	0.0	0.0	0.0	0.0	0.0	0.0		80	20		0.42	64.6	10200
1040	245.0	10.6	31.0	58.4	0.0	0.0	0.0	0.0	0.0	0.0		80	20		0.39	65.8	10400
1080	308.0	8.4	91.6	0.0	ERR	0.0	0.0	0.0	0.0	0.0		80	20		0.45	65.0	10800
1200	465.0	31.4	68.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0		50	50		0.52	67.3	12000
1500	379.0	24.8	75.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0		50	50		0.43	67.8	15000
2000	340.0	31.4	30.0	38.6	0.0	0.0	0.0	0.0	0.0	0.0		50	50		0.36	67.9	20000
2015	270.0	97.0	3.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0		50	50		0.76	62.7	20150
2046	480.0	24.8	13.3	61.0	0.0	0.0	0.0	0.0	0.0	0.8		50	50		0.84	68.8	20460
2058	351.0	20.3	0.0	73.2	0.0	2.3	0.0	3.7	0.0	0.6		50	50		0.70	70.3	20580
2064	290.0	20.3	0.0	74.5	0.0	0.0	0.0	0.0	0.0	5.2		50	50		0.40	70.5	20620
2070	554.0	4.9	46.4	43.7	0.0	0.0	0.0	1.4	0.0	3.6		50	50		0.62	71.0	20700
2086	549.0	10.0	6.6	83.4	0.0	0.0	0.0	0.0	0.0	0.0		50	50		0.60	70.1	20900
2200	144.0	17.3	5.6	77.1	0.0	0.0	0.0	0.0	0.0	0.0		80	20		0.49	65.7	22000
2530	410.0	13.8	1.7	83.0	0.0	0.0	0.0	0.0	0.0	1.5		50	50		0.36	70.2	25300
2570	485.0	48.9	44.3	6.8	0.0	0.0	0.0	0.0	0.0	0.0		80	20		0.62	62.0	25700
3000	254.0	40.6	22.4	32.7	4.3	0.0	0.0	0.0	0.0	0.0		80	20		0.60	63.4	30000
3025	236.0	22.1	0.0	77.1	0.8	0.0	0.0	0.0	0.0	0.0		80	20		0.32	65.4	30250
3035	589.0	14.1	0.0	84.0	0.0	1.9	0.0	0.0	0.0	6.8		80	20		0.43	72.7	30350
3055	560.0	7.7	0.0	83.2	0.0	2.0	0.0	0.0	0.0	7.1		80	20		0.50	68.8	30600
3068	302.0	24.3	0.0	11.2	18.8	0.0	0.0	24.1	0.0	21.6		80	20		0.44	76.6	30660
3086	296.0	32.0	0.0	68.0	0.0	0.0	0.0	0.0	0.0	0.0		80	20		0.49	64.4	30880
3092	618.9	9.6	0.0	2.4	82.3	0.4	0.0	0.0	0.0	5.3		80	20		0.73	71.7	30920
3094	545.4	5.1	0.0	0.0	88.2	4.0	2.7	0.0	0.0	0.0		80	20		0.34	71.8	30935
3096	750.0	4.0	0.0	0.8	57.5	8.2	10.0	14.1	0.0	5.4		80	20		0.52	76.2	30960

TABLE 4-5
(CONTINUED)

DIFFICULT RUN
SUBBASIN CHARACTERISTICS FOR HYDROLOGIC MODELING FUTURE LAND USE

Subbasin Id.	Area (acres)	Percent Land Use Category: FOR/OPEN 1	LLSF 2	LDSF 3	MDSF 4	INSTIT 5	MDR 6	IND/OFF 7	COMM>50 8	COMM<50 9	% Hyd. Soil Group: A	B	C	D	Tc (HRS)	Curve Number	EXTRAN Node
3100	143.0	37.0	40.6	22.4	0.0	0.0	0.0	0.0	0.0	0.0		80	20		0.39	63.2	31000
3350	220.0	21.4	14.1	48.6	0.0	0.0	0.0	0.0	0.0	15.9		80	20		0.38	69.4	33500
3500	460.0	41.8	0.0	58.2	0.0	0.0	0.0	0.0	0.0	0.0		80	20		0.37	63.5	35000
4010	458.0	36.2	2.4	60.3	1.1	0.0	0.0	0.0	0.0	0.0		80	20		0.35	64.0	40100
4025	588.8	7.6	0.0	89.6	2.2	0.6	0.0	0.0	0.0	0.0		80	20		0.38	66.8	40250
4045	779.0	15.3	0.0	4.2	62.4	3.9	2.3	4.2	0.0	7.7		80	20		0.81	72.5	40400
4150	168.0	44.6	26.2	29.2	0.0	0.0	0.0	0.0	0.0	0.0		80	20		0.29	62.7	40000
4350	369.0	15.7	32.0	0.0	0.0	0.0	0.0	52.3	0.0	0.0		80	20		0.37	75.9	43500
4351	296.0	22.3	77.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0		80	20		0.59	63.9	43500
5000	409.0	23.9	69.0	0.0	0.0	0.0	0.0	7.1	0.0	0.0		80	20		0.57	65.3	50000
5001	301.0	29.1	70.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0		80	20		0.64	63.4	50000
5010	270.0	23.7	7.8	53.7	12.2	0.0	0.0	2.6	0.0	0.0		80	20		0.29	66.1	50100
5016	226.0	9.7	44.2	36.7	0.0	0.0	0.0	9.4	0.0	0.0		80	20		0.32	67.6	50160
5025	275.0	38.4	10.9	50.7	0.0	0.0	0.0	0.0	0.0	0.0		80	20		0.52	63.6	50250
5056	384.0	16.1	0.6	83.3	0.0	0.0	0.0	0.0	0.0	0.0		80	20		0.50	65.9	50560
5063	379.0	14.5	0.0	85.5	0.0	0.0	0.0	0.0	0.0	0.0		80	20		0.64	66.0	50630
5500	245.0	17.5	65.1	10.4	0.0	7.1	0.0	0.0	0.0	0.0		80	20		0.55	65.4	55000
6000	491.0	12.6	4.5	80.7	0.0	0.0	0.0	2.2	0.0	0.0		80	20		0.52	66.6	60000
6110	223.0	19.8	0.0	80.2	0.0	0.0	0.0	0.0	0.0	0.0		80	20		0.43	65.5	61100
6155	325.0	21.0	0.0	64.9	12.2	0.0	0.0	1.5	0.0	0.4		90	10		0.52	65.2	61550
6300	343.0	28.1	3.9	68.0	0.0	0.0	0.0	0.0	0.0	0.0		80	20		0.39	64.7	63000
6600	195.0	32.3	0.0	67.7	0.0	0.0	0.0	0.0	0.0	0.0		80	20		0.49	64.4	66000
7300	405.0	13.9	0.0	86.1	0.0	0.0	0.0	0.0	0.0	0.0		90	10		0.35	64.9	73000
7600	374.0	7.0	0.0	83.7	0.0	9.3	0.0	0.0	0.0	0.0		90	10		0.51	66.5	76000
8000	385.9	8.6	0.0	31.6	21.4	0.0	0.0	10.0	0.0	28.4		90	10		0.54	76.4	80000

TABLE 4-6

HORSEPEN CREEK
SUBBASIN CHARACTERISTICS FOR HYDROLOGIC MODELING FUTURE LAND USE

Subbasin Id.	Area (acres)	Percent Land Use Category FOR/OPEN 1	LLSF 2	LDSF 3	MDSF 4	INSTIT 5	HDR 6	IND/OFF 7	COMM>50 8	COMM<50 9	% Hyd Soil Group A	B	C	D	Tc (HRS)	Curve No.	Extran Node
H-1	76.0	0.0	0.0	46.0	54.0	0.0	0.0	0.0	0.0	0.0	0	0	80	20	0.67	79.6	10600
H-2	101.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0	0.0	0.0	0	0	80	20	0.48	90.6	21000
103	120.0	0.0	0.0	47.0	53.0	0.0	0.0	0.0	0.0	0.0	0	0	80	20	0.72	79.6	30000
104	43.0	0.0	0.0	0.0	100.0	0.0	0.0	0.0	0.0	0.0	0	20	80	0	0.67	78.0	30000
106	624.5	10.6	0.0	51.2	27.6	0.0	0.0	10.6	0.0	0.0	0	0	80	20	0.81	79.5	20300
H-7	78.0	0.0	0.0	18.0	82.0	0.0	0.0	0.0	0.0	0.0	0	20	80	0	0.73	77.4	30100
H-9	100.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0	0.0	0.0	0	0	80	20	0.42	90.6	10500
H-13	291.0	0.0	0.0	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0	20	80	0	0.55	74.6	30100
H-15	239.0	2.0	0.0	1.0	97.0	0.0	0.0	0.0	0.0	0.0	0	20	80	0	0.77	77.7	25000
H-16	80.0	4.0	0.0	96.0	0.0	0.0	0.0	0.0	0.0	0.0	0	20	80	0	0.55	74.3	33000
117	258.0	0.0	0.0	26.3	9.0	0.0	0.0	40.7	0.0	24.0	0	0	80	20	0.78	87.5	10600
H-18	152.5	11.0	0.0	0.0	89.0	0.0	0.0	0.0	0.0	0.0	0	0	80	20	0.77	79.9	20300
119	279.0	0.0	0.0	0.0	13.0	0.0	47.0	36.0	0.0	4.0	0	0	80	20	1.09	87.7	0
1000	191.5	0.0	0.0	43.0	25.0	0.0	1.0	12.0	0.0	19.0	0	0	80	20	0.38	83.6	0
1020	138.5	14.5	0.0	34.9	0.0	0.0	0.0	50.6	0.0	0.0	0	0	80	20	0.26	83.4	10400
1050	270.0	9.0	0.0	54.0	0.0	0.0	0.0	29.0	0.0	8.0	0	0	80	20	0.64	82.4	10500
1700	498.5	7.5	0.0	60.0	0.0	0.0	0.0	32.5	0.0	0.0	0	0	80	20	0.37	81.6	18000
2020	374.0	9.0	0.0	78.0	0.0	0.0	0.0	11.0	0.0	2.0	0	0	80	20	0.87	79.1	20300
2100	330.0	12.0	0.0	54.0	1.0	0.0	0.0	32.0	0.0	1.0	0	0	80	20	0.46	81.4	21000
2300	276.0	10.0	0.0	23.0	46.0	0.0	0.0	16.0	0.0	5.0	0	0	80	20	0.60	81.6	23000
3000	154.0	9.0	0.0	21.0	70.0	0.0	0.0	0.0	0.0	0.0	0	20	80	0	0.71	76.3	30100
3100	204.0	12.0	0.0	44.0	44.0	0.0	0.0	0.0	0.0	0.0	0	0	80	20	0.82	78.5	31000
3300	386.0	8.6	0.0	62.7	5.2	0.0	0.0	21.8	0.0	1.7	0	0	80	20	0.54	80.6	33000
3301	396.0	7.5	0.0	89.0	2.5	0.0	0.0	0.0	0.0	1.0	0	20	80	0	0.70	74.3	33000
3010	212.0	0.0	0.0	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0	20	80	0	0.55	74.6	30100

TABLE 4-7

SUGARLAND RUN
SUBBASIN CHARACTERISTICS FOR HYDROLOGIC MODELING FUTURE LAND USE

Subbasin Id.	Area (acres)	Percent Land Use Category: FOR/OPEN 1	LLSF 2	LDSF 3	MDSF 4	INSTIT 5	HDR 6	IND/OFF 7	COMM>50 8	COMM<50 9	% Hyd. Soil Group: A	B	C	D	Tc (HRS)	Curve No.	Extran Node
1	77.0	0.0	0.0	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0	50	50	0	0.59	71.0	18000
2	142.0	0.0	0.0	83.1	0.0	0.0	0.0	16.9	0.0	0.0	0	50	50	0	0.44	74.0	21200
4	55.0	0.0	0.0	0.0	85.4	0.0	14.6	0.0	0.0	0.0	0	50	50	0	0.68	76.2	18400
5	264.0	6.8	2.2	84.1	0.0	0.4	0.0	0.0	0.0	6.5	0	50	50	0	0.56	72.0	9000
7	453.0	3.4	0.0	78.5	11.6	2.7	0.0	0.0	0.0	3.8	0	50	50	0	0.65	72.3	18000
900	213.0	5.6	7.5	79.4	0.0	0.0	0.0	0.0	0.0	7.5	0	50	50	0	0.64	72.2	9000
1000	150.0	7.3	0.0	90.7	0.0	0.0	0.0	0.0	0.0	2.0	0	50	50	0	0.44	70.8	11000
1110	687.0	6.3	0.0	34.9	7.3	0.0	40.5	1.2	0.0	9.8	0	50	50	0	0.67	78.1	11000
1430	796.0	0.0	0.0	47.7	20.9	0.0	31.4	0.0	0.0	0.0	0	50	50	0	0.84	75.6	14300
1700	279.0	22.6	0.0	35.8	41.6	0.0	0.0	0.0	0.0	0.0	0	50	50	0	0.41	70.7	15000
1800	221.0	17.2	0.0	24.0	58.8	0.0	0.0	0.0	0.0	0.0	0	50	50	0	0.47	71.9	18000
1820	339.0	12.7	0.0	13.0	74.3	0.0	0.0	0.0	0.0	0.0	0	50	50	0	0.49	72.9	18100
1840	159.0	11.9	0.0	5.7	19.5	5.7	57.2	0.0	0.0	0.0	0	50	50	0	0.55	78	18400
1860	312.0	0.0	0.0	33.8	51.6	0.0	14.6	0.0	0.0	0.0	0	50	50	0	0.64	75	18600
1870	541.0	15.9	0.0	0.0	8.9	1.3	66.9	0.0	0.0	7.0	0	50	50	0	0.79	79.8	18600
1871	436.0	4.5	0.0	0.0	4.5	1.6	79.6	0.0	0.0	9.8	0	50	50	0	0.77	83	18600
2100	249.0	10.3	0.0	33.5	39.3	0.0	0.0	16.9	0.0	0.0	0	50	50	0	0.49	74.7	21000
2120	184.0	0.0	0.0	40.5	1.1	0.0	0.0	58.4	0.0	0.0	0	50	50	0	0.62	81.3	21200
2200	295.0	11.9	0.0	8.1	45.1	34.9	0.0	0.0	0.0	0.0	0	50	50	0	0.41	75	22000
2300	554.0	2.7	0.0	22.8	2.7	0.0	0.0	71.5	0.0	0.3	0	50	50	0	0.37	83.5	24000
2400	450.0	9.2	0.0	16.3	10.4	0.7	44.2	7.6	0.0	11.6	0	50	50	0	0.70	80.1	24000
2700	1014.0	8.3	0.0	22.2	0.0	0.9	14.6	41.6	0.0	12.4	0	50	50	0	0.58	82.3	27000
2800	484.0	0.7	0.0	6.7	24.9	0.0	16.3	43.0	0.0	8.4	0	50	50	0	0.60	83.4	29000
2900	677.0	4.4	0.0	47.8	7.1	0.0	0.0	39.0	0.0	1.7	0	50	50	0	0.57	78.1	30000

TABLE 4-8

POHICK CREEK
SUBBASIN CHARACTERISITCS FOR HYDROLOGIC MODELING FUTURE LAND USE

Subbasin Id.	Area (acres)	Percent Land Use Category FOR/OPEN 1	LLSF 2	LDSF 3	MDSF 4	INSTIT 5	HDR 6	IND/OFF 7	COMM>50 8	COMM<50 9	% Hyd. Soil Group A	B	C	D	Tc (HRS)	Curve No.	Extran Node
1	137.00	8.0	0.0	87.6	0.0	0.0	0.0	4.4	0.0	0.0	0	90	10	0	0.26	66	0
2	205.00	0.0	0.0	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0	90	10	0	0.50	66	0
3	72.00	0.0	0.0	89.0	11.0	0.0	0.0	0.0	0.0	0.0	0	90	10	0	0.47	67	0
4	226.00	0.0	0.0	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0	90	10	0	0.49	66	0
5	51.00	0.0	0.0	67.0	33.0	0.0	0.0	0.0	0.0	0.0	0	90	10	0	0.42	68	0
6	184.00	3.0	0.0	97.0	0.0	0.0	0.0	0.0	0.0	0.0	0	90	10	0	0.57	66	0
7	122.00	17.2	0.0	82.8	0.0	0.0	0.0	0.0	0.0	0.0	0	90	10	0	0.55	65	0
8	110.00	0.0	4.8	95.2	0.0	0.0	0.0	0.0	0.0	0.0	0	90	10	0	0.57	66	0

TABLE 4-9

LONG BRANCH
SUBBASIN CHARACTERISTICS FOR HYDROLOGIC MODELING FUTURE LAND USE

Subbasin	Area	Percent Land Use Category									% Hyd Soil Group				Tc	Curve	Extran
Id.	(acres)	OPEN 1	LLSF 2	LDSF 3	MDSF 4	INST 5	HDR 6	IND 7	COM>50 8	COM<50 9	A	B	C	D	(HRS)	No	Node
1	90.00	0.0	0.0	0.0	100.0	0.0	0.0	0.0	0.0	0.0	0	50	50	0	0.66	75.0	10700
2	94.00	19.1	0.0	0.0	80.9	0.0	0.0	0.0	0.0	0.0	0	50	50	0	0.89	72.6	10700
5	136.00	0.0	0.0	59.0	11.0	0.0	0.0	8.0	0.0	22.0	0	50	50	0	0.69	78.0	10810
6	102.00	0.0	0.0	23.0	31.0	0.0	0.0	22.0	0.0	24.0	0	50	50	0	0.58	81.7	10750
7	128.00	0.0	0.0	46.9	27.3	0.0	0.0	25.8	0.0	0.0	0	50	50	0	0.43	76.6	10610
9	197.60	0.0	0.0	6.4	0.0	57.3	0.0	21.3	0.0	15.0	0	50	50	0	0.63	83.4	20000
10	449.00	11.2	0.0	7.3	21.3	0.0	0.0	25.8	0.0	34.4	0	50	50	0	1.20	83.5	10810
103	114.00	0.0	0.0	38.4	61.6	0.0	0.0	0.0	0.0	0.0	0	50	50	0	0.54	73.5	10100
110	114.00	16.7	0.0	47.4	5.3	0.0	0.0	3.5	0.0	27.1	0	50	50	0	0.49	76.8	10110
111	460.00	5.4	0.0	61.9	3.8	0.8	14.6	12.0	0.0	1.5	0	50	50	0	1.06	75.0	10820
120	191.00	18.3	0.0	30.6	11.2	0.0	9.3	10.1	0.0	20.4	0	50	50	0	0.32	77.6	10200
130	231.00	39.3	0.0	38.5	1.8	0.0	0.0	6.8	0.0	13.6	0	50	50	0	0.46	72.1	10400
140	200.00	14.3	0.0	22.3	4.6	0.0	0.0	41.4	0.0	17.5	0	50	50	0	0.39	81.3	10610
150	153.00	10.5	0.0	82.1	0.0	0.0	0.0	2.0	0.0	5.4	0	50	50	0	0.64	71.7	10650
160	238.00	17.1	0.0	24.6	51.0	0.0	0.0	7.3	0.0	0.0	0	50	50	0	0.48	72.9	10700
170	349.00	5.9	0.0	62.5	7.2	1.5	11.8	9.7	0.0	1.4	0	50	50	0	0.71	74.4	10800
180	121.00	0.0	0.0	74.5	0.0	0.0	0.0	25.5	0.0	0.0	0	50	50	0	0.46	75.5	10820
190	115.00	0.0	0.0	75.9	0.0	0.0	3.1	21.0	0.0	0.0	0	50	50	0	0.99	75.0	10820
200	107.00	16.4	0.0	0.0	0.0	0.0	0.0	51.3	0.0	32.3	0	50	50	0	0.29	86.0	20000
991	54.00	6.9	0.0	0.0	0.0	0.0	0.0	10.0	83.1	0.0	0	50	50	0	0.35	89.2	10200
992	113.00	0.0	0.0	70.1	1.1	0.0	9.1	0.0	0.0	19.7	0	50	50	0	0.67	77.0	20000

In Cub Run watershed, 12 County detention basins were modeled. Table 4-10 gives the name of the County pond and the corresponding model subbasin numbers which are located on the Regional Detention Basin Sites map of Figure 3-1. Seven County detention basins were modeled in Little Rocky Run watershed and these ponds are listed in Table 4-11. The locations of these basins are given on Figure 3-2, Regional Detention Basin Sites. For Difficult Run, two County detention basins and six lakes were modeled using storage-discharge relationships to route upstream hydrographs. Table 4-12 gives a list of the detention basins and lakes. Their locations are shown on Figure 3-3. In Horsepen Run, one County detention pond in Chantilly Highlands was modeled; the corresponding subbasin number is HP-15 and the location is shown on Figure 3-4. No County detention ponds or lakes were modeled for the remaining three watersheds: Pohick Creek, Sugarland Run, and Long Branch.

Data obtained from the design plans were used to develop the storage-discharge relationships for the County detention basins. Design plans or previously developed storage-discharge relationships were used to develop the storage-discharge relationships for the modeled lakes.

Proposed Regional Detention Basins

The routing of inflow hydrographs through the regional detention basins was performed by two different methods, one for conventional design and one for the maximum efficiency detention basins.

Routing for Conventional Design. A conventional detention basin design achieves a peak release rate which is equal to the predevelopment peak flow from the facility drainage area. Hydrograph routing for a conventional design was performed for the proposed detention basins by applying the STORMLINK option to input the specific outflow structure geometry. The model internally generates a storage-discharge relationship used to route the inflow hydrographs base upon the input geometry.

The outflow design for modeling purposes was based on the control of the 10-year and/or 2-year storm, depending on the type of detention basin for a

TABLE 4-10

CUB RUN
EXISTING COUNTY DETENTION BASINS
INCLUDED IN HYDROLOGIC MODEL

Model Subbasin	Name of Development and Basins
CP-1	Centre Ridge: 2A, 2B, 2C (3 ponds in series)
CP-2	Centre Ridge: 1A, 1B (2 ponds in series)
CP-13	Sully Station
CP-27	Krause Property, Sully Business Center
CP-36	Westport Pond 'cd'
CP-52	Waverly Pond
CP-56	Gate Post Estates: Pond No. 2
CP-61	TRW Defense System Park: Pond No. 1
CP-64	Poplar Tree Estates
CP-1200	Fairfax Center Area
CP-1400	Fairfax Center Area: Lake No. 1
CP-34	Newgate

TABLE 4-11

LITTLE ROCKY RUN
EXISTING COUNTY DETENTION BASINS
INCLUDED IN HYDROLOGIC MODEL

Model Subbasin	Name of Development and Basins
RP-6	Little Rocky Run: Basin No. 4
RP-5	Little Rocky Run: Pond
RP-7	Compton Woods: Pond No. 2
RP-8	Compton Woods: Pond No. 3
RP-9	Little Rocky Run: Pond F-3
RP-10	Little Rocky Run: Pond F-2
RP-14	Little Rocky Run (2nd Edition)

TABLE 4-12

DIFFICULT RUN
EXISTING COUNTY DETENTION BASINS AND LAKES
INCLUDED IN HYDROLOGIC MODEL

Model Subbasin	Name of Development and Basins
DP-70	Penderbrook: North Pond
DP-75	Penderbrook: South Pond
	Lakes:
DP-120	Lake Fairfax
DP-121	Lake Anne
DP-124	Lake Audubon
DP-123	Lake Thoreau
DP-4	Woodside Lake
DP-10	Fox Lake
DP-18	Fox Heritage

given site. In all but a few special cases, the outflow geometry was based on a six-inch slot within a riser to control the two-year storm. The length of the slot was adjusted to achieve the required predevelopment peak release rate with the future land use inflow hydrograph. The invert of the two-year slot was placed at the top (plus 0.1 ft for model stability) of the water quality pool whether a wet or extended dry detention basin. Releases from the extended dry zone of the detention basin were not considered in this study as part of the storage-discharge relationship because of their small magnitude. For a detention basin which could only control the two-year storm, the invert of the emergency spillway was placed at the top (plus 0.1 ft) of the two-year pool.

For a detention basin which could also control the 10-year storm, a six-inch slot was also used with the invert placed at the top of the two-year pool. The slot length was adjusted to produce an outflow peak equal to the 10-year predevelopment peak as was done for the two-year storm. The emergency spillway invert was set at the top of the 10-year pool elevation. The emergency spillway lengths were set by determining the length required to pass the emergency spillway storm such that a one-foot freeboard would be maintained between the maximum pool to the top of the dam. The configurations used to model the outflow from the detention basins are <u>for modeling purposes only</u> and do <u>not</u> constitute a detailed riser and emergency spillway design. The development of final designs was outside the scope of this study. Final designs must be developed for each site as the County develops the detailed plans for the regional detention basins. Tables 4-13 through 4-19 show the outlet structure characteristics used to route the flows through the conventional design detention basins. For each watershed, the table gives the detention basin number, the type of detention basin design (2-year or 10-year), and the invert and length of orifice No. 1 which is for the 2-year storm, orifice No. 2 which is for the 10-year storm and the emergency spillway invert and length. The slot height for both the 2-year and 10-year slots was set at 6 inches which is indicated in the table by "(H = 0.5 ft)". As may be seen, orifice No. 2 inverts and lengths (which represent the 10-year control) are not given for the 2-year design detention basins.

TABLE 4-13

CUB RUN
OUTLET STRUCTURE CHARACTERISTICS FOR DETENTION BASINS

BASIN NO.	DESIGN DETENTION	ORIFICE #1 (H = 0.5) INV.	L.	ORIFICE #2 INV.	L.	SPILLWAY INV.	L.
3	EXTDRY-10	255.5	12.0	258.2	20.0	260.9	129.0
4	WET-10	229.9	15.0	231.2	27.0	232.4	54.0
11	EXTDRY-2	253.0	6.5	------	------	255.8	95.0
12	WET-10	254.3	5.0	257.5	14.0	259.0	51.0
21	WET-2	222.8	11.5	------	------	224.2	81.0
23	WET-10	240.6	7.0	242.3	15.0	243.7	53.0
24	WET-10	255.1	18.0	255.9	21.0	256.8	50.0
25	EXTDRY-2	269.8	16.5	------	------	270.9	137.5
39	EXTDRY-2	293.6	9.0	------	------	296.3	53.0
40	EXTDRY-2	283.6	9.0	------	------	286.0	54.0
41	WET-2	275.0	9.0	------	------	276.2	53.0
43	WET-10	315.7	9.5	317.8	18.5	319.3	50.0
44	EXTDRY-2	379.8	17.5	------	------	381.2	68.0
46	WET-10	287.0	17.0	288.9	40.0	289.6	52.0
47	WET-10	248.5	10.0	250.9	31.0	251.9	51.0
50	WET-10	254.9	21.0	257.2	48.5	258.5	90.0
53	EXTDRY-10	313.3	7.5	317.4	16.5	320.2	52.0
62	WET-2	241.3	7.0	------	------	242.8	57.0
63	EXTDRY-2	232.5	15.8	------	------	236.2	78.0

NOTE: C46 IN SERIES WITH C50
C19 IN SERIES WITH C63

NOTE: Conventional design parameters

TABLE 4-13
CONTINUED

CUB RUN
OUTLET STRUCTURE CHARACTERISTICS FOR DETENTION BASINS

BASIN NO.	DESIGN DETENTION	ORIFICE #1 INV.	ORIFICE #1 (H = 0.5) L.	ORIFICE #2 INV.	ORIFICE #2 L.	SPILLWAY INV.	SPILLWAY L.
5	WET-10	190.9	12.0	192.9	18 5	194.9	51.0
18	WET-10	311.4	27	313.8	40	316.2	149.0
19	WET-10	278.3	23.0	279.6	40	280.7	61.0
20	WET-10	355.0	12.5	356.2	17	357.6	54.0
22	EXTDRY-10	221.9	11.5	223.4	13.5	225.3	52.0
28	WET-10	188 8	19.0	190.1	36.0	191.2	52.0
30	WET-10	296.5	13.0	298.0	24.0	299.2	51.0
35	WET-10	189.8	11.5	190.9	16.0	192.1	55.0
37	WET-10	258.8	97.0	259.5	115.0	260.2	155
49	WET-10	210.7	20.0	211.6	28.0	212.4	54.0
54	EXTDRY-10	351.5	34.0	353.5	54.0	355.5	82.6
57	EXTDRY-2	340.3	8.0	------	------	342.4	52.0

NOTE: C57 IS IN SERIES WITH C18
C19 IS IN SERIES WITH C63

NOTE: Conventional design parameters

TABLE 4-14

LITTLE ROCKY RUN
OUTLET STRUCTURE CHARACTERISTICS FOR DETENTION BASINS

BASIN NO.	DESIGN DETENTION	ORIFICE #1 INV.	ORIFICE #1 L.	ORIFICE #2 (H = 0.5) INV.	ORIFICE #2 L.	SPILLWAY INV.	SPILLWAY L.
2	10-WET	195.5	25.0	198.0	20.0	200.0	105.9
5	10-WET	265.7	10.0	267.7	15.0	268.7	51.0
6	2-WET	374.1	60.0	-----	-----	375.7	51.0
7	10-WET	353.8	10.0	355.1	10.0	356.0	55.0
8	10-WET	394.6	8.0	395.7	20.0	397.1	50.0
9	2-WET	376.7	4.0	-----	-----	377.8	52.0
10	2-WET	395.7	24.0	-----	-----	397.0	55.0
11	2-WET	366.0	9.0	-----	-----	367.4	62.0
12	10-WET	403.0	3.5	404.3	20.0	405.7	58.0
13	2-WET	331.3	30.0	-----	-----	333.0	53.0
16	EXTDRY-2	309.5	4.0	-----	-----	311.2	53.0
17	EXTDRY-2	348.7	3.0	-----	-----	350.0	65.0
19	2-WET	380.8	60.0	-----	-----	382.4	50.0

NOTE: Conventional design parameters

TABLE 4-15

DIFFICULT RUN
OUTLET STRUCTURE CHARACTERISTICS FOR DETENTION BASINS

BASIN NO.	DESIGN DETENTION	ORIFICE #1 (H = 0.5) INV.	ORIFICE #1 L.	ORIFICE #2 INV.	ORIFICE #2 L.	SPILLWAY INV.	SPILLWAY L.
1	EXTDRY-10	370.2	9.0	372.7	25.0	374.8	75.0
2	EXTDRY-2	317.9	12.0	------------		320.4	50.0
3	EXTDRY-10	352.9	5.0	355.1	10.0	358.0	52.0
4	EXTDRY-10	359.7	10.0	362.4	28.0	364.5	52.0
5	EXTDRY-2	287.0	18.0	------------		289.6	54.0
6	EXTDRY-10	237.2	5.0	240.1	12.0	242.7	51.0
7	EXTDRY-10	237.3	14.0	239.7	30.0	242.5	51.0
9	EXTDRY-10	191.2	24.0	192.8	83.0	194.2	59.0
10	EXTDRY-10	195.2	4.5	197.2	15.0	199.9	54.0
11	EXTDRY-10	207.4	2.0	210.8	7.0	214.6	60.0
12	EXTDRY-10	225.8	9.0	228.3	25.0	230.4	50.0
13	EXTDRY-10	297.6	3.0	300.5	10.0	304.0	50.0
14	EXTDRY-10	240.1	4.5	244.0	15.0	247.0	52.0
15	EXTDRY-10	241.3	3.0	243.9	10.0	246.1	51.0
16	EXTDRY-10	286.0	2.0	289.0	7.0	292.1	52.0
17	EXTDRY-10	229.8	2.0	233.4	7.0	237.8	57.0
18	EXTDRY-10	262.2	2.1	264.0	7.5	266.2	54.0
19	EXTDRY-10	234.1	5.0	236.1	17.0	238.5	54.0
20	EXTDRY-10	229.2	7.0	232.6	31.0	235.5	72.0
21	EXTDRY-10	210.9	3.0	213.6	13.0	216.1	60.0

NOTE: Conventional design parameters

TABLE 4-15
CONTINUED

DIFFICULT RUN
OUTLET STRUCTURE CHARACTERISTICS FOR DETENTION BASINS

BASIN NO.	DESIGN DETENTION	ORIFICE #1 (N = 0.5) INV.	L.	ORIFICE #2 INV.	L.	SPILLWAY INV.	L.
23	EXTDRY-10	259.2	2.0	262.1	7.0	265.5	66.0
24	EXTDRY-10	242.7	5.0	244.5	15.0	247.5	98.0
25	EXTDRY-10	236.5	2.3	238.7	7.0	241.5	51.0
26	EXTDRY-10	241.3	7.0	244.2	25.0	247.5	50.0
27	EXTDRY-10	280.6	2.9	283.0	13.0	285.2	51.0
28	EXTDRY-10	337.6	3.0	339.4	7.0	342.0	53.0
29	EXTDRY-2	305.8	5.5	------------		309.9	66.0
30	EXTDRY-2	321.8	11.0	------------		325.3	50.0
31	EXTDRY-2	317.8	7.5	------------		319.7	59.0
32	EXTDRY-2	319.8	2.5	------------		321.5	53.0
33	EXTDRY-10	318.3	1.4	320.6	5.0	322.8	54.0
34	EXTDRY-10	315.9	1.4	318.0	5.3	320.7	51.0
35	EXTDRY-10	305.8	2.5	308.3	9.0	311.4	56.0
36	EXTDRY-10	340.5	3.5	343.3	15.6	347.2	50.0
37	EXTDRY-10	295.6	3.5	298.0	10.0	301.1	51.0
38	EXTDRY-10	288.9	3.5	291.4	10.0	294.8	59.0
39	EXTDRY-2	346.8	16.0	-----------		348.1	88.0
71	EXTDRY-10	370.7	6.5	372.7	26.0	375.0	57.0
73	EXTDRY-2	359.0	4.5	-----------		361.2	78.0

NOTE: Conventional design parameters

TABLE 4-15
CONTINUED

DIFFICULT RUN
OUTLET STRUCTURE CHARACTERISTICS FOR DETENTION BASINS

BASIN NO.	DESIGN DETENTION (ALL DRY)	ORIFICE #1 (H = 0.5) INV.	ORIFICE #1 L.	ORIFICE #2 INV.	ORIFICE #2 L.	SPILLWAY INV.	SPILLWAY L.
40	EXTDRY-10	365.2	10.0	367.2	16.0	369.7	58.0
41	EXTDRY-10	367.0	11.0	369.0	35.0	371.5	52.0
43	EXTDRY-10	328.2	3.4	330.3	11.0	333.1	55.0
45	EXTDRY-2	358.3	7.0	------	------	360.3	50.0
46	EXTDRY-10	354.3	3.5	357.4	12.0	360.8	50.0
47	EXTDRY-10	385.8	1.5	389.0	2.0	391.5	51.0
49	EXTDRY-10	386.1	3.5	388.0	14.0	390.4	50.0
51	EXTDRY-10	240.1	9.4	243.3	40.0	246.7	51.0
52	EXTDRY-10	236.5	8.0	239.4	25.0	242.9	117.4
54	EXTDRY-10	238.2	5.0	239.6	10.0	242.0	52.0
56	EXTDRY-10	266.1	1.5	269.8	8.8	272.4	64.0
58	EXTDRY-10	370.9	3.0	372.7	10.0	374.7	55.0
59	EXTDRY-10	295.6	2.5	297.7	10.0	300.1	53.0
61	EXTDRY-10	316.2	5.0	318.1	18.0	320.7	52.0
64	EXTDRY-10	291.8	6.0	293.8	18.0	296.0	50.0
65	EXTDRY-10	208.7	1.5	211.6	4.5	215.2	51.0
66	EXTDRY-10	310.3	2.8	313.6	10.0	317.1	51.0
67	EXTDRY-2	347.0	20.1	------	------	349.0	50.0

NOTE: Conventional design parameters

TABLE 4-15
CONTINUED

DIFFICULT RUN
OUTLET STRUCTURE CHARACTERISTICS FOR DETENTION BASINS

BASIN NO.	DESIGN DETENTION (ALL DRY)	ORIFICE #1 INV.	ORIFICE #1 L.	ORIFICE #2 INV.	ORIFICE #2 L.	SPILLWAY INV.	SPILLWAY L.
		(H = 0.5)					
69	EXTDRY-10	363.2	5.0	364.7	10.0	367.5	53.0
72	EXTDRY-10	280.3	3.0	282.4	10.0	284.5	53.0
74	EXTDRY-10	298.0	4.0	299.8	11.0	302.2	53.0
76	EXTDRY-2	186.9	14.0	------	------	190.3	53.0
77	EXTDRY-10	395.8	3.0	398.4	13.0	401.1	50.0
79	EXTDRY-10	315.6	6.0	317.7	20.0	320.1	50.0

NOTE: Conventional design parameters

TABLE 4-16

HORSEPEN CREEK
OUTLET STRUCTURE CHARACTERISTICS FOR DETENTION BASINS

		ORIFICE #1		ORIFICE #2		SPILLWAY	
BASIN NO.	DESIGN DETENTION	INV.	L.	INV.	L.	INV.	L.
1	EXTDRY-10	377.7	10.0	379.3	10.0	380.8	51.0
9	EXTDRY-10	307.1	11.0	309.2	14.0	311.1	56.0
13	EXTDRY-2	353.0	23.0	------	------	355.7	51.0
16	EXTDRY-10	341.6	7.0	343.9	11.0	346.1	56.0
18	EXTDRY-2	370.9	17.0	------	------	372.8	128.0
			OTHER DESIGNES				
			CIRC. PIPE DIAM.		CIRC. PIPE DIAM.		
2	EXTDRY-10	297.7	24"	301.4	30"	304.9	51.0
7	EXTDRY-10	328.9	21"	331.2	30"	333.3	50.0

NOTE: Conventional design parameters

TABLE 4-17

SUGARLAND RUN
OUTLET STRUCTURE CHARACTERISTICS FOR DETENTION BASINS

TOP 50 PONDS

BASIN NO.	DESIGN DETENTION	ORIFICE #1 INV.	ORIFICE #1 L.	ORIFICE #2 INV.	ORIFICE #2 L.	SPILLWAY INV.	SPILLWAY L.
1	EXTDRY-10	248.5	24.0	251.9	28.0	259.7	86.0
2	EXTDRY-10	330.2	6.0	332.8	12.0	335.7	51.0
4	EXTDRY-10	301.1	3.0	303.6	8.3	305.6	57.0
5	EXTDRY-10	278.8	13.0	281.7	28.0	285.1	68.0
7	EXTDRY-2	282.3	22.0	------	------	285.7	51.0

NOTE: 7 IS IN SERIES WITH 1

NOTE: Conventional design parameters

TABLE 4-18

POHICK CREEK
OUTLET STRUCTURE CHARACTERISTICS FOR DETENTION BASINS

		ORIFICE #1		ORIFICE #2		SPILLWAY	
BASIN NO.	DESIGN DETENTION	INV.	L.	INV.	L.	INV.	L.
1	EXTDRY-10	355.2	9.0	356.0	14.0	357.9	50.0
2	EXTDRY-10	349.4	8.5	351.1	38.0	353.0	52.0
3	EXTDRY-10	339.5	2.5	341.2	9.5	343.3	52.0
4	EXTDRY-10	321.0	9.5	322.4	28.0	324.1	78.0
5	EXTDRY-10	334.6	2.5	335.7	5.0	337.7	53.0
6	EXTDRY-2	325.0	18.0	------	------	326.7	51.0
7	EXTDRY-10	322.6	5.5	324.4	18.0	326.5	53.0
8	EXTDRY-10	386.4	3.5	387.9	12.0	389.9	51.0

NOTE: 8 DISCHARGES INTO 2; 2 AND 1 INTO 6; 3 INTO 7

NOTE: Conventional design parameters

TABLE 4-19

LONG BRANCH
OUTLET STRUCTURE CHARACTERISTICS FOR DETENTION BASINS

BASIN NO.	DESIGN DETENTION	ORIFICE #1 INV.	ORIFICE #1 L.	ORIFICE #2 INV.	ORIFICE #2 L.	SPILLWAY INV.	SPILLWAY L.
5	EXTDRY-10	188.9	5.5	191.7	12.0	195.0	53.0
6	EXTDRY-10	188.1	3.5	191.3	9.0	194.2	52.0
7	EXTDRY-10	141.0	8.5	143.1	18.0	145.6	51.0
9	EXTDRY-2	154.7	11.0	------------		158.2	113.0
10	EXTDRY-2	170.5	16.0	------------		173.6	73.0
				OTHER DESIGNS			
			CIRC. PIPE DIAM.		CIRC. PIPE DIAM.		
1	EXTDRY-10	154.2	18"	156.4	27"	159.0	55.0
2	EXTDRY-10	153.3	15"	156.4	27"	158.8	54.0

NOTE: 5 IS IN SERIES WITH 10.

NOTE: Conventional design parameters

Routing for Maximum Efficiency Detention Basins. Due to constraints on the scope of this study, detailed evaluations of outlet structure characteristics were not performed for maximum efficiency detention basins. As a result, a more approximte flow routing method was used to evaluate these facilities. Hydrograph routing was performed using a special technique developed to maximize the use of available storage and at the same time to minimize the release rate from the detention basin. The lower limit for the release rate was set at 33 percent of the predevelopment peak flow. A statistical analysis of the inflow and outflow hydrographs of 25 proposed detention basins within the County was performed to develop a synthetic, "characteristic" hydrograph to approximate the outflow response at different release rates. The characteristic hydrograph gives a good representation of the outflow hydrograph from a regional detention basin facility; however, detailed designs will have to be performed to establish the outflow structure characteristics.

For each site, the potential for a maximum efficiency design was initially evaluated by setting the peak outflow rate at 33 percent of the pre-development peak flow. If sufficient storage was available at the site after accounting for the emergency spillway design storm and freeboard, then the outflow hydrograph (with a peak flow of 33 percent of the predevelopment peak flow) was computed based on the inflow hydrograph, storage and characteristic outflow hydrograph. If insufficient storage were available for the peak release rate set at 33% of the predevelopment peak flow, the model would increase the release rate (up to the predevelopment peak flow) until a level compatible with the available storage was achieved. The characteristic outflow hydrograph was then used to produce the actual outflow hydrograph for the evaluation of watershedwide benefits of the maximum efficiency basins.

4.2 HYDRAULIC MODEL

4.2.1 SWMM/EXTRAN MODEL DESCRIPTION

EXTRAN was originally developed for the City of San Francisco in 1973 (Shubinski, 1973; and Kibler, 1975). At that time it was called the San

Francisco Model and (more properly) the WRE Transport Model. In 1974, EPA acquired this model and incorporated it into the SWMM package, calling it the Extended Transport Model (EXTRAN) to distinguish it from the TRANSPORT Module developed by the University of Florida as part of the original SWMM package (Roesner, 1981). Since that time, the model has been refined, particularly in the way the flow routing is performed under surcharge conditions. The version of the model used in this Fairfax County study has been enhanced by Camp Dresser & McKee (CDM) to simulate irregular cross-sections and includes other refinements.

EXTRAN is a hydraulic flow routing model for open channel and/or closed conduit systems. The model performs dynamic routing of stormwater flows through the major storm drainage system to the points of outfall to the receiving water system. The program will simulate branched or looped networks, backwater due to tidal or nontidal conditions, free-surface flow, pressure flow or surcharge, flow reversals, flow transfer by weirs, orifices and pumping facilities, and storage at on- or off-line facilities. Types of channels that can be simulated include irregular cross-sections, plus circular, rectangular, horseshoe, egg-shaped, baskethandle pipes, and trapezoidal channels. Model output includes a time series of water surface elevations and discharges at selected system locations.

4.2.2 MODEL SET-UP FOR FAIRFAX COUNTY WATERSHEDS

EXTRAN is a link-node type hydraulic model in which certain data are used to describe channel properties between the nodes or junctions. Open channel properties include lengths, slopes, Manning's roughness coefficients, and cross sections. For the Fairfax County plan, the lengths of the channels were measured from the 1"-500' topographic maps. USGS channel cross-section data (USGS, 1976; USGS, 1977a; USGS, 1977b; USGS, 1978a; USGS, 1978b) provided channel invert elevations used to calculate the channel slope. Manning's "n" were also provided by the USGS for the main channel and the right and left overbanks. Channel cross sections were obtained directly from the USGS data. Where USGS data were not available for a modeled stream reach, supplemental cross-section data were measured from the 1"-500' five-foot contour topographic maps and were determined from the field reconnaissance performed by the County.

Stream crossings were also modeled with EXTRAN to simulate the flow through culverts and bridge openings, and across the top of roadways as required. Short conduits can cause model stability problems and they were replaced by equivalent conduit systems. An equivalent conduit is the computational substitution of an actual element of the drainage system by an imaginary conduit which is hydraulically identical to the element it replaces. In order to achieve numerical stability in the EXTRAN model, crossing lengths were extended. With the new equivalent length, an equivalent Manning's roughness coefficient was calculated and input into the model with the shape parameters (diameter for circular openings, and height and width for rectangular openings). Model parameters to simulate the overtopping of a roadway crossing were developed and included a weir length and discharge coefficient.

4.3 SUBBASIN DELINEATIONS AND MODEL SCHEMATICS

Each of the seven watershed study areas was divided into subbasins for modeling purposes. Initially individual subbasins were developed for each proposed regional detention basin and for the existing County regional detention basins included in the model. The remaining area of each watershed was subdivided into subbasins in order to model the hydrographs produced from areas where regional detention basins could not be located. The hydrologic model, STORMLINK, was used to produce runoff hydrographs for each of the subbasins within a watershed. The STORMLINK model also routed hydrographs through the proposed regional detention basins and the County regional detention basins. Figure 4-1 presents the subbasin delineations for the Cub Run watershed. A "C" prefix assigned to the subbasin ID number indicates the areas which drain to a recommended regional detention basin with the same number (e.g., C-35). A "CP" prefix indicates subbasins which drain to existing County regional detention basins that are modeled.

The model schematic diagrams for each of the seven watersheds describe the EXTRAN link-node system and the STORMLINK subbasins which are assigned to an EXTRAN node. The model schematic for Cub Run is given in Figures 4-2a through 4-2h. Each node, represented by a circle, includes the corresponding model node number.

