Section 2.2
Hydrology

Design Standards and Policies
Revised January 1993

Chapter 2
Drainage

City of Scottsdale,
Arizona

Design Standards and Policies Manual
Chapter 2 of 7
Section 2 of 3

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Section 2.2

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Hydrology

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Section 2.2

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SECTION 2.2
HYDROLOGY

2-201 INTRODUCTION

A. General Comments

This manual section describes the City's policies concerning hydrologic analysis procedures to be used in the City of Scottsdale for the planning and design of drainage and flood control facilities and the preparation of accompanying drainage reports. This manual contains recommended procedures, equations, data and basic assumptions which the planner or designer is generally required to use. If a situation is encountered in which the use of other methods or data in addition to or instead of those presented here are believed to be more appropriate, then City Drainage Planning staff should be consulted and advance approval must be received before using them. When methods or data not described in this booklet are used, the drainage report must include enough information to enable the City Staff to fully evaluate the applicability of the methods and data. If a computer program is used that the City does not have in its software library, the consultant must provide the City with a fully usable copy of the appropriate software, or show adequate comparisons with known procedures.

For flood control projects that are cost-shared with the Flood Control District of Maricopa County, the hydrologic design procedure contained in Vol. I, Hydrology of the Drainage Design Manual for Maricopa County must be used.

B. Goals and Objectives

The following are the basic goals and objectives used as a guide in preparing this manual:

1. Reflect current requirements of the City floodplain and drainage ordinance, as well as other City ordinances and applicable County, State or Federal regulations.

2. Use the best and most current data and methods available.

3. Provide guidance for hydrologic design methods that:

   a. reflect commonly accepted state of the art procedures;

   b. produce safe, reasonable results (within an acceptable range of values);

   c. gives flexibility to the designer while at the same time maintains a reasonable level of design consistency in order to facilitate design review;

   d. are not unnecessarily complex or confusing;

   e. does not require more detailed or complex input data than is commonly available;

   f. are technically and legally defensible;

   g. provide results that are consistent with adjacent jurisdictions, primarily the City of Phoenix, the Flood Control District of Maricopa County (FCDMC) and ADOT.

Because of our efforts to meet the above goals and objectives, some options in this manual differ slightly from adjacent jurisdictions, such as the Flood Control District of Maricopa County. However, results do not differ significantly. The sensitivity analysis conducted by Ward verified that results are consistent and within acceptable ranges of seven other methods and six different envelope curves. In addition, results were found to be comparable to: an envelope curve of one hundred year frequency peak discharge values for Maricopa County, prepared by ADWR; a preliminary plot of flood frequency data for USGS streamflow data from 64 gages located in the Central Region of Arizona, obtained from ADOT; and the sample problem in the FCDMC's Hydrology Manual.

C. Application and Limitations

The purpose of this manual is to provide a means of assisting in the prediction of runoff which might result from a design storm of a given return interval. However, the sensitivity analysis by Ward and the comparisons referred to above were by no means comprehensive in testing the entire range of possible conditions that may be encountered.

Hydrology is a discipline which requires not only technical competence but also experience and good judgement. The City does not warrant or guarantee the reliability of the hydrologic methods, techniques, and/or parameter values described herein. The user of this manual is thus expected to validate the reasonableness of the predicted values by: applying alternative methods or other appropriate checks which have been developed for this area. Failure to do so may result in erroneous values.

It is not the intent nor purpose of this manual to inhibit sound innovative design or the use of new techniques. Therefore as mentioned previously, where special conditions or needs exist, other methods and procedures may be used with prior approval.

It is anticipated that, over time, as more data becomes available and/or more appropriate techniques are developed, this manual will be revised. Such revisions will probably take place annually or as needed. If any inadequacies or inaccuracies are found with any of these procedures, they should be brought to the City's attention immediately.

D. Acknowledgments

The information and procedures that are presented in this manual are mainly the result of previously published efforts of many talented individuals. The author of this manual has made every effort to cite the original authors and researchers whose contributions to this manual, and to the science of hydrology, are gratefully appreciated.