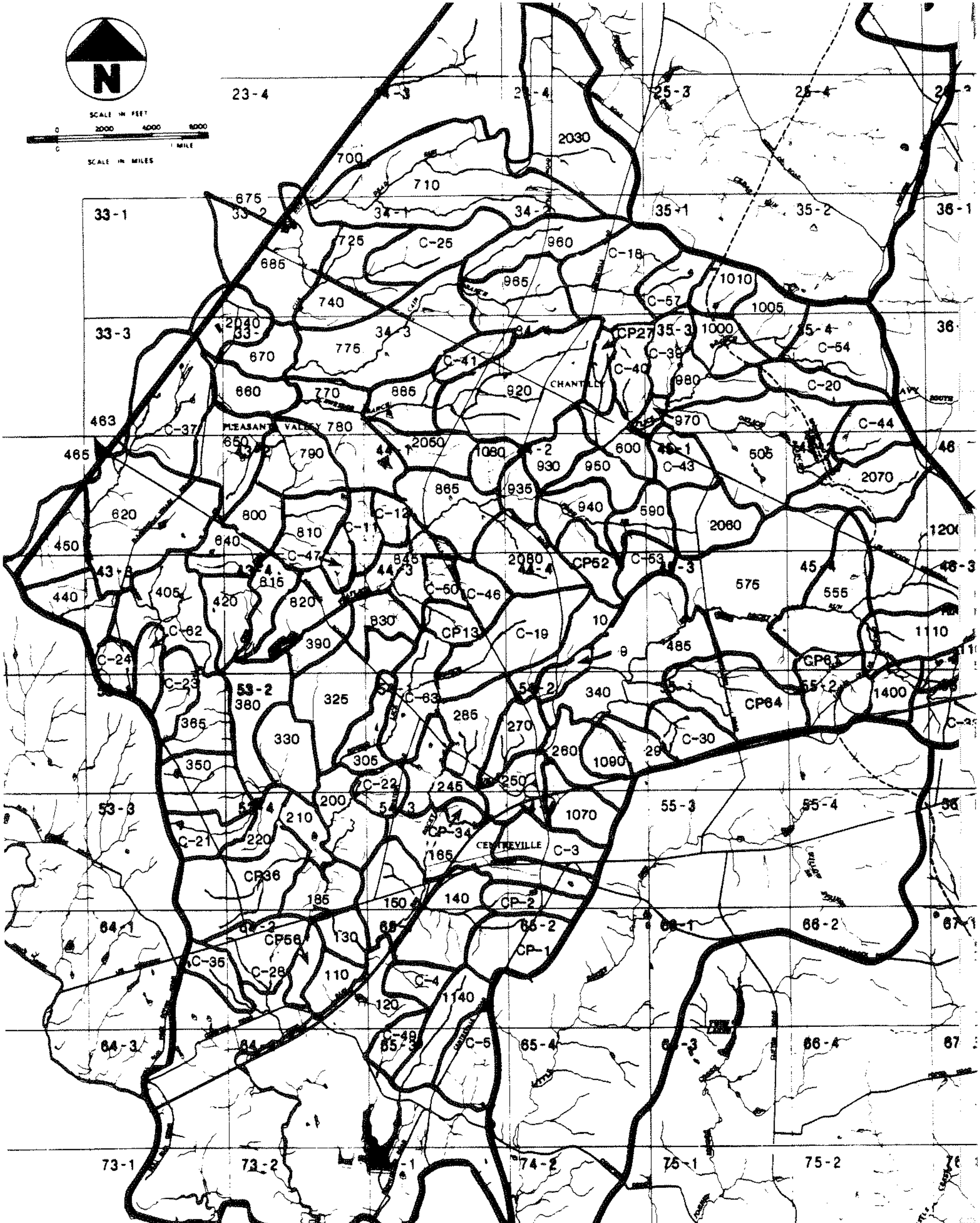


Figure 4-1. Cub Run: Subbasin Delineation

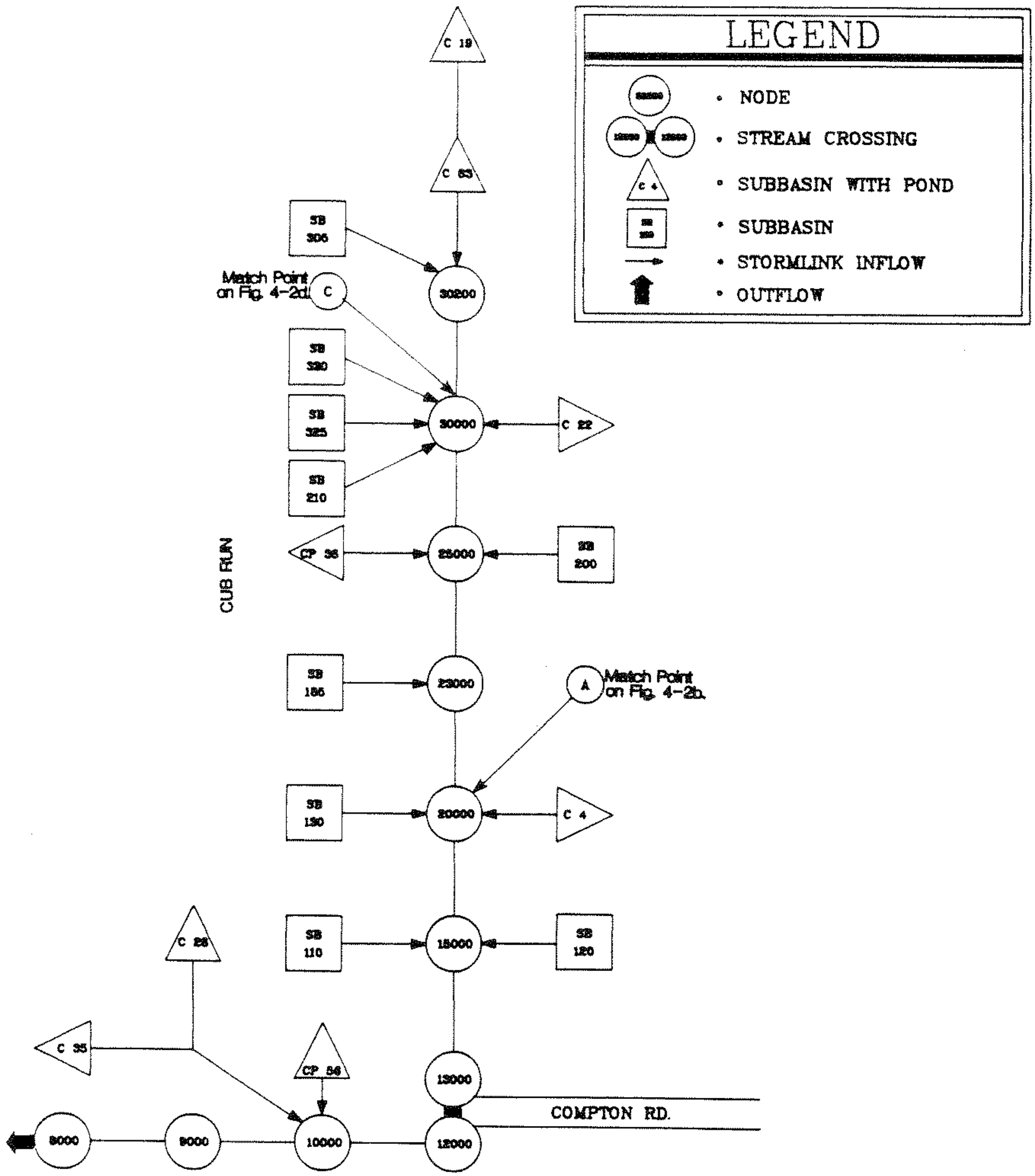


Figure 4-2a. Cub Run: Model Schematic

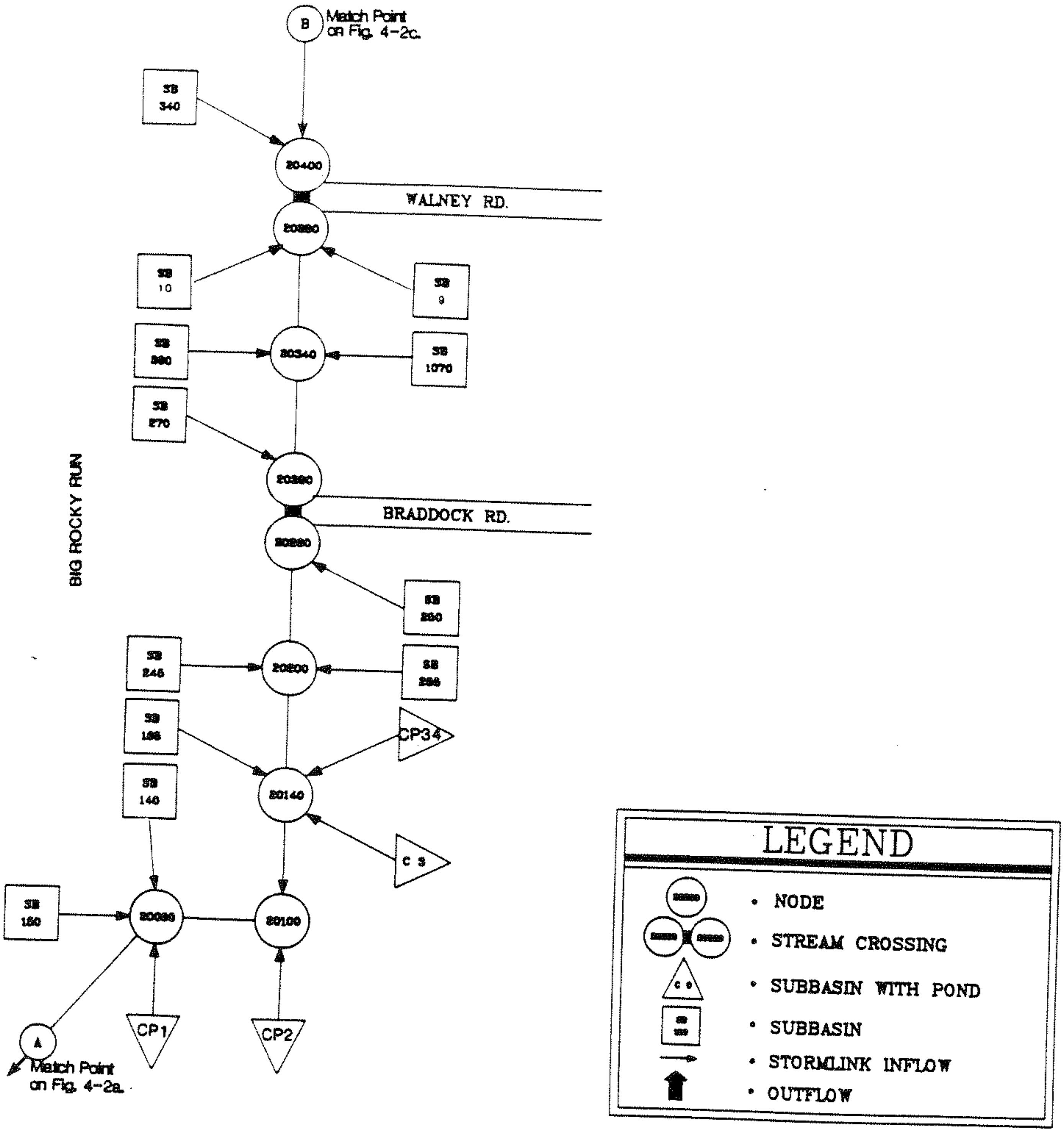


Figure 4-2b. Cub Run: Model Schematic

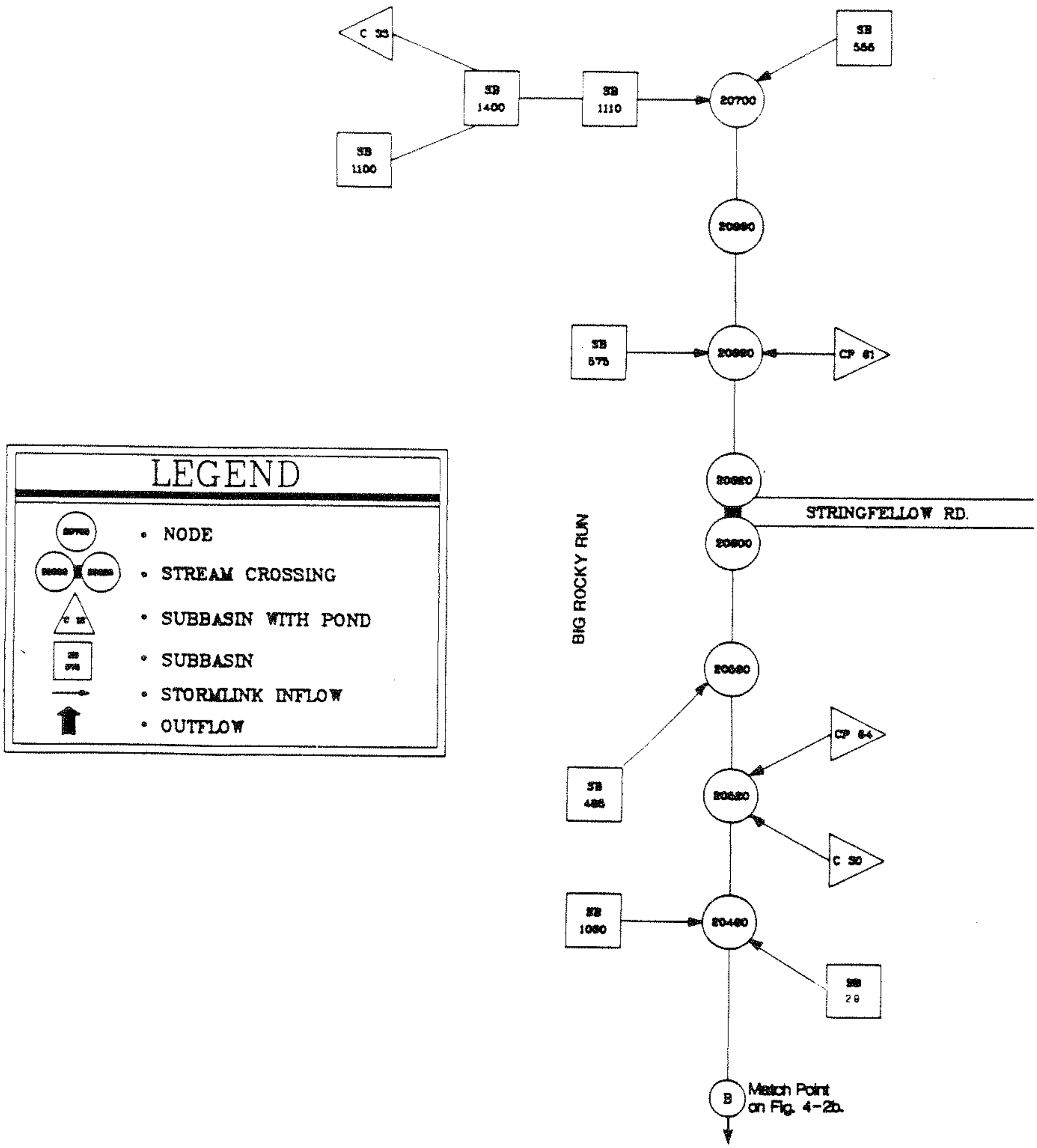


Figure 4-2c. Cub Run: Model Schematic

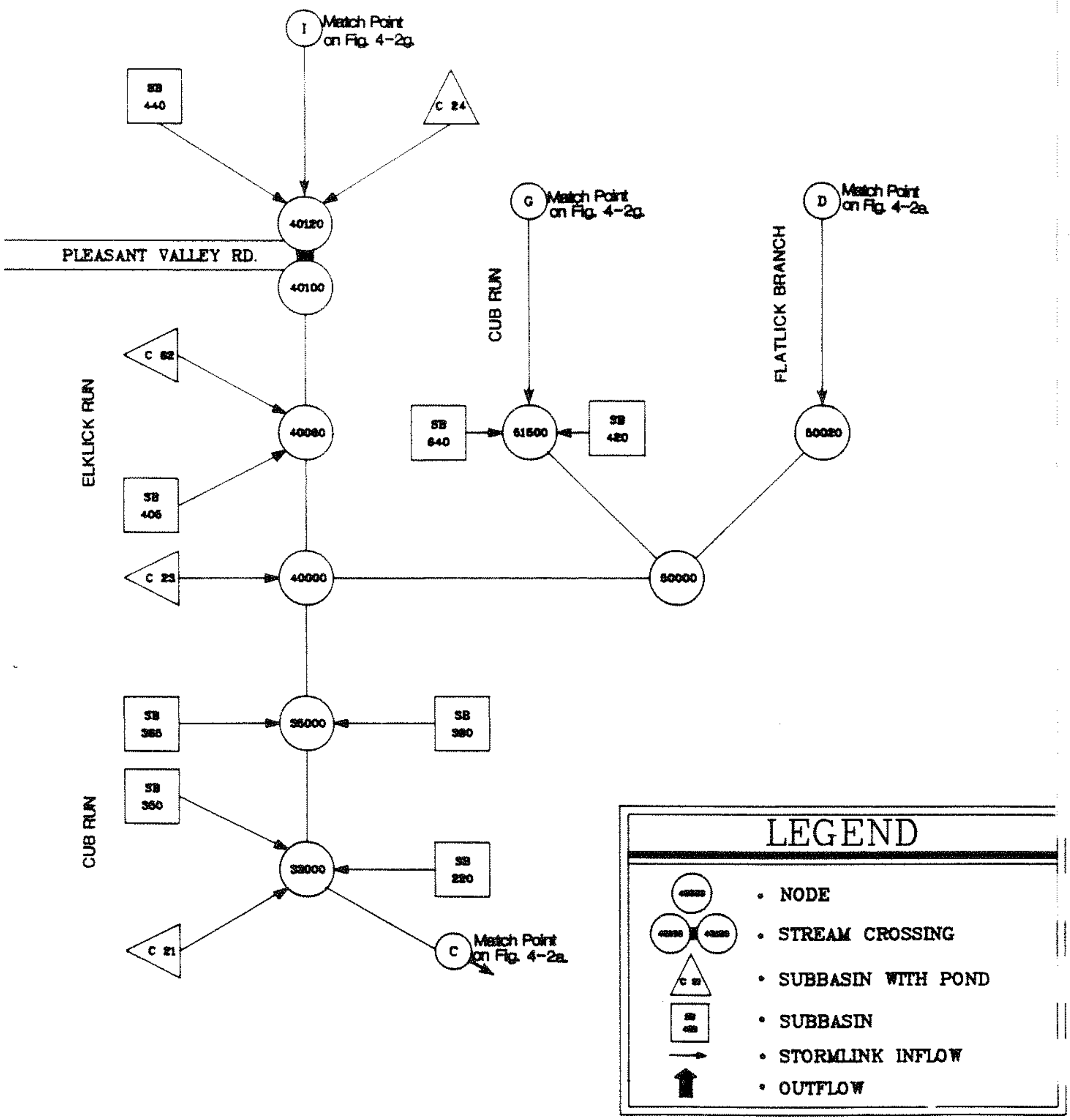


Figure 4-2d. Cub Run: Model Schematic

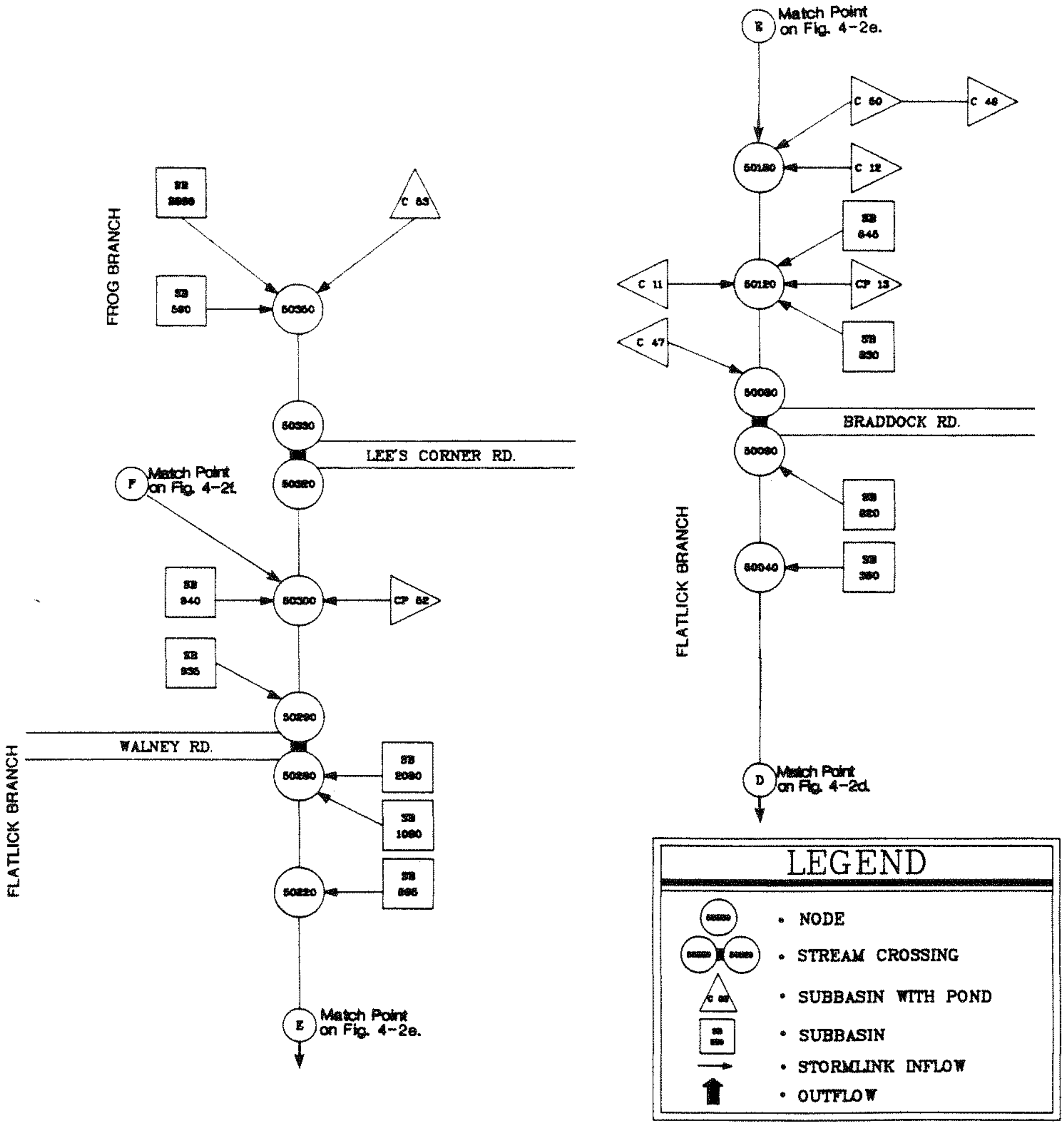


Figure 4-2e. Cub Run: Model Schematic

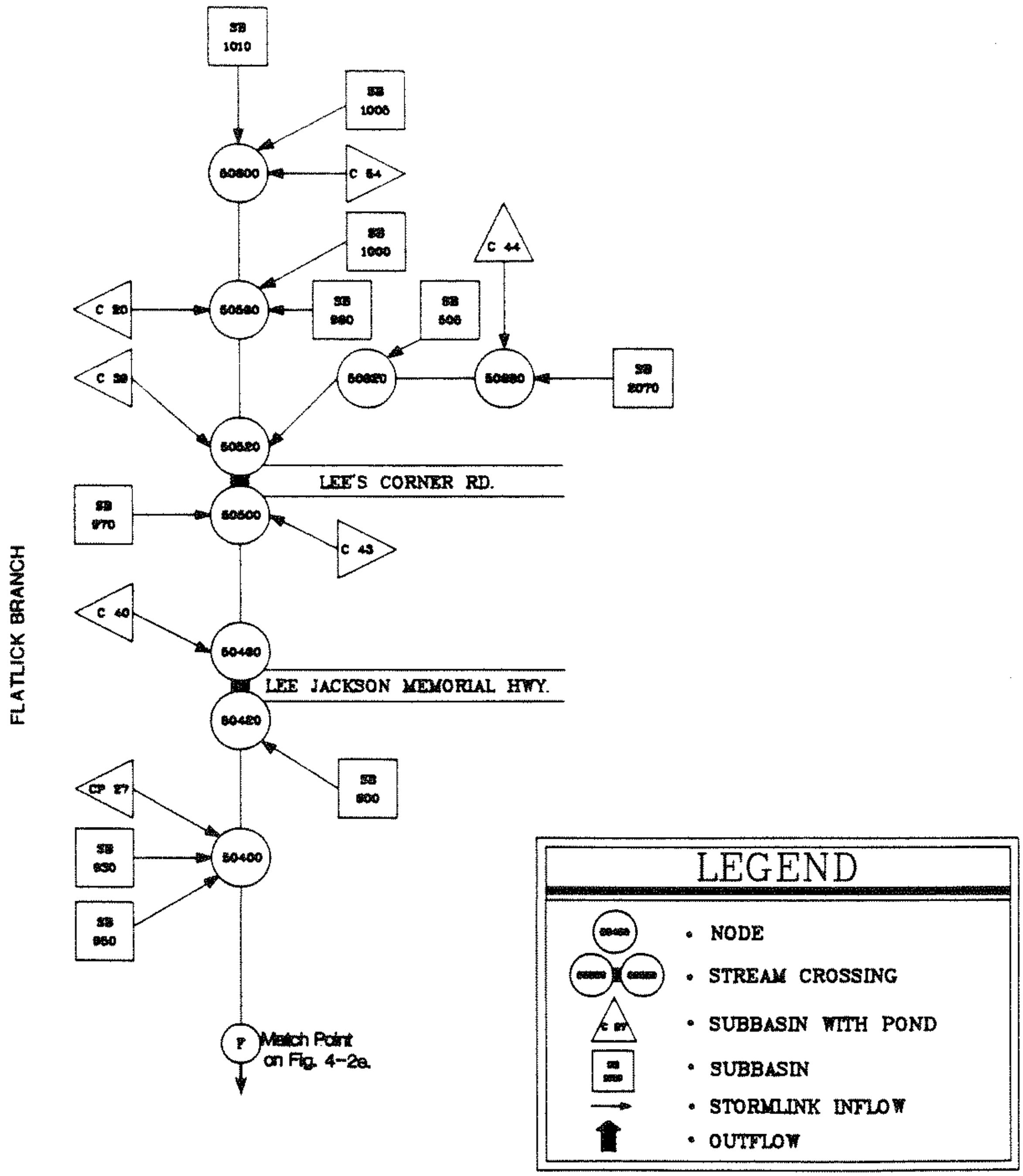


Figure 4-2f. Cub Run: Model Schematic

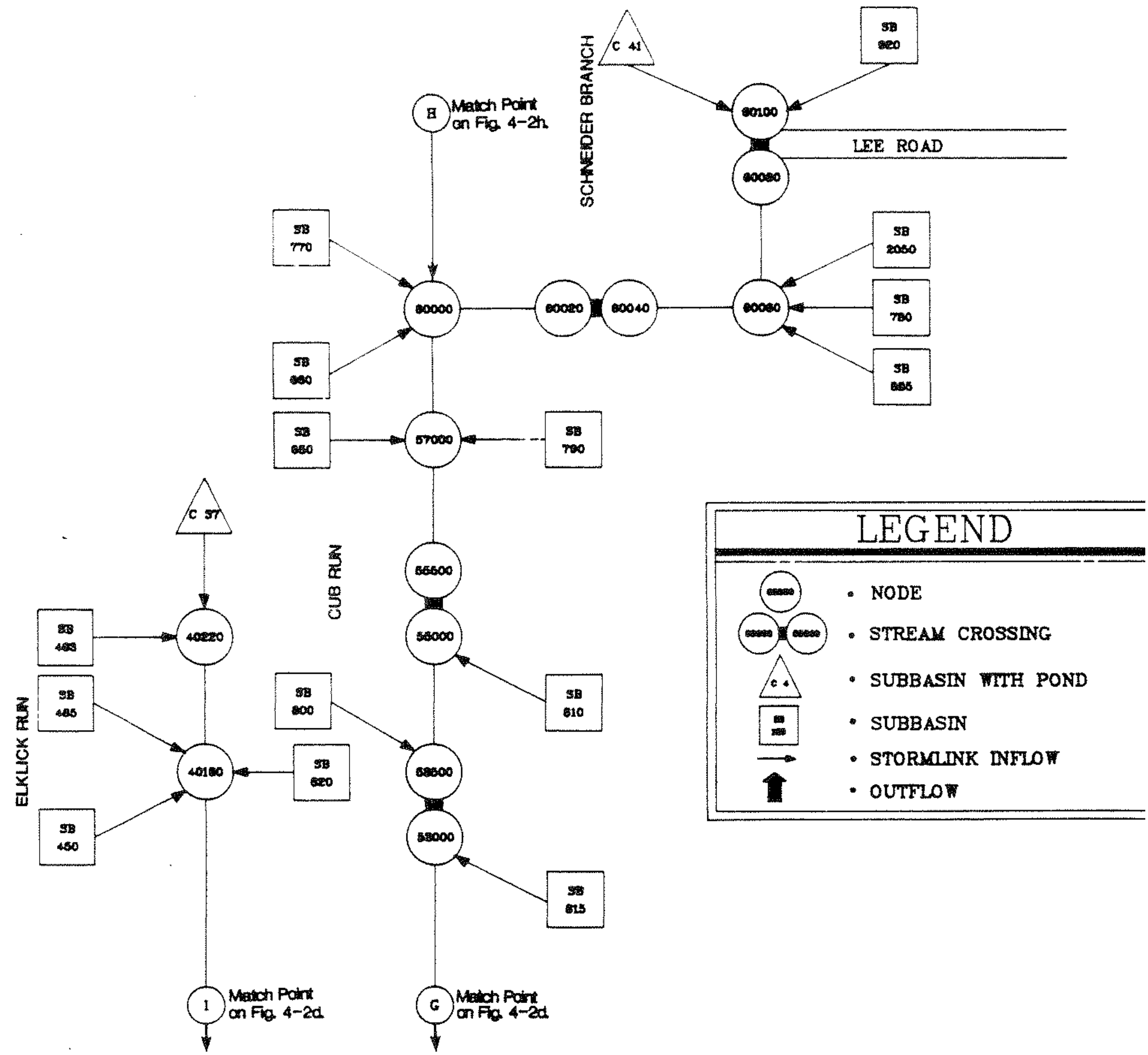


Figure 4-2q. Cub Run: Model Schematic

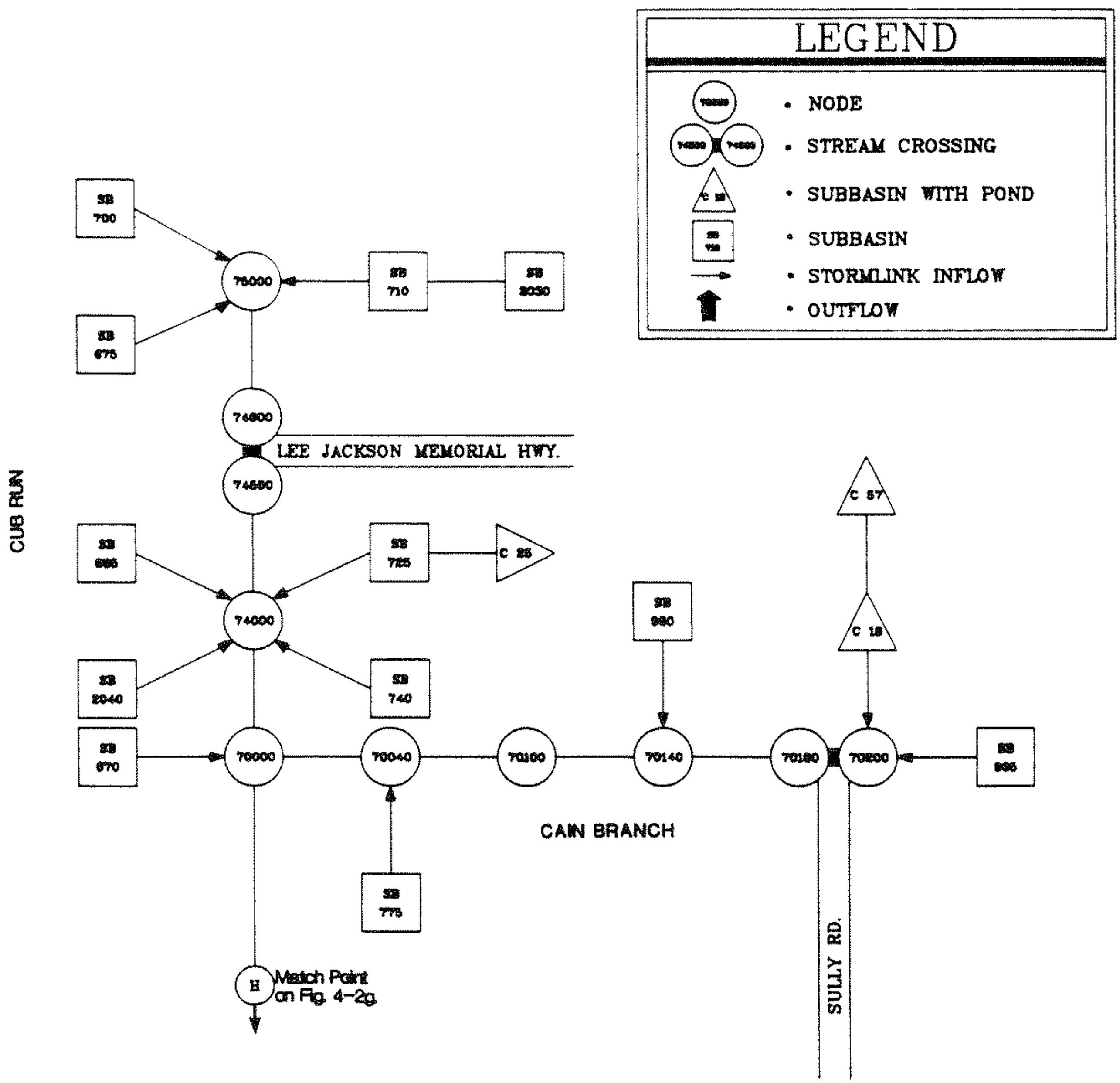


Figure 4-2h. Cub Run: Model Schematic

Subbasins without detention basins are represented by squares which include the subbasin numbers. Triangular subbasins represent subbasins with regional detention basins. As on the subbasin delineation maps, detention basins designated with a "C" are proposed regional basins and detention basins designated with a "CP" are County regional detention basins.

For Little Rocky Run, Figure 4-3 gives the subbasin delineation map, and Figure 4-4 gives the model schematic. In both figures, subbasin numbers prefixed with an "R" represent proposed regional detention basins and subbasins prefixed with an "RP" represent County regional detention basins.

Figures 4-5 and 4-6 show the subbasin delineation map and model schematic for the Difficult Run watershed. As with all the watersheds, the proposed regional detention basins are indicated with a letter to represent the watershed (e.g., "D" for Difficult Run) and with two letters, the watershed letter and a "P" for pond (e.g., "DP" for Difficult Run) to represent an existing County regional detention basin.

The Horsepen Creek subbasin delineation map is given in Figure 4-7 and the model schematic in Figure 4-8. For Sugarland Run, Figure 4-9 presents the subbasin delineations and Figure 4-10 presents the model schematic. For the Pohick Creek watershed, the STORMLINK model was developed for eight regional detention basins which drain to Burke Lake. Hydraulic modeling (EXTRAN) was not performed for either Burke Lake or the downstream river reaches. For the area above Burke Lake, Figure 4-11 shows the subbasins delineated for each regional detention basin and Figure 4-12 shows, in a schematic diagram, how the subbasins and regional detention basins are modeled in STORMLINK. Long Branch, a tributary to Accotink Creek was modeled with STORMLINK and EXTRAN. Figure 4-13 presents the subbasin delineations, and Figure 4-14 presents the EXTRAN link-node system with the STORMLINK subbasins.

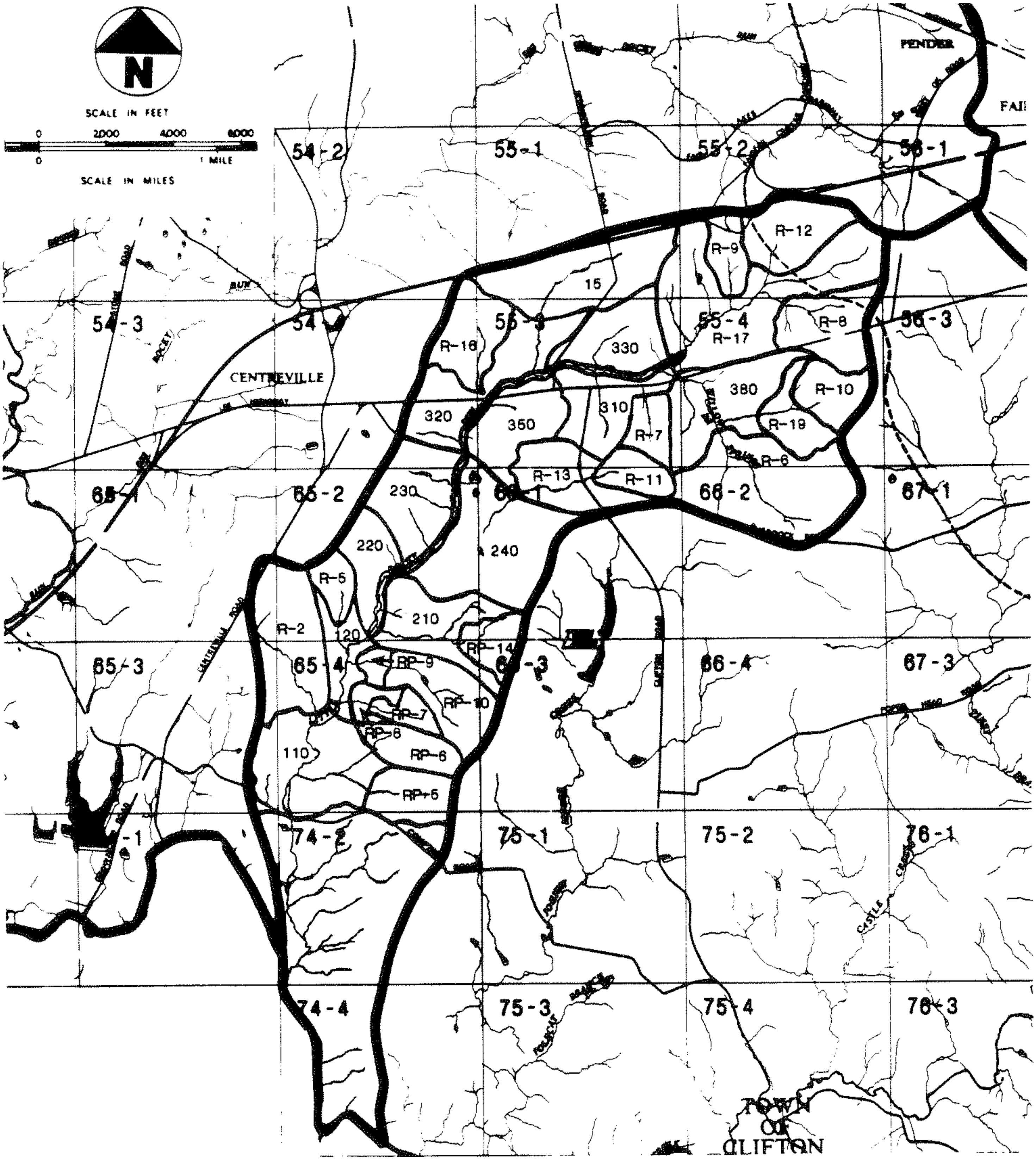


Figure 4-3. Little Rocky Run: Subbasin Delineation

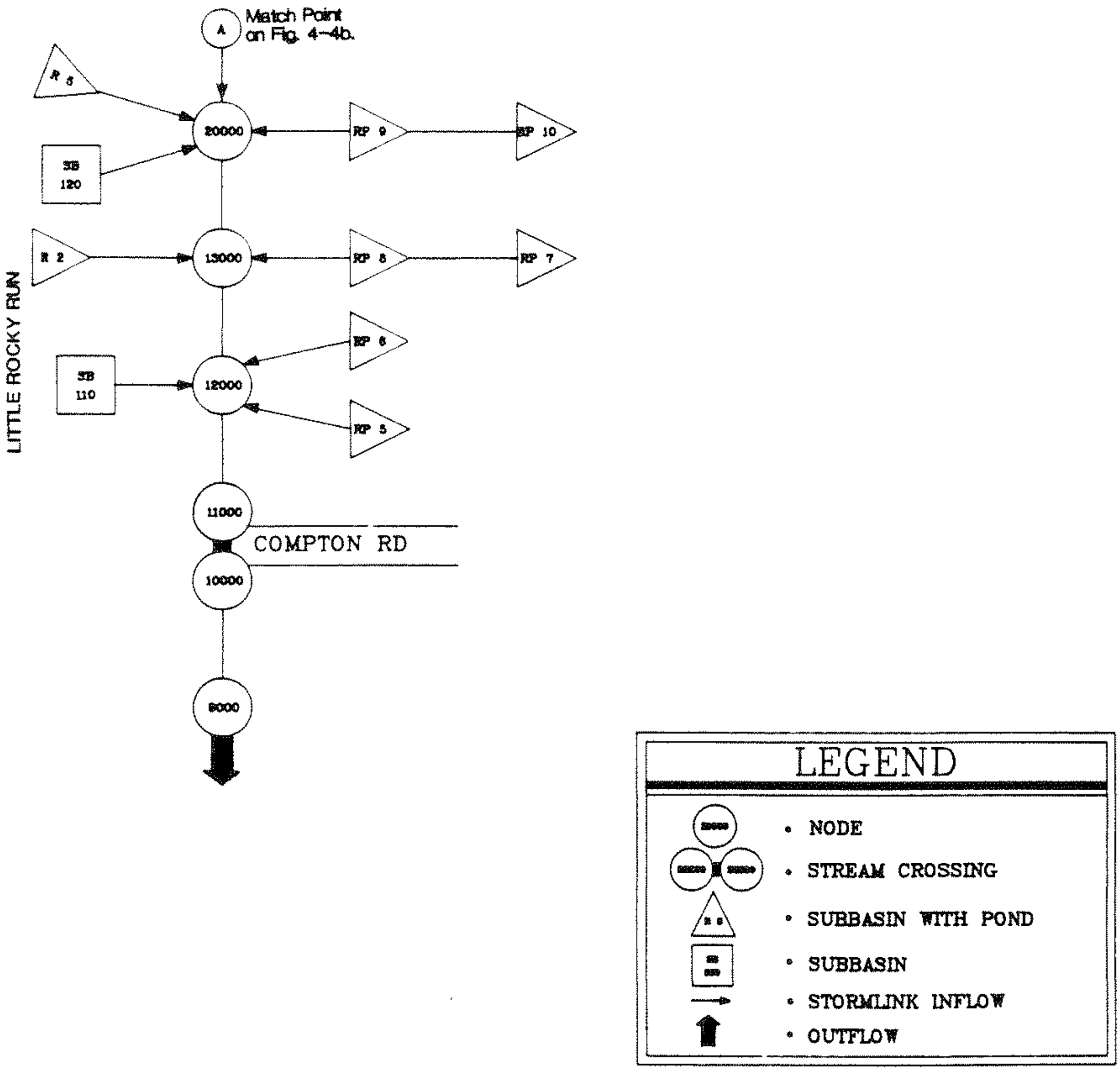


Figure 4-4a. LIttle Rocky Run: Model Schematic

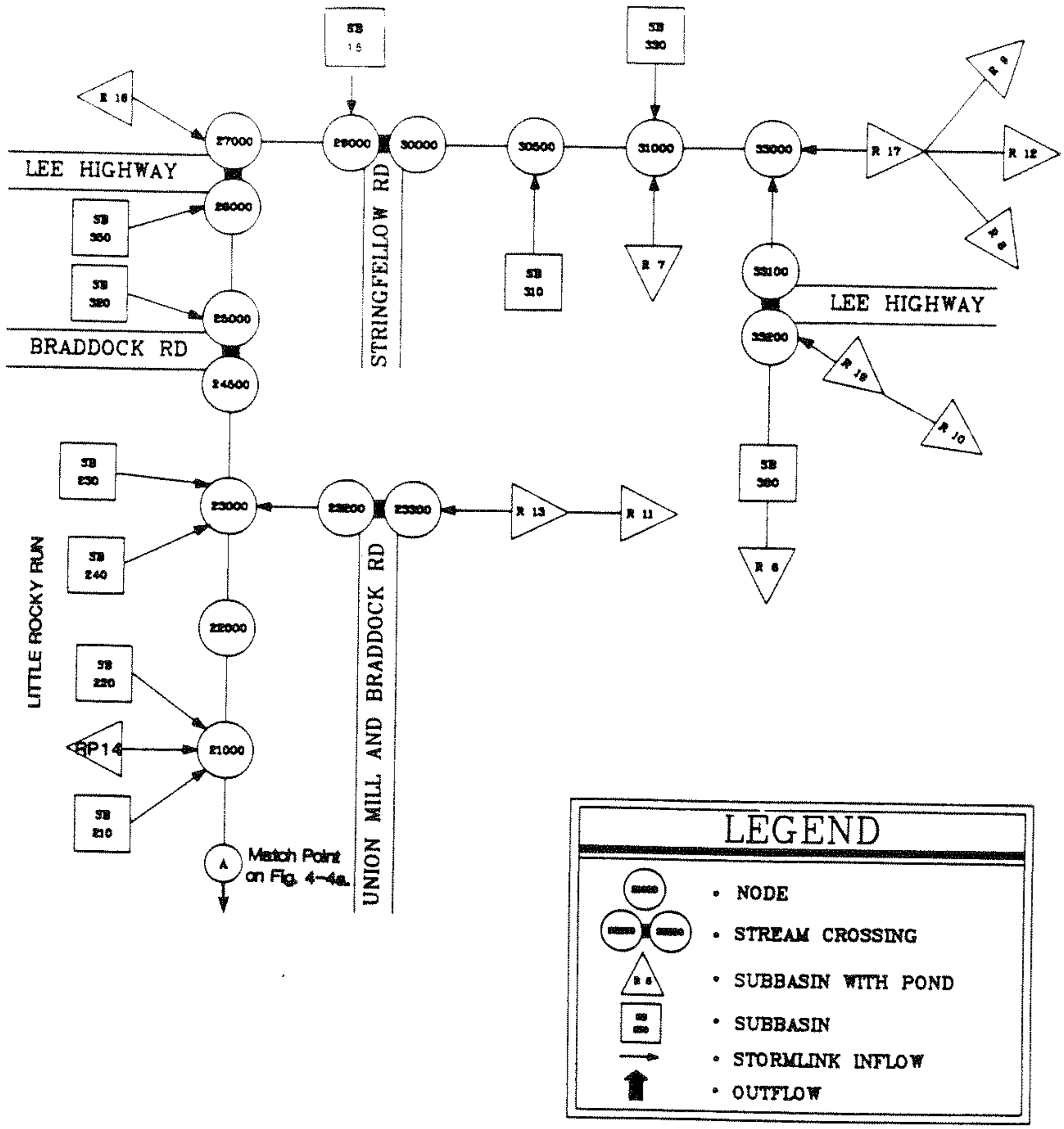


Figure 4-4b. Little Rocky Run: Model Schematic

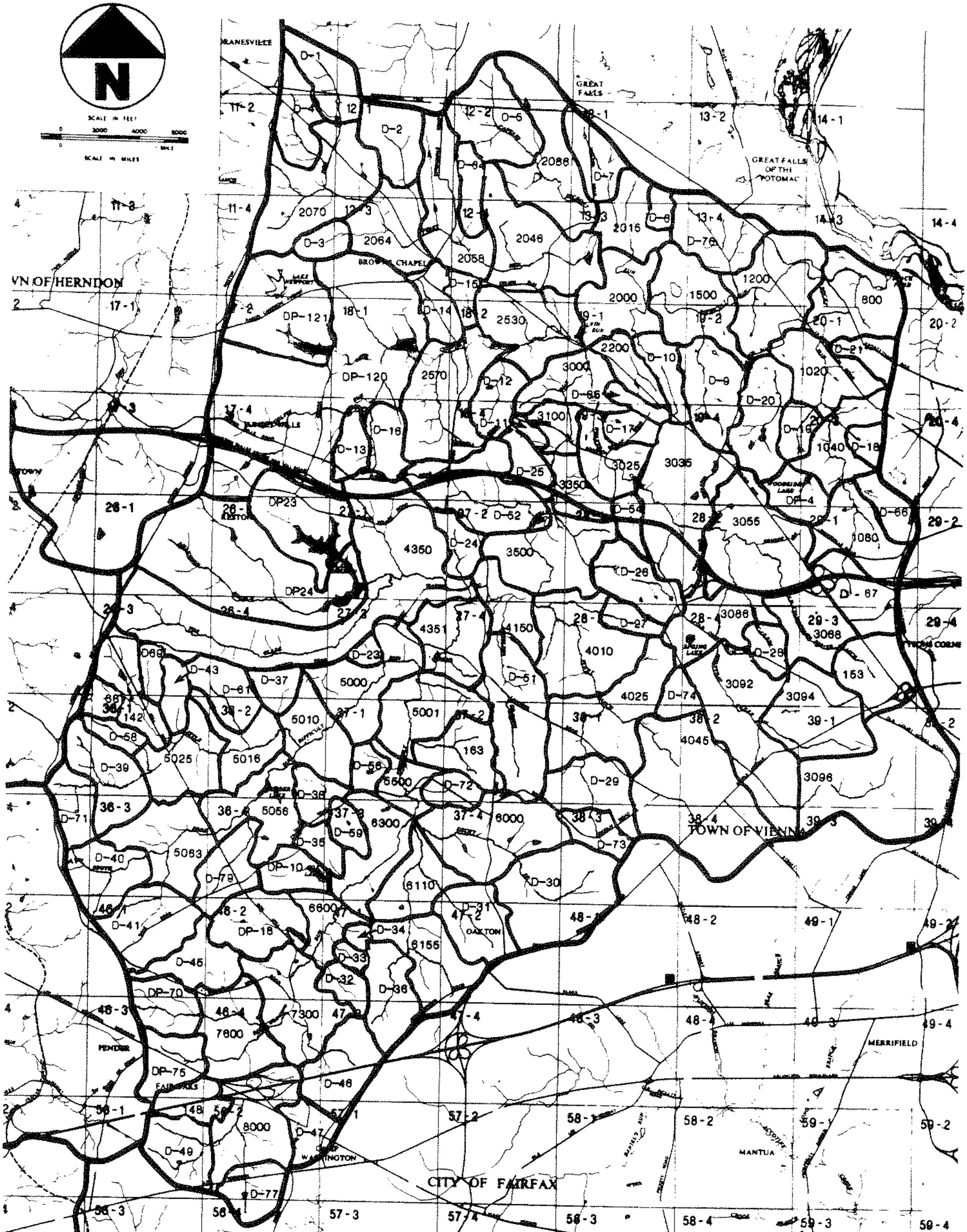


Figure 4-5. Difficult Run: Subbasin Delineation

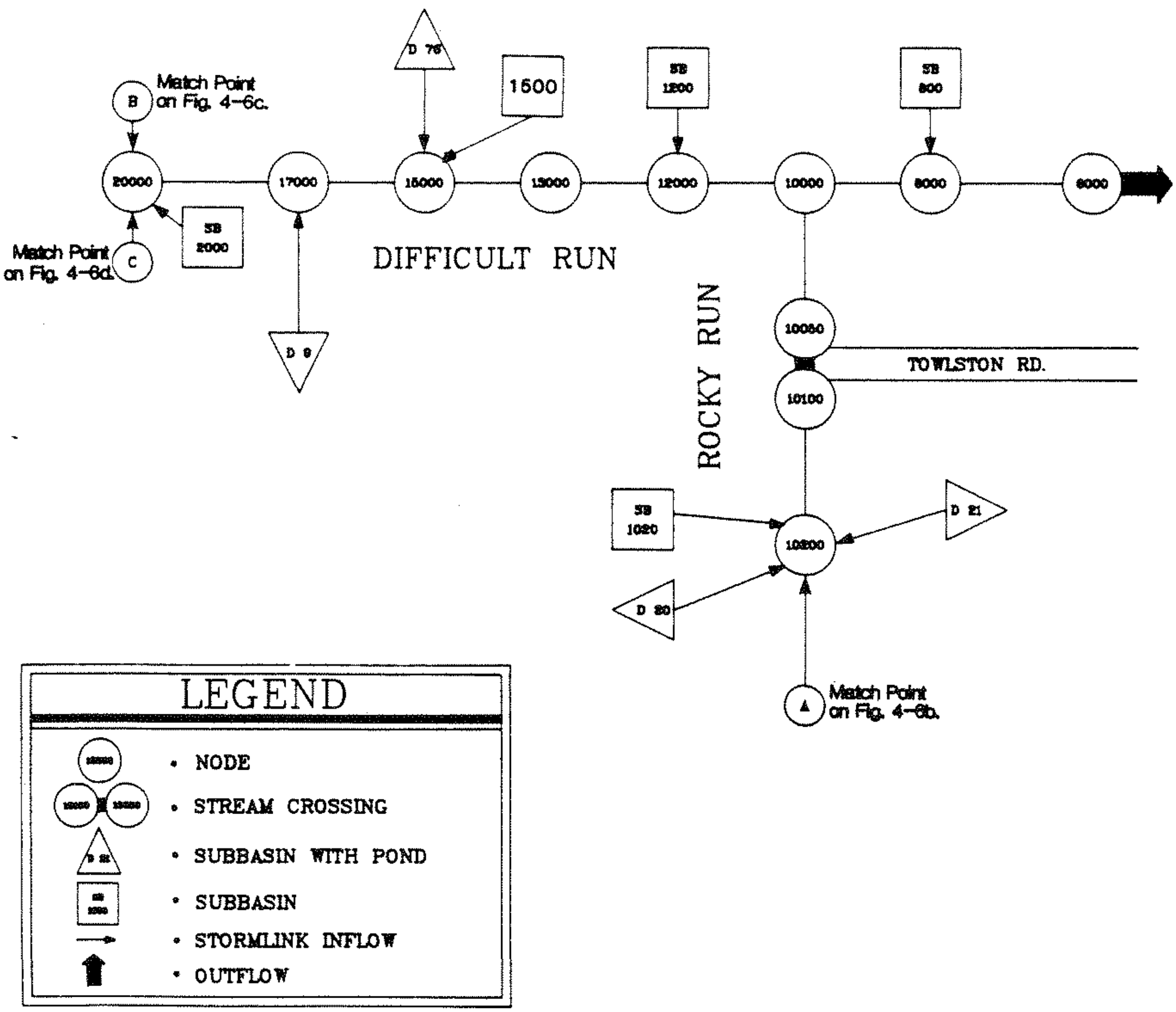


Figure 4-6a. Difficult Run: Model Schematic

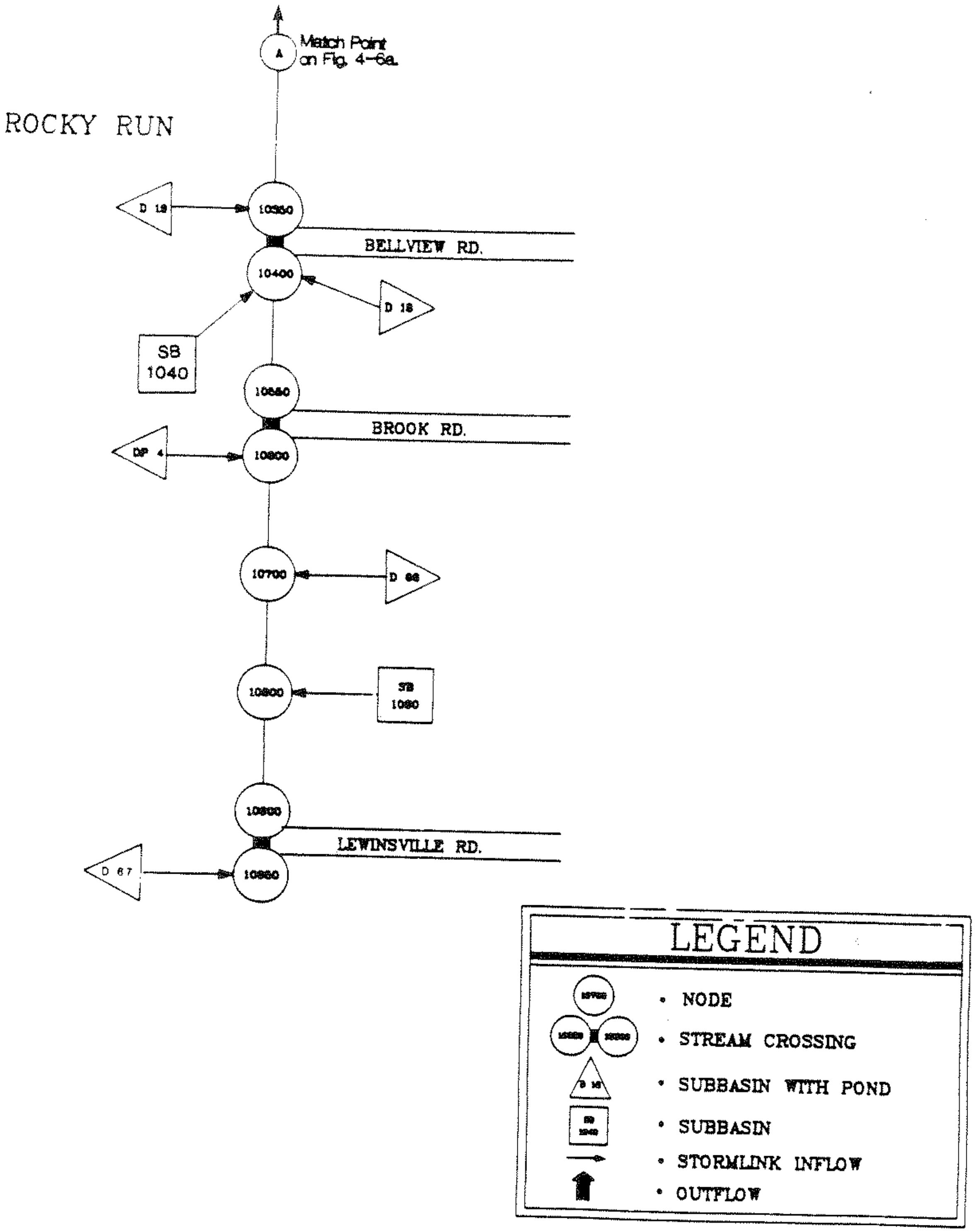


Figure 4-6b. Difficult Run: Model Schematic

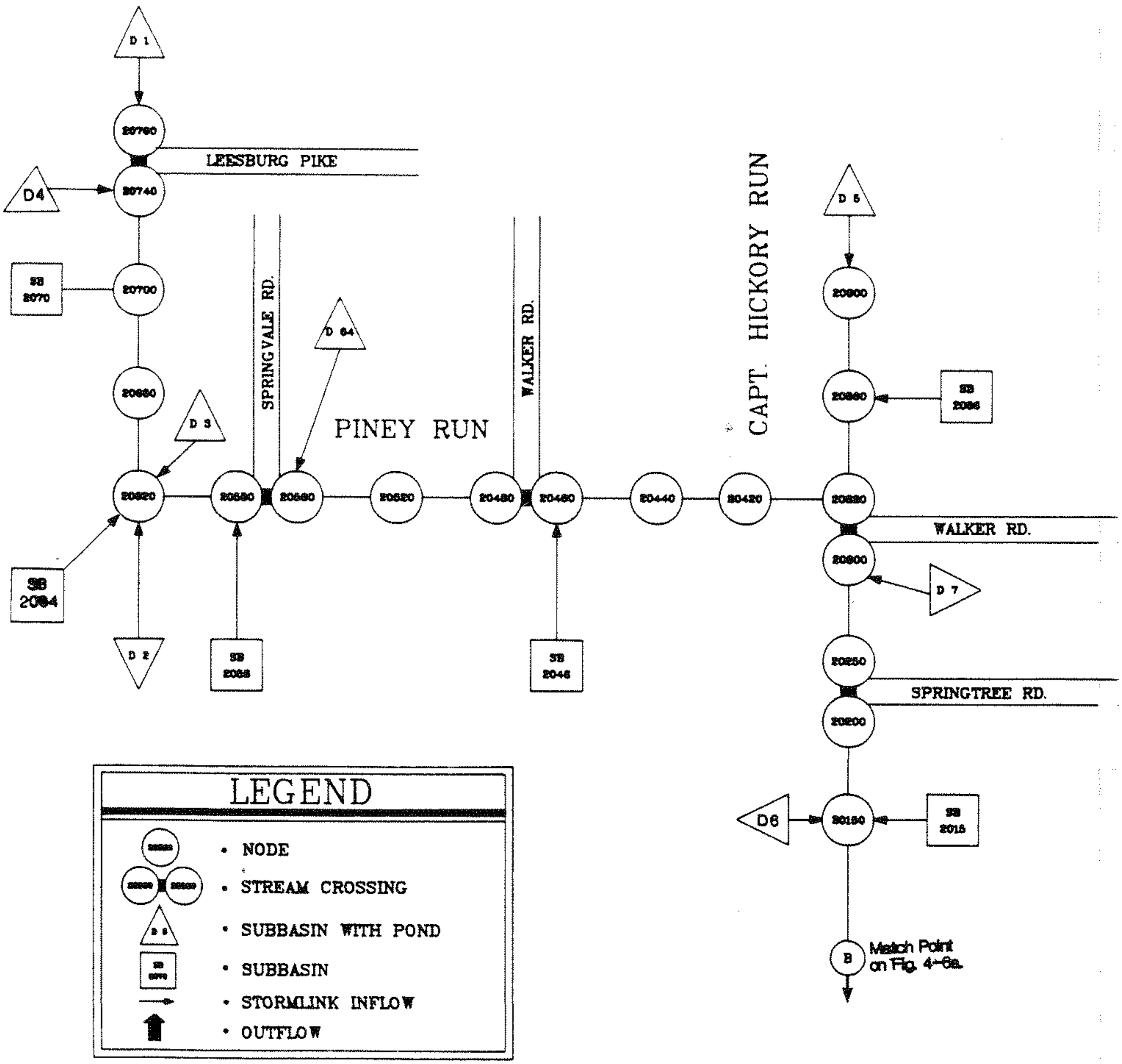


Figure 4-6c. Difficult Run: Model Schematic

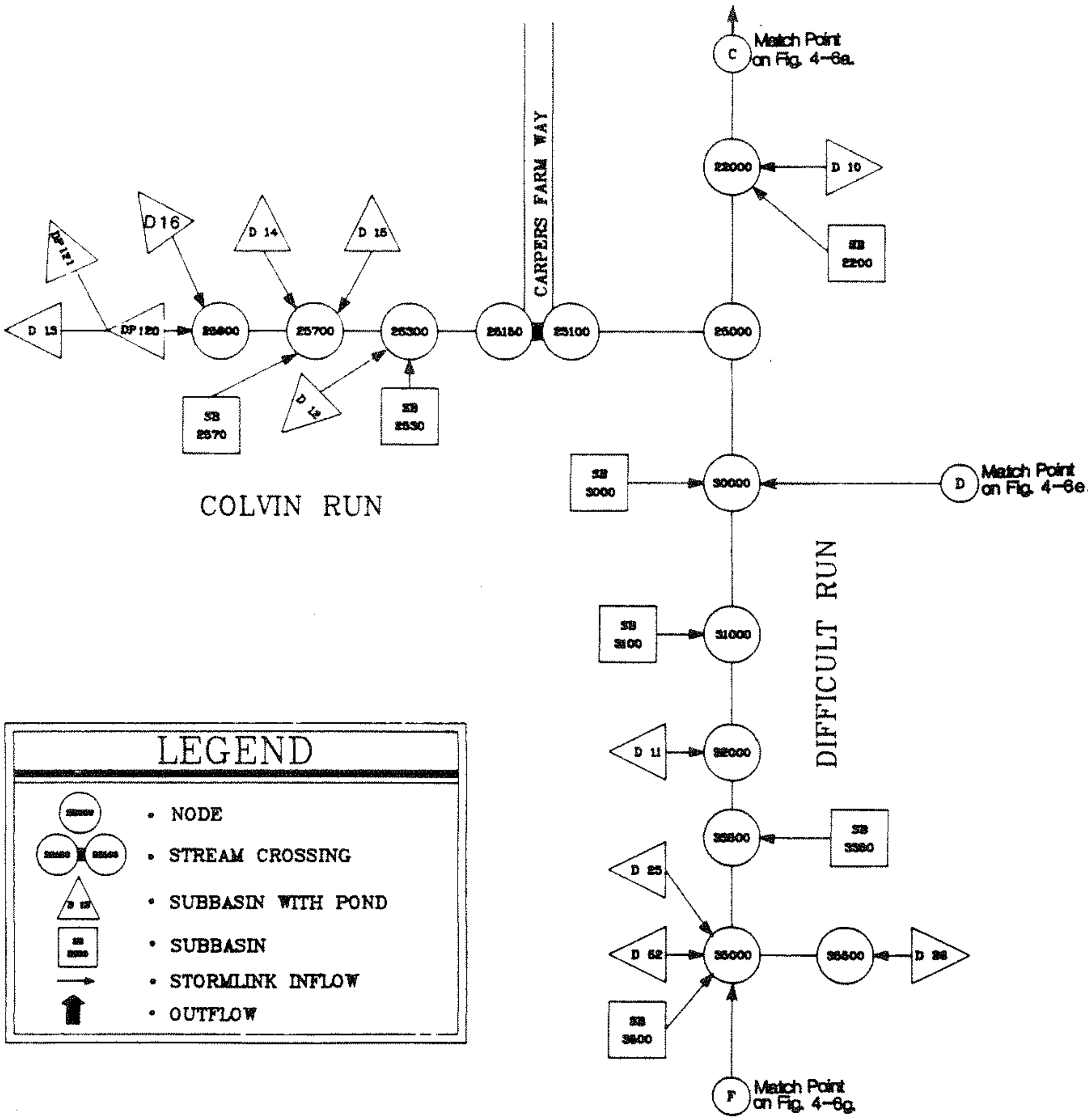


Figure 4-6d. Difficult Run: Model Schematic

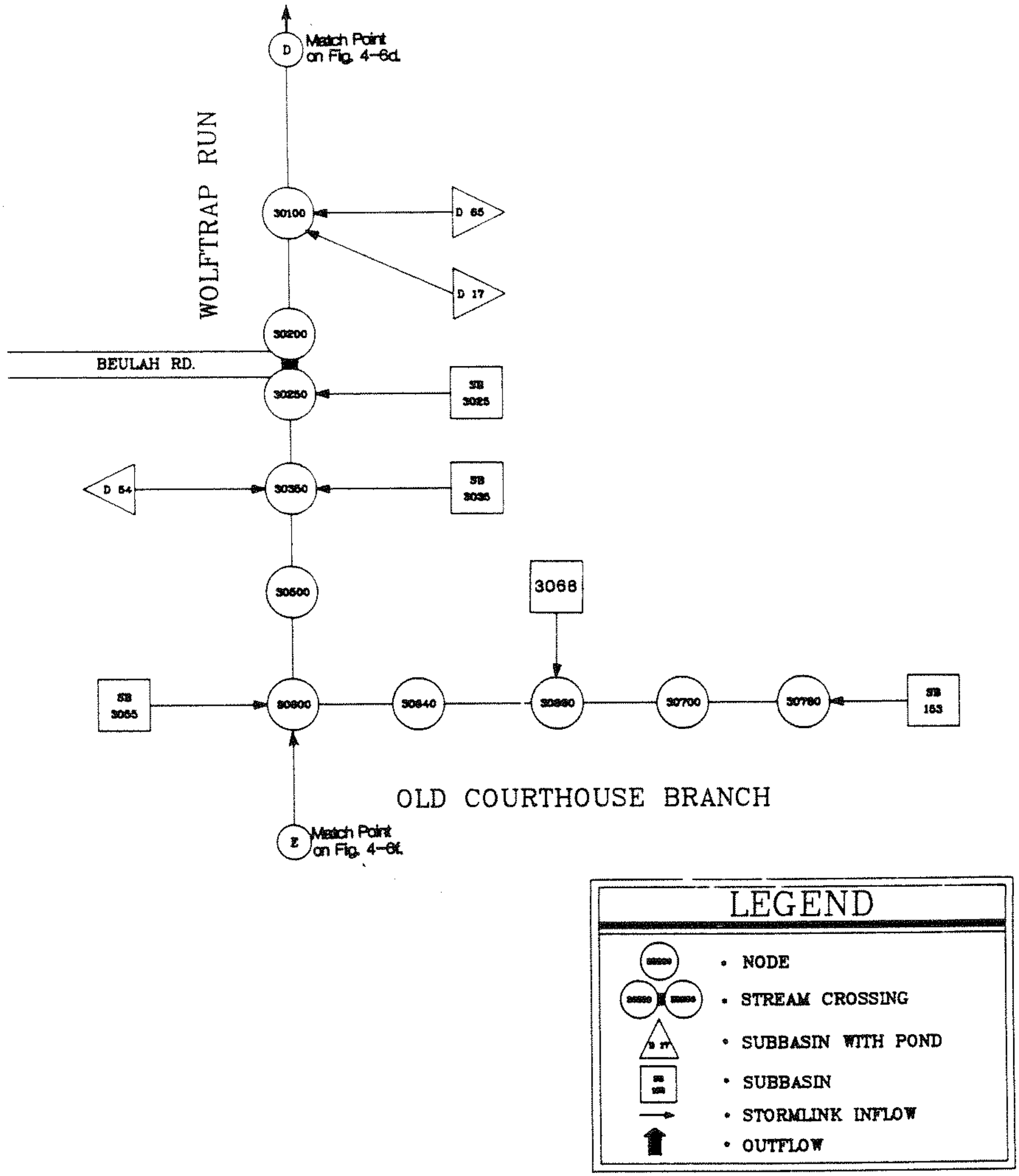


Figure 4-6e. Difficult Run: Model Schematic

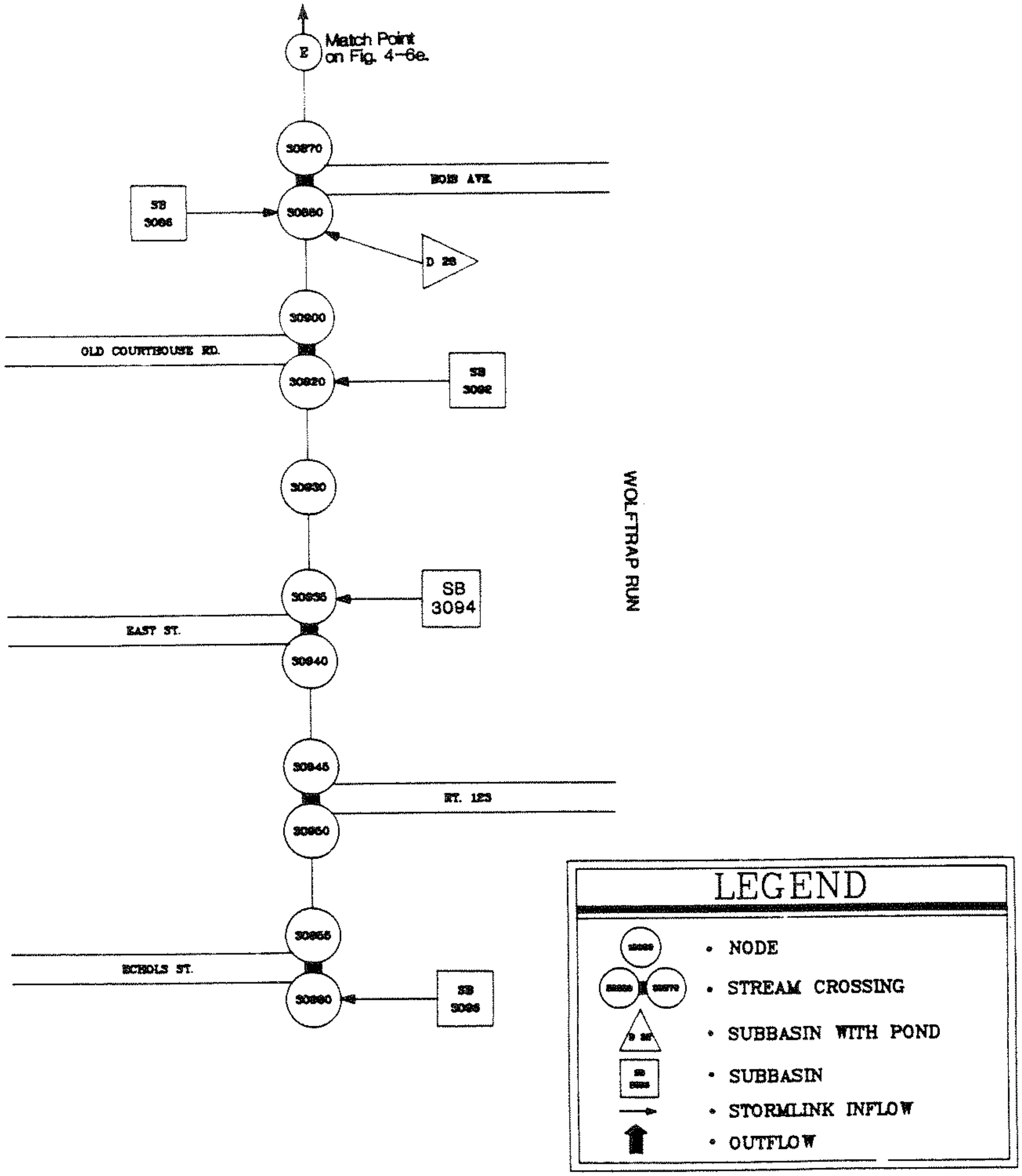


Figure 4-6f. Difficult Run: Model Schematic

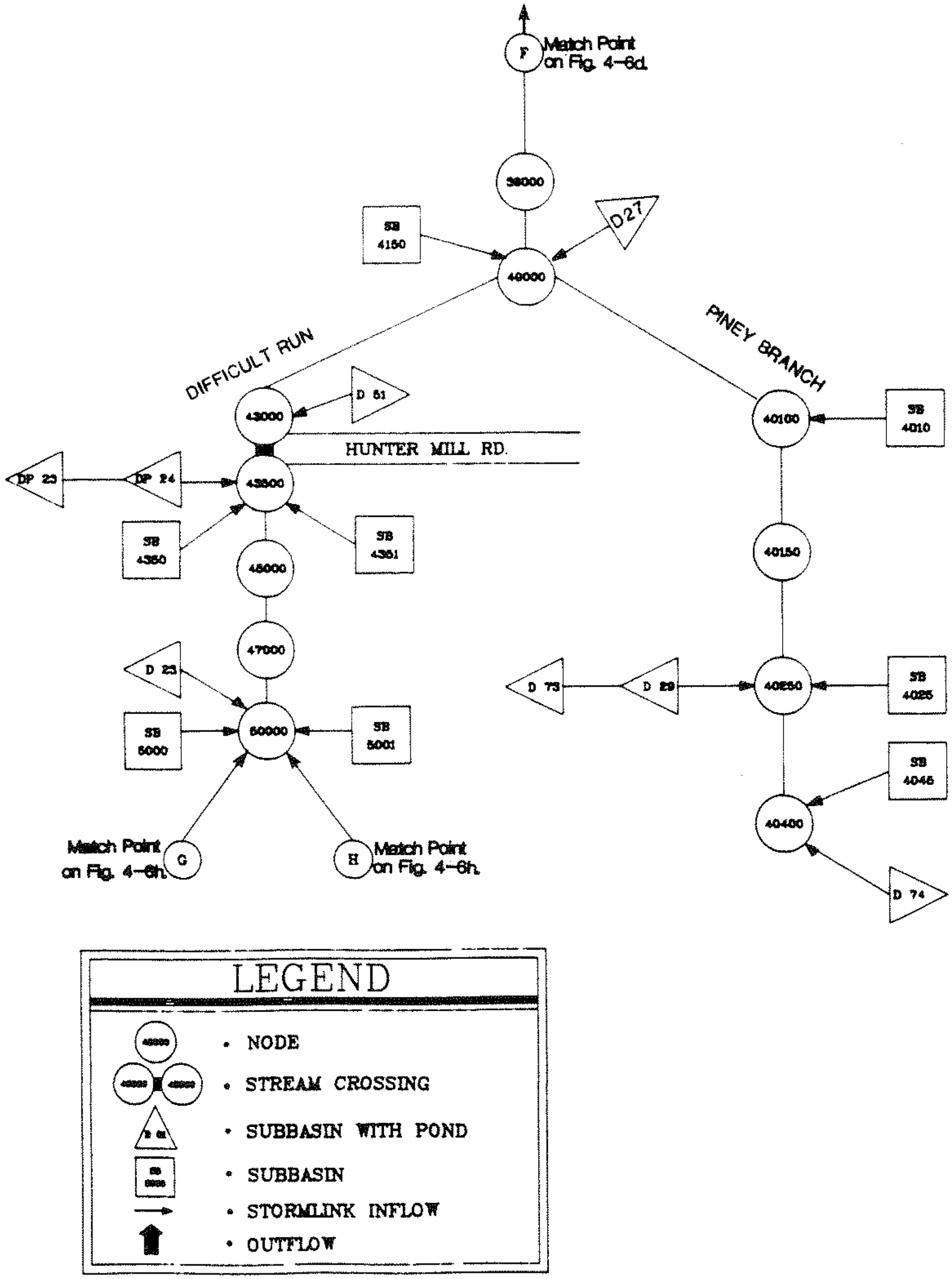


Figure 4-6g. Difficult Run: Model Schematic

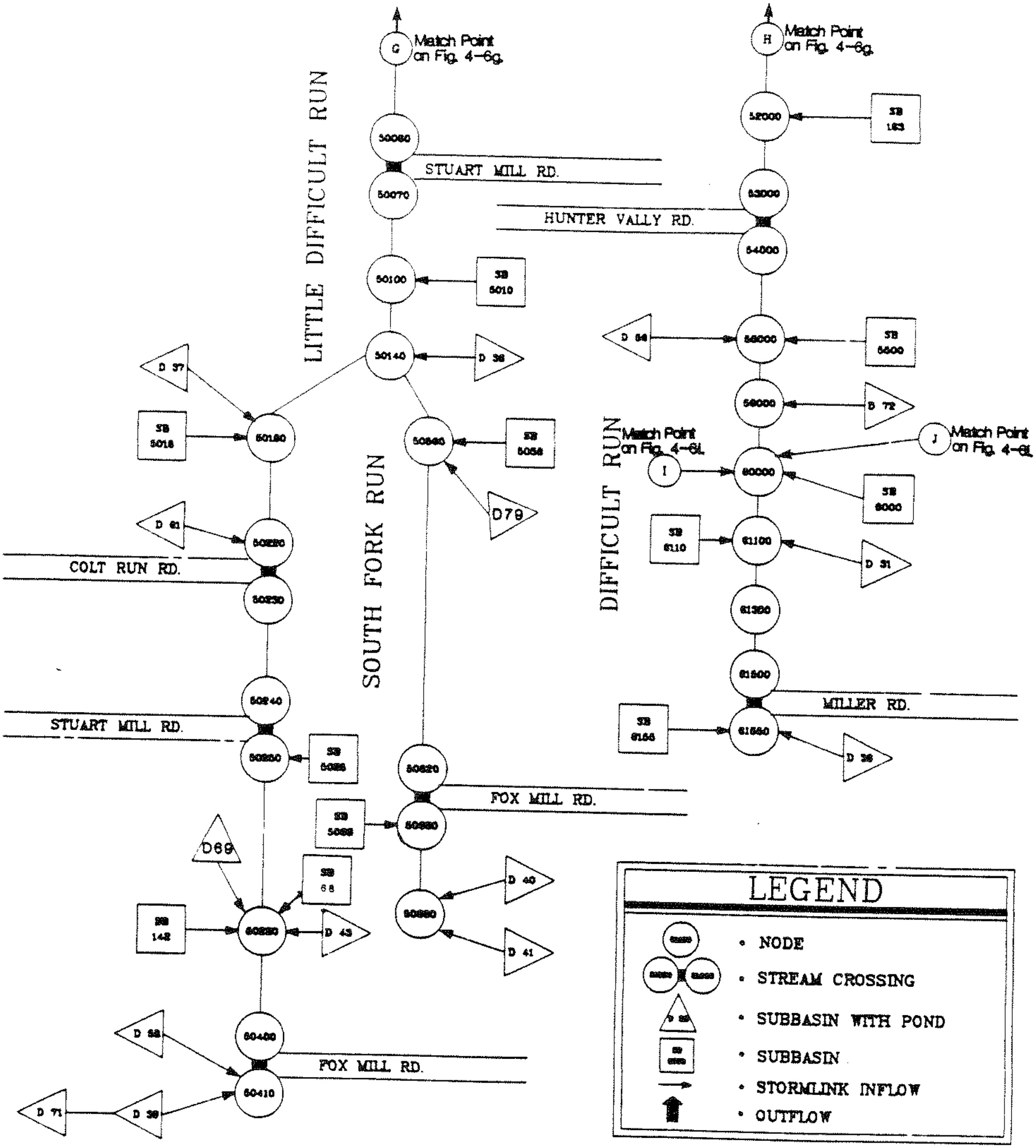


Figure 4-6h. Difficult Run: Model Schematic

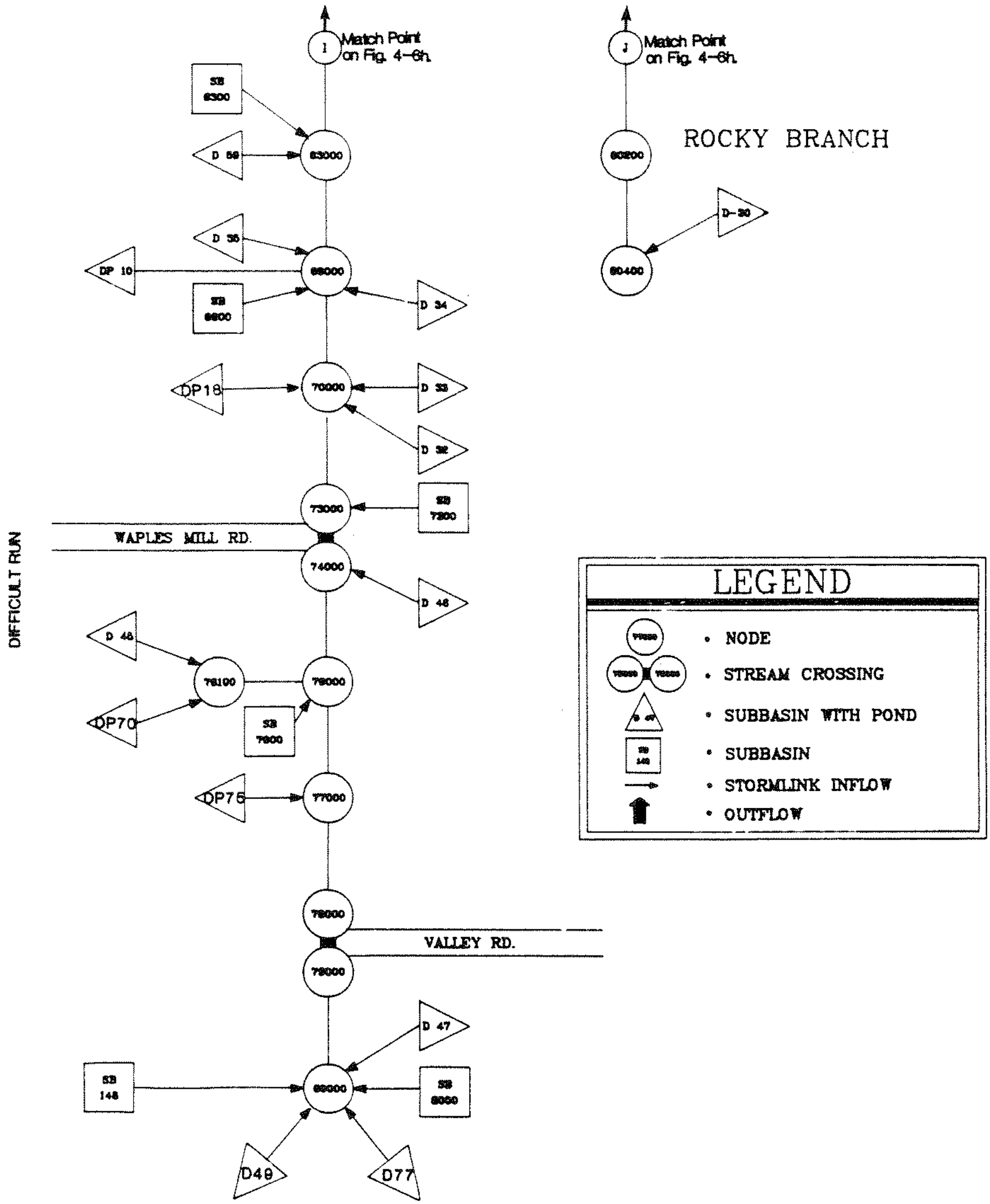


Figure 4-6i. Difficult Run: Model Schematic

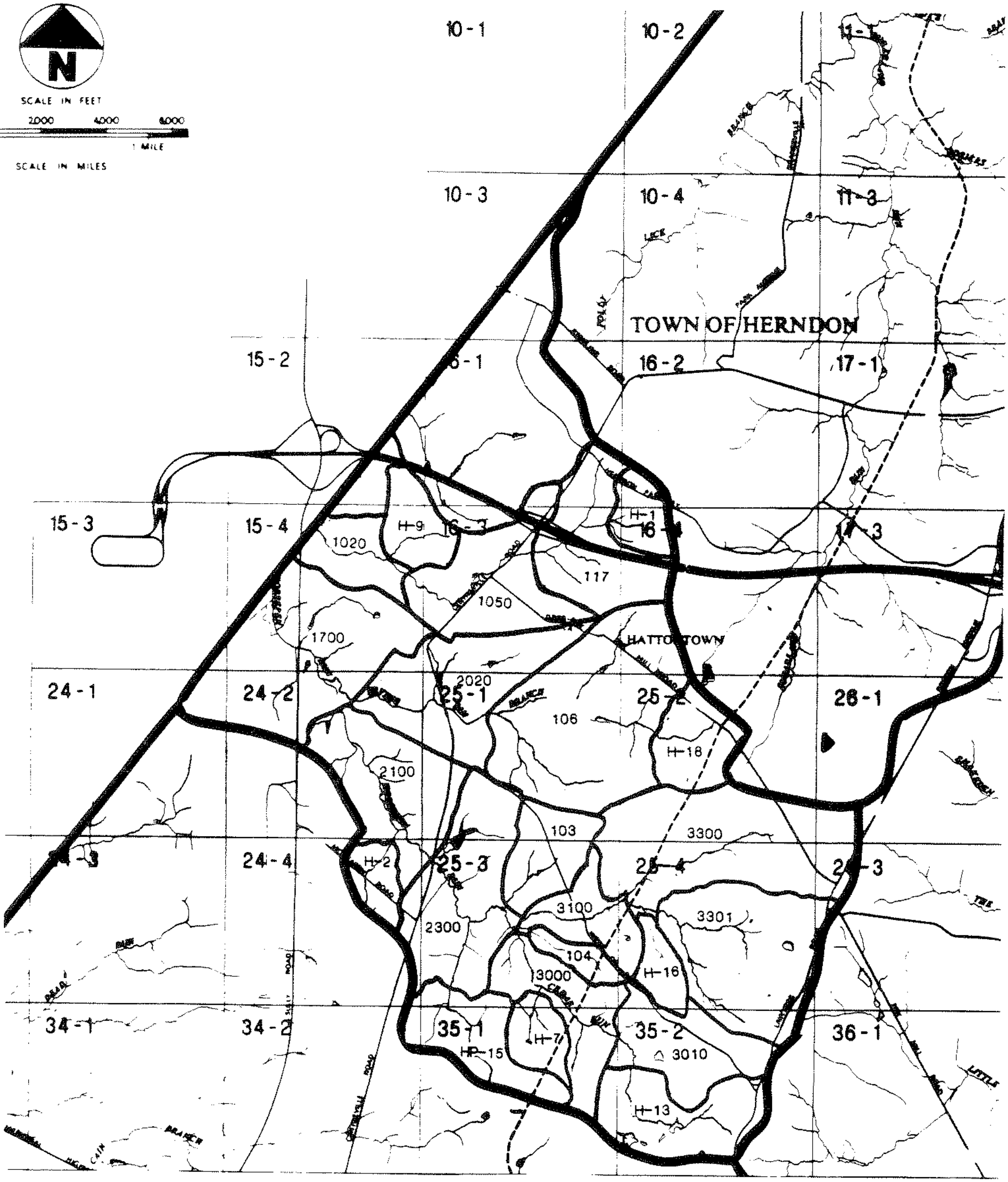


Figure 4-7. Horsepen Creek: Subbasin Delineation

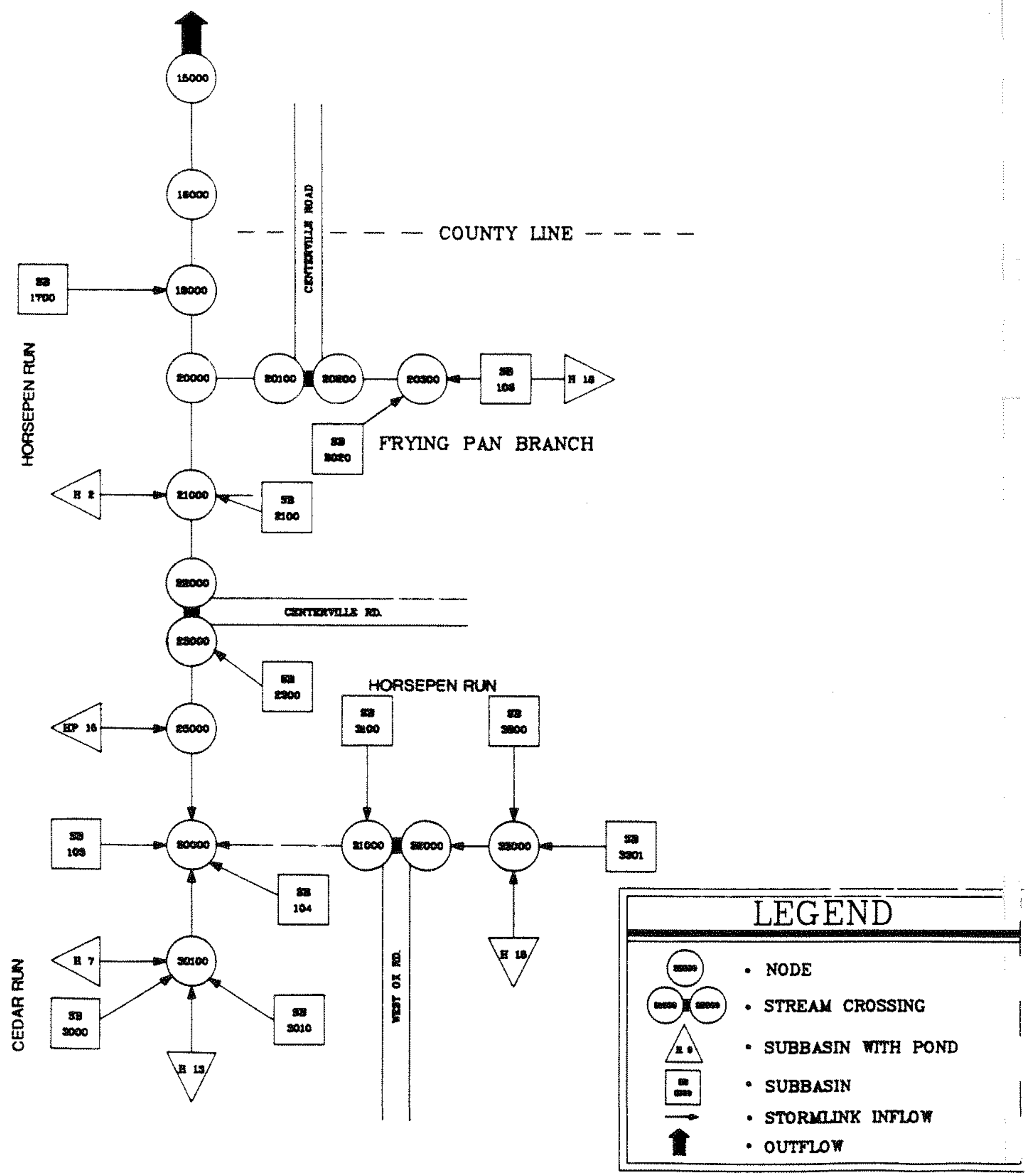


Figure 4-8a. Horsepen Creek: Model Schematic

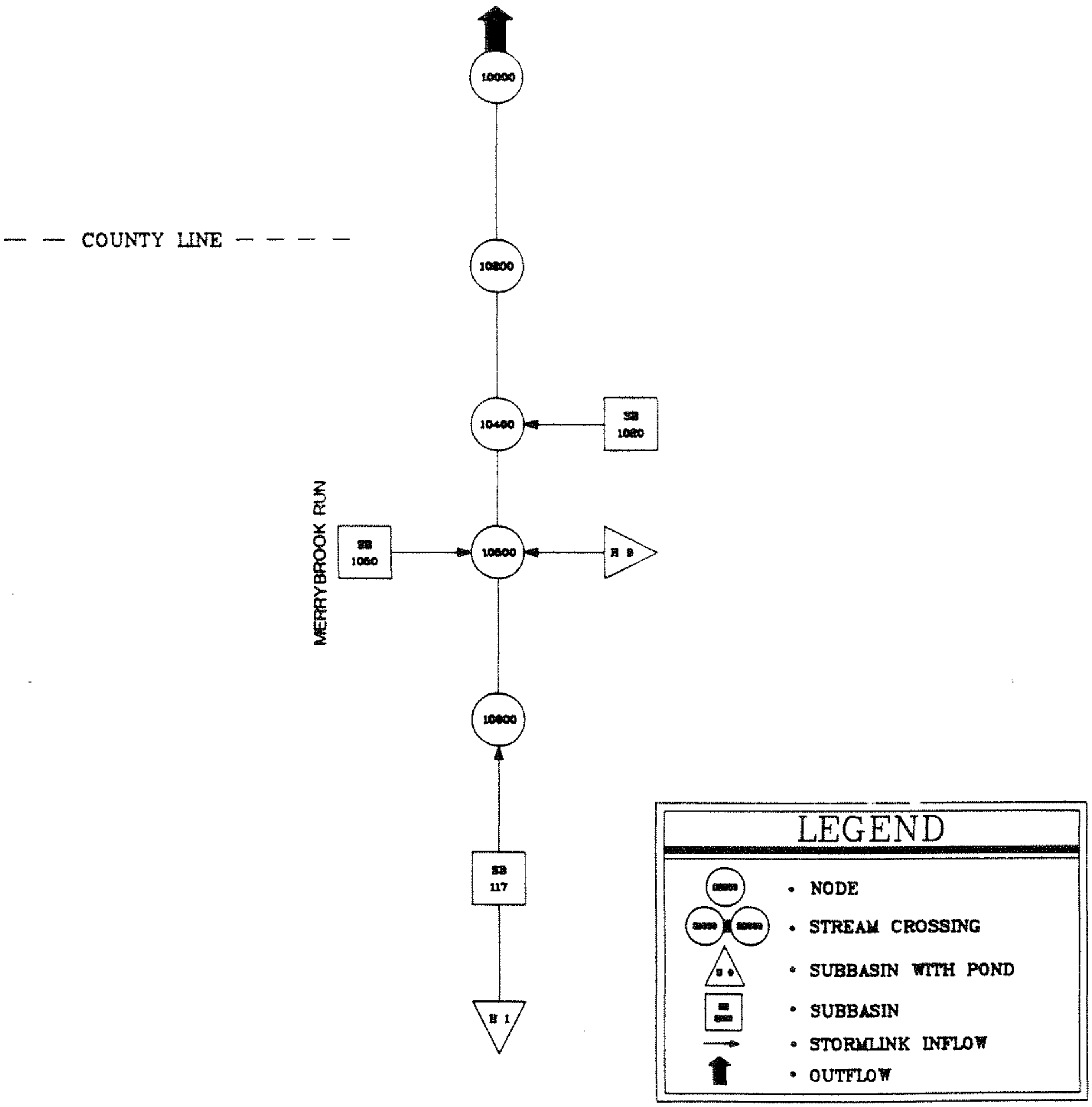


Figure 4-8b. Horsepen Creek: Model Schematic

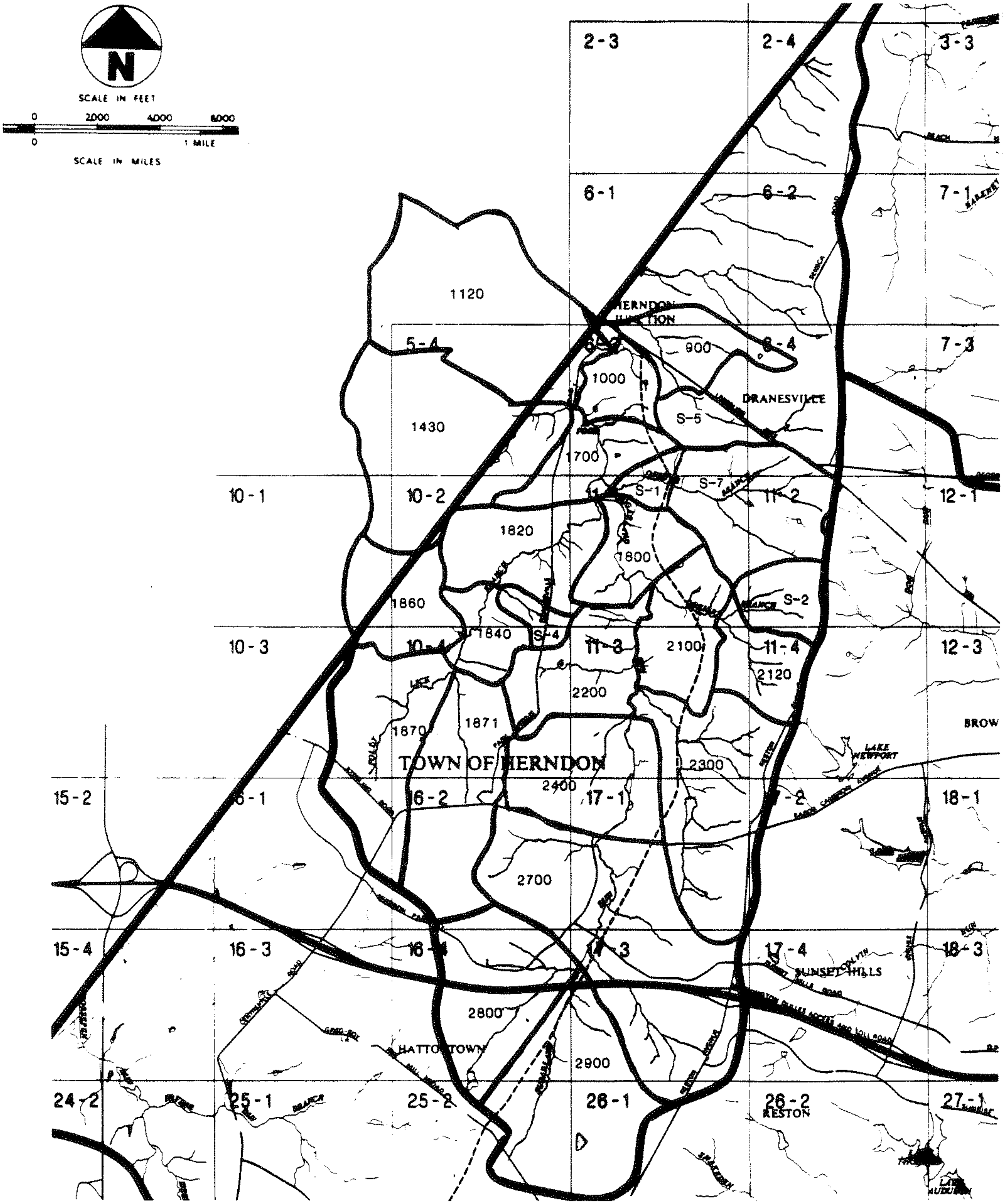


Figure 4-9. Sugarland Run: Subbasin Delineation

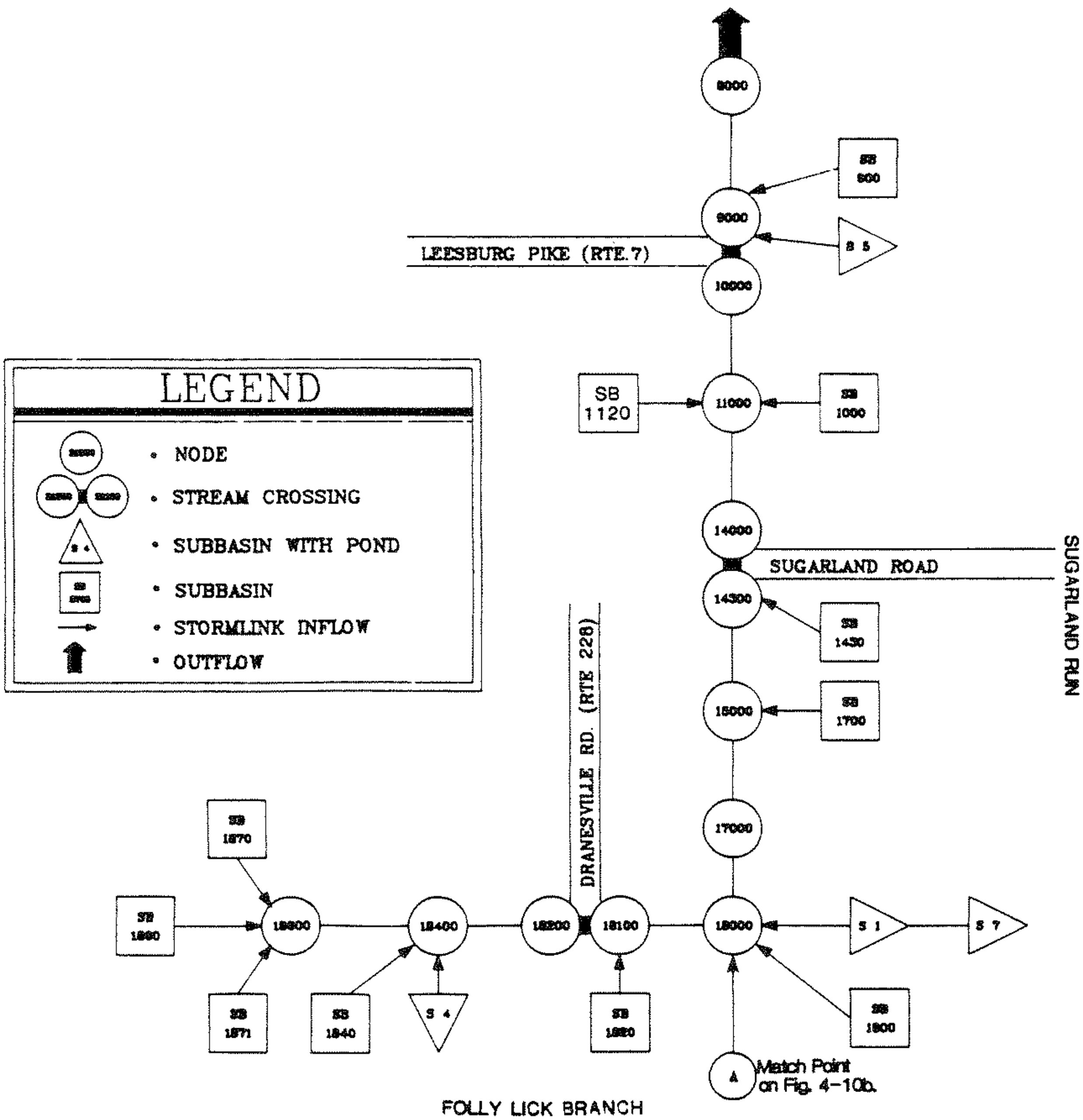


Figure 4-10a. Sugarland Run: Model Schematic

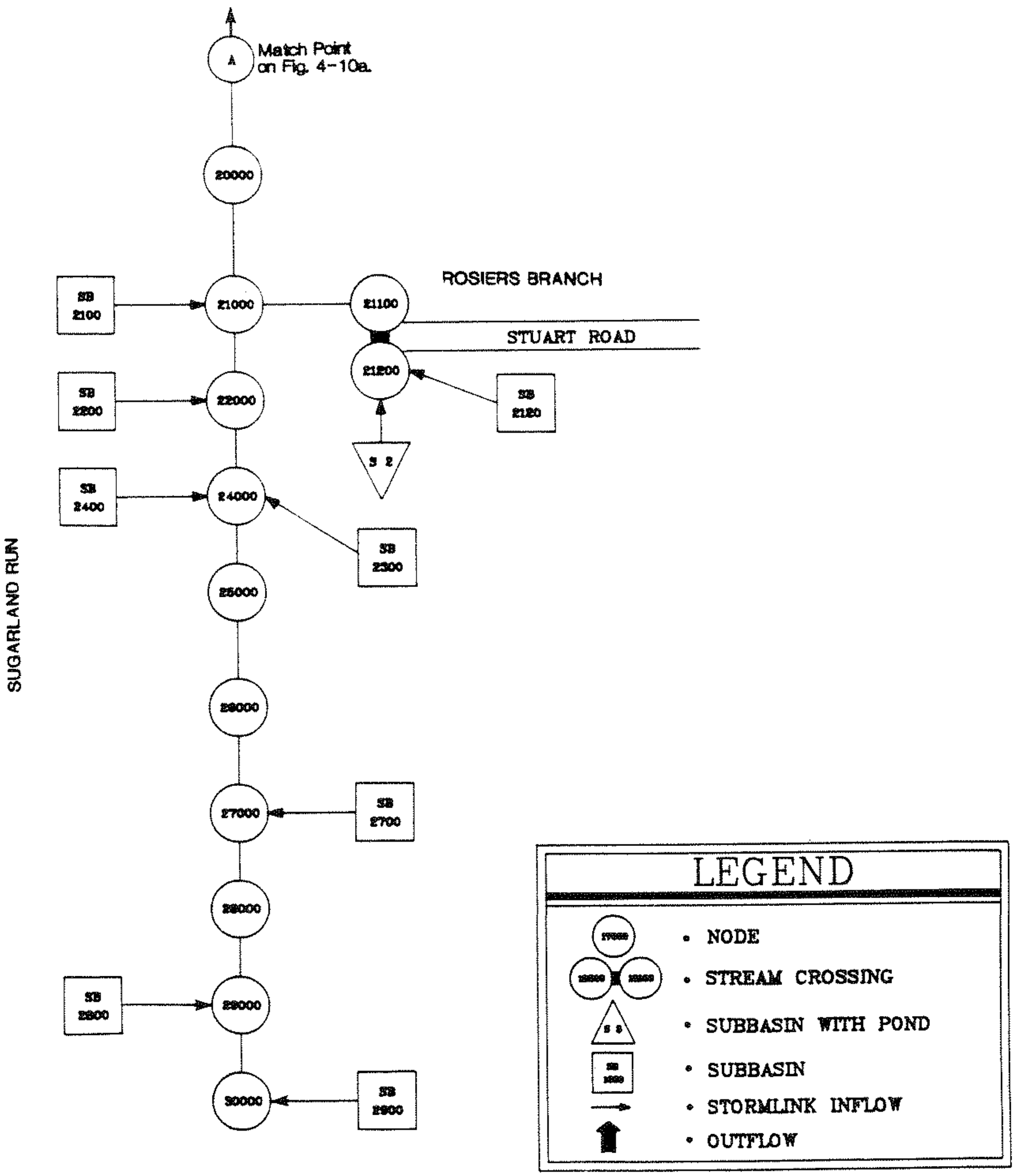


Figure 4-10b. Sugarland Run: Model Schematic

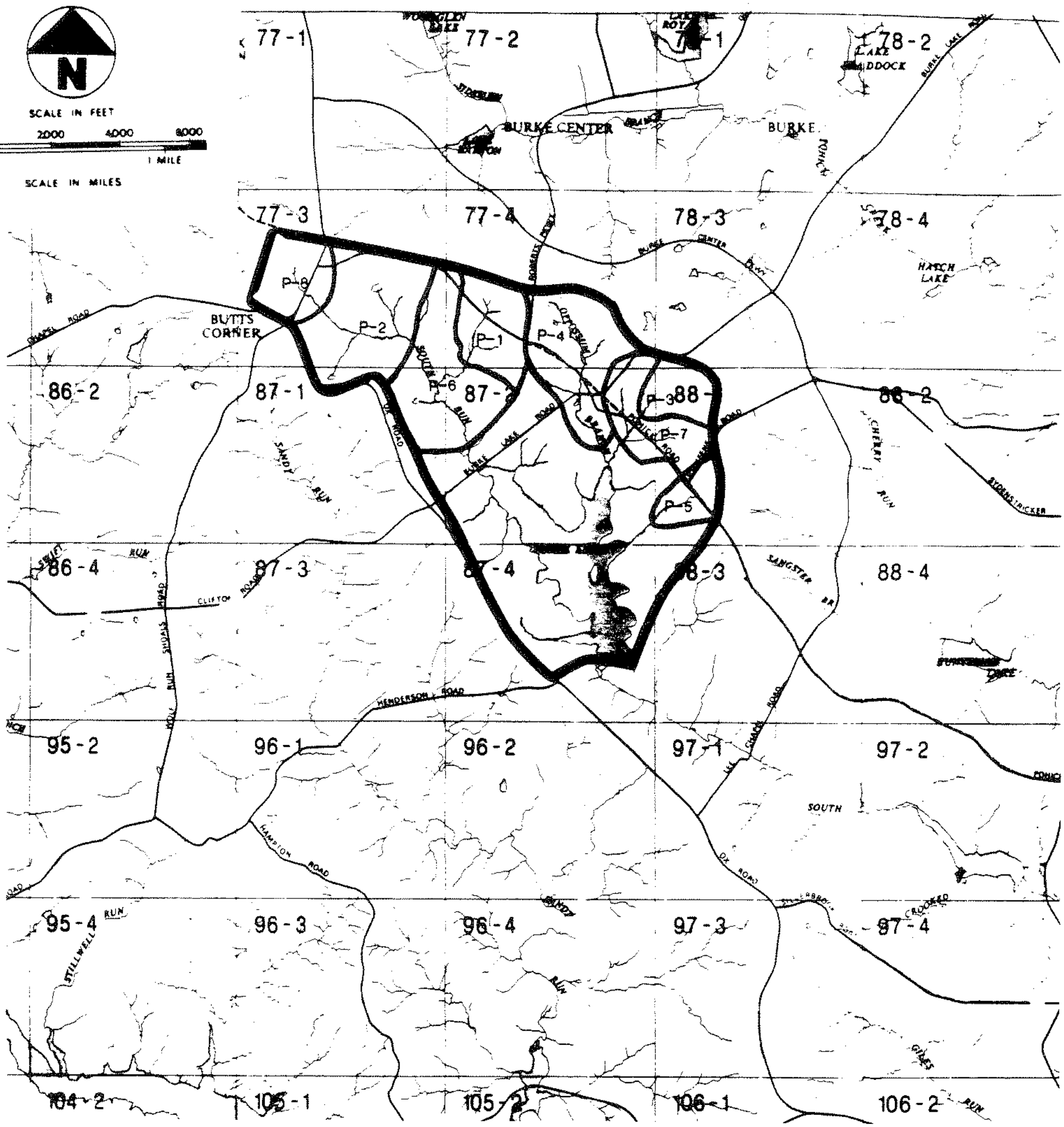


Figure 4-11. Pohick Creek: Subbasin Delineation

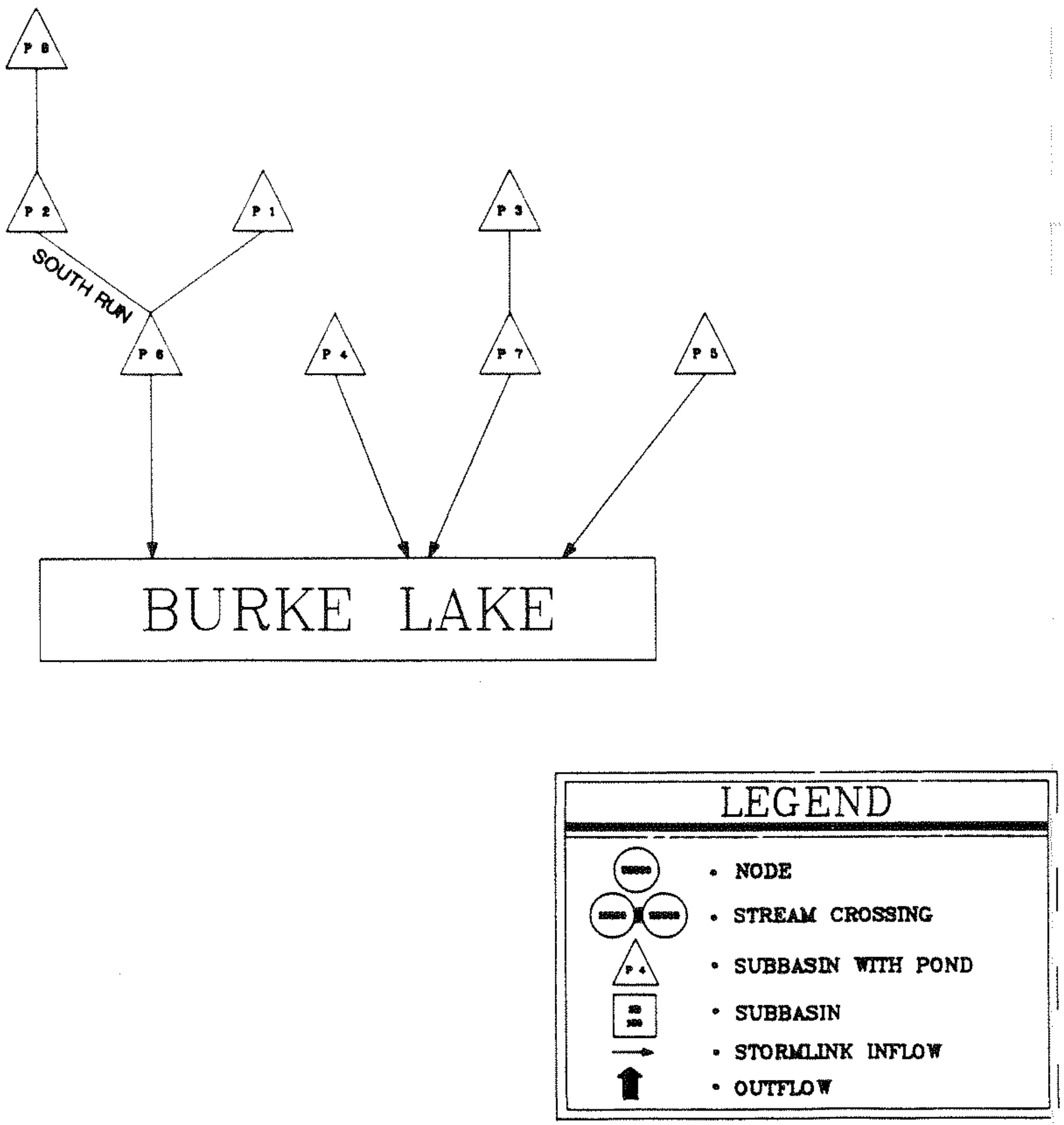


Figure 4-12. Pohick Creek: Model Schematic

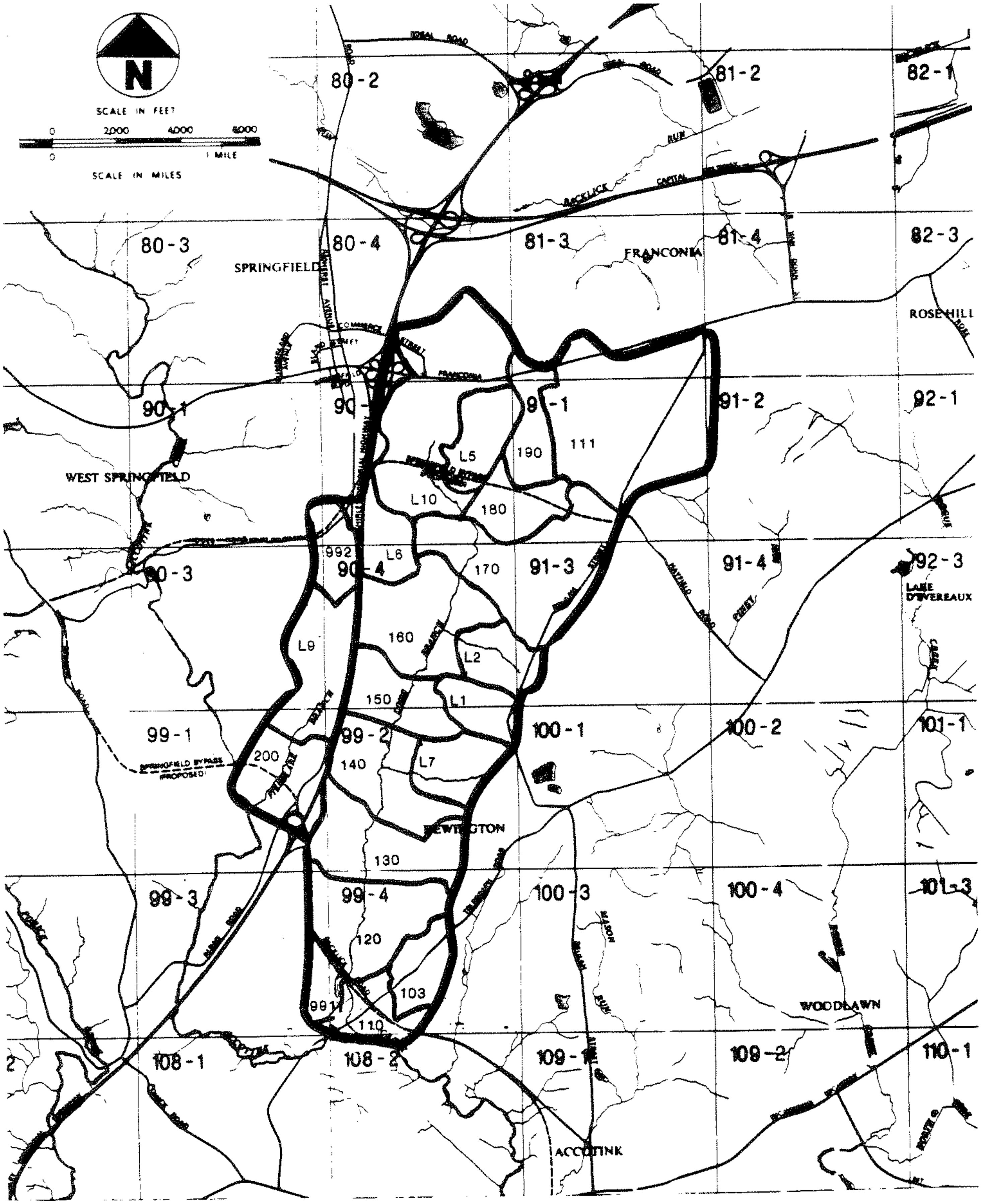


Figure 4-13. Long Branch: Subbasin Delineation

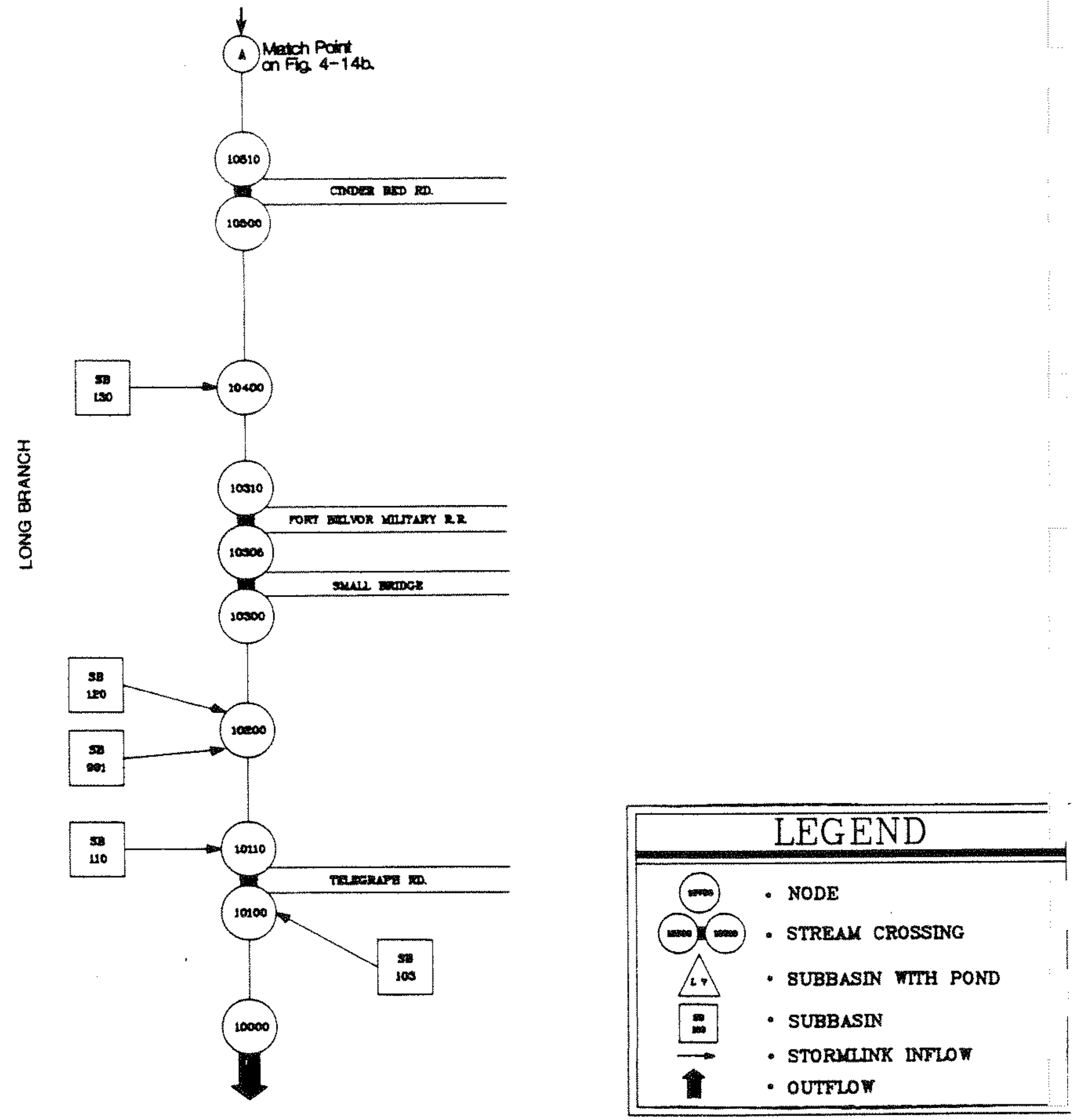


Figure 4-14a. Long Branch: Model Schematic

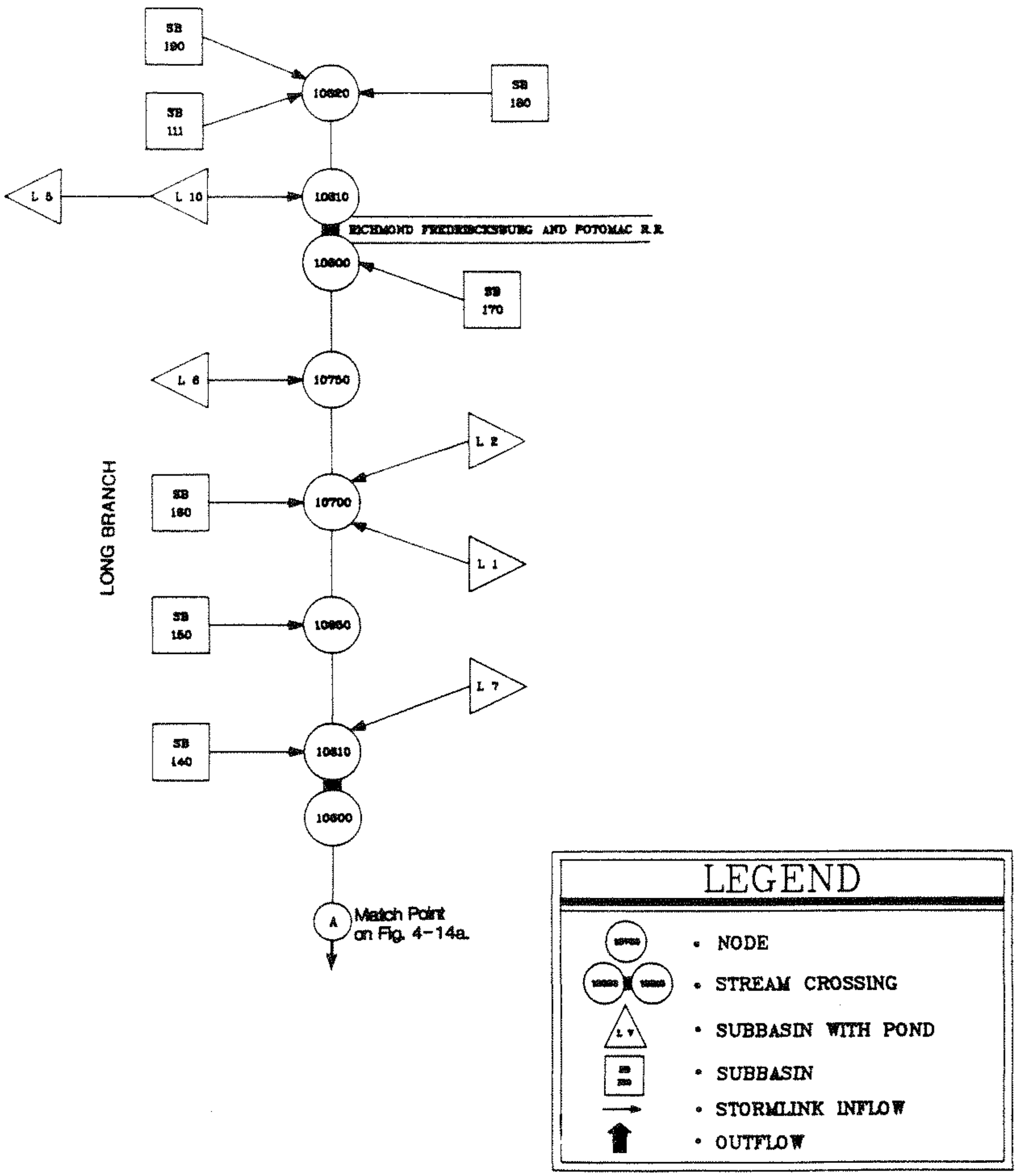


Figure 4-14b. Long Branch: Model Schematic

5.0 EVALUATION OF BENEFITS OF REGIONAL DETENTION BASIN SYSTEM

5.1 STUDY PROCEDURES

Based on the preliminary evaluations of siting and storage requirements regional detention basins were located at the most feasibile sites within the seven study area watersheds. For Cub Run and Little Rocky Run watersheds, which are in the Occoquan Basin, wet detention basins were given preference over extended dry detention basins. For those sites where sufficient storage was available, facilities were sized to achieve both 2-year and 10-year control. If the storage at the site was limited, then detention basins were sized either for wet detention plus 2-year control (Occoquan Basin) or extended dry detention plus 2-year control.

STORMLINK and EXTRAN model simulations were performed to evaluate the benefits of the regional detention basin systems in each of the seven study area watersheds. The 2-year and 10-year design storms were evaluated with and without detention basins for the future land use scenarios. The STORMLINK model was used to evaluate the peak flows at the regional detention basin sites. The EXTRAN model was used to evaluate the watershedwide peak flow reduction benefits of the regional detention basin system by routing the hydrographs produced from STORMLINK through the channel system.

MAXIMUM EFFICIENCY DETENTION BASINS

Initially, regional detention basins were sized to produce a peak release rate for the future land use scenario inflow hydrographs equal to the predevelopment land use peak flow for the 2-year storm and 10-year storm where feasible. These basins are referred to herein as "conventional" detention basin designs. Although reductions in peak flow were detected immediately downstream from the regional detention basin, watershedwide benefits were typically insignificant in most areas due to the drainage area which is not served by the regional detention basin system. These "uncontrolled" areas include existing development which may or may not have onsite detention systems and future development where regional detention basins were not feasible due to various constraints. In order to compensate for areas not controlled by regional detention basins, the concept "maximum efficiency" detention basins was developed. Regional detention basins with a maximum efficiency design achieve smaller release rates than conventional designs by maximizing the use of available storage at the site.

The minimum release rate for all maximum efficiency basins was set equal to 33 percent of the predevelopment peak flow for the 2-year and 10-year storms, storage permitting. If there were not enough storage available to release the 33 percent, then a larger percentage was released as a function of the available storage. For example, in some cases, the release was 50 or 70 percent of the predevelopment peak, and in other cases the peak release rate was equal to the predevelopment release rate (i.e., 100%) used for a conventional basin design because additional storage was not available.