The author of this manual is indebted to the many individuals and organizations, including the staff at City of Scottsdale that have supported this effort through recommendations, technical guidance, encouragement, and review of draft sections of this manual. In particular, the following people have provided immeasurable assistance without which this manual could not have been completed in this form. Those individuals, in alphabetical order, are:

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Marilyn Suco, formerly City of Scottsdale.
Bob Ward, Consulting Engineer, Mesa, AZ.

2-202 DRAINAGE REPORT PREPARATION

A. Requirements for a Drainage Report

A drainage report is required by the City Floodplain and Drainage Ordinance to document the effect that a proposed project would have upon stormwater runoff in the vicinity of the project; to provide data to insure that the project is designed to be protected from flooding; and to provide data supporting the design of facilities to be constructed for the management of stormwater runoff. Each drainage report must consider runoff from storms with a return frequency up to and including a 100-year storm. The complexity of the report depends upon the nature of the project and the site on which the project will occur.

A drainage report must be prepared by a qualified professional drainage designer and sealed by a professional Civil Engineer registered in the State of Arizona. The design and drainage report must be prepared in accordance with the City's current Floodplain and Drainage Ordinance; the criteria and direction contained within Sections 2.1 - 2.3 of the Drainage Design Manual; and other applicable City policies and criteria. A drainage report shall be submitted by an applicant requesting one of the following:

- Approval of a subdivision plat (preliminary and final).
- A permit for grading, unless the requirement is waived by the Floodplain Administrator.
- A permit to construct right-of-way improvements.
- A permit to construct any structure, unless the structure is to be a single family residential structure without a basement in Flood Hazard Zones X, B, C, or D and is to be located at a site which the Floodplain Administrator has determined will not be in the vicinity of a watercourse in which the flow of rainfall runoff might be hazardous to the structure or its occupants.
- Zoning case approval.
- Development review case approval.

B. The Purpose of a Drainage Report

The purpose of a drainage report is to document that stormwater runoff has been considered in the planning of each project and that the public and its property will be protected from damage by runoff flows and flooding. The requirement for this protection not only applies to those who will own and/or use a proposed project but also to those who own or occupy property adjacent to or near enough upstream or downstream to be affected by the proposed project.

C. Six Elements of a Drainage Report

There are six elements of a drainage report which normally must be present to demonstrate that the effects of stormwater runoff have been considered and that the runoff will be properly managed by the project. Subparagraphs 1, 2, 3 and 6, below, are elements found in "conceptual" or "master reports;" and subparagraphs 4 and 5, below, could be submitted as supplemental reports to support design choices shown on construction plans. There will, of course, be cases when one or more of these elements would not be applicable, and there could be special projects requiring analysis or information not covered in these six elements. The six elements are described in the following subparagraphs. In addition, refer to the Drainage Report Outline Checklist in section 2-204 for specific items that might be included within a drainage report.

1. Description of the Property and the Watersheds:
Each drainage report must have a section which includes a narrative, topographic maps and aerial photographs that describes the location and condition of the property the project is located on (on-site conditions) and the upstream (off-site) watersheds as well as any downstream constraints which affect the property.

a. On-site Conditions: An essential part of each report is a topographic map which shows the location of the project area. The map need not be elaborate, but it must show the location of the property with respect to the street system and other features such as the Arizona Canal or the CAP Aqueduct. A City of Scottsdale 400 scale Existing Drainage Network aerial photograph (the most current available) must accompany each drainage report which shows existing on-site drainage conditions on the property. The narrative description should include the following basic information about the property, as applicable:

- Description of existing drainage patterns including natural and man-made channels and watershed boundaries on the property.

- Description of the existing ground cover conditions and the identification of the SCS hydrologic soil group(s) or appropriate Green-Amp soil characteristics found on the property.

- Description of how existing development located on the property affects drainage.