Recent evaluations of erosion control criteria in other areas (e.g., State of Maryland) have concluded that a peak release rate based upon a 2-year predevelopment peak flow may not maintain post-development stream channel erosion at predevelopment levels. It is being suggested that release rates considerably less than the 2-year predevelopment peak flow are required to prevent post-development increases in erosion. The peak release rate (33% of the predevelopment peak flow) used for maximum efficiency detention basins (2-year control) in this study is equivalent to 0.05-0.1 in/hr or less. This release rate is consistent with some of the preliminary results of erosion control standard evaluations carried out in other areas. Of course, it is not feasible to achieve a peak release rate of 33% of the predevelopment peak flow for all regional detention basin sites due to storage constraints; however, the reduced release rates achieved at most maximum efficiency sites are still preferable to conventional release rates from an erosion control standpoint and offer the added advantage of affecting some of the impacts of uncontrolled areas.

Peak flow reduction benefits were evaluated at the detention basin sites and watershedwide for the maximum efficiency detention basins.

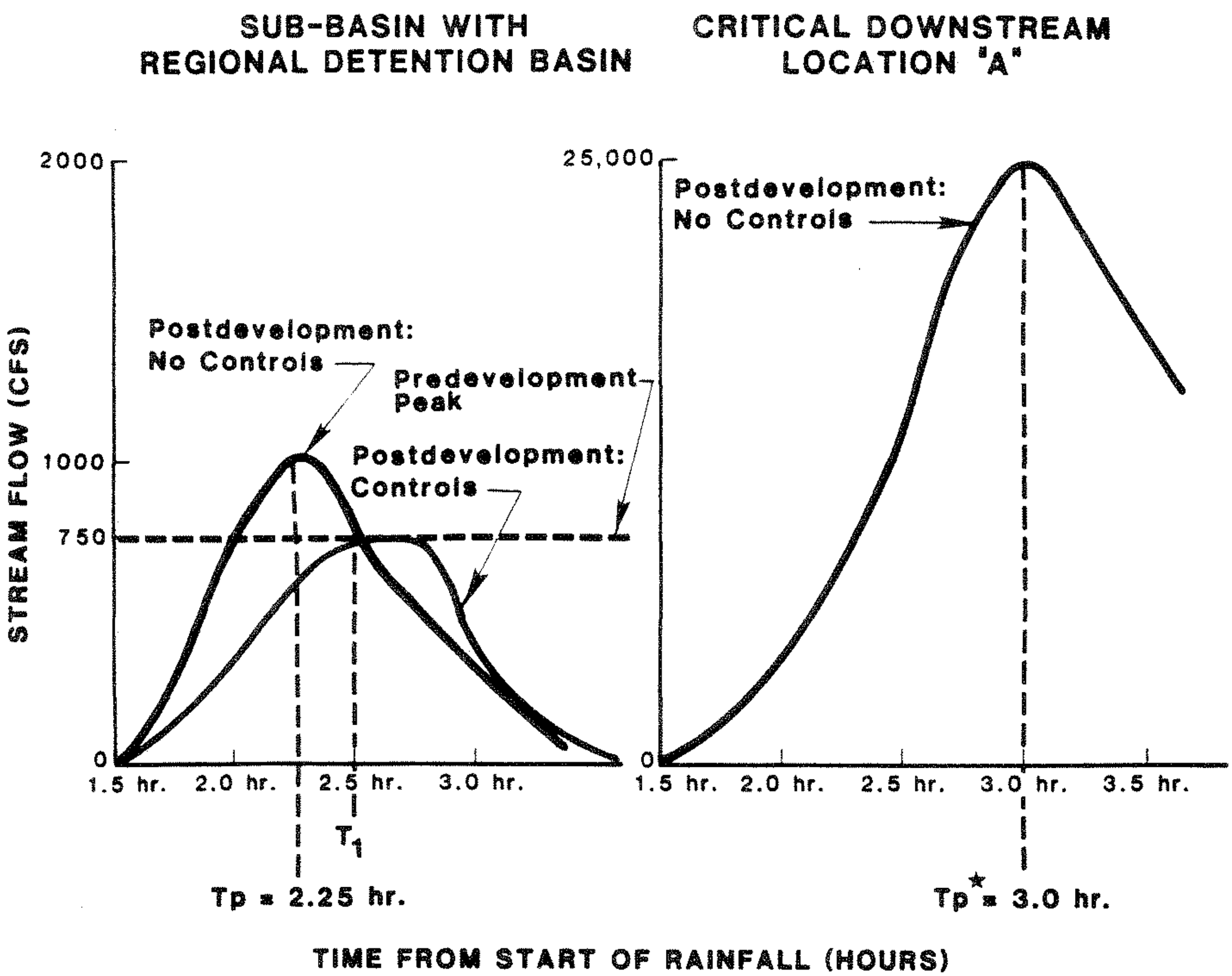
TIME OF TRAVEL EVALUATIONS

Time of travel studies were performed to evaluate the most effective detention basin locations by analyzing the impacts of the regional basins at various key locations within each of the seven watershed study areas.

The benefit of an upstream detention basin on the peak flow at a downstream location is a function of the timing of the detention basin outflow hydrograph, the timing of the downstream hydrograph peak at the location of interest, and the time of travel associated with the distance from the detention basin to the downstream locations of interest.

Figure 5-1 presents an example of the relationship of the controlled hydrograph timing to the timing of the downstream hydrograph peak.

The detention basin reduces each inflow hydrograph ordinate through time T_1 (or 2.5 hours). The impact on the downstream hydrograph with a time to peak of 3.0 hours (T_p*) depends on the time of travel of the controlled hydrograph to the downstream location. If the upstream detention basin is far enough away and the time of travel is greater than the downstream hydrograph time to peak, then there would be no downstream benefit. That is, the peak flow reduction at the detention basin site would not be detected downstream until <u>after</u> the peak flow had occurred at the downstream site. In a similar manner, if the upstream detention basin is too close and the time of travel is less than the time to peak of the downstream hydrograph minus the time to peak of the controlled hydrograph ($T_p^* - T_1$), then there would be no downstream benefit. That is, the peak flow reductions at the detention basin site would be detected downstream <u>before</u> the occurrence of the downstream hydrograph peak. There would also be negative impacts in the main stem for detention basins which lag the inflow hydrograph such that the outflow hydrograph value is greater than the inflow hydrograph value at the time of the downstream peak.



A. "MOST EFFECTIVE" DETENTION LOCATIONS: 0.5 hr to 3.0 hr travel time

Max. Travel Time $= T_p^* = 3.0$

Min. Travel Time $= T_p^* - T_1 = 3.0 - 2.5 = 0.5$ hr

B. "LEAST EFFECTIVE" DETENTION LOCATIONS: Travel time less than 0.5 hr

Travel Time $= T_p^* - T_1 = 3.0 - 2.5 = 0.5$ hr

C. "NO IMPACT" LOCATIONS: Travel time greater than 3.0 hr

Travel Time $= T_p^* = 3.0$

Figure 5-1. Example: Impact of Peak Shaving on Downstream Location

The time of travel study was conducted using the 2-year storm to evaluate impacts of the regional detention basins. Time of travel contours were mapped for each watershed by determining the time of travel from stormwater model junctions to the mouth of the watershed. The total time of travel was the sum of the individual segment time of travel values which were based on the segment length and the peak bankfull velocity within the segment.

The example in Figure 5-1 presents an application of a conventional detention basin which releases the predevelopment peak flow. For this study, maximum efficiency basins were evaluated which produce peak outflows less than the predevelopment peak and also control or reduce the inflow hydrograph ordinates for a greater period of time. Thus, the maximum efficiency detention basins achieve greater benefits at more downstream locations than conventional detention basin designs at the same sites.

For each watershed, individual detention basins or groups (clusters) of detention basins located close together were evaluated by determining their impact on selected downstream key locations based on the influence of hydrograph timing. The maximum travel time (time to peak of downstream hydrograph) and the minimum travel time (time to peak of downstream hydrograph minus time to peak of controlled hydrograph) were determined to establish the "range of effective timing". If the time of travel from a given detention basin location to the specific key location was within the maximum and minimum range, then the downstream location was influenced by the upstream detention basin controls. The impacts of the detention basins based on the time of travel study are included in the evaluation summaries presented in the following sections.

5.2 PEAK FLOW REDUCTION BENEFITS

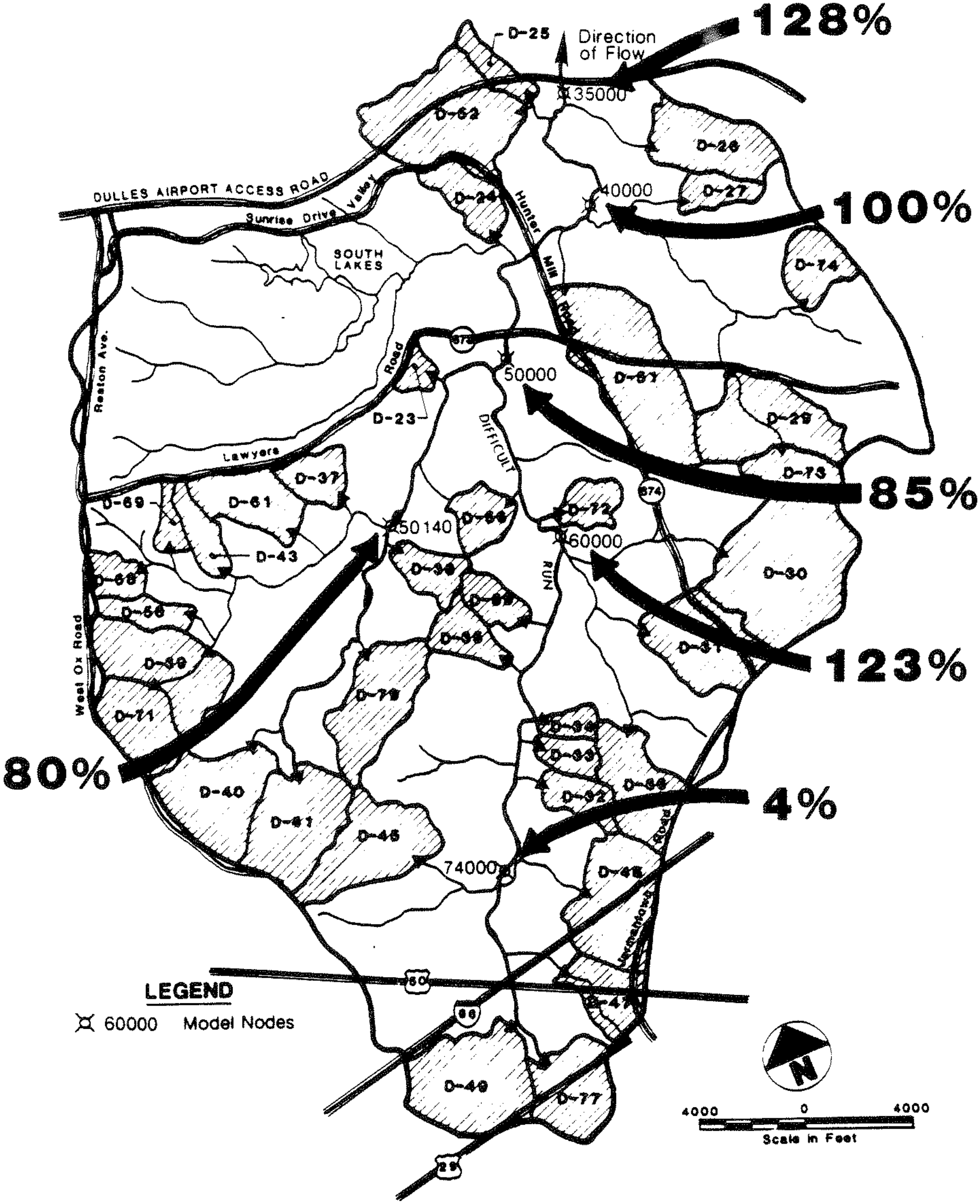
For each of the seven watershed study areas, the 2-year storm and the 10-year storm were evaluated to determine the erosion control and flood control benefits of the regional detention basin system. Benefits are expressed in terms of peak flow reductions at the detention basin site and watershedwide.

The following sections present tables which summarize the peak flows at the regional detention basin sites. The peak flows with maximum efficiency detention and without detention for future land use are presented and compared to the predevelopment peak flows at each site. Maximum efficiency basins produce peak flows which are less than the predevelopment peaks. (If only conventionally regional detention basin designs were evaluated, then the peak flows with detention would be equal to the predevelopment peak flow).

Tables which compare watershedwide peak flows with and without maximum efficiency detention basins are also presented in the following sections for each watershed. Maximum efficiency detention basins can provide up to a 100 percent increase in 2-year peak-shaving benefits for the local and downstream areas especially where large clusters of detention basins are located upstream.

In other areas of a watershed, maximum efficiency detention basins, although providing greater local benefits than conventional detention basin designs, do not achieve significant increases in areawide benefits. This occurs especially in those areas where the majority of the flow is generated from areas that cannot be controlled from regional detention basins.

As an example of benefits, Figure 5-2 presents a portion of the Difficult Run watershed showing the increase in 2-year peak-shaving benefits achieved by smaller detention basin release rates. The percentages on the figure represent the percent increase in peak flow control benefits of the maximum efficiency regional detention basins compared to conventional detention basin designs. For example, at location number 50140, the conventional detention basin design achieves a peak flow reduction of 30 percent while the maximum efficiency basins produced a peak flow reduction of 54 percent. Thus, the increase in 2-year peak-shaving benefits was 80 percent for the maximum efficiency design.



INCREASE IN 2-YEAR PEAK-SHAVING BENEFITS ACHIEVED BY SMALLER DETENTION BASIN RELEASE RATES (33% of Predevelopment Peak Flow)

Figure 5-2. Difficult Run Example of Maximum Efficiency Basin Benefits

5.2.1 CUB RUN

Detention Basin Control

A summary of the peak flows at the regional detention basin sites is given in Table 5-1. For each detention basin, 2-year and 10-year peak flows are given for the predevelopment land use and the future land use with maximum efficiency basin detention and without detention. For the detention basins which have 2-year and 10-year control (e.g., C-4 which is a WET-10 basin type), the peak flows are given for the 2-year and 10-year storms. However, for detention basins which only had sufficient storage for 2-year control (e.g., C-3 which is an EXTDRY-2 basin type), only the 2-year peak flows are given in the table.

Twenty-four of the 31 regional detention basins had sufficient storage to reduce the peak release rate to less than the predevelopment peak flows for the 2-year storm. Of the 24 maximum efficiency basins, 18 provided release rates of 33 percent of the predevelopment peak for the 2-year storm, and six other detention basins provided release rates less than the predevelopment peak but greater than the 33 percent. The remaining seven detention basins had sufficient storage to produce a peak release rate equal to the predevelopment peak flow.

Watershedwide Benefits

The watershedwide benefits of the regional detention basins for future land use conditions were evaluated by selecting key locations throughout the watershed for comparisons of peak flow reduction benefits. In addition to the 31 proposed regional detention basins, 12 County detention basins, as shown in Table 4-10, were modeled to produce the peak flow reductions. Figure 5-3 shows the key locations in Cub Run watershed for peak flow comparisons. This figure also shows the locations of the regional detention basins. The key locations are given with the corresponding EXTRAN model junction numbers shown in the flow comparison tables. Table 5-2 presents the 2-year and 10-year peak flow comparisons with and without the maximum efficiency detention basins at each key location. The percent reductions in peak flows are also given.

TABLE 5-1

CUB RUN
SUMMARY OF PEAK FLOWS AT DETENTION BASIN SITES

Basin Number	Basin Type	2-year Storm Predev. LU (cfs)	2-year Storm Future Land Use Without Detention (cfs)	2-year Storm Future Land Use With Detention (cfs)	10-year Storm Predev. LU (cfs)	10-year Storm Future Land Use Without Detention (cfs)	10-year Storm Future Land Use With Detention (cfs)
C-3	EXTDRY-2	52.3	333.6	17.3*	—	—	—
C-4	WET-10	42.9	99.9	14.2*	131.4	233.4	43.4*
C-5	WET-10	42.9	111.2	14.2*	131.2	264.3	83.3*
C-11	WET-2	28.9	183.7	19.5*	—	—	—
C-12	WET-10	23.2	153.7	7.7*	70.5	270.2	23.3*
C-18	WET-2	108.0	292.5	35.6*	—	—	—
C-19	WET-10	61.2	134.4	61.1	189.8	323.2	192.3
C-20	WET-2	32.9	74.5	10.9*	—	—	—
C-21	WET-2	31.2	62.6	32.9	—	—	—
C-22	EXTDRY-2	32.6	113.8	10.8*	—	—	—
C-23	WET-10	24.6	50.9	8.1*	75.9	126.1	25.0*
C-24	WET-2	34.2	69.4	11.3*	—	—	—
C-25	EXTDRY-2	40.3	133.3	13.3*	—	—	—
C-28	WET-2	53.3	118.7	27.6*	—	—	—
C-30	WET-10	38.1	99.5	12.6*	116.5	230.1	33.0*
C-35	WET-10	27.9	59.9	9.2*	86.5	145.2	68.5*
C-37	WET-10	149.0	213.3	148.1	458.4	536.6	466.4
C-39	EXTDRY-2	39.8	95.6	33.1*	—	—	—
C-40	EXTDRY-2	35.8	106.0	21.8*	—	—	—
C-41	WET-2	25.5	86.5	11.7*	—	—	—
C-43	WET-10	34.0	86.8	11.2*	103.3	198.4	44.1*
C-44	EXTDRY-2	50.5	138.6	16.7*	—	—	—
C-46	WET-10	58.0	186.0	19.1*	171.3	345.2	146.5*

NOTE: "*" indicates maximum efficiency detention basin.

TABLE 5-1

CUB RUN
SUMMARY OF PEAK FLOWS AT DETENTION BASIN SITES
(CONTINUED)

		2-year Storm			10-year Storm		
			Future Land Use			Future Land Use	
Basin Number	Basin Type	Predev. LU (cfs)	Without Detention (cfs)	With Detention (cfs)	Predev. LU (cfs)	Without Detention (cfs)	With Detention (cfs)
C-47	WET-10	40.8	148.6	13.5*	122.6	263.3	40.5*
C-49	WET-2	39.2	74.6	12.9*	—	—	—
C-50	WET-10	82.4	266.1	82.2	241.8	477.0	239.8
C-53	EXTDRY-2	39.7	78.2	13.1*	—	—	—
C-54	EXTDRY-2	124.6	242.7	41.1*	—	—	—
C-57	EXTDRY-2	29.5	67.4	32.3	—	—	—
C-62	WET-2	19.6	39.9	20.7	—	—	—
C-63	EXTDRY-2	80.8	222.0	81.0	—	—	—

NOTE: "*" indicates maximum efficiency detention basin.

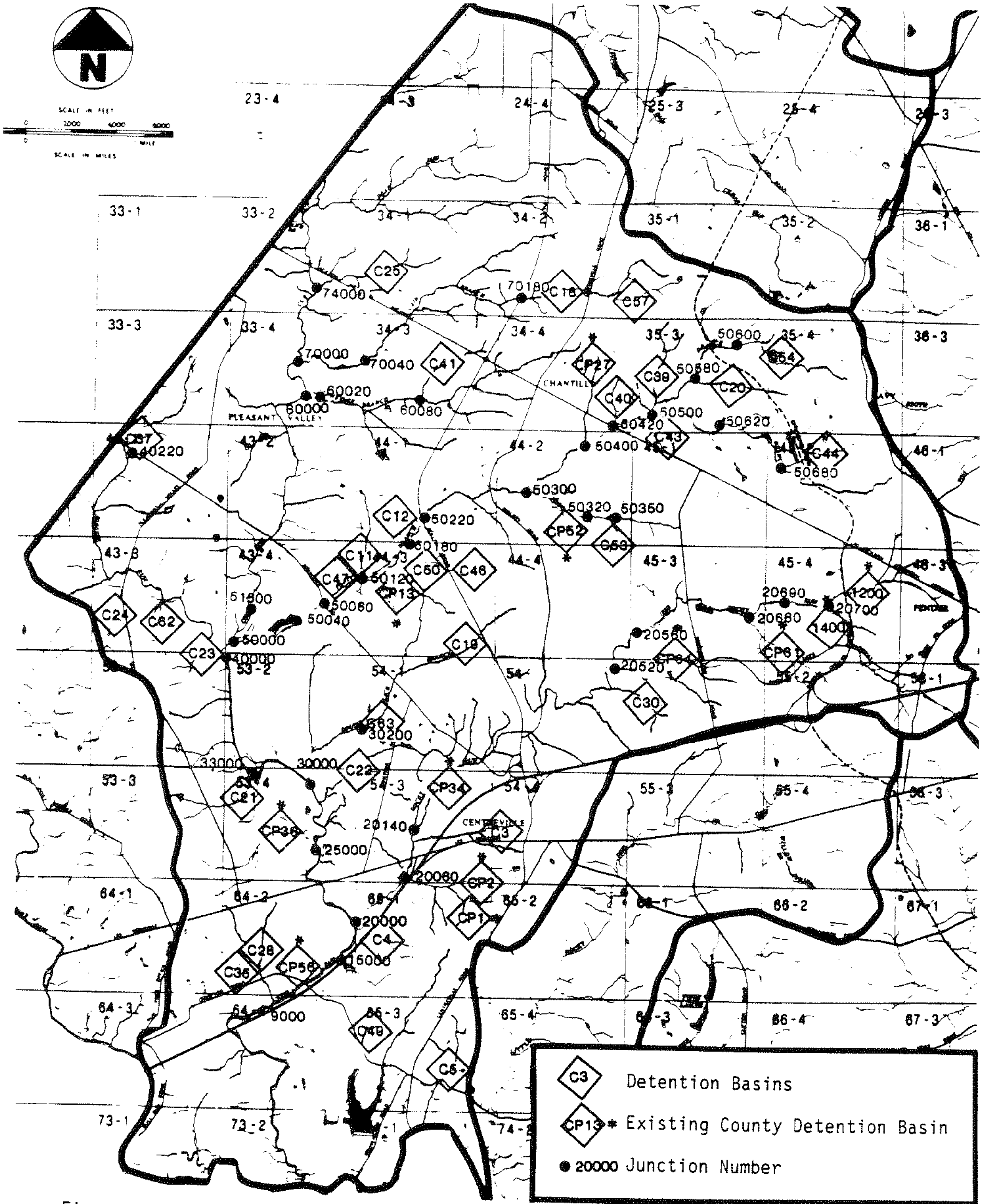


Figure 5-3. Cub Run: Key Locations (Junction Number) for Peak Flow Comparisons

TABLE 5-2

CUB RUN
WATERSHEDWIDE PEAK FLOW COMPARISONS
(FUTURE LAND USE)

	2 YEAR STORM			10 YEAR STORM		
	WITHOUT DETENTION BASIN	WITH MAX. EFFICIENCY BASIN		WITHOUT DETENTION BASIN	WITH MAX. EFFICIENCY BASIN	
JUNCTION NUMBER	FLOW (cfs)	FLOW (cfs)	% REDUCED	FLOW (cfs)	FLOW (cfs)	% REDUCED
74000	736.6	715.5	2.9	1445.7	1425.9	1.4
70180	405.3	273.6	32.5	676.9	483.0	28.6
70040	604.3	509.3	15.7	1149.5	1079.8	6.1
70000	978.4	866.2	11.5	1946.6	1879.2	3.5
60080	538.6	469.9	12.8	1028.9	965.3	6.2
60020	787.0	735.2	6.6	1462.9	1393.9	4.7
60000	1176.4	1064.8	9.5	2291.8	2213.0	3.4
51500	1226.8	1128.4	8.0	2273.6	2207.6	2.9
50680	312.3	190.1	39.1	727.4	613.0	15.7
50620	662.6	632.7	4.5	1250.9	1187.2	5.1
50600	252.2	84.7	66.4	744.6	586.6	21.2
50580	266.0	124.6	53.2	930.1	720.8	22.5
50500	592.0	436.6	26.2	1788.5	1379.5	22.9
50420	667.1	491.1	26.4	1889.7	1487.7	21.3
50400	859.9	643.5	25.2	1990.1	1591.6	20.0
50350	413.3	348.5	15.7	898.9	826.4	8.1
50320	299.8	253.2	15.5	612.0	569.1	7.0
50300	858.0	663.6	22.7	2237.5	1890.8	15.5
50220	902.1	731.9	18.9	2274.4	1964.8	13.6
50180	894.5	748.3	16.3	2240.3	2042.3	8.8
50120	902.0	788.5	12.6	2236.2	2063.6	7.7
50060	900.5	802.9	10.8	2238.3	2097.3	6.3
50040	905.5	808.4	10.7	2296.6	2156.2	6.1
50000	1967.7	1762.9	10.4	3640.1	3628.3	0.3
40220	256.8	195.2	24.0	539.3	470.5	12.8
40000	2558.6	2346.5	8.3	5501.0	5441.0	1.1
33000	2494.8	2306.5	7.5	5373.0	5312.1	1.1
30200	318.4	93.5	70.6	694.9	413.1	40.6
30000	2387.8	2249.1	5.8	5306.1	5273.2	0.6
25000	2374.7	2257.4	4.9	5265.8	5233.1	0.6
20700	1137.9	578.2	49.2	2581.2	1778.3	31.1
20690	893.0	499.9	44.0	2042.4	1474.3	27.8
20660	1225.0	1211.1	1.1	2541.6	2127.1	16.3
20560	1010.5	722.2	28.5	2120.4	1688.0	20.4
20520	1046.0	746.0	28.7	2293.2	1796.7	21.7
20140	1042.9	852.0	18.3	2388.6	1960.7	17.9
20060	1063.6	899.1	15.5	2429.2	2142.0	11.8
20000	3093.1	2937.2	5.0	6173.7	6227.2	*
15000	3088.8	2936.5	4.9	6181.7	6234.6	*
9000	3088.4	2956.5	4.3	6188.9	6239.4	*

* Peak flow not reduced . (In some cases decreased flow downstream causes reduction in downstream elevation which produces greater hydraulic grade line thus increasing upstream flow.)

The percentage of peak reductions are greater for the 2-year storm than for the 10-year storm, as all detention basins control the 2-year storm but not all basins control the 10-year storm. In some cases, as noted on the table, there is no reduction of the peak discharge at a given junction number.

Peak flow reduction benefits for the 2-year storm range from 3 percent to 70 percent. The key locations which show the greatest benefits are immediately downstream of a single detention basin or a cluster of detention basins. Cub Run areas that show peak flow benefits greater than 20 percent are located in the upper reaches of Flatlick Branch (junction numbers above 50300), in the upper reaches of Big Rocky Run (junction numbers above 20520), along Round Lick Branch (junction number 30200), and the headwater areas of Elklick Run (junction number 40220) and Cain Branch (junction number 70180). The percent reductions in peak flow diminish for locations further downstream on the major tributaries until the reduction is near five percent in the vicinity and downstream of the Big Rocky Run confluence with Cub Run.

Detention Basin Locations for Maximum Watershedwide Benefits

Time of travel studies, as described in Section 5.1, were performed to evaluate which stream segments showed the greatest benefit from specific groups or clusters of regional detention basins. Table 5-3 presents the key locations which have the greatest benefit from the regional detention basin clusters. Based on the timing of the downstream hydrograph, the timing of the regulated outflow hydrograph from detention basins and the time of travel to the key locations, several clusters are located at points which have a beneficial impact on the tributary and mainstem locations.

In summary, the Cub Run regional detention basins were shown to be most effective for peak flow reduction in the Flatlick Branch and Big Rocky Run tributaries where larger clusters of detention basins are located. In

The percentage of peak reductions are greater for the 2-year storm than for the 10-year storm, as all detention basins control the 2-year storm but not all basins control the 10-year storm. In some cases, as noted on the table, there is no reduction of the peak discharge at a given junction number.

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In summary, the Cub Run regional detention basins were shown to be most effective for peak flow reduction in the Flatlick Branch and Big Rocky Run tributaries where larger clusters of detention basins are located. In

TABLE 5-3

CUB RUN
TIME OF TRAVEL EVALUATION

Cluster	Regional Detention Basin	Key Locations Showing Greatest Regional Benefits
A	C-30	9000, 20000, 20060
B	C-3	9000, 20000, 20060
C	C-4, C-28, C-35	*
D	C-22	9000, 20000
E	C-19, C-63, C-21	9000, 20000, 30200
F	C-37	9000, 20000, 40220
G	C-23, C-24, C-62	9000, 20000
H	C-11, C-12, C-46, C-47, C-50	9000, 20000, 50120
I	C-20, C-39, C-40, C-43, C-44, C-54	9000, 20000, 30000, 40000, 50120, 50300, 50500
J	C-53	9000, 20000, 50120, 30000, 50300, 40000
K	C-41	9000, 20000, 30000, 40000, 60020, 60000
L	C-18, C-57	9000, 20000, 30000, 40000, 70000, 70040
M	C-25	9000, 20000, 30000, 40000, 70000, 74000

* Local benefits only

other areas where the regional detention basins are more dispersed, they only provided localized benefits (i.e., immediately downstream of detention basin). Along the main stem of Cub Run below the confluence with Elklick Run (junction number 40000), peak flow reduction benefits are minimal with reductions of less than 10 percent.

5.2.2 LITTLE ROCKY RUN

Detention Basin Control

For each of the 13 regional detention basins, Table 5-4 presents a peak flow summary for the 2-year and 10-year storms. The peak flows are given for the predevelopment land use and for the future land use with and without detention. All but four of the regional detention basins had adequate storage to reduce the peak release rate to less than the predevelopment peak flows. The remaining detention basins (R-6, R-9, R-13 and R-16) had sufficient storage to achieve a peak release rate equal to the 2-year predevelopment peak flow. Four of the maximum efficiency detention basins provide protection for both the 2-year and 10-year storms, and the peak releases for these four basins were equal to 33 percent of the predevelopment peak for both storms.

Watershedwide Benefits

Key locations throughout the Little Rocky Run watershed were selected to evaluate the peak flow reduction impact of the regional detention basins. Figure 5-4 presents the key locations along the main stem which correspond to EXTRAN model junctions. The locations of the regional detention basins are also shown in the figure. The 13 proposed regional detention basins were included in the analysis as were the seven County regional basins listed in Table 4-11.

For each key location (junction number), the peak flows for the 2-year and 10-year storms with and without the maximum efficiency detention basins are summarized in Table 5-5 for future land use conditions. This table also presents peak flow reduction achieved by the detention basins.

TABLE 5-4

LITTLE ROCKY RUN
SUMMARY OF PEAK FLOWS AT DETENTION BASIN SITES

		2-year Storm			10-year Storm		
			Future Land Use			Future Land Use	
Basin Number	Basin Type	Predev. LU (cfs)	Without Detention (cfs)	With Detention (cfs)	Predev. LU (cfs)	Without Detention (cfs)	With Detention (cfs)
R-2	WET-2	100.2	193.7	33.07*	—	—	—
R-5	WET-10	35.1	93.6	11.58*	82.4	168.8	27.19*
R-6	WET-2	182.1	311.2	183.9	—	—	—
R-7	WET-10	25.0	43.4	8.25*	58.1	88.2	19.17*
R-8	WET-10	19.0	74.1	6.27*	94.2	216.8	31.09*
R-9	WET-2	8.7	34.3	8.6	—	—	—
R-10	WET-2	69.2	122.8	62.84*	—	—	—
R-11	WET-2	28.7	49.8	19.47*	—	—	—
R-12	WET-10	10.3	46.4	3.40*	45.0	127.2	14.85*
R-13	WET-2	98.7	176.7	96.9	—	—	—
R-16	EXTDRY-2	12.2	46.2	13.1	—	—	—
R-17	EXTDRY-2	66.8	223.9	32.04*	—	—	—
R-19	WET-2	110.4	198.9	76.43*	—	—	—

NOTE: "*" indicates maximum efficiency detention basin.

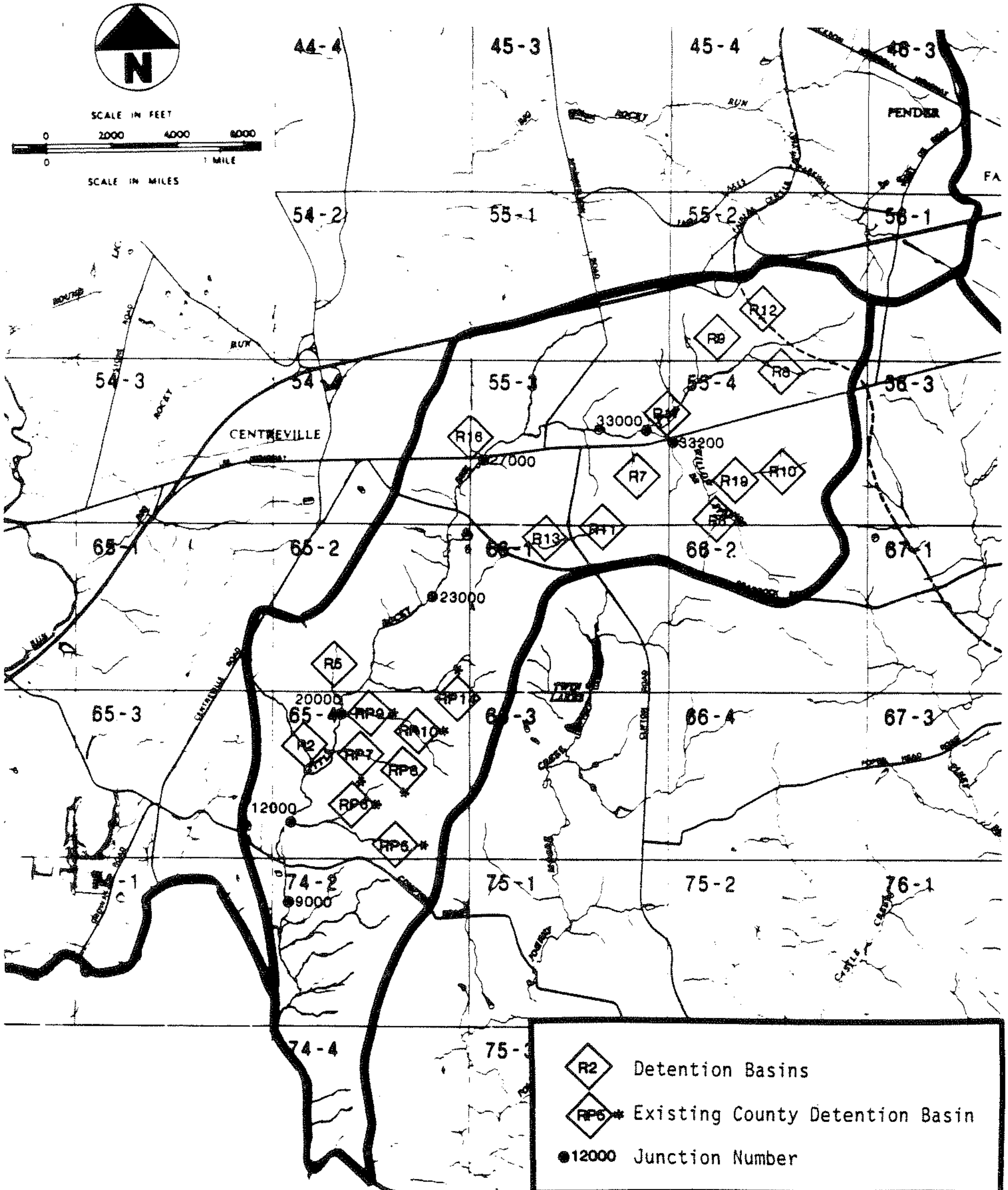


Figure 5-4. Little Rocky Run: Key Locations (Junction Number) for Peak Flow Comparisons

TABLE 5-5

LITTLE ROCKY RUN
WATERSHEDWIDE PEAK FLOW COMPARISONS
(FUTURE LAND USE)

	2 YEAR STORM			10 YEAR STORM		
	WITHOUT DETENTION BASIN	WITH MAX. EFFICIENCY BASIN		WITHOUT DETENTION BASIN	WITH MAX. EFFICIENCY BASIN	
JUNCTION NUMBER	FLOW (cfs)	FLOW (cfs)	% REDUCED	FLOW (cfs)	FLOW (cfs)	% REDUCED
9000	1138.9	791.1	30.5	2402.6	2013.5	16.2
12000	1146.6	821.1	28.4	2417.4	2025.0	16.2
20000	915.0	773.2	15.5	1847.4	1610.6	12.8
23000	498.9	361.0	27.6	1120.2	846.3	24.5
27000	646.0	316.1	51.1	1702.1	954.5	43.9
33000	683.9	282.6	58.7	1666.3	1031.8	38.1
33200	342.6	55.0	83.9	752.3	148.2	80.3

Because of the large number of maximum efficiency detention basins which had sufficient storage to achieve a peak release rate of 33 percent of the predevelopment peak flow, peak flow reduction benefits were all greater than 20 percent for the 2-year storm except at one location (junction number 2000). Lesser peak flow reduction benefits were projected for the 10-year storm because of the limited number of 10-year detention basins. The 2-year peak flow reductions are approximately 30 percent for the lower reaches of Little Rocky Run, almost 50 percent for upper reaches, and 80 percent on the upstream Willow Springs Branch which has three proposed regional detention basins within its drainage area.

Detention Basin Locations for Maximum Watershedwide Benefits

Time of travel studies were performed on three clusters of proposed detention basins. Table 5-6 presents the detention basin assigned to each cluster and the stream segments showing the greatest regional benefits noted by the key location (junction numbers). In Little Rocky Run, the clusters had a beneficial impact on all downstream key locations. The timing of the outflow hydrographs from the maximum efficiency detention basins, the time of travel to a downstream key location and the peak timing of the downstream hydrograph in addition to the distribution and size of the detention basins provided a substantial peak flow reduction throughout the watershed.

In summary, the regional detention basins in Little Rocky Run not only provide local benefits immediately downstream of the basin site, but they are also very effective in reducing the peak flows for erosion and flooding control along the main stem of Little Rocky Run.

5.2.3 DIFFICULT RUN

Detention Basin Control

Table 5-7 presents a summary of peak flows at the detention basin sites. Peak flows are given for the 2-year and 10-year predevelopment land use scenario and the future land use scenario with and without detention. Of

TABLE 5-6

LITTLE ROCKY RUN
TIME OF TRAVEL EVALUATION

Cluster	Regional Detention Basin	Key Locations Showing Greatest Regional Benefits
A	R-2, R-5	9000
B	R-11, R-13, R-16	9000, 12000, 20000, 23000, 27000
C	R-6, R-7, R-8, R-9, R-10, R-12, R-17, R-19	9000, 12000, 20000, 23000, 27000, 33000, 33200

TABLE 5-7

DIFFICULT RUN
SUMMARY OF PEAK FLOWS AT DETENTION BASIN SITES

Basin Number	Basin Type	2-year Storm			10-year Storm		
			Future Land Use			Future Land Use	
		Predev. LU (cfs)	Without Detention (cfs)	With Detention (cfs)	Predev. LU (cfs)	Without Detention (cfs)	With Detention (cfs)
D-1	EXTDRY-2	39.0	101.9	12.9*	—	—	—
D-2	EXTDRY-2	49.3	143.6	26.3*	—	—	—
D-3	EXTDRY-10	19.8	124.5	6.5*	75.0	262.6	24.8*
D-4	EXTDRY-10	43.2	110.8	14.3*	166.2	299.2	54.8*
D-5	EXTDRY-2	76.0	184.6	55.1*	—	—	—
D-6	EXTDRY-10	23.1	57.5	7.6*	93.9	158.0	31.0*
D-7	EXTDRY-2	54.5	160.0	18.0*	—	—	—
D-9	EXTDRY-10	73.5	126.0	24.3*	379.4	395.0	125.2*
D-10	EXTDRY-10	17.1	62.6	5.6*	90.5	195.3	29.9*
D-11	EXTDRY-10	10.2	33.4	3.4*	54.6	106.2	18.0*
D-12	EXTDRY-10	37.9	88.8	12.5*	143.9	247.8	47.5*
D-13	EXTDRY-10	14.0	79.0	4.6*	68.1	199.0	22.5*
D-14	EXTDRY-10	24.4	65.3	8.1*	92.0	180.8	30.4*
D-15	EXTDRY-10	13.9	42.0	4.6*	51.8	110.7	17.1*
D-16	EXTDRY-10	9.2	18.2	3.0*	46.7	72.3	15.4*
D-17	EXTDRY-10	10.5	40.9	3.5*	56.0	123.4	18.5*
D-18	EXTDRY-10	7.9	29.5	2.6*	40.7	91.5	13.4*
D-19	EXTDRY-10	17.1	55.7	5.6*	91.7	171.6	30.3*
D-20	EXTDRY-10	36.7	122.4	12.1*	189.3	391.5	112.5*
D-21	EXTDRY-10	13.5	42.0	4.5*	71.6	137.5	23.6*
D-23	EXTDRY-10	8.8	24.2	2.9*	47.7	83.0	15.7*
D-24	EXTDRY-2	15.6	90.3	5.1*	—	—	—
D-25	EXTDRY-2	8.1	38.9	2.7*	—	—	—

NOTE: "*" indicates maximum efficiency detention basin.

TABLE 5-7

DIFFICULT RUN
SUMMARY OF PEAK FLOWS AT DETENTION BASIN SITES
(CONTINUED)

		2-year Storm			10-year Storm		
			Future Land Use			Future Land Use	
Basin Number	Basin Type	Predev. LU (cfs)	Without Detention (cfs)	With Detention (cfs)	Predev. LU (cfs)	Without Detention (cfs)	With Detention (cfs)
D-26	EXTDRY-10	33.2	108.0	11.0*	176.7	359.6	58.3*
D-27	EXTDRY-10	11.6	40.3	3.8*	61.9	128.6	20.4*
D-28	EXTDRY-10	9.7	43.6	3.2*	50.1	127.0	16.5*
D-29	EXTDRY-2	33.6	133.9	11.1*	—	—	—
D-30	EXTDRY-2	57.1	202.0	54.9	—	—	—
D-31	EXTDRY-2	29.9	201.3	9.9*	—	—	—
D-32	EXTDRY-2	10.1	36.1	3.3*	—	—	—
D-33	EXTDRY-2	5.1	23.7	1.7*	—	—	—
D-34	EXTDRY-10	6.4	25.4	2.1*	33.4	78.1	11.0*
D-35	EXTDRY-10	12.5	50.0	4.1*	65.9	151.8	21.7*
D-36	EXTDRY-10	19.7	83.7	6.5*	115.9	271.7	38.2*
D-37	EXTDRY-10	14.1	180.0	4.7*	75.0	369.1	24.8*
D-38	EXTDRY-2	13.7	45.2	4.5*	—	—	—
D-39	EXTDRY-2	43.9	82.6	40.9	—	—	—
D-40	EXTDRY-2	38.4	147.8	12.7*	—	—	—
D-41	EXTDRY-2	39.3	129.0	13.0*	—	—	—
D-43	EXTDRY-10	12.5	28.9	4.1*	66.6	112.4	21.8*
D-45	EXTDRY-2	26.0	11.4	8.6*	—	—	—
D-46	EXTDRY-2	15.9	119.1	5.2*	—	—	—
D-47	EXTDRY-10	7.3	113.9	2.4*	39.5	214.3	23.0*
D-49	EXTDRY-2	12.5	77.3	4.1*	—	—	—
D-51	EXTDRY-2	53.8	163.3	27.8*	—	—	—
D-52	EXTDRY-2	34.9	176.7	11.5*	—	—	—
D-54	EXTDRY-10	13.5	77.3	4.5*	71.6	195.2	23.6*

NOTE: "*" indicates maximum efficiency detention basin.

TABLE 5-7

DIFFICULT RUN
SUMMARY OF PEAK FLOWS AT DETENTION BASIN SITES
(CONTINUED)

		2-year Storm			10-year Storm		
			Future Land Use			Future Land Use	
Basin Number	Basin Type	Predev. LU (cfs)	Without Detention (cfs)	With Detention (cfs)	Predev. LU (cfs)	Without Detention (cfs)	With Detention (cfs)
D-56	EXTDRY-10	9.9	39.4	3.3*	51.5	116.0	17.0*
D-58	EXTDRY-10	9.7	40.1	3.2*	51.4	120.2	17.0*
D-59	EXTDRY-10	10.3	31.5	3.4*	54.5	96.4	18.0*
D-61	EXTDRY-10	18.6	146.8	6.1*	99.2	333.4	72.7*
D-64	EXTDRY-10	22.4	60.6	7.4*	90.0	168.9	49.7*
D-65	EXTDRY-10	6.8	25.8	2.2*	35.8	81.2	11.8*
D-66	EXTDRY-10	13.7	50.1	4.5*	70.8	156.1	23.4*
D-67	EXTDRY-2	41.5	569.1	41.5*	—	—	—
D-69	EXTDRY-10	14.5	143.8	4.8*	54.7	106.0	25.6*
D-71	EXTDRY-10	27.4	106.0	9.0*	145.7	320.4	48.1*
D-72	EXTDRY-10	10.4	32.5	3.4*	54.7	106.0	18.1*
D-73	EXTDRY-2	18.6	97.8	16.1*	—	—	—
D-74	EXTDRY-10	13.4	55.1	4.4*	69.7	166.3	23.0*
D-76	EXTDRY-2	72.0	170.8	53.8*	—	—	—
D-77	EXTDRY-10	12.9	86.1	4.3*	70.5	217.8	43.3*
D-79	EXTDRY-10	23.0	79.6	7.6*	113.0	234.7	47.3*

NOTE: "*" indicates maximum efficiency detention basin.

the 63 regional detention basins, only three basins (D-30, D-39 and D-67) did not have sufficient storage to achieve peak release rates less than predevelopment peak flow for the 2-year storm. All of the detention basins which were also designed to control the 10-year storm achieved peak release rates that were less than the 10-year predevelopment peak flow. For the 60 maximum efficiency detention basins that provided less than predevelopment peak flow releases all but two have sufficient storage to release 33 percent of the predevelopment peak for the 2-year storm.

Watershedwide Benefits

Key locations throughout the watershed were selected to evaluate the watershedwide benefits of the regional detention basins. The key locations are shown in Figure 5-5. This figure also shows the location of the regional detention basins. For the key locations (junction numbers), Table 5-8 presents the peak flows with and without detention basins for the 2-year and 10-year storms for future land use conditions. In addition to the 63 proposed regional detention basins, two County regional detention basins were included in the analysis as indicated in Table 4-12.

Peak flow reduction benefits greater than 20 percent occurred along the upper reaches of the Difficult Run main stem (junction numbers from 60000 to 74000), on Little Difficult Run (junction numbers 50140 to 50410), on Piney Branch (junction number 40250), and on Piney Run (junction number 20580). The greater peak flow reductions for these areas were caused by the relatively large number of detention basins in the subwatershed above the key locations. Below the confluence of Little Difficult Run and Difficult Run, the maximum efficiency detention basins produced between a 10 percent and 15 percent reduction in the 2-year peak flow. Ten-year peak flow reductions were typically less than the 2-year peak flow reductions.

Detention Basin Locations for Maximum Watershedwide Benefits

Several clusters of detention basins were evaluated throughout the watershed. Table 5-9 gives the detention basins included in each cluster

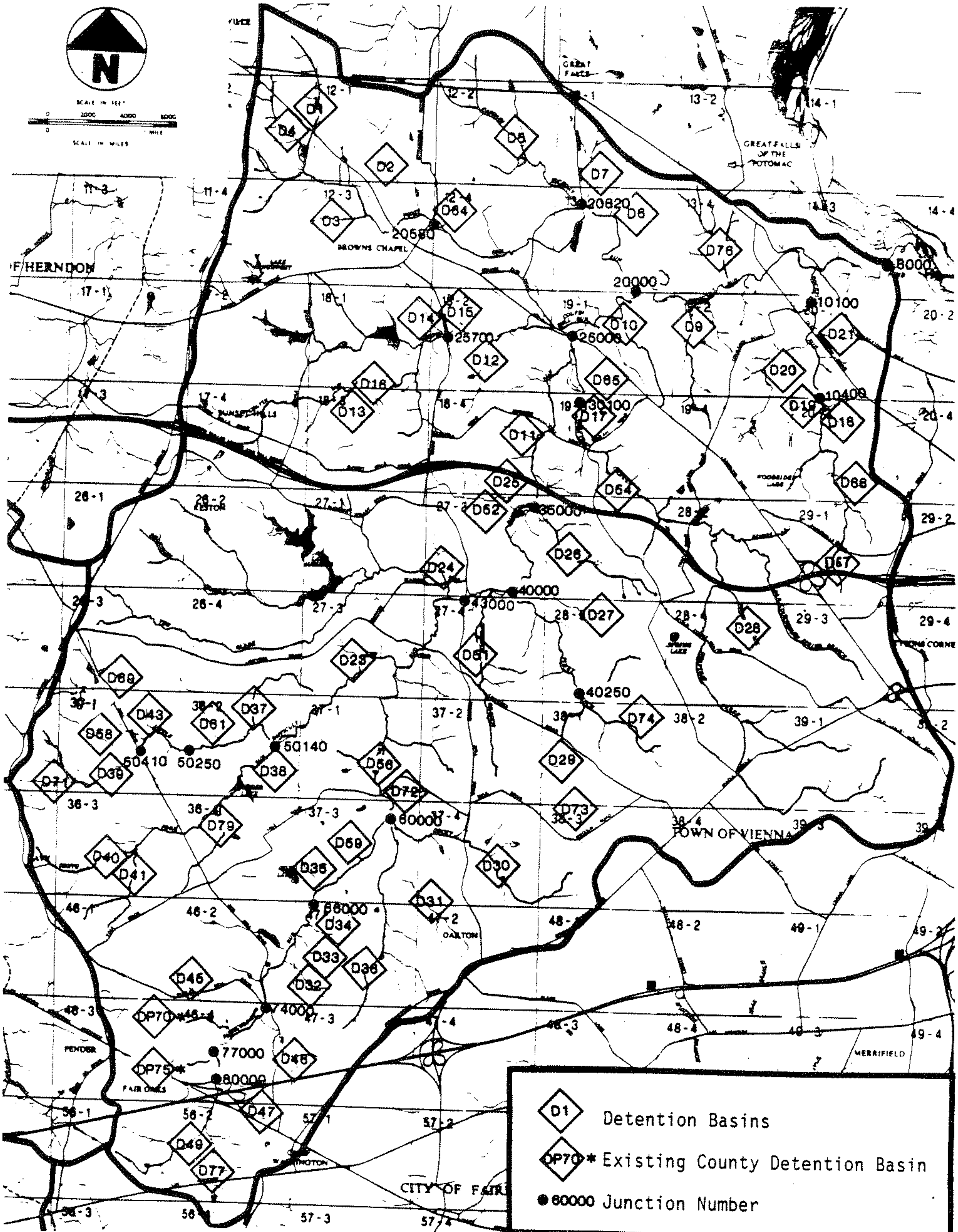


Figure 5-5. Difficult Run: Key Locations (Junction Number) for Peak Flow Comparisons

TABLE 5-8

DIFFICULT RUN
WATERSHEDWIDE PEAK FLOW COMPARISONS
(FUTURE LAND USE)

	2 YEAR STORM			10 YEAR STORM		
	WITHOUT DETENTION BASIN	WITH MAX. EFFICIENCY BASIN		WITHOUT DETENTION BASIN	WITH MAX. EFFICIENCY BASIN	
JUNCTION NUMBER	FLOW (cfs)	FLOW (cfs)	% REDUCED	FLOW (cfs)	FLOW (cfs)	% REDUCED
6000	2182.5	1927.3	11.7	6850.8	6483.8	5.4
10100	435.2	372.4	14.4	555.8	551.8	0.7
10400	391.5	359.3	8.2	776.2	655.2	15.6
20000	2107.4	1843.9	12.5	6930.4	6486.5	6.4
20580	552.0	269.5	51.2	1490.5	1205.2	19.1
20820	225.3	239.0	*	598.6	512.3	14.4
25000	1879.3	1665.2	11.4	5864.2	5560.7	5.2
25700	1043.6	960.8	7.9	2396.3	2170.7	9.4
30100	699.3	681.3	2.6	1891.9	1853.4	2.0
35000	1161.1	976.3	15.9	3516.6	3109.6	11.6
40000	1286.5	1126.5	12.4	3564.2	3384.4	5.0
40250	482.3	359.4	25.5	1420.9	1140.4	19.7
43000	1192.3	1033.2	13.3	3258.0	2859.3	12.2
50140	445.4	211.7	52.5	1463.9	864.3	41.0
50250	381.1	182.7	52.1	1398.9	537.4	61.6
50410	198.6	31.5	84.1	681.9	226.5	66.8
60000	642.7	463.0	28.0	1934.2	1531.9	20.8
66000	630.6	449.6	28.7	1773.4	1333.2	24.8
74000	394.5	291.6	26.1	878.6	642.8	26.8
77000	574.4	496.1	13.6	1430.9	1062.9	25.7
80000	578.8	470.2	18.8	1295.5	956.1	26.2

* Peak flow not reduced. (In some cases decreased flow downstream causes reduction in downstream elevation which produces greater hyc lic de th incr ing tre low)

TABLE 5-9

DIFFICULT RUN
TIME OF TRAVEL EVALUATION

Cluster	Regional Detention Basin	Key Locations Showing Greatest Regional Benefits
A	D-18, D-19, D-20, D-21, D-66,D-67	10100
B	D-9, D-10	*
C	D-5, D-6, D-7	*
D	D-1, D-2, D-3, D-4, D-64	20820
E	D-12, D-14, D-15	*
F	D-17, D-28, D-54, D-65,	*
G	D-11, D-25, D-26, D-52	25000
H	D-27, D-29, D-73, D-74	6000, 20000, 25000, 35000
I	D-23, D-24, D-51	40000
J	D-37, D-38, D-61, D-79	6000, 20000, 25000, 35000, 40000, 50140
K	D-39, D-43, D-58, D-69, D-71	6000, 20000, 25000, 35000, 40000, 50140
L	D-40, D-41	6000, 20000, 25000, 35000, 40000, 50140
M	D-56, D-72	6000, 20000, 25000, 35000, 40000
N	D-30, D-31, D-32, D-33, D-34, D-35, D-36, D-59	6000, 20000, 25000, 35000, 40000
O	D-45, D-46, D-47, D-49, D-77	6000, 20000, 25000, 35000, 40000, 60000, 74000

* Local benefits only

and the key locations showing the greatest benefits from the maximum efficiency basins within each cluster.

Clusters that are located in the downstream region of the watershed (A through F) did not have a major impact on the Difficult Run main stem because the basin outflow hydrograph peaks precede the peak flow along the downstream portion of the main stem. Those clusters which are located in the middle and upper regions of the watershed exhibited a positive impact on the tributary and mainstem key locations.

In summary, the larger clusters of regional detention basins in the upper reaches of Difficult Run and Little Difficult Run produced the greatest percentage peak flow reductions for their subwatershed areas. Although these upstream clusters and other detention basins in the middle of the watershed, had an impact on peak flow reduction along the Difficult Run main stem the flow reduction benefits along the main stem were not as great as the benefits projected for the upstream regions of the two major branches.

5.2.4 HORSEPEN CREEK

Detention Basin Control

There are seven proposed detention basins in the Horsepen Creek watershed. Table 5-10 presents a summary of the 2-year and 10-year storm peak flows for the predevelopment land use, and for the future land use with and without detention. Five of the seven detention basins have sufficient storage to limit the peak release rate to 33 percent of the predevelopment peak for the 2-year storm. Two of the extended dry plus 10-year control basins had sufficient storage to also release 33 percent of the 10-year predevelopment peak flow. The other two released less than the predevelopment peak flow but at higher percentages.

TABLE 5-10

HORSEPEN CREEK
SUMMARY OF PEAK FLOWS AT DETENTION BASIN SITES

		2-year Storm			10-year Storm		
			Future Land Use			Future Land Use	
Basin Number	Basin Type	Predev. LU (cfs)	Without Detention (cfs)	With Detention (cfs)	Predev. LU (cfs)	Without Detention (cfs)	With Detention (cfs)
H-1	EXTDRY-10	29.5	70.8	9.7*	77.0	150.8	25.4*
H-2	EXTDRY-10	37.0	189.9	12.2*	97.1	328.6	62.0*
H-7	EXTDRY-10	21.0	60.2	6.9*	64.5	134.8	21.3*
H-9	EXTDRY-10	41.0	202.0	13.5*	107.4	349.2	85.4*
H-13	EXTDRY-2	102.2	231.0	98.9	—	—	—
H-16	EXTDRY-2	27.2	62.3	9.0*	—	—	—
H-18	EXTDRY-2	60.7	130.7	60.2	—	—	—

NOTE: "*" indicates maximum efficiency detention basin.