- Description of how existing and/or proposed developments on adjacent properties affect drainage on the project area.

b. Off-site Watershed Conditions: Watersheds above the project area from which stormwater runoff enters or affects the project's property must be delineated on topographic maps. These maps should be prepared at a scale which will clearly show the drainage areas so that the watershed boundaries can be drawn with accuracy. Contour lines should be shown on the maps at an interval appropriate to the ground slope and complexity of the terrain. Recent aerial photographs of every part of the City are available at scales 1 inch = 100; 400; and 800 feet. An aerial photograph(s) of appropriate scale, the most current available, must be included in each drainage report which shows the off-site watershed areas and adjacent properties in relation to the project site.

The narrative description should include the following things:

- Existing upstream and downstream drainage patterns on the watersheds.
- The natural ground cover and the SCS hydrologic soil group(s) or Green Ampt soil classes found on the watersheds.
- Existing development on the watersheds and how this affects drainage.
- The location and type of development that would exist on the watersheds if the land were developed in accordance with the Land Use Element of the current General Plan for Scottsdale as approved by the City Council, and the probable effect of this project on drainage.
- Any condition which would significantly affect the way the runoff from the watershed would be analyzed.

2. Estimation of Stormwater Runoff:
The report must provide estimates for selected storm return frequencies of peak stormwater runoff rates at concentration points entering and leaving the property, or site, from on-site, as well as Off-site, watershed areas. (See paragraphs under 2-203.) In addition, the report must include estimates of stormwater runoff volumes from the project area or development site that are required to be stored on-site in accordance with City Ordinance requirements. (See paragraphs 2-203)

3. Evaluation of the Effects of The Project:
The report must show how stormwater runoff will be handled when the project has been completed and how the project will affect stormwater runoff.

Depicting Pre- and Post-Project Topography: Prior to the project or development of a piece of property, topographic conditions exist on the property which will influence and direct the flow of drainage water which enters the property from watersheds above it or which originates on the property. When the project has been completed, certain topographic changes will have occurred which influence the drainage flows and resulting time of concentration. It is necessary that the drainage report include sufficient pre- and post-project topographic information to demonstrate the effects of the project. This information should be depicted on contour maps. In addition to showing the developer's property, these maps should also show enough of the adjacent property to give a clear picture of what exists, what will affect drainage, and what will be affected by drainage on the property being developed. Information about adjacent property, such as significant differences in elevation, walls, drainage structures, buildings with their floor elevations, etc. must be included.

Pre- and Post-Project Stormwater Runoff: The amount and type of stormwater runoff that would exit the property prior to the project and after the project must be depicted for a 2-year, a 10-year and a 100-year storm. If, as a result of the project, drainage flows will be reduced by facilities such as retention or detention basins, the effect of these facilities on flows exiting the property should be described and depicted on appropriate maps. Construction of roads, parking areas, roofs, channels, and other project features generally increases the runoff volume and peak discharge and reduces the time of concentration.

4. Presentation of the Basis for Design of Facilities to Manage Runoff:
   This presentation includes a summary of the design criteria used, a brief description of the design approach and methods used. The sketches, data, and calculations which support the selection of materials, the locations, and design of facilities should be included in the Appendix. (See Section 2.1 for design criteria and policy guidance and Section 2.3, Hydraulics, for design guidance of the specific drainage facility.)

5. Presentation of the Basis for Selecting Elevations for the Lowest Floor:
   Elevations must be selected to provide protection from flooding. The basis for the selection of a floor elevation or the design of protection for the interior of the building must be presented. (See Manual Sections 2.1 and 2.3)

6. Description of the Provisions for Project Phasing:
   Any project, particularly a large one, may have stormwater runoff, flooding, and erosion problems during the construction phases which would not exist after the project has been completed. The report must indicate how the phasing will occur, what interim drainage problems are anticipated, and what must be done to alleviate these problems.

   As of October 1, 1992, the National Pollutant Discharge Elimination System (NPDES) General Permit for stormwater discharges requires all owners/operators of construction projects disturbing five or more acres to prepare a Storm Water Pollution Prevention Plan (SWPPP) and file a Notice of Intent (NOI). The NOI must be sent to the United States Environmental Protection Agency with a copy to the city of Scottsdale 48 hours before construction begins (The city must have evidence of this permit before a development permit will be issued). The goal of this NPDES storm water permit for construction activities is to reduce erosion potential, minimize sedimentation, and to eliminate non-stormwater discharges for construction sites.