Watershedwide Benefits

The key locations used to evaluate the watershedwide benefits of the regional detention basin system are given in Figure 5-6. This figure also shows the location of the regional detention basins. The watershedwide peak flow comparison at the key locations (junction numbers) is given in Table 5-11 without detention basins and with maximum efficiency basins for the 2-year and 10-year storms for future land use conditions. The greatest percent reductions occurred on Cedar Run (junction numbers 25000 to 30100) in the headwaters of Horsepen Creek and on Merry Brook Run (junction numbers 10200 to 10600). Percent reductions in peak flow were less toward the middle and lower reaches of the Creek.

Detention Basin Locations for Maximum Watershedwide Benefits

Table 5-12 presents the key locations which have the greatest benefits based on the time of travel studies as described in Section 5.1. For Merry Brook Run, regional detention basins impacted the peak flows throughout the entire channel reaches. The detention basins along the main stem system had a beneficial impact on the main stem and tributary reaches. However, the regional detention basins (except for H-2), did not impact the most downstream junction (16000) because the time of travel from the basin sites was greater than the maximum time of hydrograph ordinate reduction which could be expected from the upstream detention basins. In summary, the regional detention basins were shown to be most effective in the upper reach of the main stem Horsepen Creek area and on the northern tributary (Merry Brook Run).

5.2.5 SUGARLAND RUN

Detention Basin Control

Along the lower reaches of Sugarland Run, downstream of the Town of Herndon, five regional detention basins are proposed. A summary of the peak flows at the detention basin sites is given in Table 5-13. For the 2-year storm, four of the five detention basins have sufficient storage to

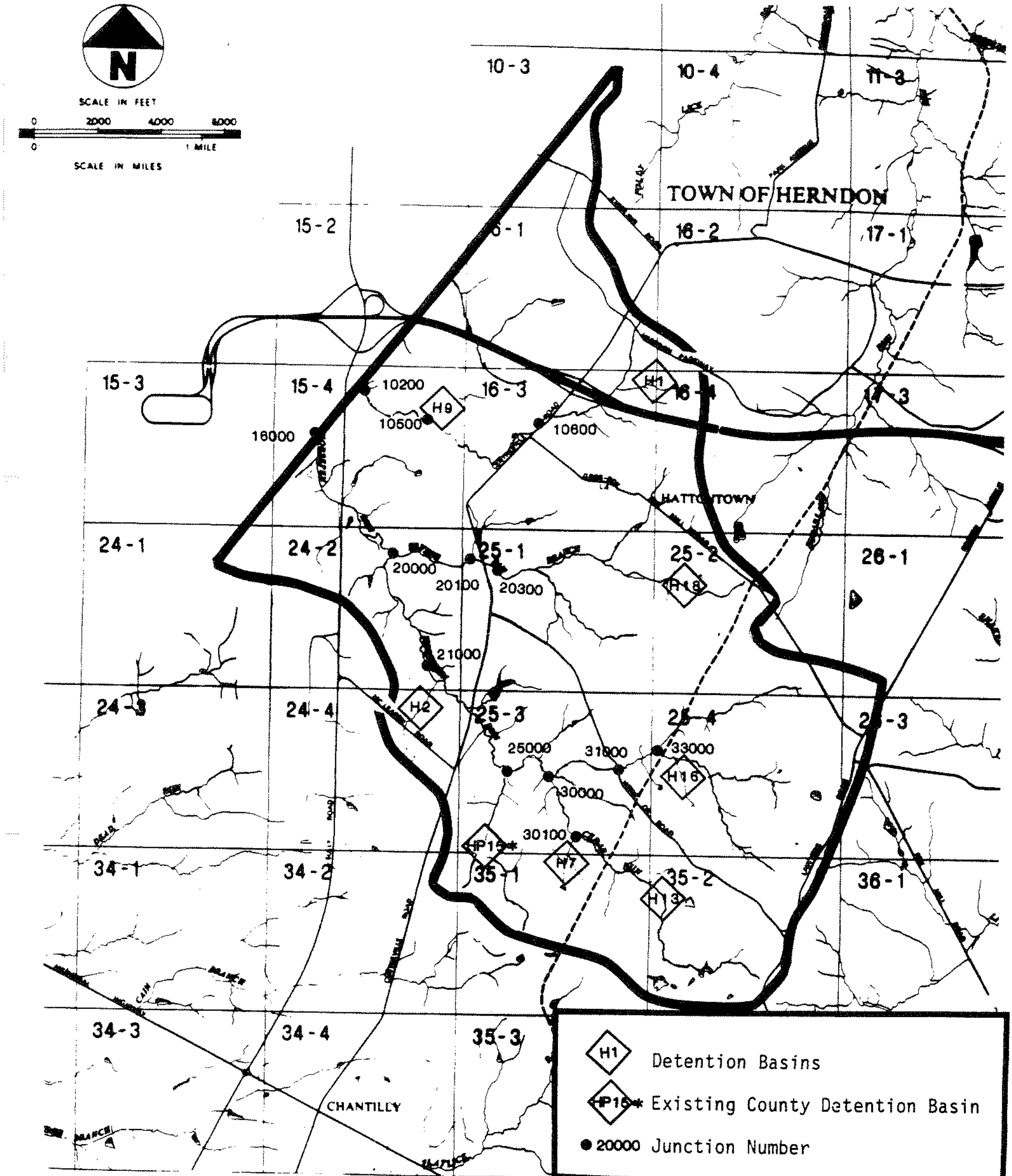


Figure 5-6. Horsepen Creek: Key Locations (Junction Number) for Peak Flow Comparisons

TABLE 5-11

HORSEPEN CREEK
WATERSHEDWIDE PEAK FLOW COMPARISONS
(FUTURE LAND USE)

	2 YEAR STORM			10 YEAR STORM		
	WITHOUT DETENTION BASIN	WITH MAX. EFFICIENCY BASIN		WITHOUT DETENTION BASIN	WITH MAX. EFFICIENCY BASIN	
JUNCTION NUMBER	FLOW (cfs)	FLOW (cfs)	% REDUCED	FLOW (cfs)	FLOW (cfs)	% REDUCED
10200	410.7	315.4	23.2	823.3	655.8	20.3
10500	461.7	338.8	26.6	844.1	657.7	22.1
10600	190.9	173.1	9.3	374.4	327.8	12.4
16000	681.1	654.0	4.0	1643.7	1508.7	8.2
20000	658.4	638.5	3.0	1723.1	1567.7	9.0
20100	492.2	470	4.5	1408.9	1391.4	1.2
20300	747.2	676.1	9.5	1776.6	1705.7	4.0
21000	546.0	494	9.5	1375.7	1232.7	10.4
25000	831.2	682.1	17.9	2094.6	1768.3	15.6
30000	937.2	811.2	13.4	2294.9	2049.9	10.7
31000	640.3	587.7	8.2	1627.8	1561.0	4.1
33000	661.4	606.5	8.3	1509.0	1428.9	5.3
30100	337.5	218.7	35.2	778.2	569.6	26.8

TABLE 5-12

HORSEPEN CREEK
TIME OF TRAVEL EVALUATION

Regional Detention Basin	Key Locations Showing Greatest Regional Benefits
H-1	10200, 10500, 10600
H-2	16000, 20000, 21000
H-7	20000, 21000, 25000, 30000, 30100
H-9	10200
H-13	20000, 21000, 25000, 30000, 30100
H-16	20000, 21000, 25000, 30000, 31000, 33000
H-18	20000, 20100, 20300

TABLE 5-13

SUGARLAND RUN
SUMMARY OF PEAK FLOWS AT DETENTION BASIN SITES

		2-year Storm			10-year Storm		
			Future Land Use			Future Land Use	
Basin Number	Basin Type	Predev. LU (cfs)	Without Detention (cfs)	With Detention (cfs)	Predev. LU (cfs)	Without Detention (cfs)	With Detention (cfs)
S-1	EXTDRY-2	121.4	298.4	110.1*	—	—	—
S-2	EXTDRY-10	24.5	125.1	8.1*	92.3	269.9	30.5*
S-4	EXTDRY-10	12.8	41.6	4.2*	49.3	95.9	16.3*
S-5	EXTDRY-2	60.7	173.7	20.0*	—	—	—
S-7	EXTDRY-2	109.4	273.7	107.5	—	—	—

NOTE: "*" indicates maximum efficiency detention basin.

release less than the predevelopment peak flow, and the two extended dry plus 10-year control basins also released less than the predevelopment peak flow for the 10-year storm.

Watershedwide Benefits

Figure 5-7 presents the key locations (junction numbers) for the watershedwide benefit evaluation. Table 5-14 presents the peak flow reduction benefits for the maximum efficiency basins at each junction number for the 2-year and 10-year storms for future land use conditions. For the key locations, the only location that exhibits a significant benefit is junction 21100 downstream of S-2 on Rosiers Branch. The remaining detention basins provide localized benefits, but only minimal benefits along the Sugarland Run main stem because of the large uncontrolled drainage area upstream of the proposed regional basins.

Detention Basin Locations for Maximum Watershedwide Benefits

Based on the time of travel studies, the maximum efficiency basins impact the peak flows on their tributaries and in the mainstem as shown in Table 5-15. However, although the timing of the delayed outflow hydrograph was beneficial to the downstream areas, the flows in the main stem were so great from the large upstream drainage area that peak flow reductions either were not detected or were minimal. In summary, only localized benefits were realized from the detention basins located on tributary streams.

5.2.6 POHICK CREEK

Detention Basin Control

The study area of the Pohick Creek watershed includes the drainage area above Burke Lake. Within this watershed, eight regional detention basins are proposed. Table 5-16 gives a summary of the peak flows at each detention basin site for the 2-year and 10-year storms with and without detention. All basins are maximum efficiency basins except P-6 which

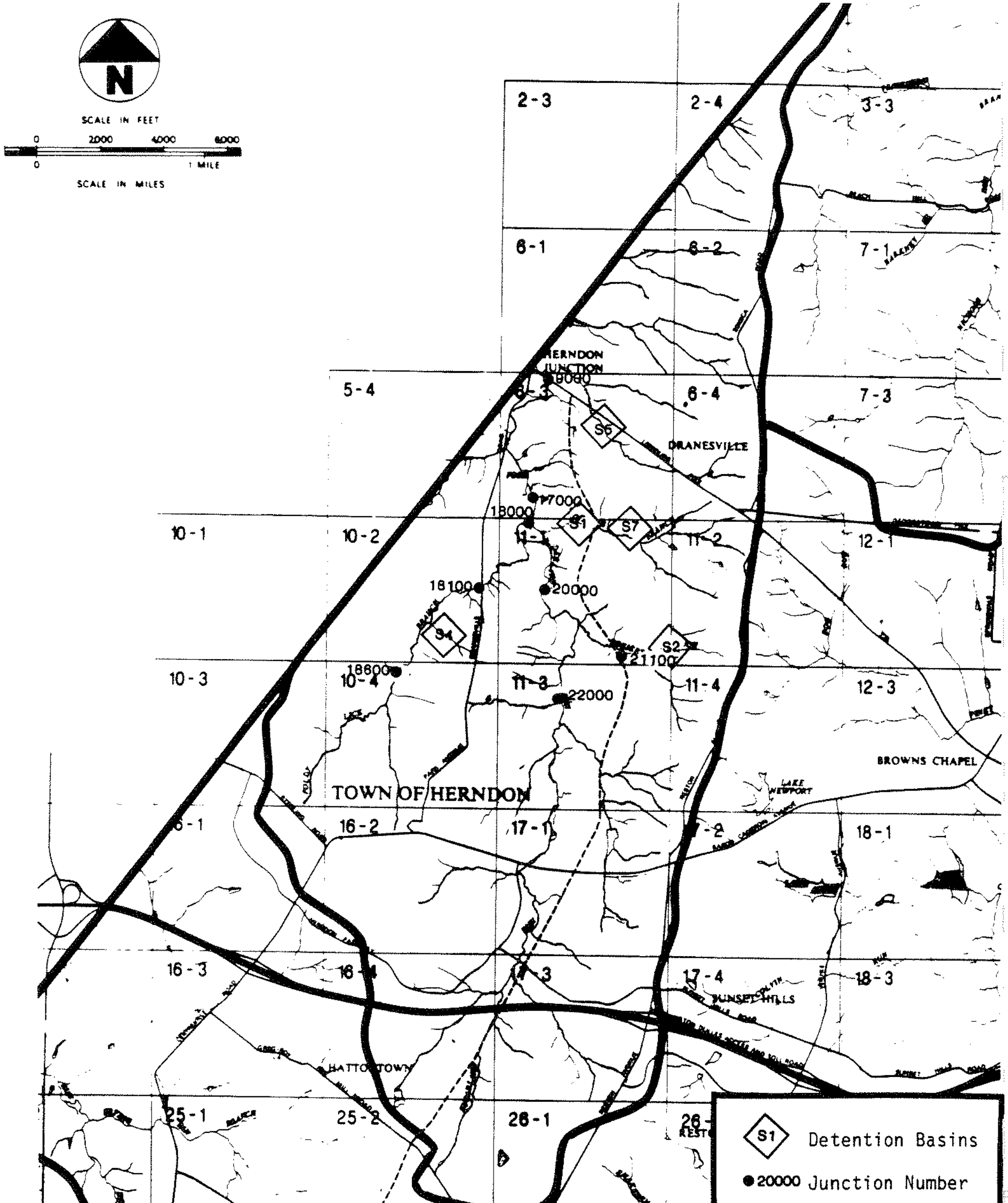


Figure 5-7. Sugarland Run: Key Locations (Junction Number) for Peak Flow Comparisons

TABLE 5-14

SUGARLAND RUN
WATERSHEDWIDE PEAK FLOW COMPARISONS
(FUTURE LAND USE)

JUNCTION NUMBER	2 YEAR STORM: WITHOUT DETENTION BASIN FLOW (cfs)	2 YEAR STORM: WITH MAX. EFFICIENCY BASIN FLOW (cfs)	2 YEAR STORM: WITH MAX. EFFICIENCY BASIN % REDUCED	10 YEAR STORM: WITHOUT DETENTION BASIN FLOW (cfs)	10 YEAR STORM: WITH MAX. EFFICIENCY BASIN FLOW (cfs)	10 YEAR STORM: WITH MAX. EFFICIENCY BASIN % REDUCED
9000	1691.8	1609.0	4.9	4083.6	4099.0	
17000	1778.9	1675.2	5.8	3952.0	3925.9	0.7
18000	1832.5	1718.8	6.2	4065.5	4035.2	0.7
18100	984.2	979.9	0.4	2177.0	2202.5	*
18600	1025.1	1071.9	*	2209.4	2262.4	*
20000	1075.8	1048.2	2.6	2634.3	2639.3	*
21100	283.1	174.1	38.5	632.5	357.8	43.4
22000	1014.5	1018.8	*	2618.9	2651.1	*

* Peak flow not reduced. (In some cases decreased flow downstream causes reduction in downstream elevation which produces greater hydraulic grade line thus increasing upstream flow.)

TABLE 5-15

SUGARLAND RUN
TIME OF TRAVEL EVALUATION

Regional Detention Basin	Key Locations Showing Greatest Regional Benefits
S-1, S-7	9000, 17000, 18000
S-2	9000, 17000, 18000, 20000, 21100
S-4	9000, 17000, 18000, 18100
S-5	9000

TABLE 5-16

POHICK CREEK
SUMMARY OF PEAK FLOWS AT DETENTION BASIN SITES

		2-year Storm			10-year Storm		
			Future Land Use			Future Land Use	
Basin Number	Basin Type	Predev. LU (cfs)	Without Detention (cfs)	With Detention (cfs)	Predev. LU (cfs)	Without Detention (cfs)	With Detention (cfs)
P-1	EXTDRY-10	15.5	88.6	5.1*	90.4	269.4	29.8*
P-2	EXTDRY-10	30.2	121.7	10.0*	183.1	405.2	120.4*
P-3	EXTDRY-10	7.9	35.7	2.6*	46.5	108.8	15.3*
P-4	EXTDRY-10	24.7	98.9	8.2*	144.1	310.4	47.6*
P-5	EXTDRY-10	5.5	29.4	1.8*	32.2	85.7	10.6*
P-6	EXTDRY-2	59.6	243.7	60.4	—	—	—
P-7	EXTDRY-10	18.2	75.0	6.0*	110.0	250.2	36.3*
P-8	EXTDRY-10	10.5	43.5	3.5*	60.4	138.6	19.9*

NOTE: "*" indicates maximum efficiency detention basin.

cannot be designed to release less than the predevelopment peak flow because of limited storage at the site. For the Pohick Creek watershed, the regional detention basins provide local benefits along the immediate tributaries and overall reductions in peak flows reaching Burke Lake during storm events.

5.2.7 LONG BRANCH

Detention Basin Control

Table 5-17 presents the summary of peak flows for the seven regional detention basins in the Long Branch watershed which is tributary to Accotink Creek. Six of the seven regional detention basins are maximum efficiency basins and of those six, all basins have sufficient storage to produce a peak outflow for the 2-year storm which is 33 percent of the predevelopment peak except for L-10 which produces 87 percent of the predevelopment peak. The four maximum efficiency basins with 10-year control produce a reduced outflow of 33 percent except for L-7 which produces 90 percent of the predevelopment peak.

Watershedwide Benefits

Peak flow comparisons for the watershedwide benefit analysis are presented in Table 5-18 for future land use conditions. Figure 5-8 shows the locations of the junction numbers listed in Table 5-18. Without detention for the 2-year and 10-year storms, the most upstream reach of the watershed shows a greater peak than the downstream reaches. This downstream attenuation in peak was produced because of the significant channel storage in Long Branch and the fact that the drainage basin is narrow in the middle and lower portions. Thus, any incremental inflow to the mainstem precedes the attenuated peak from upstream areas, meaning that these incremental inflows do not add to the magnitude of the peak.

The maximum efficiency basins located in the headwaters and on the tributaries produce relatively large reductions in peak flow throughout the

TABLE 5-17

LONG BRANCH
SUMMARY OF PEAK FLOWS AT DETENTION BASIN SITES

		2-year Storm			10-year Storm		
			Future Land Use			Future Land Use	
Basin Number	Basin Type	Predev. LU (cfs)	Without Detention (cfs)	With Detention (cfs)	Predev. LU (cfs)	Without Detention (cfs)	With Detention (cfs)
L-1	EXTDRY-10	16.5	64.6	5.4*	61.9	153.3	20.4*
L-2	EXTDRY-10	13.8	46.4	4.6*	50.9	118.1	16.8*
L-5	EXTDRY-2	24.6	112.6	8.1*	—	—	—
L-6	EXTDRY-10	17.0	115.0	5.6*	64.0	234.8	21.1*
L-7	EXTDRY-10	31.8	133.3	10.5*	122.1	300.5	110.3*
L-9	EXTDRY-2	56.1	288.2	56.6	—	—	—
L-10	EXTDRY-2	74.4	404.3	64.6*	—	—	—

NOTE: "*" indicates maximum efficiency detention basin.

TABLE 5-18

LONG BRANCH
WATERSHEDWIDE PEAK FLOW COMPARISONS
(FUTURE LAND USE)

JUNCTION NUMBER	2 YEAR STORM: WITHOUT DETENTION BASIN FLOW (cfs)	2 YEAR STORM: WITH MAX. EFFICIENCY BASIN FLOW (cfs)	2 YEAR STORM: WITH MAX. EFFICIENCY BASIN % REDUCED	10 YEAR STORM: WITHOUT DETENTION BASIN FLOW (cfs)	10 YEAR STORM: WITH MAX. EFFICIENCY BASIN FLOW (cfs)	10 YEAR STORM: WITH MAX. EFFICIENCY BASIN % REDUCED
10100	348.1	234.6	32.6	714.7	606.1	15.2
10400	340.2	223.3	34.4	700.2	592.4	15.4
10600	353.2	222.2	37.1	688.7	579.7	15.8
10700	395.9	193.6	51.1	840.5	664.2	21.0
10750	424.9	211.1	50.3	893.3	700.2	21.6
10800	646.9	460.3	28.8	1177.1	980.4	16.7

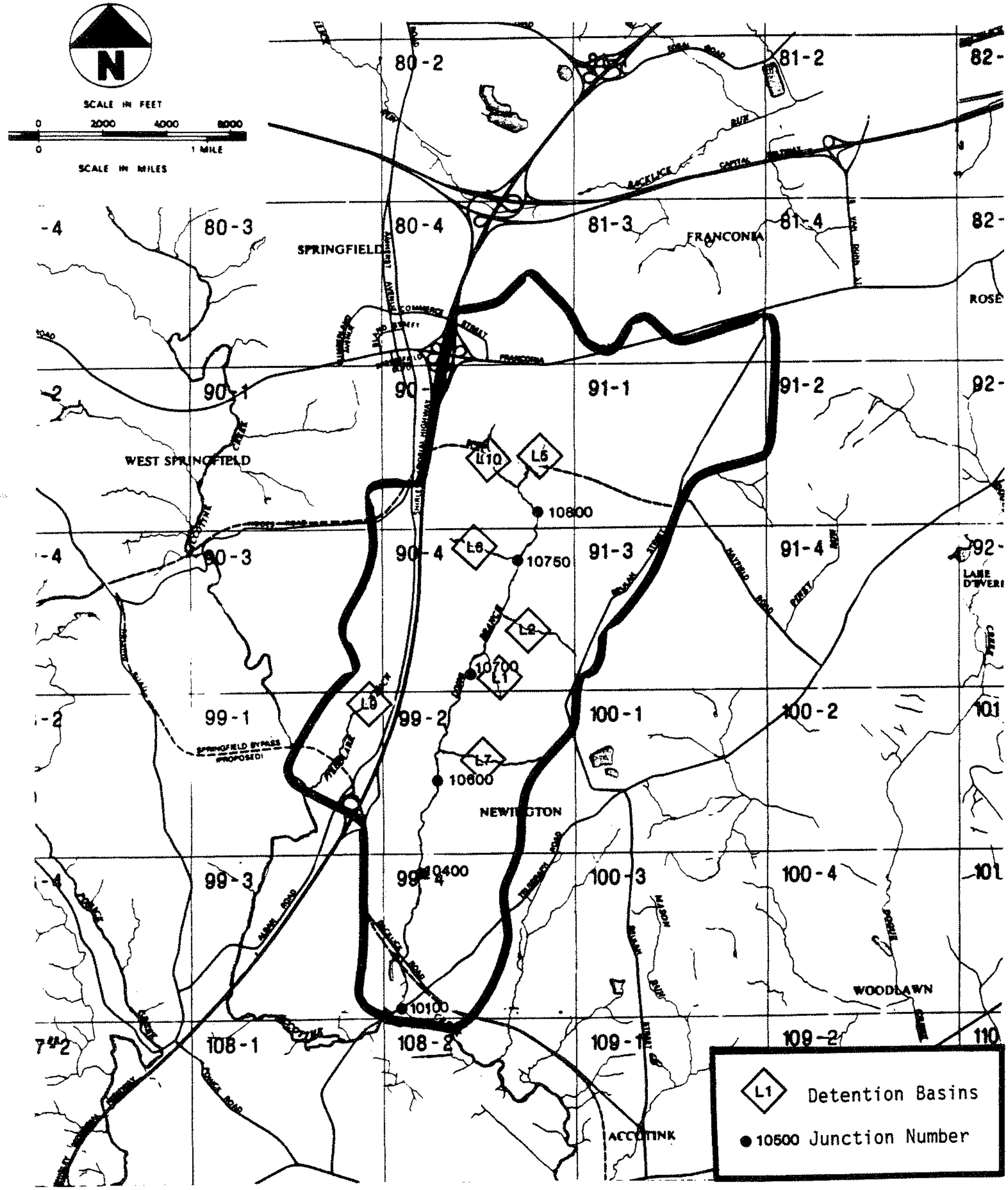


Figure 5-8. Long Branch: Key Locations (Junction Number) for Peak Flow Comparisons

watershed for the 2-year storm (30 to 50 percent), and about half the 2-year flow reduction benefits for the 10-year storm (15 to 20 percent).

Detention Basin Locations for Maximum Watershedwide Benefits

Table 5-19 presents the key locations showing the greatest regional benefits based on the time of travel studies. Except for L-7 which only has localized benefits, the maximum efficiency basins control the inflow peaks such that benefits are projected for the immediate downstream area and at each key location down to the confluence with Accotink Creek. In summary, peak flow timing is such that maximum efficiency basins achieve a significant peak flow reduction benefit throughout Long Branch watershed.

5.2.8 SUMMARY OF EVALUATION OF BENEFITS FOR ENTIRE STUDY AREA

Detention Basin Location and Distribution

In each watershed, the maximum number of detention basin sites were selected based on the available storage and other site constraints. The evaluation has shown that each detention basin provides localized benefits immediately downstream. However, the watershedwide impacts are largely a function of the total area controlled by the detention basins, the number of maximum efficiency basins and the distribution of the detention basins. The watershed evaluations have demonstrated that the greatest benefits for downstream areas are produced when several detention basins are clustered together in the upstream area thus controlling more of the drainage area tributary to downstream locations. Although they may control immediate downstream areas, a more scattered detention basin network, especially along the main stem, cannot produce the same level of benefits in the downstream areas as do detention basins which are clustered together in the upstream areas.

Effective Drainage Area Controlled by Maximum Efficiency Basins

Maximum efficiency detention basins were analyzed to take advantage of the available storage at each site in order to reduce release rates to levels

TABLE 5-19

LONG BRANCH
TIME OF TRAVEL EVALUATION

Regional Detention Basin	Key Locations Showing Greatest Regional Benefits
L-1	10100, 10400, 10600
L-2	10100, 10400, 10600
L-6	10100, 10400, 10600, 10700, 10750
L-7	*
L-5, L-10	10100, 10400, 10600, 10700, 10750, 10800

*Local benefits only

below the 2-year and 10-year predevelopment peak flows. Smaller release rates provide a mechanism for regional detention basins to compensate for runoff from uncontrolled downstream areas. An analysis was performed to determine the additional "effective area of control" provided by the maximum efficiency basins. For the 2-year and 10-year storms in each watershed, differences were calculated between the unregulated future peak flow and the regulated peak flow with conventional control, and the unregulated future peak flow and the regulated peak flow with maximum efficiency control at each site. The total difference for conventional designs was then compared to the total difference produced by the maximum efficiency basins for the 2-year storm and the 10-year storm. The ratios of the conventional differences to the maximum efficiency differences were calculated. The ratios ranged from 77 to 92 percent. These ratios were used to estimate the effective area of control. For example, the Cub Run ratio was 80 percent for the 2-year storm. Therefore, given an actual controlled drainage area of 7.3 sq mi in the Cub Run watershed, the effective area of control is (7.3 ÷ 0.80) 9.1 sq mi.

Table 5-20 summarizes the effective drainage area controlled by the maximum efficiency regional detention basin system. For each watershed, the actual controlled drainage area is given followed by the effective drainage area for the 2-year and 10-year storms. For the entire study area the effective area of control for the maximum efficiency detention basins was approximately 20 percent greater than the actual area of control for the 2-year and 10-year storms.

Impact of Type of Basin

For each detention basin site, 2-year erosion control and 10-year flood control were achieved by the design if adequate storage was available. For areas with limited storage, only a 2-year level of control was evaluated.

TABLE 5-20

EFFECTIVE DRAINAGE AREA CONTROLLED BY
MAXIMUM EFFICIENCY REGIONAL DETENTION BASIN SYSTEM

Watershed	2-yr Storm Drainage Area (sq mi)		10-yr Storm Drainage Area (sq mi)	
	Actual	Effective	Actual	Effective
Cub Run	7.3	9.1	7.3	8.4
Little Rocky Run	3.2	4.0	3.2	3.7
Difficult Run	17.3	20.7	17.3	22.1
Horsepen Creek	1.4	1.6	1.4	1.7
Long Branch	1.9	2.1	1.9	2.1
Pohick Creek	1.7	1.9	1.7	2.2
Sugarland Run	1.5	1.7	1.5	1.7
TOTAL	34.3	41.1	34.3	41.9

Within each watershed, detention basins designed for a 2-year storm only could not control the 10-year peaks to predevelopment peak levels; however, the maximum efficiency 10-year basins were designed to release peak flows which were less than the predevelopment peak flows. For some watersheds, the increased benefits from the maximum efficiency 10-year detention basins were able to offset the lack of 10-year control achieved by the 2-year detention basins.

To evaluate the increased benefits of the maximum efficiency basins for the 10-year storm, the predevelopment 10-year peak was subtracted from the peak flow produced by the 2-year control detention basins for the 10-year storm. The differences for each 2-year basin were summed to calculate a total "deficit" for the watershed. The deficit was compared to the total "benefits" produced by the additional reduction in peak flows achieved by the 10-year maximum efficiency basins.

Table 5-21 compares the benefits and the deficits for each of the seven study watersheds. As may be seen, the maximum efficiency detention basins reduce the deficit caused by the 2-year detention basins to varying degrees. Table 5-21 shows that for three watersheds Difficult Run, Horsepen Creek and Pohick Creek - the net benefits produced by the 10-year maximum efficiency detention basins are actually greater than the net deficits caused by the 2-year detention basins. Further net benefits and net deficits are relatively close for Cub Run watershed and the total net benefits are about 25 percent greater than the total net deficits when tabulated for the entire study area. The 2-year detention basins considered in this analysis were conventionally designed basins. The method of developing the maximum efficiency basin outflow hydrographs did not allow for a 10-year storm to be routed through a 2-year maximum efficiency basin. Therefore, the actual peak flow deficits for 2-year basins would be less than those presented in Table 5-21, and thus the actual 10-year net benefits would be even greater than those reported in the table.

TABLE 5-21

MAXIMUM EFFICIENCY DETENTION BENEFITS
FOR 10-YEAR STORM

Watershed	Peak Flow Indicator for 10-yr Storm	
	Net 10-yr Basin Benefits (cfs)	Net 2-yr Basin Deficits (cfs)
Cub Run	510	770
Little Rocky Run	190	230
Difficult Run	2,170	1,040
Horsepen Creek	150	130
Sugarland Run	90	170
Pohick Creek	380	30
Long Branch	120	530
STUDY AREA TOTAL:	3,610	2,900

Regional Detention Basin Benefits

Regional detention basins are an alternative to onsite controls. In many cases, the regional approach to stormwater detention offers advantages such as: increased effectiveness, reduction in capital and maintenance costs, opportunities to manage existing as well as projected stormwater problems, opportunities to provide water quality management as well as erosion and flood control protection, and increased opportunities for open space protection and recreational uses.

For 2-year erosion control and 10-year flood control, regional detention basins produce the same overall benefits as do onsite control measures for newly developing areas. However, one of the principal advantages of a regional detention basin system for Fairfax County is that the selected regional basin locations will not only control future development but will also control portions of the upstream drainage areas which are already developed. A second major benefit of a regional detention basin system is the use of available storage to develop maximum efficiency detention basins which can release less than the predevelopment peak to compensate for minimally controlled or uncontrolled areas. Therefore, maximum efficiency regional detention basins provide benefits which are typically greater than onsite controls. In some areas of the watersheds where regional detention basins could not be located or the benefits of maximum efficiency regional detention basins could not be detected, onsite controls will be required. Suggested guidelines for onsite detention are presented in Section 6.0.

5.3 WATER QUALITY BENEFITS OF RECOMMENDED PLAN

5.3.1 GENERAL METHODOLOGY

This section summarizes the water quality benefits of the recommended regional detention basin system for each watershed. The water quality benefits for all of the watersheds except the Occoquan Basin are expressed in terms of the percent reduction in future nonpoint pollution loadings.

Occoquan Basin Evaluations

For the watersheds (Cub Run and Little Rocky Run) in the Occoquan Basin, water quality impacts are primarily based on conformance with the annual total phosphorus (P) loading target (25,100 lbs/yr total P) specified in the County's Occoquan Basin Study (March 1982). This total P loading target represents the average annual loadings from the existing plus committed land use in the Occoquan Basin, as of 1980. Conformance with this "nondegradation" loading target means that future development in the Occoquan Basin will not result in loading increases beyond the level assigned to 1980 conditions.

For the Occoquan Basin evaluations, nonpoint pollution loadings were projected for the entire 100.8 sq mi area tributary to the Occoquan Reservoir. This means that future land use data had to be compiled for several tributary watersheds besides Cub Run and Little Rocky Run. The future land use plan recommended in the County's 1982 Occoquan Basin Study was used in this water quality evaluation. Data on the existing/committed land use pattern were compiled from previous water quality modeling studies by the Northern Virginia Planning District Commission.

The water quality evaluations assumed that future nonpoint pollution loadings could be reduced by onsite BMP's as well as regional BMP's. However, it was assumed that onsite BMP's would only be applied to development which occurred after 1980. In other words, existing development would not be served by onsite BMP's and could only be served by regional BMP's. To determine how much urban development in the Occoquan

Basin could be served by onsite BMP's, existing development had to be distinguished from future development. Since the land use tabulations for the regional detention basin watersheds were restricted to future land use conditions, the existing land use served by the regional BMP's had to be estimated.

Based upon visual screening of aerial photographs for the study area, it was decided that it would be reasonable to assume that existing development covered about 25% to 50% of the urban drainage area served by the regional BMP system. The amount of existing development located outside the regional BMP drainage areas was calculated by subtracting the area served by regional BMP's from the total amount of existing land use in the Occoquan Basin. The nonpoint pollution loadings from existing land use outside the regional BMP drainage areas was assumed to be uncontrollable with onsite BMP's. New development outside the regional BMP drainage areas was assumed to be served by onsite BMP's.

Another point which should be noted about the Occoquan Basin evaluations is that the future land use plan already includes extensive coverage of land use control BMP's. The 1982 Occoquan Basin downzoning resulted in the restriction of more than 20,000 acres to 5-acre lot single family residential development in order to protect water quality in the Occoquan Reservoir. Therefore, the annual nonpoint pollution loadings from "future land use with no BMP's" reported in the following tables for the Occoquan Basin have already been significantly reduced by land use control BMP's.

Evaluations of Other Watersheds

Nonpoint pollution loadings from other watersheds were evaluated using methods similar to the Occoquan Basin evaluations. Onsite BMP's were assumed to be applied to new development in each watershed. Since existing land use data was not compiled for these watersheds, the existing land use was estimated. It was assumed that existing development covered 25% to 50% of the urban drainage area served by the regional BMP system.

For Pohick Creek watershed, the entire drainage area of Burke Lake was included in the analysis.

5.3.2 BMP-SPREADSHEET MODEL

The water quality evaluations relied upon CDM's BMP-SPREADSHEET model which is a simple screening tool for evaluating the benefits of BMP plans. The microcomputer model operates with LOTUS 1-2-3 software which manipulates land use data, pollution loading factors, and BMP efficiencies to calculate watershed loadings "with" and "without" BMP's.

Nonpoint Pollution Loading Factors

Annual nonpoint pollution loading factors (lbs/acre/yr) for each land use category were based upon monitoring studies of test watersheds in the Washington metropolitan area. These studies were performed under the 208 Planning Program (NVPDC, 1979), the U.S. Environmental Protection Agency (EPA) Chesapeake Bay Program (NVPDC, 1983a), and the EPA Nationwide Urban Runoff Program (NURP) (NVPDC, 1983b), as well as other local monitoring studies within the Occoquan Reservoir watershed in northern Virginia (NVPDC, 1978). Loading factors applied to the Fairfax County watersheds for this study are presented in Table 5-22. The development of these loading factors is described below.

The primary source of loading factor data is the "Guidebook for Screening Urban Nonpoint Pollution Management Practices" developed for northern Virginia (NVDPC, 1979). To derive these loading factors, the EPA NPS model was used to generate annual loading projections for individual land uses which were further refined to include loading factors for different ranges of imperviousness and soil textures. To account for differences in soil characteristics, the acreage in different hydrologic soil groups was determined for each land use scenario. The "Guidebook" loading factors rely on soil texture classifications which were related to hydrologic soil groups for this study.

TABLE 5-22

SUMMARY OF
NONPOINT POLLUTION LOADING FACTORS
APPLIED TO FAIRFAX COUNTY WATERSHEDS
BY HYDROLOGIC SOILS GROUP

Land Use	TOTAL-P (lb/ac-yr)				TOTAL-N (lb/ac-yr)			
	A	B	C	D	A	B	C	D
FOREST	0.08	0.08	0.08	0.08	1.3	1.3	1.3	1.3
LLSF	0.30	0.33	0.33	0.35	3.9	4.1	4.1	4.1
LDSF	0.60	0.80	0.90	0.90	5.7	6.7	6.6	6.5
MDSF	0.80	1.00	1.00	1.00	7.1	8.0	8.0	7.8
INSTIT	0.80	1.00	1.00	1.00	7.1	8.0	8.0	7.8
HD RESID	1.20	1.20	1.20	1.20	10.1	10.3	10.1	10.1
IND/OFF	1.20	1.20	1.20	1.20	10.1	10.3	10.1	10.1
COMM<50%	0.80	1.00	1.00	1.00	7.1	8.0	8.0	7.8
COMM>50%	1.50	1.50	1.50	1.50	13.2	13.2	13.2	13.2

Land Use	LEAD (lb/ac-yr)				ZINC (lb/ac-yr)			
	A	B	C	D	A	B	C	D
FOREST	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
LLSF	0.09	0.10	0.10	0.10	0.07	0.09	0.10	0.11
LDSF	0.16	0.17	0.18	0.18	0.15	0.20	0.21	0.22
MDSF	0.29	0.34	0.36	0.36	0.23	0.27	0.29	0.30
INSTIT	0.29	0.34	0.36	0.36	0.23	0.27	0.29	0.30
HD RESID	1.39	1.42	1.42	1.42	0.69	0.71	0.72	0.72
IND/OFF	1.73	1.76	1.77	1.77	1.38	1.40	1.40	1.40
COMM<50%	0.29	0.34	0.36	0.36	0.23	0.27	0.29	0.30
COMM>50%	2.48	2.48	2.48	2.48	2.06	2.06	2.06	2.06

The EPA NURP study of the Washington metropolitan area is another source of nonpoint pollution loading factors. One of the results of the NURP study was to corroborate and refine many of the relationships between urban nonpoint pollution loading factors and land use categories developed during the 208 program (NVPDC, 1983b).

BMP Efficiencies

Average annual pollution removal rates for different BMP's are based upon EPA NURP study of the Washington metropolitan area. Field studies of two wet detention basins (Burke and Westleigh) are the source of efficiency data for wet detention basin BMP's. Settling column studies performed by Virginia Tech for the NURP study are the source of efficiency data for extended dry detention basin BMP's. The BMP efficiencies used in the BMP-SPREADSHEET model for this study are as follows:

	Average BMP Efficiency (%)	
Pollutant	Wet Detention	Extended Dry Detention
Total P	50%	30%
Total N	30%	15%
Lead	80%	80%
Zinc	70%	25%

As may be seen, wet detention basin BMP's achieve considerably higher efficiencies for nutrients due to the higher pollutant removal rates for dissolved phosphorus and nitrogen. Extended dry detention basins must rely solely on solids settling processes for pollution removal, meaning that pollutants with significant dissolved fractions (e.g., nutrients, zinc) exhibit relatively low removal efficiencies. Because of the greater pollutant removal efficiencies, wet detention basin BMP's are the preferred BMP for the Occoquan Basin and other critical watersheds. Sensitivity studies were performed with the BMP-SPREADSHEET model to compare the benefits of extended dry detention BMP's and wet detention BMP's for the Occoquan Basin.

To evaluate the pollutant loading reductions achieved by the regional BMP system, the annual loadings from the future land use tributary to each regional BMP was adjusted by the BMP efficiencies shown above. To evaluate the loading reductions achieved by onsite BMP's, annual loadings from the future development located outside the regional BMP drainage areas were adjusted by the BMP efficiencies. Annual loadings from existing development outside the regional BMP drainage areas were assumed to be uncontrollable.

An important assumption in evaluating the impacts of onsite BMP's is the percentage of the area served. For this study, it was assumed that 75% to 100% of the future development outside the regional BMP drainage areas would be served by onsite BMP's. Further, it was assumed that onsite BMP would not be applied to 5-acre lot single family development, since this land use category is typically regarded as a nonstructural BMP (e.g., Occoquan Basin).

5.3.3 NONPOINT POLLUTION LOADING PROJECTIONS

Annual nonpoint pollution loading projections for the Occoquan Basin are shown in Tables 5-23 and 5-24. Table 5-23, which summarizes total P loadings for different BMP scenarios, can be used to evaluate conformance with the nondegradation loading target of 25,100 lbs/yr total P. The lower end of the loading range assumed that 50% of the regional BMP drainage area is covered with existing land use, while the upper end assumes that only 25% is covered with existing land use. As may be seen, the use of regional BMP's alone will not achieve the total P loading target. In order to maintain annual total P loadings at 25,100 lbs/yr or less, the recommended regional BMP system plus onsite <u>wet</u> detention basins are required (i.e., with approximately 100% coverage by onsite BMP's). To evaluate tradeoffs between wet detention basins and extended dry detention basins, the BMP-SPREADSHEET model was used to project loadings assuming that all regional and onsite BMP's were restricted to extended dry detention. As may be seen (line F), extended dry detention systems can not achieve the nondegradation loading target. The excess total P loadings from the extended dry detention system would range from 2,400 to 3,400 lbs/yr.

TABLE 5-23

AVERAGE ANNUAL NONPOINT POLLUTION
LOADINGS OF TOTAL PHOSPHORUS:
OCCOQUAN BASIN FUTURE LAND USE (100.8 SQ MI)

BMP Scenario	Annual Total P Load (lbs/yr)
A. No Structural BMP's	34,000
B. Recommended Regional Detention BMP's Only*	30,200
C. Recommended Regional Detention BMP's + Onsite Wet Detention BMP's*	
a. 100% onsite coverage	24,700 - 25,500
b. 75% onsite coverage	25,900 - 26,400
D. Recommended Regional Detention BMP's + Onsite Extended Dry Detention BMP's	
a. 100% onsite coverage	26,500 - 27,000
b. 75% onsite coverage	27,200 - 27,500
E. Regional Extended Dry Detention BMP's + Onsite Wet Detention Basins**	
a. 100% onsite coverage	25,700 - 26,400
b. 75% onsite coverage	26,800 - 27,400
F. Regional Extended Dry Detention BMP's + Onsite Extended Dry Detention Basins	
a. 100% onsite coverage	27,500 - 27,900
b. 75% onsite coverage	28,200 - 28,500

*Recommended regional detention basin system includes 34 wet detention basins (serving 64% of regional BMP drainage area) and 14 extended dry detention basins (serving 36% of regional BMP drainage area).

**Assumes that all regional detention basins are extended dry detention basins.

TABLE 5-24

AVERAGE ANNUAL NONPOINT
POLLUTION LOADINGS: OCCOQUAN BASIN
FUTURE LAND USE (100.8 SQ MI)

BMP Scenario	Total P	Total N	Lead	Zinc
A. Annual Load (1,000 lbs/yr): No BMP's	34.0	321.5	19.1	15.4
B. Efficiency of BMP System (%)				
1. Regional BMP's Only	11%	7%	27%	13%
2. Regional + Onsite Wet Detention BMP's				
a. 100% onsite coverage	25-27%	14-15%	50-52%	38-40%
b. 75% onsite coverage	22-24%	13-14%	43-46%	33-35%
3. Regional + Onsite Extended Dry Detention BMP's				
a. 100% onsite coverage	21-22%	12%	50-52%	26-27%
b. 75% onsite coverage	19-20%	11%	43-46%	25%

Table 5-24 summarizes the efficiencies of the BMP system for different pollutants. Total nitrogen (N) was included in the analysis as well as lead and zinc, the two metals which exhibit the highest per acre loadings in urban runoff. The addition of onsite BMP's to the regional BMP plan increases pollutant removal efficiency by about 213% - 245% for total P, 202% - 227% for total N, 180% - 202% for lead, and 270% - 305% for zinc. Depending upon the assumed coverage and type of onsite BMP, the overall pollutant removal efficiencies for the regional plus onsite BMP scenario are on the order of 20% to 30% for total P, 10% to 15% for total N, 40% to 50% for lead, and 25% to 40% for zinc. As indicated above, the higher pollutant removal efficiencies are associated with the wet detention basin BMP's.

Tables 5-25 through 5-29 summarize the efficiencies of the BMP system for the other five watersheds. As may be seen, the overall pollutant removal efficiencies for the regional BMP system only are on the order of 5% to 15% for total P, 2% - 10% for total N, 5% - 50% for lead, and 5% - 20% for zinc. For the regional BMP plus onsite BMP scenario, the overall pollutant removal efficiencies are on the order of 20% to 30% for total P, 10% to 15% for total N, 50% to 80% for lead, and 15% to 25% for zinc.

This type of BMP evaluation may prove very useful to the County in demonstrating compliance with EPA's upcoming NPDES permitting program for stormwater discharges and compliance with the Chesapeake Bay Initiatives.

TABLE 5-25

AVERAGE ANNUAL NONPOINT
POLLUTION LOADINGS: DIFFICULT RUN WATERSHED
FUTURE LAND USE (56.4 SQ MI)

BMP Scenario	Total P	Total N	Lead	Zinc
A. Annual Load (1,000 lbs/yr): No BMP's	25.8	225.3	16.0	13.6
B. Efficiency of BMP System (%)				
1. Regional BMP's Only	15%	7%	49%	15%
2. Regional + Onsite Wet Detention BMP's				
a. 100% onsite coverage	22-23%	11%	64-66%	20-21%
b. 75% onsite coverage	20-21%	10%	60-62%	18-19%

NOTE: All regional and onsite BMP's are extended dry detention basins.

TABLE 5-26

AVERAGE ANNUAL NONPOINT
POLLUTION LOADINGS: HORSEPEN CREEK WATERSHED
FUTURE LAND USE (9.2 SQ MI)

BMP Scenario	Total P	Total N	Lead	Zinc
A. Annual Load (1,000 lbs/yr): No BMP's	5.6	43.8	3.5	2.9
B. Efficiency of BMP System (%)				
1. Regional BMP's Only	7%	3%	14%	3%
2. Regional + Onsite Wet Detention BMP's				
a. 100% onsite coverage	25-27%	13%	70-73%	22-23%
b. 75% onsite coverage	21-22%	10-11%	56-58%	17-18%

NOTE: All regional and onsite BMP's are extended dry detention basins.

TABLE 5-27

AVERAGE ANNUAL NONPOINT
POLLUTION LOADINGS: SUGARLAND RUN WATERSHED
FUTURE LAND USE (14.1 SQ MI)

	BMP Scenario	Total P	Total N	Lead	Zinc
A.	Annual Load (1,000 lbs/yr): No BMP's	8.9	73.7	7.4	5.4
B.	Efficiency of BMP System (%)				
	1. Regional BMP's Only	3%	2%	3%	2%
	2. Regional + Onsite Wet Detention BMP's				
	a. 100% onsite coverage	28%	14%	77-78%	24%
	b. 75% onsite coverage	21-22%	11%	59-60%	18-19%

NOTE: All regional and onsite BMP's are extended dry detention basins.

TABLE 5-28

AVERAGE ANNUAL NONPOINT
POLLUTION LOADINGS: POHICK CREEK WATERSHED
FUTURE LAND USE (3.2 SQ MI)

	BMP Scenario	Total P	Total N	Lead	Zinc
A.	Annual Load (1,000 lbs/yr): No BMP's	1.3	10.8	0.3	0.3
B.	Efficiency of BMP System (%)				
	1. Regional BMP's Only	15%	10%	55%	17%
	2. Regional + Onsite Wet Detention BMP's				
	a. 100% onsite coverage	21%	10%	56-58%	18%
	b. 75% onsite coverage	21%	10%	56-57%	18%

NOTE: All regional and onsite BMP's are extended dry detention basins.

TABLE 5-29

AVERAGE ANNUAL NONPOINT
POLLUTION LOADINGS: LONG BRANCH WATERSHED
FUTURE LAND USE (5.9 SQ MI)

BMP Scenario	Total P	Total N	Lead	Zinc
A. Annual Load (1,000 lbs/yr): No BMP's	3.6	29.5	2.8	2.3
B. Efficiency of BMP System (%)				
1. Regional BMP's Only	11%	5%	33%	11%
2. Regional + Onsite Detention BMP's				
a. 100% onsite coverage	22–25%	11–12%	56–64%	17–20%
b. 75% onsite coverage	20–21%	10–11%	50–56%	16–18%

NOTE: All regional and onsite BMP's are extended dry detention basins.

6.0 RECOMMENDED REGIONAL STORMWATER MANAGEMENT PLAN

6.1 FACILITIES PLANS FOR INDIVIDUAL WATERSHEDS

Analyses have been performed to determine the best site locations for regional detention basins and the types of basins (wet or extended dry, 2-year control or 2-year and 10-year control) which could be supported by the available storage and other conditions at the site. Wet detention basins were the preferred control measures for Cub Run and Little Rocky Run which are located in the Occoquan watershed and extended dry detention basins were considered for the other study areas. At each site where feasible, maximum efficiency detention basins were recommended which used the available storage to produce release rates that were less than the predevelopment inflow peaks. Peak flow reduction evaluation for the 2-year and 10-year storms and time of travel studies were performed to determine the magnitude of the regional benefits and the location and distribution of detention basins for maximum watershedwide benefits. Table 6-1 summarizes the distribution of regional detention basins for each of the seven watersheds. The table presents the number of wet and extended dry detention basins, the total drainage area controlled, and the total top of dam storage.

For the total study area, 134 detention basins are recommended in this master plan. For the Occoquan watershed (Cub Run and Little Rocky Run) 16 wet basins with 2-year control and 16 wet basins with 2-year and 10-year control are recommended. There are also 12 extended dry 2-year control basins in the Occoquan watershed. For the remaining watersheds in the study area, the recommended extended dry 2-year detention basins total 33 and the recommended extended dry 2-year and 10-year basins total 57.

The recommended regional detention basins for each watershed are presented in the following sections.

TABLE 6-1

FAIRFAX COUNTY
REGIONAL STORMWATER MANAGEMENT PLAN

DETENTION BASIN SUMMARY

Watershed	Regional Detention Basins Total No.	Wet 2-yr	Wet 10-yr	ExtDry 2-yr	ExtDry 10-yr	Drainage Area Controlled (ac)	Total Top of Dam Storage (ac-ft)
Cub Run	31	9	12	10	—	4,680	824
Little Rocky Run	13	7	4	2	—	2,068	254
Difficult Run	63	—	—	23	40	11,099	1,017
Horsepen Creek	7	—	—	3	4	879	127
Sugarland Run	5	—	—	3	2	991	107
Pohick Creek	8	—	—	1	7	1,107	110
Long Branch	7	—	—	3	4	1,197	207
TOTAL	134	16	16	45	57	22,021	2,646

6.1.1 CUB RUN

A total of 31 regional detention basins are recommended for the Cub Run watershed. To maximize water quality benefits for the Occoquan Basin, wet detention basin are recommended wherever feasible. Adequate storage was available to provide 2-year and 10-year control for 12 wet detention basins and 2-year control for 9 wet detention basins. At the remaining 10 sites, storage was limited; and 2-year control for extended dry detention basins are recommended at these sites.

Table 6-2 presents the list of recommended detention basins. The detention basin type is given for each basin number. The basin design indicates whether the detention is a maximum efficiency basin or a conventional design basin. Of the 12 wet detention basins providing 2-year and 10-year controls, maximum efficiency basins are recommended for 9 basins and conventional designs are required for 3 basins (C-19, C-37 and C-50).

Maximum efficiency detention is recommended for all wet detention basin with 2-year control except for one (C-21) which is limited to a conventional design. For the 10 extended dry basin with 2-year control all but three are recommended for maximum efficiency detention. For the remaining three (C-57, C-62 and C-63), which are limited by available storage, conventional design detention basins are recommended. For each of the recommended regional detention basins the top of dam elevation and storage are summarized in Table 6-3. An Asterisk (*) indicates which detention basins are maximum efficiency basins.

Throughout Cub Run the greatest watershedwide benefits were shown to occur where clusters of regional basins were located on major tribularies to the mainstream (See Figure 5-3 for location of regional detention basins). Those regional detention basins providing maximum watershedwide benefits are recommended for high priority implementation. They are as follows:

TABLE 6-2

CUB RUN
RECOMMENDED DETENTION BASINS

Basin Number	Basin Type	Basin Design
C-3	EXTDRY-2	A
C-4	WET-10	A
C-5	WET-10	A
C-11	WET-2	A
C-12	WET-10	A
C-18	WET-2	A
C-19	WET-10	B
C-20	WET-2	A
C-21	WET-2	B
C-22	EXTDRY-2	A
C-23	WET-10	A
C-24	WET-2	A
C-25	EXTDRY-2	A
C-28	WET-2	A
C-30	WET-10	A
C-35	WET-10	A
C-37	WET-10	B
C-39	EXTDRY-2	A
C-40	EXTDRY-2	A
C-41	WET-2	A
C-43	WET-10	A
C-44	EXTDRY-2	A
C-46	WET-10	A
C-47	WET-10	A
C-49	WET-2	A
C-50	WET-10	B
C-53	EXTDRY-2	A
C-54	EXTDRY-2	A
C-57	EXTDRY-2	B
C-62	WET-2	B
C-63	EXTDRY-2	B

Note: "A" indicates maximum efficiency detention basin.
"B" indicates conventional design detention basin.

TABLE 6-3

CUB RUN
DETENTION BASIN CHARACTERISTICS

		Top of Dam	
Basin Number	Type of Control	Elev. (ft)	Storage (ac-ft)
C-3	EXTDRY-2	262.9	27.1*
C-4	WET-10	237.3	24.3*
C-5	WET-10	200.6	47.6*
C-11	WET-2	259.7	29.5*
C-12	WET-10	264.5	35.4*
C-18	WET-2	322.1	104.1*
C-19	WET-10	284.6	53.7
C-20	WET-2	359.5	18.8*
C-21	WET-2	225.8	12.7
C-22	EXTDRY-2	228.6	16.4*
C-23	WET-10	248.4	19.2*
C-24	WET-2	258.5	18.0*
C-25	EXTDRY-2	274.6	40.2*
C-28	WET-2	194.5	36.5*
C-30	WET-10	304.5	51.3*
C-35	WET-10	195.1	23.3*
C-37	WET-10	263.7	85.8
C-39	EXTDRY-2	299.7	8.0*
C-40	EXTDRY-2	290.0	13.2*
C-41	WET-2	279.9	31.1*
C-43	WET-10	324.9	24.7*
C-44	EXTDRY-2	385.0	17.1*
C-46	WET-10	294.3	37.9*
C-47	WET-10	257.9	35.9*
C-49	WET-2	213.9	16.2*
C-50	WET-10	262.0	36.5
C-53	EXTDRY-2	323.1	7.3*
C-54	EXTDRY-2	359.7	33.4*
C-57	EXTDRY-2	344.5	8.7
C-62	WET-2	244.4	7.9
C-63	EXTDRY-2	240.1	36.5

NOTE: "*" indicates maximum efficiency detention basin.

Subwatershed	Regional Detention Basins
Flatlick Branch	C-20, C-39, C-40, C-43, C-44, C-53, C-54
Big Rocky Run	C-3, C-30
Cain Branch	C-18, C-57
Round Lick Branch	C-19, C-63

The remaining regional detention basins which provide water quality benefits, and local erosion and flood control benefits, with some watershedwide benefits are recommended to be considered for implementation on a case by case basis.

6.1.2 LITTLE ROCKY RUN

Thirteen regional detention basins are recommended for the Little Rocky Run watershed which include 11 wet detention basins to maximize the water quality benefits in the Occoquan watershed. Of the 11 wet basins, four provide 2-year and 10-year control. The remaining two regional detention basins provide 2-year control with extended dry detention. Table 6-4 presents the recommended regional detention basins and gives the basin type and basin design.

Maximum efficiency detention basins are recommended for all the wet detention basins with 2-year and 10-year control. Four of the seven wet detention basins with 2-year control are recommended as maximum efficiency basins, the remaining are limited to convention design detention basins. In two areas of limited storage, extended dry detention basins with 2-year control are recommended (R-16, R-17). One of these basins (R-17) has maximum efficiency detention and the other (R-16) requires a conventional design detention basin. For each of the recommended regional detention basins Table 6-5 presents detention basin characteristics which

TABLE 6-4

LITTLE ROCKY RUN
RECOMMENDED DETENTION BASINS

Basin Number	Basin Type	Basin Design
R-2	WET-2	A
R-5	WET-10	A
R-6	WET-2	B
R-7	WET-10	A
R-8	WET-10	A
R-9	WET-2	B
R-10	WET-2	A
R-11	WET-2	A
R-12	WET-10	A
R-13	WET-2	B
R-16	EXTDRY-2	B
R-17	EXTDRY-2	A
R-19	WET-2	A

Note: "A" indicates maximum efficiency detention basin
"B" indicates conventional design detention basin.

TABLE 6-5

LITTLE ROCKY RUN
DETENTION BASIN CHARACTERISTICS

		Top of Dam	
Basin Number	Type of Control	Elev. (ft)	Storage (ac-ft)
R-2	WET-2	203.8	41.5*
R-5	WET-10	273.3	23.7*
R-6	WET-2	379.9	50.1
R-7	WET-10	360.2	13.0*
R-8	WET-10	401.7	35.1*
R-9	WET-2	379.8	7.3
R-10	WET-2	399.8	17.7*
R-11	WET-2	369.7	9.9*
R-12	WET-10	408.5	15.4*
R-13	WET-2	335.3	24.7
R-16	EXTDRY-2	313.2	4.9
R-17	EXTDRY-2	355.0	34.7*
R-19	WET-2	384.1	18.5*

NOTE: "*" indicates maximum efficiency detention basin.

include type of control and the top of dam elevation and storage. An asterisk (*) denotes the maximum efficiency detention basins.

The recommended regional detention basins for Little Rocky Run not only provide local water quality and erosion/flooding benefits but also provide benefits along the mainstream. The recommended regional detention basins in the upper portion of the watershed act to provide watershedwide benefits while in the lower portion of the watershed benefits are increased by the existing county regional detention basins (See Figure 5-4 for location of regional detention basins).

All regional detention basins are contributing to the watershedwide peak flow reductions; however, the high priority basins recommended for implementation include the eleven wet detention basins to maximize the water quality protection, and one extended dry detention basin (R-17) which acts in series with three upstream wet detention basins. The remaining basin (R-16) is an extended dry basin with 2-year control and it should have a lower priority for implementation.

6.1.3 DIFFICULT RUN

For the Difficult Run watershed, 63 extended dry regional detention basins are recommended. Control of the 2-year and 10-year storms are provided by 40 basins and control of the 2-year storm is provided by 23 basins. Table 6-6 gives a list of the recommended detention basins with the basin type and basin design for each. All of the Difficult Run detention basins provide maximum efficiency detention with the exception of D-30 and D-39 for which conventional design detention basins are required. The detention basin characteristics are given in Table 6-7 for the recommended basins. The characteristics include the top of dam elevation and storage.

The greatest watershedwide benefits for Difficult Run are provided by the regional detention basins in the upper reaches of Difficult Run and Little Difficult Run where large clusters of basins are located. (See Figure 5-5 for location of regional detention basins). Smaller tributary areas which show peak flow reduction benefits include Piney Branch, Piney Run and

TABLE 6-6

DIFFICULT RUN
RECOMMENDED DETENTION BASINS

Basin Number	Basin Type	Basin Design
D-1	EXTDRY-2	A
D-2	EXTDRY-2	A
D-3	EXTDRY-10	A
D-4	EXTDRY-10	A
D-5	EXTDRY-2	A
D-6	EXTDRY-10	A
D-7	EXTDRY-2	A
D-9	EXTDRY-10	A
D-10	EXTDRY-10	A
D-11	EXTDRY-10	A
D-12	EXTDRY-10	A
D-13	EXTDRY-10	A
D-14	EXTDRY-10	A
D-15	EXTDRY-10	A
D-16	EXTDRY-10	A
D-17	EXTDRY-10	A
D-18	EXTDRY-10	A
D-19	EXTDRY-10	A
D-20	EXTDRY-10	A
D-21	EXTDRY-10	A
D-23	EXTDRY-10	A
D-24	EXTDRY-2	A
D-25	EXTDRY-2	A
D-26	EXTDRY-10	A
D-27	EXTDRY-10	A
D-28	EXTDRY-10	A
D-29	EXTDRY-2	A
D-30	EXTDRY-2	B
D-31	EXTDRY-2	A
D-32	EXTDRY-2	A
D-33	EXTDRY-2	A
D-34	EXTDRY-10	A
D-35	EXTDRY-10	A
D-36	EXTDRY-10	A
D-37	EXTDRY-10	A
D-38	EXTDRY-2	A
D-39	EXTDRY-2	B

Note: "A" indicates maximum efficiency detention basin.
"B" indicates conventional design detention basin.

TABLE 6-6

DIFFICULT RUN
RECOMMENDED DETENTION BASINS
(CONTINUED)

Basin Number	Basin Type	Basin Design
D-40	EXTDRY-2	A
D-41	EXTDRY-2	A
D-43	EXTDRY-10	A
D-45	EXTDRY-2	A
D-46	EXTDRY-2	A
D-47	EXTDRY-10	A
D-49	EXTDRY-2	A
D-51	EXTDRY-2	A
D-52	EXTDRY-2	A
D-54	EXTDRY-10	A
D-56	EXTDRY-10	A
D-58	EXTDRY-10	A
D-59	EXTDRY-10	A
D-61	EXTDRY-10	A
D-64	EXTDRY-10	A
D-65	EXTDRY-10	A
D-66	EXTDRY-10	A
D-67	EXTDRY-2	B
D-69	EXTDRY-10	A
D-71	EXTDRY-10	A
D-72	EXTDRY-10	A
D-73	EXTDRY-2	A
D-74	EXTDRY-10	A
D-76	EXTDRY-2	A
D-77	EXTDRY-10	A
D-79	EXTDRY-10	A

Note: "A" indicates maximum efficiency detention basin.
"B" indicates conventional design detention basin.

TABLE 6-7

DIFFICULT RUN
DETENTION BASIN CHARACTERISTICS

Basin Number	Type of Control	Top of Dam Elev. (ft)	Top of Dam Storage (ac-ft)
D-1	EXTDRY-2	378.1	27.3*
D-2	EXTDRY-2	324.4	18.2*
D-3	EXTDRY-10	363.1	20.4*
D-4	EXTDRY-10	370.2	33.9*
D-5	EXTDRY-2	294.9	29.2*
D-6	EXTDRY-10	247.3	10.4*
D-7	EXTDRY-2	248.7	50.5*
D-9	EXTDRY-10	203.0	35.9*
D-10	EXTDRY-10	205.4	15.4*
D-11	EXTDRY-10	219.9	6.4*
D-12	EXTDRY-10	235.6	22.4*
D-13	EXTDRY-10	310.4	38.0*
D-14	EXTDRY-10	253.4	22.0*
D-15	EXTDRY-10	250.8	15.0*
D-16	EXTDRY-10	297.5	8.1*
D-17	EXTDRY-10	244.2	7.8*
D-18	EXTDRY-10	270.0	8.8*
D-19	EXTDRY-10	243.7	10.7*
D-20	EXTDRY-10	241.7	43.2*
D-21	EXTDRY-10	221.6	9.7*
D-23	EXTDRY-10	271.6	4.4*
D-24	EXTDRY-2	251.5	13.3*
D-25	EXTDRY-2	245.7	9.7*
D-26	EXTDRY-10	253.8	27.5*
D-27	EXTDRY-10	289.3	9.7*
D-28	EXTDRY-10	346.2	13.1*
D-29	EXTDRY-2	320.0	46.1*
D-30	EXTDRY-2	328.5	24.1
D-31	EXTDRY-2	324.7	29.9*
D-32	EXTDRY-2	324.8	5.8*
D-33	EXTDRY-2	325.5	5.5*
D-34	EXTDRY-10	324.8	6.5*
D-35	EXTDRY-10	316.5	12.0*
D-36	EXTDRY-10	354.5	31.3*
D-37	EXTDRY-10	307.0	31.9*
D-38	EXTDRY-2	299.0	8.4*
D-39	EXTDRY-2	353.3	28.9
D-40	EXTDRY-2	378.5	77.6*
D-41	EXTDRY-2	376.4	30.4*
D-43	EXTDRY-10	339.1	7.2*

NOTE: "*" indicates maximum efficiency detention basin.

TABLE 6-7

DIFFICULT RUN
DETENTION BASIN CHARACTERISTICS
(CONTINUED)

		Top of Dam	
Basin Number	Type of Control	Elev. (ft)	Storage (ac-ft)
D-45	EXTDRY-2	365.1	24.5*
D-46	EXTDRY-2	365.0	45.8*
D-47	EXTDRY-10	393.9	28.9*
D-49	EXTDRY-2	396.2	51.3*
D-51	EXTDRY-2	251.7	41.9*
D-52	EXTDRY-2	249.3	67.6*
D-54	EXTDRY-10	246.9	16.4*
D-56	EXTDRY-10	276.6	10.7*
D-58	EXTDRY-10	378.5	10.9*
D-59	EXTDRY-10	305.1	9.3*
D-61	EXTDRY-10	325.8	32.1*
D-64	EXTDRY-10	300.1	14.6*
D-65	EXTDRY-10	220.0	6.4*
D-66	EXTDRY-10	323.1	19.7*
D-67	EXTDRY-2	350.0	32.1
D-69	EXTDRY-10	372.4	21.8*
D-71	EXTDRY-10	381.4	35.7*
D-72	EXTDRY-10	288.7	9.1*
D-73	EXTDRY-2	364.2	8.3*
D-74	EXTDRY-10	306.4	16.7*
D-76	EXTDRY-2	194.4	15.3*
D-77	EXTDRY-10	407.4	58.6*
D-79	EXTDRY-10	324.9	31.0*

NOTE: "*" indicates maximum efficiency detention basin.

Rocky Run. The regional detention basins in those areas which provide maximum watershedwide benefits are recommended for implementation on a high priority basis:

Subwatershed	Regional Detention Basins
Difficult Run upstream of Little Difficult Run Confluence	D-30, D-31, D-32, D-33, D-34, D-35, D-36, D-45, D-46, D-47, D-49, D-56, D-59, D-72, D-77
Little Difficult Run	D-37, D-38, D-39, D-40, D-41, D-43, D-58, D-61, D-69, D-71
Piney Branch	D-27, D-29, D-73, D-74
Piney Run	D-1, D-2, D-3, D-4, D-64
Rocky Run	D-18, D-19, D-20, D-21, D-66, D-67

The remaining regional detention basins provide local benefits and some watershedwide benefits. Implementation for remaining basins is recommended to be of a lower priority.

6.1.4 HORSEPEN CREEK

The seven recommended regional detention basins for the Horsepen Creek watershed are listed in Table 6-8. Four extended dry basin provide 2-year and 10-year control and three provide 2-year control. Maximum efficiency detention is recommended at all sites except H-13 and H-18 which require conventional design detention basins. Table 6-9 presents the top of dam elevation and storage for each regional detention basin.

The most effective basin locations which provided the greatest study area benefits were in the headwater locations of Horsepen Creek, including Cedar Run, and on Merrybrook Run located to the north of the mainstream. (See Figure 5-6 for regional detention basin locations). Therefore, the

TABLE 6-8

HORSEPEN CREEK
RECOMMENDED DETENTION BASINS

Basin Number	Basin Type	Basin Design
H-1	EXTDRY-10	A
H-2	EXTDRY-10	A
H-7	EXTDRY-10	A
H-9	EXTDRY-10	A
H-13	EXTDRY-2	B
H-16	EXTDRY-2	A
H-18	EXTDRY-2	B

Notes: "A" indicates maximum efficiency detention basin.
"B" indicates conventional design detention basin.

TABLE 6-9

HORSEPEN CREEK
DETENTION BASIN CHARACTERISTICS

Basin Number	Type of Control	Top of Dam Elev. (ft)	Top of Dam Storage (ac-ft)
H-1	EXTDRY-10	384.6	21.2*
H-2	EXTDRY-10	310.4	36.8*
H-7	EXTDRY-10	338.0	15.9*
H-9	EXTDRY-10	315.6	35.4*
H-13	EXTDRY-2	359.5	24.0
H-16	EXTDRY-2	347.7	6.2*
H-18	EXTDRY-2	375.1	17.3

NOTE: "*" indicates maximum efficiency detention basin.

following regional detention basins are recommended for high priority implementation:

Subwatershed	Regional Detention Basins
Headwater area of Horsepen Creek	H-7, H-13, H-16
Merrybrook Run	H-1, H-9

Although H-2 and H-18 have local benefits, they are not included for high priority implementation. H-18, however provides a greater benefit to a longer downstream reach than does H-2 which is located on a tributary a short distance from the mainstream.

6.1.5 SUGARLAND RUN

Five regional detention basins are recommended for the Sugarland Run watershed. Table 6-10 presents the type of basin for each and the basin design. Two of the extended dry basins have 2-year and 10-year control and three have 2-year control. All the regional detention basins are maximum efficiency detention basins except S-7 which requires a conventional design. Table 6-11 presents the top of dam elevation and storage for the five regional detention basins.

The regional detention basins in Sugarland Run provide local benefits but do not provide main stem benefits. The main stem flows are dominated by the large upstream area of the Town of Herndon. (See Figure 5-7 for regional detention basin locations.) The greatest benefits on tributaries are provided by S-1 and S-7 for Offut's Branch and S-2 for Rosiers Branch. These three basins are recommended for high priority implementation. Regional detention basins S-4 and S-5 have minimal impacts watershedwide and are recommended to be of low priority.

TABLE 6-10

SUGARLAND RUN
RECOMMENDED DETENTION BASINS

Basin Number	Basin Type	Basin Design
S-1	EXTDRY-2	A
S-2	EXTDRY-10	A
S-4	EXTDRY-10	A
S-5	EXTDRY-2	A
S-7	EXTDRY-2	B

Note: "A" indicates maximum efficiency detention basin.
"B" indicates conventional design detention basin.

TABLE 6-11

SUGARLAND RUN
DETENTION BASIN CHARACTERISTICS

Basin Number	Type of Control	Top of Dam Elev. (ft)	Top of Dam Storage (ac-ft)
S-1	EXTDRY-2	260.8	15.6*
S-2	EXTDRY-10	341.2	29.9*
S-4	EXTDRY-10	309.9	9.9*
S-5	EXTDRY-2	288.3	23.9*
S-7	EXTDRY-2	291.4	33.5

NOTE: "*" indicates maximum efficiency detention basin.

6.1.6 POHICK CREEK

A total of 8 regional detention basins are recommended for the portion of the Pohick Creek watershed which drains to Burke Lake. The basin type and basin design are presented in Table 6-12 and the top of dam detention basin characteristics are presented in Table 6-13.

P-6 is the only extended dry detention basin with limited 2-year control and a conventional design. The remaining basins are all maximum efficiency detention basins with 2-year and 10-year control. The eight regional detention basins, as shown in the previous Figure 3-6, provide local benefits for their tributary location in addition to the extended dry water quality benefits and 2-year and 10-year flooding benefits to Burke Lake.

Although no hydrograph routing was performed on the tributaries to Burke Lake, clustered basins produce the greatest benefits to downstream areas. Therefore, those regional detention basin which have a high priority for implementation include all basins except P-5 which is an isolated basin having the smallest total storage of the recommended basins.

6.1.7 LONG BRANCH

The seven regional detention basins recommended for the Long Branch tributary to Accotink Creek are presented in Table 6-14. The top of dam detention basin characteristics are presented in Table 6-15. Four basins are maximum efficiency, extended dry detention basins with 2-year and 10-year control. Three are extended dry detention basins with 2-year control one of which is requested to have a conventional design due to storage limitations at the site.

All regional detention basins were shown to provide watershedwide benefits except L-7. (See Figure 5-8 for regional detention basin locations.) Detention basin L-7 provides local benefits, however, flood control benefits to the main stem occur before the mainstem hydrograph reaches its peak, and thus the detention basin does not reduce the mainstem peak. Therefore, with the exception of L-7 all regional detention basins,

TABLE 6-12

POHICK CREEK
RECOMMENDED DETENTION BASINS

Basin Number	Basin Type	Basin Design
P-1	EXTDRY-10	A
P-2	EXTDRY-10	A
P-3	EXTDRY-10	A
P-4	EXTDRY-10	A
P-5	EXTDRY-10	A
P-6	EXTDRY-2	B
P-7	EXTDRY-10	A
P-8	EXTDRY-10	A

Note: "A" indicates maximum efficiency detention basin.
"B" indicates conventional design detention basin.

TABLE 6-13

POHICK CREEK
DETENTION BASIN CHARACTERISTICS

		Top of Dam	
Basin Number	Type of Control	Elev. (ft)	Storage (ac-ft)
P-1	EXTDRY-10	362.2	22.5*
P-2	EXTDRY-10	356.8	29.6*
P-3	EXTDRY-10	347.5	9.4*
P-4	EXTDRY-10	329.1	42.7*
P-5	EXTDRY-10	340.8	7.1*
P-6	EXTDRY-2	329.4	14.0
P-7	EXTDRY-10	330.1	18.7*
P-8	EXTDRY-10	393.5	16.2*

NOTE: "*" indicates maximum efficiency detention basin.

TABLE 6-14

LONG BRANCH
RECOMMENDED DETENTION BASINS

Basin Number	Basin Type	Basin Design
L-1	EXTDRY-10	A
L-2	EXTDRY-10	A
L-5	EXTDRY-2	A
L-6	EXTDRY-10	A
L-7	EXTDRY-10	A
L-9	EXTDRY-2	B
L-10	EXTDRY-2	A

Notes: "A" indicates maximum efficiency detention basin.
"B" indicates conventional design detention basin.

TABLE 6-15

LONG BRANCH
DETENTION BASIN CHARACTERISTICS

Basin Number	Type of Control	Top of Dam Elev. (ft)	Top of Dam Storage (ac-ft)
L-1	EXTDRY-10	164.2	17.9*
L-2	EXTDRY-10	163.2	16.8*
L-5	EXTDRY-2	197.3	17.3*
L-6	EXTDRY-10	199.6	29.0*
L-7	EXTDRY-10	150.6	23.4*
L-9	EXTDRY-2	165.2	38.0
L-10	EXTDRY-2	181.5	95.8*

NOTE: "*" indicates maximum efficiency detention basin.

including the special basin on Fieldlark Branch, are recommended as high priority basins for implementation.

6.2 ONSITE DETENTION GUIDELINES

One of the major objectives of a regional detention basin master plan is to reduce the need for onsite detention systems. As indicated in an earlier chapter this objective is based upon the major advantages of the regional detention system, including lower construction costs, and greater reliability. However, some applications of onsite detention will still be required in the study area to supplement the regional detention basin network. Summarized below are general guidelines for the use of onsite detention within the study area watersheds. It should be emphasized that these guidelines are intended to apply only to the study area covered by this master plan, not to the entire County.

1. Areas Upstream of the Recommended Regional Detention Basins: The regional detention basin system serves a total area of about 35 sq mi or about 30% of the study area. Since these regional facilities are designed to at least achieve the same benefits as onsite detention systems would, supplementary onsite detention will typically not be required within the drainage area of each regional facility. This guideline should almost always apply to single family residential development, with case-by-case exceptions possible for highly impervious land uses which may require some controls to minimize stream bank erosion upstream of the regional facility.

2. Highly Impervious Land Uses Tributary to Recommended Regional Detention Basins: Significant concentrations of highly impervious development (e.g., commercial, industrial, and multifamily residential) will have the greatest potential to cause major streambank erosion upstream of the regional detention basin. Therefore, highly impervious land development projects which exceed some specified size cutoff

(e.g., 10 acres) should be required to demonstrate that the downstream channel is adequate for stormwater conveyance pursuant to the "adequate channel" requirements in the Virginia Erosion and Sediment Control Handbook. To ensure an adequate downstream channel with minimal streambank erosion impacts, onsite detention or other erosion controls (e.g., channel improvements) may be required for highly impervious land uses on a case-by-case basis.

3. Occoquan Basin: In the Occoquan Basin, the ability of future development to meet the water quality performance standards discussed in Chapter 5.0 is at least as important, if not more so, than the ability to meet peak-shaving performance standards. As indicated in Chapter 5.0, in order to achieve the "nondegradation" loading target for total P, the use of onsite BMP's (wet detention basins) is required on almost all future development which is not served by regional detention BMP's. This means that even if onsite detention is not required for 2-yr and/or 10-yr peak-shaving, onsite BMP's must be required for all future development outside the regional BMP drainage area, unless the development is a land use control BMP (5-acre lot single family development). The design of the onsite facility can be scaled back (i.e., no peak-shaving requirements) if it is only required for water quality management. Similar requirements for supplementary BMP's might be considered for the watersheds of other critical receiving waters (e.g., Burke Lake). In most other watersheds, the regional detention system alone should be capable of satisfying the upcoming EPA NPDES permitting requirements for stormwater discharges. However, in the event that the final NPDES regulations are more stringent than the current proposals, supplementary onsite BMP's to serve areas outside the regional detention basin drainage areas might be necessary.

4. Low Density Land Uses Which Should Not Require Onsite Detention: Residential land uses with very low imperviousness should be exempted from onsite detention requirements whether they are located outside the regional detention system drainage areas or not. For example, the extensive amounts of 5-acre lot single family residential development in the Occoquan Basin and Difficult Run Watershed should be exempted from onsite detention requirements since "uncontrolled" runoff impacts are insignificant and peak-shaving detention benefits are likely to be minimal. Consideration should be given to whether smaller residential lot sizes (e.g., 2-acre) should be exempted from onsite detention requirements also.

5. Effective Area of Maximum Efficiency Detention Basins: As indicated in an earlier chapter, the maximum efficiency regional detention basin system achieves an "effective" controlled area of about 42 sq mi. This effective area means that these facilities adequately compensate for a significant amount of area which can not be served by regional facilities. Onsite detention basins typically should not be required within areas where a maximum efficiency regional facility (ies) achieves adequate surplus benefits. Evaluation of how much additional area is "effectively" served by a maximum efficiency regional detention basin should be performed for each major tributary (say a 1,000 acre drainage area) in each watershed. Based on case-by-case analyses, areas which are effectively compensated for by the oversized regional detention basins should not have to provide onsite detention so long as they satisfy guidelines #2 and #3 above. For example consider a maximum efficiency regional detention basin with a 250-acre drainage area on a side tributary adjoining two 50-acre single family development projects. Assume that the maximum release rate

from the maximum efficiency detention basin is set at 7.5 cfs (33% of the predevelopment 2-yr peak of 22.5 cfs) while the total post-development 2-yr peak flow for the two 50-acre single family development is 20 cfs (i.e., 10 cfs for each 50-acre project), compared to a total predevelopment flow of 9 cfs. Therefore, the surplus peak flow reduction achieved by the regional detention is 15 cfs (22.5 cfs minus 7.5 cfs), which exceeds the post development deficit of 11 cfs (20 cfs minus 9 cfs) for the two 50-acre residential sites. Since the surplus achieved by the oversized regional basin exceeds the post development deficit for the residential sites, onsite detention may not be necessary for the two residential projects. This type of analysis must consider the relative locations of the maximum efficiency detention basin(s) and the area considered for an onsite detention waiver, as well as the comparison of surplus and deficits. It is important that the channel reach impacted by the uncontrolled site be protected by the compensatory storage at the regional detention basin(s).

In cases where an onsite detention waiver is granted (e.g., the two 50-acre single family developments in the above example), the development which is granted the waiver should be assessed a pro-rata above contribution to the cost of the maximum efficiency regional detention basin. In other words, areas which receive a waiver should contribute in a proportional agreement to the cost of the regional facility, just like development upstream of the regional detention basin.

Since the greatest amount of compensatory storage is achieved for the 2-yr design storm, this waiver analysis is most appropriate for a 2-yr storm. In cases where adequate compensatory storage is not provided for a 10-yr design storm, the County must decide whether onsite 10-yr detention is necessary. Given the rather localized benefits (i.e.

immediately downstream of detention basin) of conventional detention system designs, it may be appropriate to waive the 10-yr onsite detention requirement as long as sufficient erosion control is ensured through compensatory 2-yr storage at an oversized regional detention basin.

6. Ten-yr Storm Control Upstream of Regional Detention Basins Which Only Achieve 2-Yr Control: As indicated in an earlier chapter, some of the regional detention basins did not have sufficient storage to achieve both 2-yr and 10-yr control. Since the County directed that as many regional facilities as possible be designed as maximum efficiency detention basins, several regional facilities were reclassified from conventional designs which achieved both 2-yr and 10-yr control to maximum efficiency designs for only 2-yr control. For those regional facilities which could only achieve 2-yr control, a requirement that upstream development provide onsite detention for 10-yr control would be inconsistent with the general objectives of a regional detention basin master plan. Further, the need for 10-yr flood protection along channel reaches upstream of a regional detention basin is probably questionable. Therefore, we would recommend that 10-yr onsite detention requirements be waived upstream of 2-yr regional detention basins unless warranted by unusual circumstances.

7. Major Tributary Areas Where Onsite Detention May Be Warranted: Based upon a review of the distribution of the regional detention basin system and the onsite detention guidelines presented above, Figures 6-1 through 6-7 show the major tributary areas where onsite detention is likely to be most beneficial. Only tributary areas which were relatively undeveloped were included in the delineation, since onsite detention requirements do not apply to existing development. Although guidelines #1 through #6 were considered in delineating these areas, land development proposals within

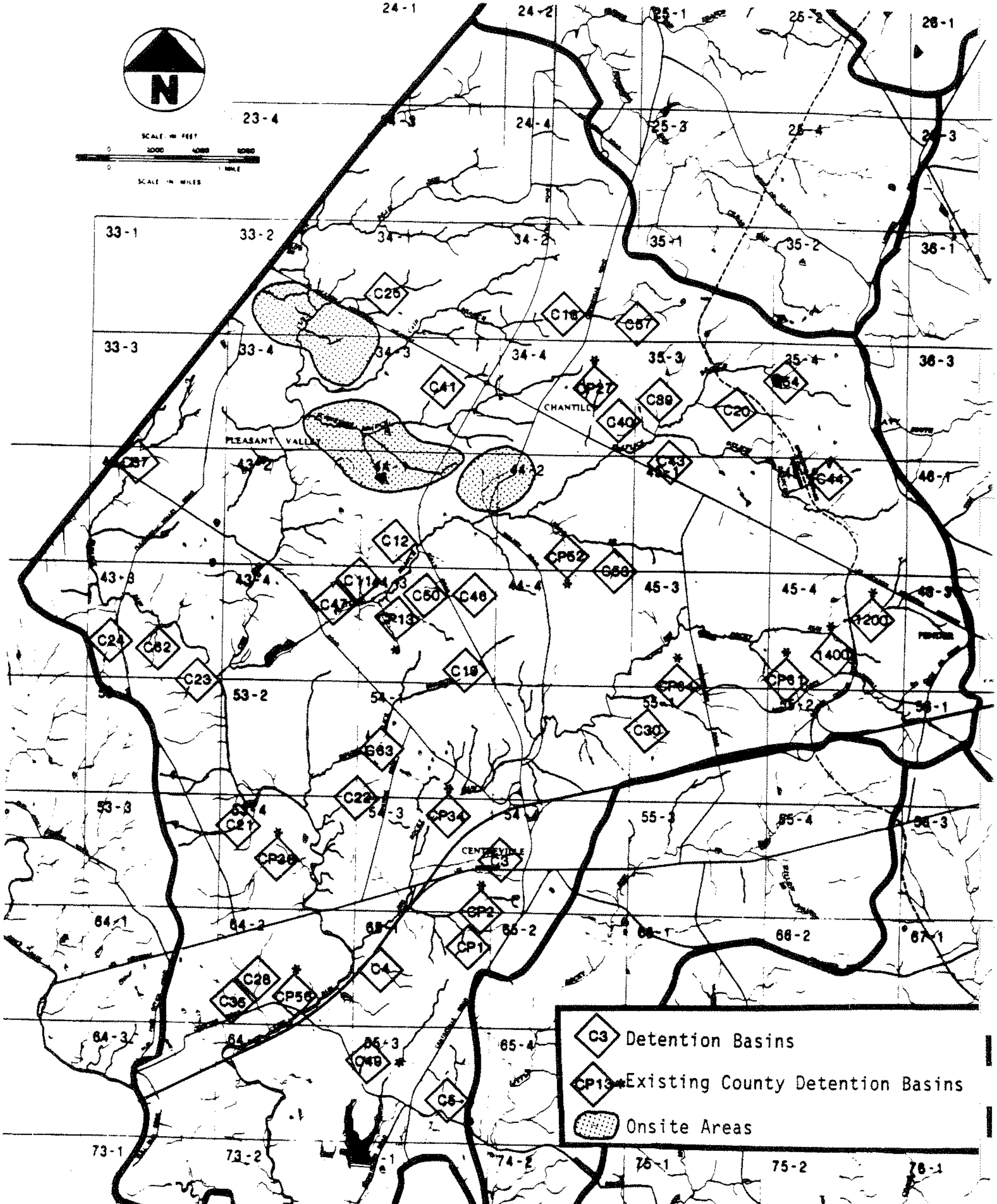


Figure 6-1. Cub Run: Locations of Major Tributaries Where Onsite Detention May Be Warranted

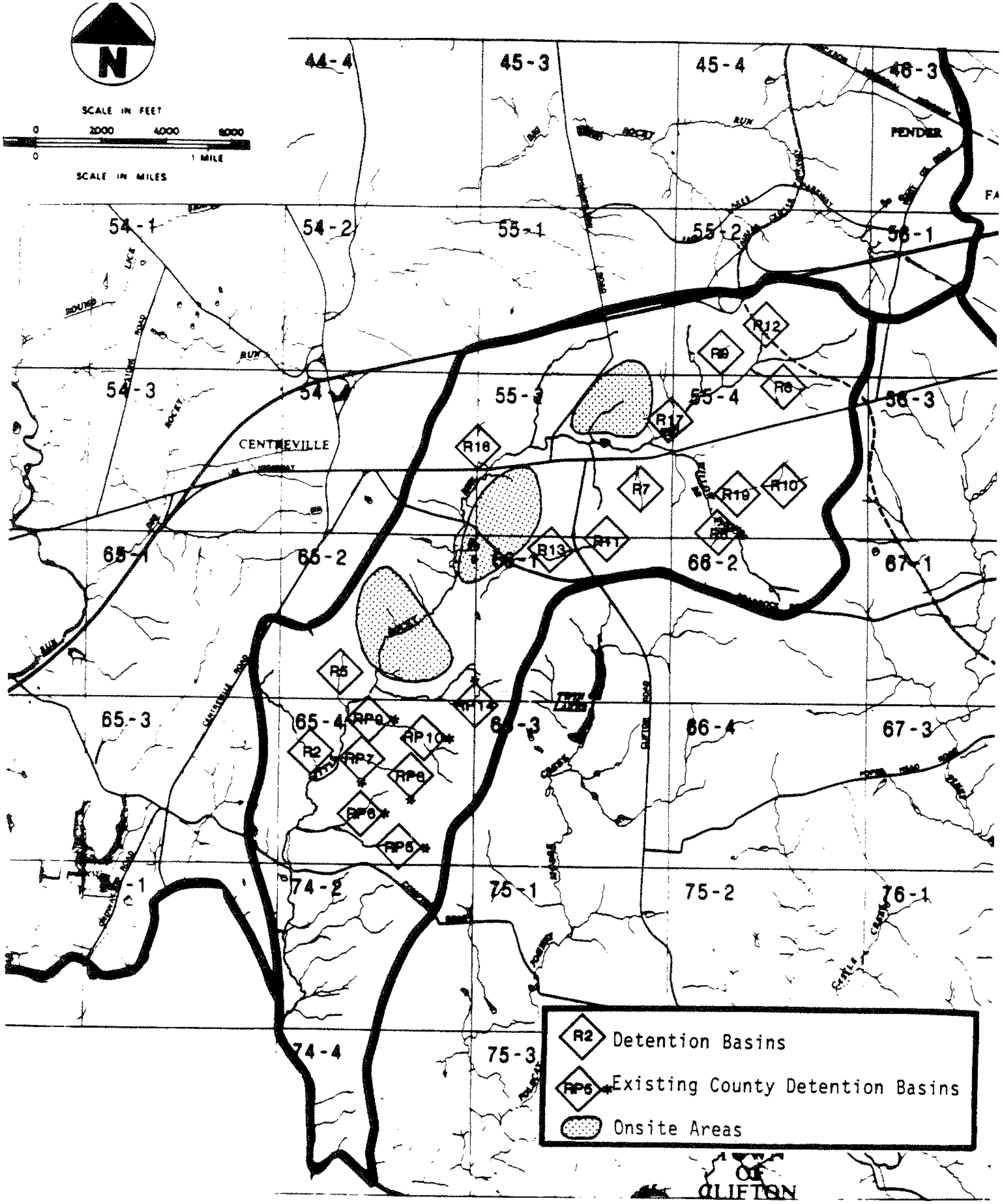


Figure 6-2. Little Rocky Run: Locations of Major Tributaries Where Onsite Detention May Be Warranted

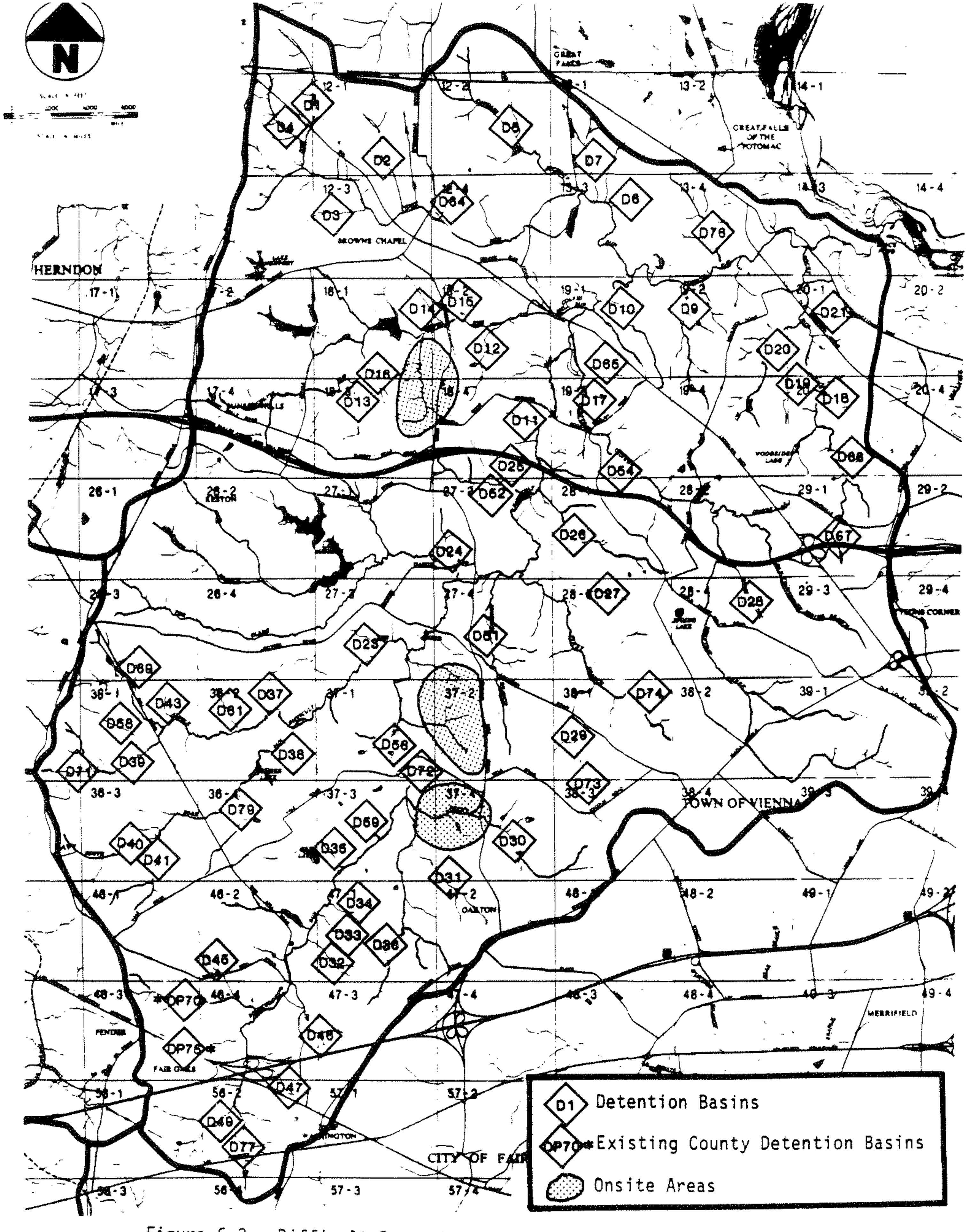


Figure 6-3. Difficult Run: Locations of Major Tributaries Where Onsite Detention May be Warranted