2-203 METHODS FOR ESTIMATING PEAK DISCHARGE

A. Introduction

Two methods are defined for the determination of peak discharges: the Rational Method, and rainfall-runoff modeling using the U.S. Army Corps of Engineers' HEC-1 Flood Hydrograph Package. For small watersheds, less than 160 acres the Rational Method is acceptable. For smaller watersheds that are non-uniform, irregular in shape, or when routing of flows are necessary, or for areas larger than 160 acres, HEC-1 modeling is required.

The City's procedures parallel those contained in the FCDMC's Hydrology Manual for Maricopa County. Scottsdale uses a six hour duration storm event. However, Scottsdale uses the original source data, NOAA Atlas II for precipitation data, and the storm distribution pattern built in HEC-1. A detailed analysis of various methodologies conducted by Robert L. Ward tested and verified that the results using the following HEC-1 methods are comparable to those of the FCDMC and others.

B. Watershed Conditions

When a peak runoff flow rate is to be used in determining the size of a drainage management facility (culverts, channels, etc.) or in determining the protection to be provided from possible flooding (lowest floor elevation, flood-proofing, etc.), the flow rate must be estimated by considering the watershed to be at a state of development which would produce the greatest peak flow rate. Usually a watershed which is fully developed in accordance with the City's General Plan Land Use Element will produce such conditions but other interim conditions such as the watershed's current state or its development in accordance with existing zoning may produce a greater peak flow rate and must be considered. Comments should be included in the report indicating the conditions considered and the choice of the watershed conditions used to calculate the peak flow rates.

C. The Rational Method

The Rational Method is limited to use on small, uniform, regularly shaped watersheds less than or equal to 160 acres in size.

$Q = C\ I\ A\ F$

Q = the peak discharge rate in cubic feet per second;

C = a dimensionless runoff coefficient (Figure 2.2-17);

I = the rainfall intensity in inches per hour;

A = the watershed area in acres.

F = a frequency adjustment factor (per FCDMC, Hydrology Manual, 6-92)

The Rational Method generates an instantaneous peak discharge rate in cubic feet per second. It does not generate a runoff hydrograph and cannot be used to determine runoff volumes. Calculations must be submitted on figure 2.2-18 or a similar form containing the same data and information. Frequency adjustment factors are included in Figure 2.2-18.

PRECIPITATION: precipitation data is not required; rainfall intensity (I) is obtained directly from Figure 2.2-13, which applies Citywide. The time of concentration (Tc), which is assumed to equal "Duration" in the rational method, is all that is required to determine "I" from Figure 2.2-13.

TIME OF CONCENTRATION (Tc): Time of concentration is the total time of travel from the most hydraulically remote part of the watershed to the concentration point of interest. Figures 2.2-14 and 2.2-15 can be used to estimate flow velocity for calculating the time of travel. Procedures from Chapter 3 of SCS's TR-55, contained in Appendix B, are recommended for determining Tc. The minimum time of concentration that should be used is five minutes.

CAUTION: Natural land slopes are too steep and variable in Scottsdale to add a set amount of time for lot runoff. Analyze delays from lot runoff as overland flow or sheet flow. Use the lot's size and slope to determine the actual time of travel across the lot. **Do not automatically add an additional set amount of time to the estimated TC for lot runoff delay (such as 5 or 10 minutes).**

RUNOFF COEFFICIENTS: Figure 2.2-17 must be used to obtain "C" values. Composite "C" values for the appropriate zoning category or weighted average values calculated for the specific site, are both acceptable approaches.

CAUTION: HEC-1 procedures (which are required on areas greater than 160 acres in size) instead of the Rational Method are recommended on areas between 40 and 160 acres in size if the watershed is non-uniform, irregular in shape, or if routing of flows is necessary.

D. The Corps of Engineer's HEC-1 Computer Model

HEC-1 procedures are applicable for any watershed area over 40 acres and up to 100 square miles in size; and is required for analyzing drainage areas over 160 acres in size. Minimum required submittals if using HEC-1 is a printout of: the input data; a schematic diagram of the stream network; the runoff summary output table; and a diskette with the input file(s).