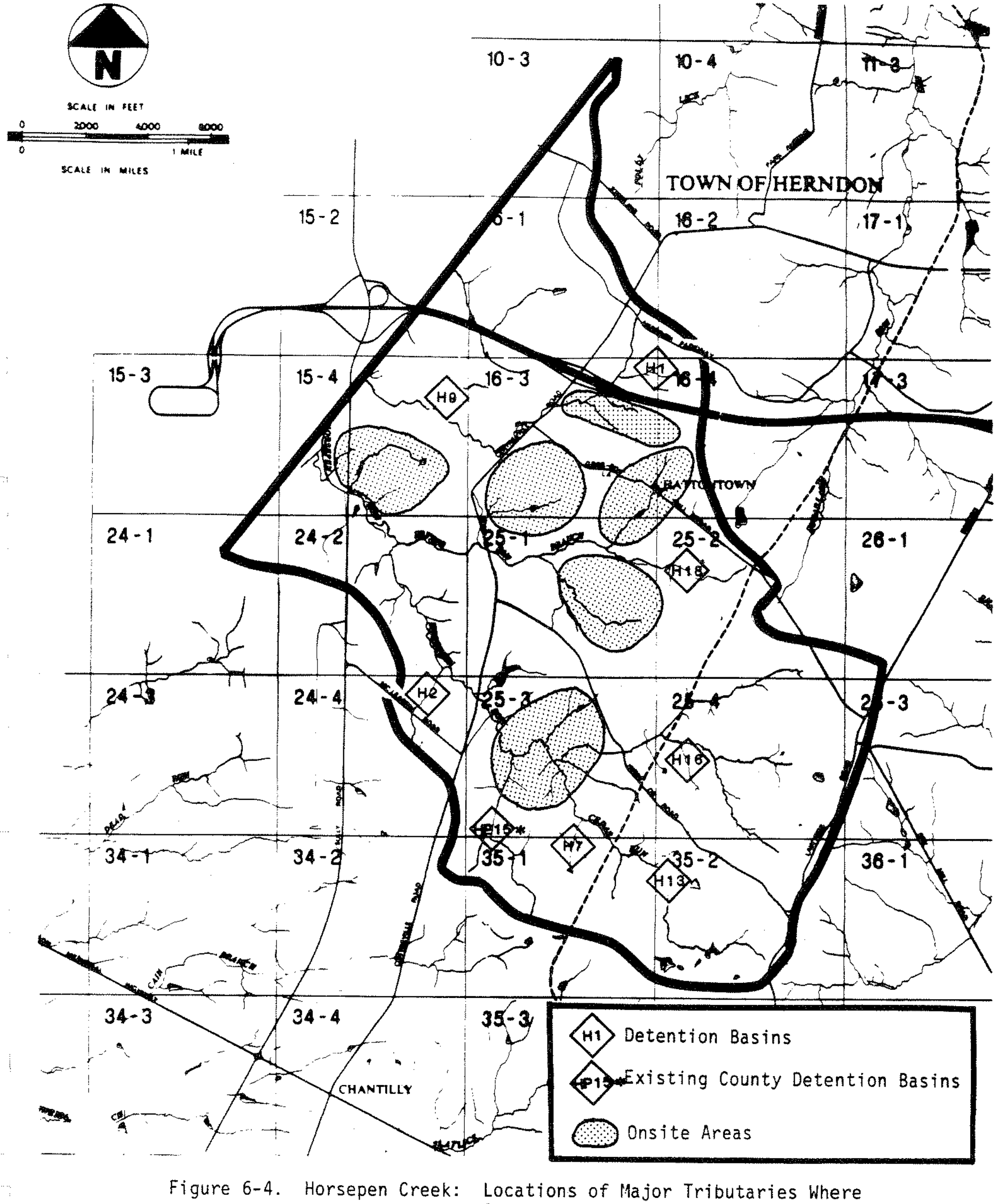


Figure 6-4. Horsepen Creek: Locations of Major Tributaries Where Onsite Detention May Be Warranted

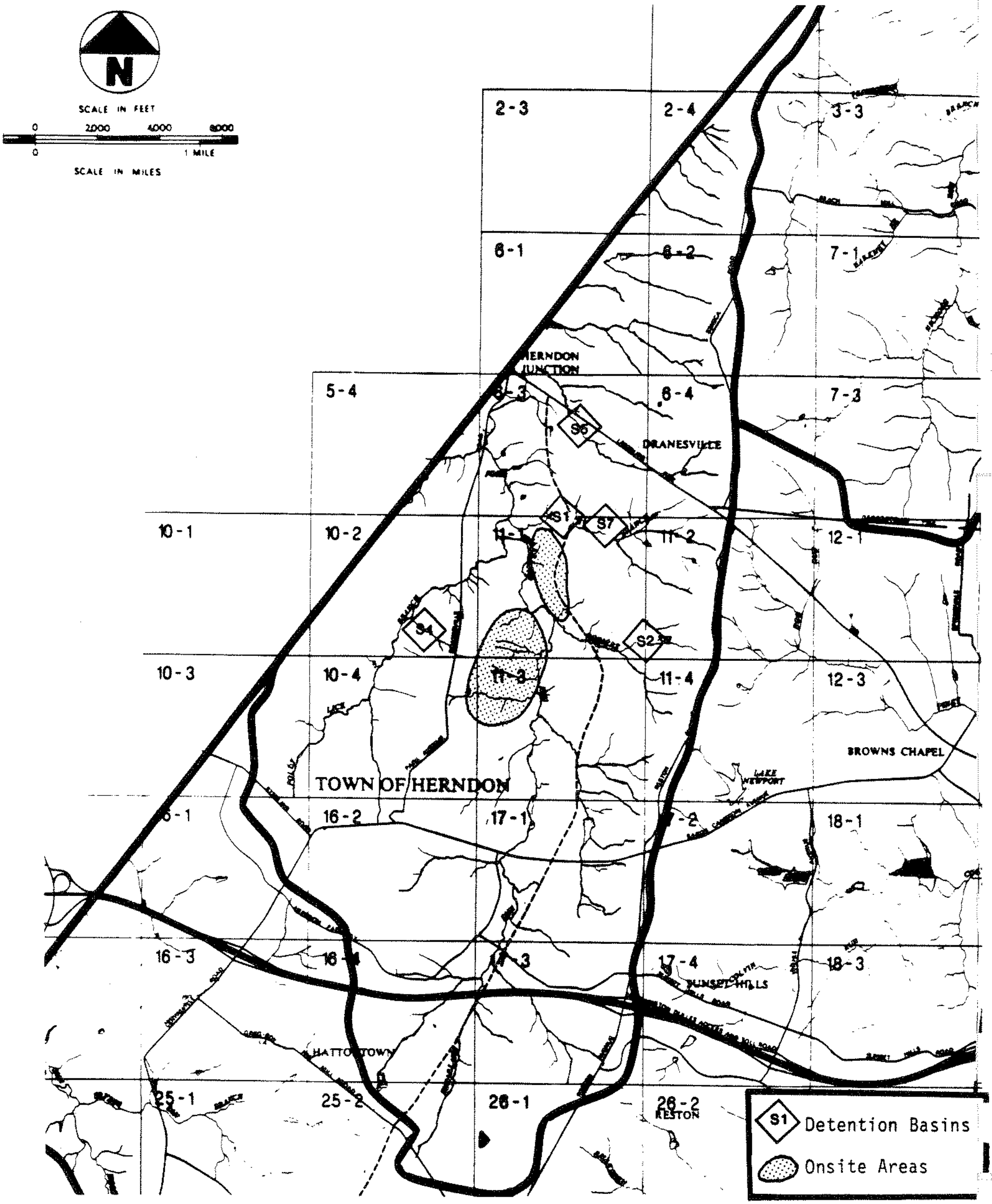


Figure 6-5. Surgarland Run: Locations of Major Tributaries Where Onsite Detention May Be Warranted

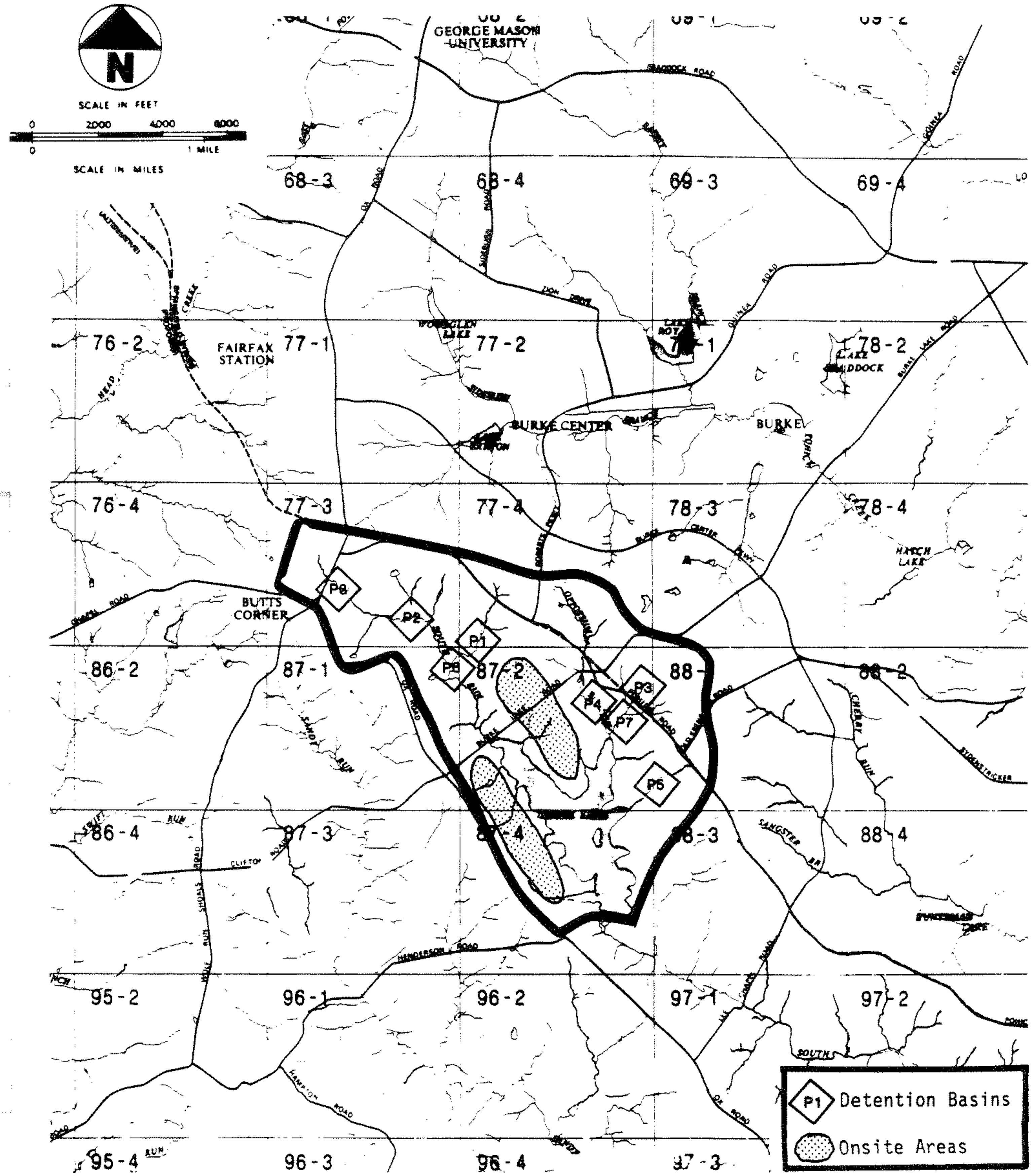


Figure 6-6. Pohick Creek: Locations of Major Tributaries Where Onsite Detention May Be Warranted

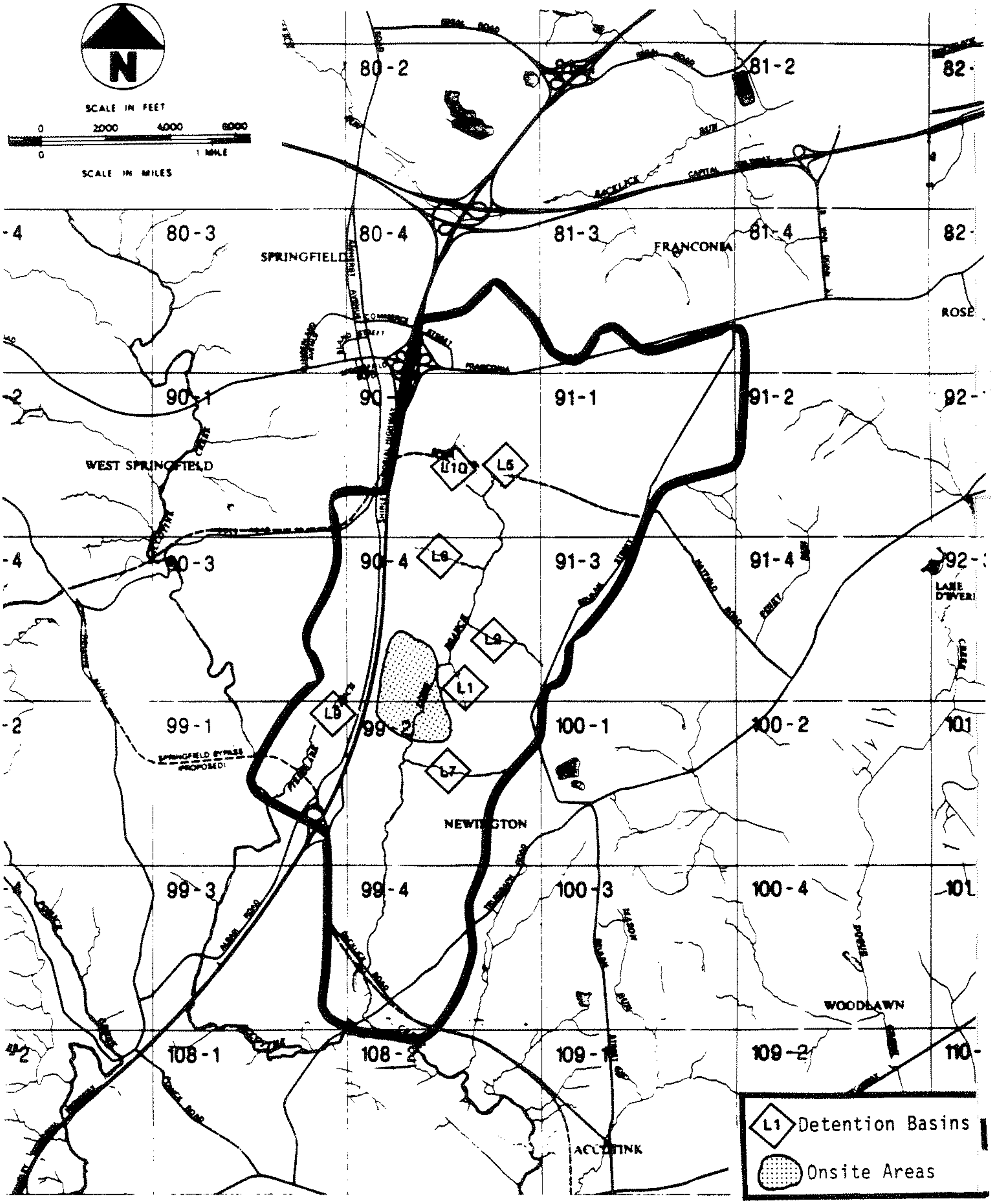


Figure 6-7. Long Branch: Locations of Major Tributaries Where Onsite Detention May Be Warranted

these onsite detention zones should be screened on a case-by-case basis to determine whether an onsite exemption or waiver may be appropriate.

Other smaller areas which are not highlighted in Figures 6-1 through 6-7 nor addressed by guidelines #1 through #6 should also be considered for onsite detention if significant adverse impacts on the receiving channel might occur. However, small areas that drain directly into a main stem channel can probably be granted an onsite detention waiver in most cases particularly if they are located along the lower one-third of the watershed. This "lower one-third" waiver guideline can be applied to either major tributaries or the main channel for entire watershed, depending upon the receiving water which is directly impacted by the development site.

6.3 COST ESTIMATES FOR REGIONAL DETENTION BASINS

The total capital costs and operation and maintenance costs for the proposed regional facilities were prepared by Fairfax County Department of Public Works (DPW). These figures represent total costs to Fairfax County and are given in Table 6-16 for each watershed.

The capital costs for the 134 regional ponds include design, construction, and land acquisition. The design and construction costs are based on similar ponds designed and built by Fairfax County. Land prices are based on September, 1988 market values. To derive the estimated costs to the County, an assumption was made that 15 percent of the ponds will be constructed by developers as part of private developments and that 25 percent of the capital costs will be recovered by pro rata share or other developer contributions (The figures in Table 6-16 reflect this assumption).

TABLE 6-16

ESTIMATED COUNTY COSTS FOR
REGIONAL VS. ON-SITE DETENTION PONDS

Watershed	Proposed Regional System County Capital Costs	 County Annual O&M Costs	On-Site Detention County Annual O&M Costs
Cub Run	11,811,250	657,900	2,410,200
Little Rocky Run	4,190,000	274,300	904,800
Difficult Run	20,538,000	913,500	5,475,600
Horsepen Creek	2,467,500	101,500	335,400
Sugarland Run	1,605,000	72,500	530,400
Pohick Creek	2,865,000	116,000	592,800
Long Branch	2,350,500	101,500	358,800
Total	45,827,250	2,237,200	10,608,000

The annual costs of operation and maintenance of the regional ponds are based on actual costs by DPW to maintain existing facilities. This includes inspection, routine maintenance, signage, restoration, vector control, and silt removal.

The County costs for the regional detention system were then compared to the existing alternative of continuing with the construction of on-site detention facilities for the same area of the County controlled by the regional facilities. In order to make this comparison, it was estimated that Fairfax County would maintain approximately 1360 of the 2200 comparable on-site ponds estimated to serve the same watershed area. This number of ponds maintained by the County is based on the land use in the study area. Public maintenance of on-site facilities is provided for all dry detention ponds located in residential areas. It was also assumed that all of the on-site ponds would be privately constructed by developers as is currently required. There would be no capital costs for the alternative of continuing with on site detention.

A twenty-five year life cycle analysis, presented in Table 6-17, was then prepared for the regional system and the on-site alternative using the previously developed costs. These costs are computed for a twenty-five year period and then converted to present worth 1988 dollars using a seven percent interest rate. It is assumed that the design and construction of the regional ponds will take place over a ten year period. All costs after year ten will be for operation and maintenance as illustrated in the cash flow diagram in Figure 6-8.

The present worth cost to Fairfax County over a 25-year period for this regional plan is $51,000,000. The present worth cost to continue with the on-site alternative for the same 25-year period is $89,000.000. Therefore, the regional stormwater management system is approximately fifty-seven percent to the cost to Fairfax County as a comparable on-site system over a twenty-five year life cycle.

TABLE 6-17

FINANCIAL IMPACTS TO FAIRFAX COUNTY

o COST FOR THE PROPOSED REGIONAL SYSTEM (134 PONDS)

Capital Cost (Including Land)	$78,000,000
Deduct Probable Number Constructed By Developers (Say 15%)	($12,000,000)
Deduct Probable Pro Rata Share Recovery (Say 25%)	($20,000,000)
Balance, County Capital Cost	$46,000,000

Annual Cost of Maintenance
(Includes: Inspection, Routine Maintenance, Signage, Restoration, Vector Control and silt Removal)

Dry @ $14,500/Year
Wet @ $22,300/Year

Estimated Total Annual Maintenance cost (for all 134 regional ponds)	$2,200,000/Yr.
Annual Administration Cost	$ 100,000/Yr.

o ALTERNATIVE, CONTINUE WITH ONSITE DETENTION

Comparable Number of Onsite Ponds	2,200
Number to be Maintained by Fairfax County	1,360

Annual Cost of Maintenance

(Includes: Inspection, Routine Maintenance, Signage, Restoration, Vector Control and Silt Removal)

Dry @ $7,800/Year

Annual County Cost for Maintenance of Onsite Alternative, Ponds	$11,000,000/Yr.

TABLE 6-17

FINANCIAL IMPACTS TO FAIRFAX COUNTY
(Continued)

- <u>25-YEAR LIFE CYCLE ANALYSIS, COUNTY COSTS</u>

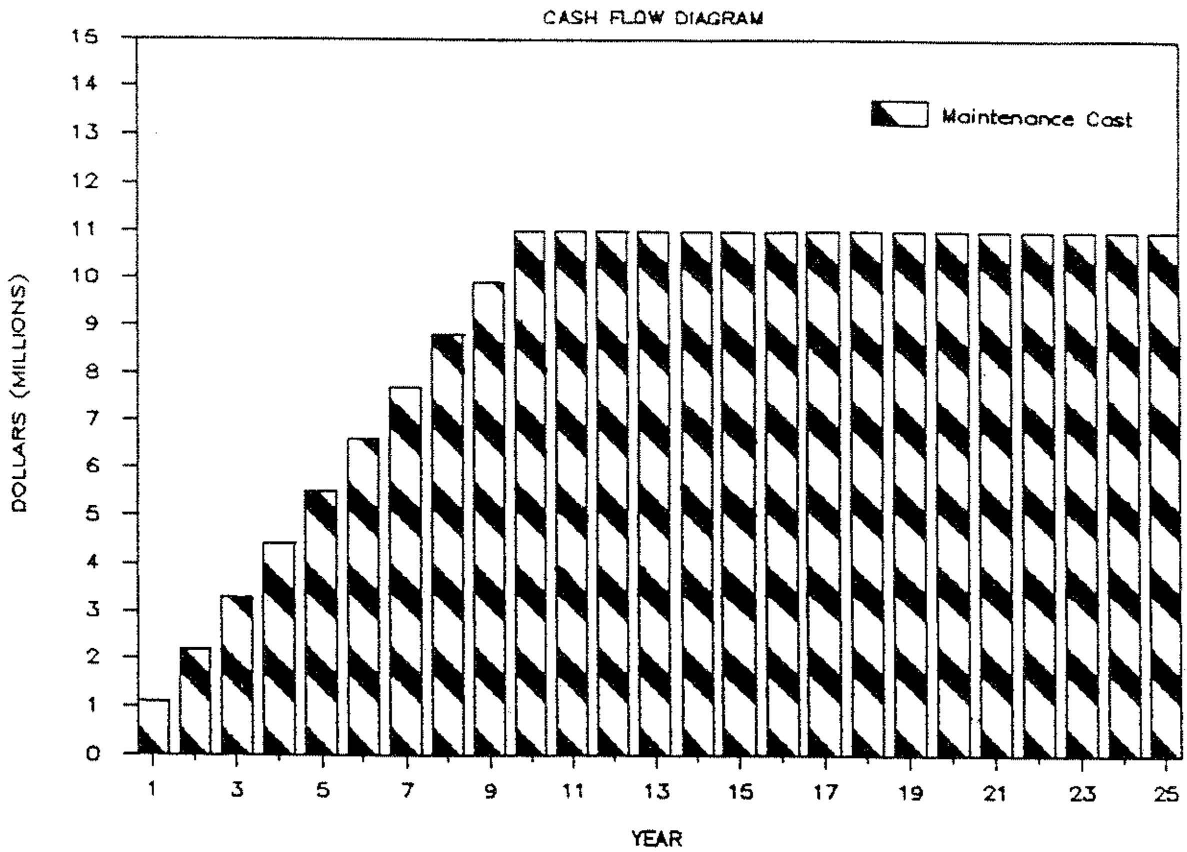
    - Total Costs Paid Out During 25 Year Period (Unadjusted)
      regional $92,000,000
      Onsite $225,500,000

    - Present Worth cost Comparison Analysis, (Present Worth in 1988 $, with 10-year Implementation Time Frame, 7% Interest Rate)

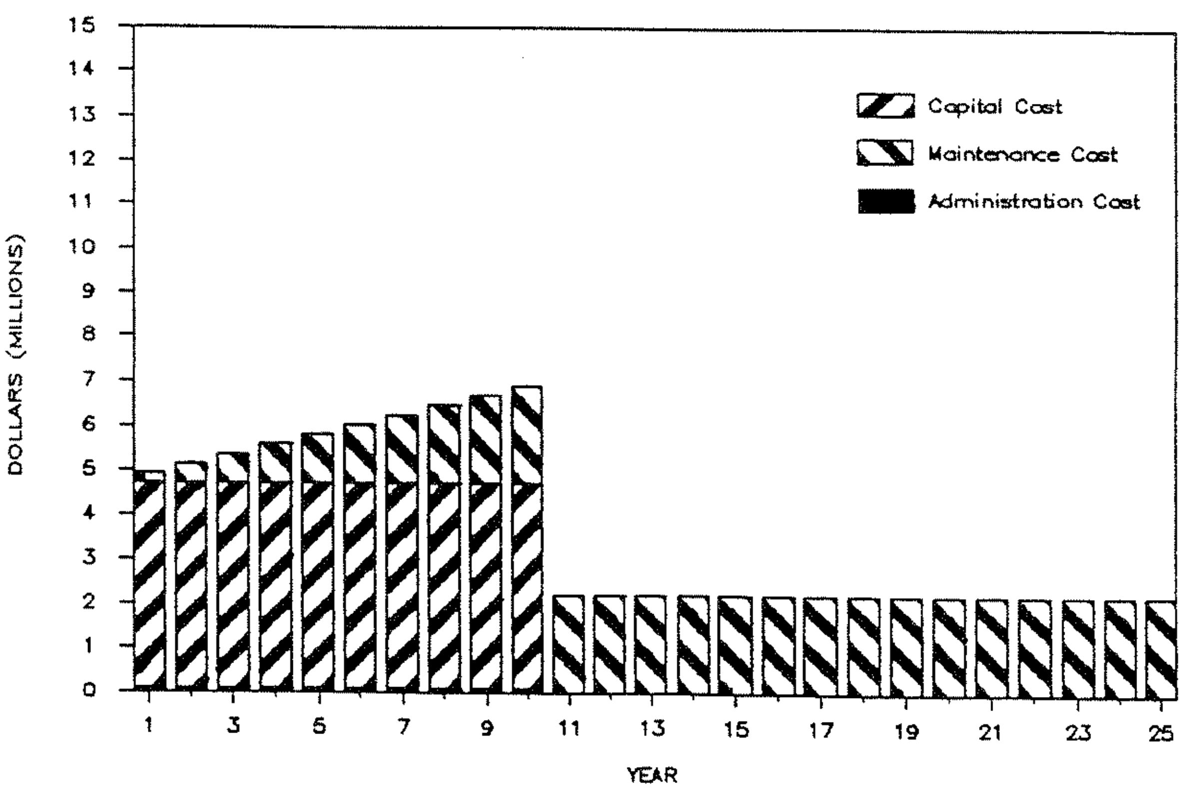
County Costs	System Regional	Onsite Alternative
Capital	$32,000,000	-0-
Maintenance	$18,000,000	$89,000,000
Administrative	$ 1,000,000	-0-
Totals	$51,000,000	$89,000,000

Therefore, the regional system is approximately fifty-seven percent the cost to Fairfax County as a comparable onsite system over a 25-year life cycle.

REGIONAL STORM WATER MANAGEMENT VS. ON SITE DETENTION



ON SITE ALTERNATIVE



REGIONAL ALTERNATIVE

Figure 6-8. Cash Flow Diagram

6.4 FINANCING MECHANISMS TO IMPLEMENT STORMWATER MANAGEMENT PLAN

6.4.1 INTRODUCTION

This section outlines alternate finance mechanisms for the County's stormwater management program. The following "participatory" and "nonparticipatory" financing methods are covered:

A. Participatory:

1. Land development fees (Pro Rata Share)
2. Special districts
3. Developer participation and reimbursement agreements
4. Stormwater utility service charges

B. Non-Participatory

1. Local general fund
2. Bond funds

Under "participatory" financing methods, the user (e.g., property owner) pays in proportion of his usage of the drainage system. For example, a land development fee for new subdivisions would be based upon the pro-rata share of total runoff contributed by each new development project which is served by the proposed stormwater management facilities. Another example is the stormwater utility whereby each property owner is assessed a monthly user charge which reflects the proportionate share of total runoff contributed to the County's drainage system.

Under "nonparticipatory" financing methods, the assessment scheme is not related to each property owner's runoff contributions to the proposed drainage improvements. Therefore, some property owners may contribute a greater proportional share of required revenue than their use of the drainage system, and vice versa.

6.4.2 PARTICIPATORY FINANCING OPTIONS

Land Development Fees (Pro Rata Share)

The Code of Virginia (Section 15.1-466) permits jurisdictions within the State to assess land development fees to developers in order to finance regional stormwater management facilities for new urban development. Rather than require each land developer to construct a stormwater management facility on his own site, each development project is assessed a fee which covers a pro-rata share of the capital cost for regional offsite facilities (e.g., channel improvement, regional detention basin, improved stream crossing).

Section 15.1-466 of the Code of Virginia requires that a general improvement program (i.e., master plan which identifies offsite controls) be developed in advance and that the pro-rata share charges only be applied to the capital cost for the regional facility, not to the annual maintenance costs. This master planning study satisfies this requirement for the seven watershed study areas covered by the plan. Three important features of this financing approach are discussed below. First, in order for the management plan to be successful, local governments must finance the construction of the regional control facilities in advance of urban development and in advance of the receipt of all pro-rata share contributions. Typically, long-term borrowing mechanisms and general fund revenue are used to finance these front-end construction costs. Second, the pro-rata share charges may only be assigned to new urban development, even though it may be desirable to strategically locate some regional facilities which control the runoff impacts of existing development as well. This funding mechanism does not provide for the recovery of any costs from existing landowners in the watershed. Since the regional detention basins recommended in this plan serve some existing development as well as future development, this issue must be addressed in developing a pro-rata share funding formula. Third, the land development fees can only cover construction costs, meaning that maintenance costs must be obtained in another manner.

The pro-rata share assigned to each developer can be based upon a number of factors, including: cost per impervious acre; cost per acre for different land use categories; and cost per development site based upon each site's contribution to the peak flow which must be controlled by the offsite facility.

For Fairfax County, we would recommend a fee schedule based upon "cost per effective impervious acre," with "effective" imperviousness defined as areas directly connected to a drainageway (e.g., only 50% of the rooftop area for low density and medium density single family development). Typical fees employed in the Virginia-Maryland region are on the order of $1,000 to several thousand dollars per impervious acre.

For example, Montgomery County, Maryland administers a fee-in-lieu of program for peak-shaving control and charges a fee on the order of $1,000 up to $2,500 per impervious acre for single family residential development, $3,000 to $4,000 per impervious acre for multi-family residential development, and $4,000 up to $6,000 per impervious acre for typical employment land uses. In addition, Montgomery County charges a water quality control fee on the order of $200 up to $300 per impervious acre for single family residential development on a 0.33-acre lot and smaller, $400 up to $600 per impervious acre for multi-family residential development, and $800 up to $2,000 per impervious acre for typical employment land uses (e.g., commercial, industrial).

Under 15.1-466, fee schedules must be developed for "an area having related and common sewer and drainage conditions." This can be interpreted to mean that a separate fee schedule can be developed for each major watershed in the County or conceivably, for a series of watersheds in the same major river basin. However, another interpretation which may be feasible is that a single Countywide fee schedule could be appropriate, assuming that drainage conditions and needs are generally similar throughout the County.

Fairfax County should pursue any enabling legislation necessary to clarify existing legislation to permit the County to develop a countywide uniform rate pro-rata share program.

Special Districts

Section 21-112 of the Code of Virginia permits the establishment of watershed improvement districts (WID) by referendum. Designation of a WID by the Virginia Soil and Water Conservation Commission must be preceded by special petition, hearings, and a referedum vote by the property owners within the watershed. Approval by two-thirds of the landowners representing at least two-thirds of the land area in the watershed is required. WID's can issue bonds and assess property owners within the watershed to finance the construction of stormwater management projects. One of the elements of the WID which may make it politically infeasible for local stormwater management activities is that it is governed by an independently elected board of directors, thereby delegating to an independent governing board some of the powers which can influence local land use decisions. Another factor that may limit its feasibility for regionwide implementation is that separate referendums would have to be approved by two-thirds of the property owners in each watershed.

It is unlikely that the establishment of WID's would be approved in every watershed in the County. A WID may be a possible source of funding for one or two specific projects for which there is a strong perceived need among landowners within a particular watershed. Consequently, special district financing is anticipated to play only a minor role in financing Countywide stormwater management projects.

Developer Participation and Reimbursement Agreements

As properties develop in the vicinity of where proposed regional facilities are located, it may be desirable for the County to participate with the developers in constructing the regional facilities. This participation could be in the form of joint projects, developer reimbursement agreements where developers construct the facility and are compensated for a portion of the costs, and "fee in lieu of" construction where developers contribute toward the construction of a regional facility in lieu of providing on-site facilities. These agreements are very site specific and depend on a number of factors, including the timing of development, the density of development and the size, type and location of the proposed facility. Agreements of this type are mutually beneficial and are a cost-effective approach to constructing regional facilities.

Stormwater Utility

The creation of a stormwater utility is currently being used in many urban areas around the U.S. as an alternative to the use of general fund revenue for financing stormwater projects. It involves creating a continuing funding source by designating stormwater management as a utility, much like sanitary sewers, gas, and electricity are considered as public utilities.

Under the stormwater utility concept, property owners within a jurisdiction are assessed a monthly fee which can cover both capital and O&M costs for stormwater management. A review of fee schedules in use or being considered around the U.S. indicates that the typical monthly charges are in the range $1.00-$4.00 per dwelling unit for single family residential land uses, with commercial and industrial charges often based upon increased imperviousness in comparison with single family residential land uses. In addition, some stormwater utilities also rely upon a "new construction fee" (e.g., $200-500 per dwelling unit for Ft. Collins, Colorado) which is related to an offsite pro-rata charge for runoff control facilities designed exclusively for new urban development.

To insure a manageable billing system, we recommend billing all single family residential parcels at a flat rate. Since single family parcels usually represent a significant percentage of the total number of parcels in the service area, this approach significantly reduces the complexity of the billing system without adversely affecting accuracy and equitability.

In other municipalities where CDM has set up a stormwater utility, we have found the single-family unit (called an equivalent residential unit or ERU) to be an equitable measure of runoff contribution.

We also recommend "piggybacking" the stormwater utility billing system on an existing utility billing system to reduce administrative costs and facilitate implementation.

An ERU represents the average impervious area (in "sq ft") of a single family residential parcel. The ERU size can be determined by calculating statistics on impervious site cover from local property assessment files. The stormwater utility rate structure is illustrated in the example in Figure 6-9. As shown, the "base unit" for the utility is a flat rate for an "equivalent residential unit" ERU. In this example, an ERU is assumed to be 2,500 sq ft. For other land uses, the number of ERUs is based upon the ratio of impervious square footage to the ERU's square footage. In Figure 6-9, an industrial site with 4,500 sq ft of impervious cover has 1.8 ERUs, and a commercial site with 12,500 sq ft of impervious cover has 5.0 ERUs. The monthly user charge for each non-single family residential site is based upon the number of ERUs times the flat rate for the ERU ($2.00/month/ERU in Figure 6-9), or $3.60/month for the industrial site and $10.00/month for the commercial site.

The financing of capital projects is accomplished with a combination of bonds and revenue from the stormwater utility fees. With the broad revenue base that is available under the stormwater utility approach, the use of revenue bonds to fund the construction of stormwater management controls becomes a more viable option. Thus, the stormwater utility provides a continuing funding source for both capital and operating costs without impacting a local government's general fund. The end result is that the County public works department will have an adequate revenue source to construct more cost-effective regional facilities and to carry out maintenance activities.

Figure 6-8

STORMWATER UTILITY RATE STRUCTURE

◆ **BASE UNIT :** FLAT RATE ($/MONTH) FOR EACH "EQUIVALENT RESIDENTIAL UNIT" (ERU)

- ERU = AVERAGE IMPERVIOUS AREA (SQ. FT.) OF SINGLE FAMILY RESIDENTIAL PARCELS

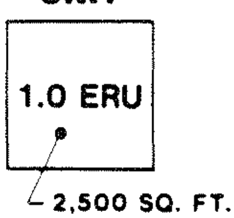
◆ **OTHER LAND USES :**

- NO. OF ERU = (IMPERVIOUS AREA) / (ERU)

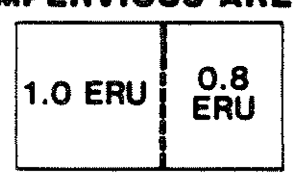
◆ **EXAMPLE :**

- ERU = 2,500 SQ. FT.
- FLAT RATE = $2.00 / MONTH / ERU

SINGLE FAMILY UNIT

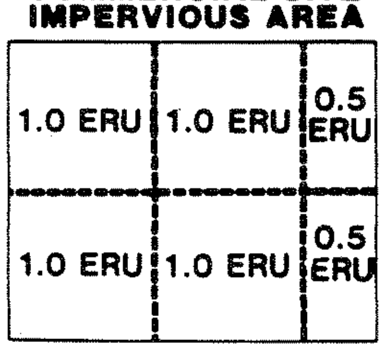


INDUSTRIAL SITE IMPERVIOUS AREA



TOTAL = 1.8 ERU
RATE = (1.8 ERU) x ($2.00) = $3.60 / MONTH

COMMERCIAL SITE IMPERVIOUS AREA



TOTAL = 5.0 ERU
RATE = (5.0 ERU) x ($2.00) = $10.00 / MONTH

CDM

The two principles which serve as the basis for the stormwater utility concept are as follows:

1. All property within each watershed will benefit from the installation of an adequate stormwater management system.

2. Since all property owners will benefit, the costs of an adequate stormwater management system should be assessed against all real property.

Arguments that are often presented to support the first principle address the ability of an adequate stormwater management program to enhance and maintain a high quality of life for all property owners, regardless of whether they reside in the upstream or downstream end of a watershed. For example, areawide contributions of an adequate stormwater management plan include the following:

- Keeping streets open to emergency vehicle traffic;

- Maintaining stormwater management facilities so that they do not become a health hazard.

Fundamental to any utility user charge system is the test of equity and fairness. The user charge system must accurately represent each property owner's runoff contribution. The correlation between the amount of a parcel's impervious area and the amount of runoff attributable to the parcel is the basis for determining the user charge. Input factors can include total area, percent imperviousness, slope, soils, ground cover and retention/detention potential. A logical balance must be drawn between the number of variables in the billing algorithm and the degree of difficulty required to derive these inputs.

Regarding legal authority for Fairfax County to set up a stormwater utility, there appears to be no straightforward authorization in any one place in the Code of Virginia. However, our legal research for other Virginia municipalities suggests that there is probably sufficient authority delegated in the following sections of the Code of Virginia to permit a municipality to implement the various elements of a stormwater utility:

- o Section 15.1-283: Provision of Adequate Drainage
- o Section 15.1-170: Public Finance Act
- o Section 15.1-466(j): Pro-rata Share Provisions of Subdivision Ordinance

Section 15.1-283 grants the County the power to provide for adequate drainage and to affect this drainage by doing anything necessary by way of installing drainage systems and appropriating money for them. This section also provides that it is to be liberally construed by courts to effectuate its purposes. The Public Finance Act grants the County the power to construct drainage projects and it provides that its powers are supplemental and additional to any other powers granted in the Code to cities. The effect of the provisions in 15.1-283 and the Public Finance Act is to give the County full power to do what is necessary to solve its drainage problems and to use the financing powers of the Public Finance Act to achieve that result.

However, because this authority has to be pieced together from different sections of the Code of Virginia, it is conceivable that bond lawyers may be uncomfortable about giving an opinion to the utility without some clarification of the laws. This potential problem could be addressed through relatively minor amendments to the Public Finance Act or Section 15.1-283 of the Code of Virginia. The County Attorney's office should be requested to review the County Charter and aforementioned enabling legislation to decide on the need for modification to clarify the authority to implement a stormwater utility. Input from the County's bond counsel should also be solicited.

The establishment of stormwater utilities is a concept which has achieved growing popularity in the western United States and is now starting to catch on in the eastern U.S. In October 1986, the City of Tallahassee, Florida implemented the first stormwater utility in the eastern United States (Camp Dresser & McKee, 1985; Camp Dresser & McKee, 1986). The starting monthly user-charge for the Tallahassee stormwater utility is a flat rate of $1.00 per single family dwelling unit, with the charge for other land uses based on the ratio of impervious cover for the land use category to the assumed imperviousness (approximately 2,700 sq ft) for a single family residential parcel. In CDM's feasibility study for Tallahassee, we recommended phasing in a higher flat rate over a five-year period to achieve a self-sustaining enterprise.

Stormwater utilities have also been approved and are currently being implemented in two other Florida cities: City of Miami (Camp Dresser & McKee, 1987a) and the City of Daytona Beach (Camp Dresser & McKee, 1987b). Included among the municipalities in Southeastern U.S. which are developing implementation programs for a stormwater utility are the following: Hillsborough County, FL; Manatee County, FL; City of Oakland Park, FL; City of Port St. Lucie, FL; and City of Ocala, FL.

In Virginia, Henrico County is currently undertaking a stormwater management study that will outline an implementation program for a county-wide stormwater utility. The City of Hampton has also considered the establishment of a citywide drainage fee over the past few years. The proposed "base fee" for the Hampton program is on the order of $3.00 to $4.00 per month for a single family residential parcel (7,000 sq ft). The user fee for more impervious land uses would be based upon the proportional increase in impervious cover beyond the 7,000 sq ft lot. The fee schedule would also accommodate monthly user fees to cover special assessments for neighborhood improvement projects.

Tables 6-18 and 6-19 summarize a preliminary assessment of a stormwater utility for Fairfax County. Table 6-18 illustrates the computation of ERUs for each land use category and the entire County, assuming that one ERU is equal to 2,700 sq ft of impervious cover. Table 6-19 summarizes revenue projects for user charges ranging from $1.00 to $4.00/month/ERU. As may be seen, a $1.00/month flat rate (i.e., $12/yr for a single family dwelling)

TABLE 6-18

SUMMARY OF EQUIVALENT RESIDENTIAL
UNITS: FAIRFAX COUNTY STORMWATER UTILITY

Land Use	Area (sq mi)	Average % Impervious	Impervious Area (sq mi)	ERU Equivalent
Single Family Residential	144.7	10%	14.5	150,000
Multi-family Residential	8.0	45%	3.6	37,171
Commercial	10.1	80%	8.1	83,429
Industrial	13.5	70%	9.5	97,574
Public/Institutional	33.4	40%	13.4	137,946
TOTALS	209.7		49.1	506,120

NOTES:

1. Utility covers all existing urban development in County (i.e., including areas outside of study area for stormwater management master plan).

2. Imperviousness calculation does not include streets.

3. An ERU is assumed to be equal to 2,700 sq ft, the typical impervious ground cover for single family residential development.

4. Land use data (January 1986) includes the towns of Vienna, Herndon, and Clifton.

TABLE 6-19

PROJECTED ANNUAL REVENUE FOR
VARIOUS ERU USER CHARGES:
FAIRFAX COUNTY STORMWATER UTILITY

User Charge	Annual Revenue
$1.00/month/ERU	$ 6.1 million
$2.00/month/ERU	$12.1 million
$3.00/month/ERU	$18.2 million
$4.00/month/ERU	$24.3 million

will generate about $6 million per year for stormwater management. The revenue projections shown in Table 6-19 for a $1.00/month flat rate are equivalent to about $9.00 per capita per year, which is consistent with our experience in other cities and counties (i.e., $7-$12/cap/yr).

6.4.3 NONPARTICIPATORY FINANCING OPTIONS

Most local governments are hard-pressed to fund completely out of the general fund major stormwater management projects like the facilities recommended herein. An example of one jurisdiction which has relied heavily upon this financing mechanism for major drainage capital improvement projects is DeKalb County, Georgia which is located in the Atlanta metropolitan area.

Long-term borrowing, in the form of storm bond funds has been one of the most popular mechanisms for financing stormwater projects. A good example of general obligation bond applications for stormwater management is Fairfax County which issued $11 million in bonds for both master planning and stormwater management in the early 1970's. Another Virginia example is the multi-million dollar general obligation bond issue approved for remedial action plans in the City of Roanoke in the early 1970's. Revenue bonds have not been too widely used for stormwater management, in part due to the higher interest rates in comparison with general obligation bonds and in part due to the lack of a significant revenue base. However, as discussed above, one of the attractive features of a stormwater utility is the creation of a guaranteed revenue base to support the use of revenue bonds.

6.4.4 RECOMMENDED APPROACH TO FINANCE IMPLEMENTATION OF THE REGIONAL SYSTEM

It is recommended that the County rely upon a combination of financing mechanisms to implement the facilities recommended in this stormwater management master plan, with the ultimate goal being the eventual establishment of a self-sustaining stormwater utility.

A land development fee program should be used to recover the costs of improvements serving future development. Examples of a pro-rata base fee structure were presented above. Separate fee structures can be developed for each major watershed or a Countywide fee structure can be used. Since some regional facilities must be on the ground before too much future development occurs, the front-end costs required to implement the improvements required for future development can be financed from the general fund or with bonds. In addition, where feasible, the County should enter participatory agreements with the development community to construct regional facilities. Once the stormwater utility has been phased in, user charge revenue and revenue bonds can be substituted for contributions from the general fund and bonds.

We have found that the acceptability of a stormwater utility tends to be much greater if the user charges are set at a level which gradually phases out general fund contributions rather than starting the rates at a level required to produce a self-sustaining program. Therefore, we would recommend that the County consider establishing a utility with an initial flat rate on the order of $1.00 to $2.00/month/ERU. After a few years of operation, accrued earnings and slight user charge adjustments should permit the elimination of general fund contributions to the County's stormwater management program.

Pursuant to this general approach, the following is recommended:

1. Set Up Capital Improvements Programs: The facilities recommended in the master plan should be prioritized by the County for funding. The County should develop a capital improvements program specifying the year of implementation for each project. For projects that require immediate implementation, rely upon a combination of general fund and bond revenue with consideration given to special assessments where appropriate.

2. Set Up Land Development Fee Programs: the County should establish a pro-rata share fee schedule to finance recommended drainage improvement projects which primarily serve future development. In order to maximize the revenue collected from future development, the pro-rata share fee program should be established as soon as possible.

3. Implement Stormwater Utility Program

    a. Perform detailed evaluations of alternate user charge schedules.

    b. Perform legal evaluations to clarify the need for a County amendment or new general legislation and pursue implementation of any required changes.

    c. Set up public information program to facilitate local acceptance of program.

    d. Set up billing system for stormwater utility.

    e. Develop and implement ordinance(s) specifying fee structure and establishment of separate accounting fund.

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