PRECIPITATION: The required precipitation input is the six hour duration storm using the model's built in hypothetical storm distribution pattern input using the PH record.

Precipitation values are to be obtained from the Isopluvial maps (figures 2.2-1 through 12) for the specific frequency desired. The 5, 15, 60 120,180, and 360 (6 hour) minute duration rainfall amounts should be calculated per the formulae and procedures in Appendix A.

INFILTRATION: Infiltration or Soil losses can be determined using SCS Runoff Curve Numbers (Use Figures 2.2-19 and 2.2-20) or Green and Ampt (G&A) procedures per FCDMC Hydrology Manual. Use the most recent published SCS soil survey maps of the area to determine the hydrologic soil group or surface soil texture for the G&A procedures.

RUNOFF CURVE NUMBERS: When using runoff curve numbers (ROCN) within the City of Scottsdale one must:

- Assume poor hydrologic condition and desert shrub cover type for natural undisturbed desert conditions in Figure 2.2-20.
- For lawns, golf courses, and other grassed open space areas, fair or poor condition must be assumed using Figure 2-19, then you must adjust the ROCN to antecedent moisture condition III (use Figure 2-21).
- For developed conditions, increase the percent impervious on the LS card without changing the ROCN (except in the case of grassed areas, in which the curve number should be adjusted up according to the above). Obtain the percent impervious from Figure 2.2-16 for residential districts or use actual amount. For commercial or industrial districts use the actual or estimated percent impervious. A minimum of 85 percent for commercial and 72 percent industrial must be used.

HYDROGRAPH GENERATION: Small basin or sub-watershed hydrographs can be generated using the SCS dimensionless unit hydrograph procedure or kinematic wave method as described in the HEC-1 Users Manual. Computation time interval should generally range from 5 to 1 minute.

TIME OF CONCENTRATION (Tc): Use the estimated time of travel, from the most hydraulically remote part of the watershed to the concentration point. The procedures from Chapter 3 of SCS's TR-55 (contained in Appendix B) are recommended for obtaining Tc. **CAUTION:** For the SCS method, remember TLAG on the UD input card is equal to .6(Tc), not Tc.

CHANNEL ROUTING: Channel routing should use the Normal Depth (Modified Puls), eight point routing procedure as described in the HEC-1 Users Manual.

CAUTIONS: For the 1990 version of the HEC-1 program do not use the Kinematic wave method with the multi-ratio JR cards, hydrographs do not combine properly. For the 1988 version don't use JD cards with the Green-Ampt method, as errors will result. HEC-1 versions prior to the 1988 version are unacceptable.

2-204 CALCULATION OF RUNOFF VOLUMES

The only method for the determination of the required volume of stormwater storage is the standard formula in 2-204-A. HEC-1 modeling can be used for storage basin design and analysis (2-204-B) or if a pre-versus post volume difference is needed. The current citywide ordinance requirement is to provide on-site storage for runoff from the 2-hour 100-year frequency event, as described below, and in Section 2.1 of the City of Scottsdale Drainage Design manual.

A. The Standard Formula

$$Vr=(P/12)\ AC$$

Vr = Storage volume in acre feet.

P = Precipitation Depth = 2.82 inches, the 100 year 2 hour duration rainfall depth in inches (applies citywide).

A = Area in acres; the developed portion of the entire site in acres, to the centerline of adjacent streets, on which any man-made change is planned, including, but not limited to: construction, excavation, filling, grading, paving, or mining. See the Stormwater Storage Policy Statement in Section 2.1.

C = Runoff Coefficient; rational method values from Figure 2.2-17, either composite or weighted.

B. HEC-1 Computer Modeling

The HEC-1 model is not to be used to determine the ordinance required 2-hour 100-year stormwater storage runoff volumes. The HEC-1 model is, however, recommended for use in storage routing for storage basin design and analysis purposes; or for a pre versus post analysis (which must use a six hour storm and procedures described under Section 203). Use modified Puls level pool routing option in HEC-1 for hydrograph routing through storage basins and lakes. For permanent lakes, assume no available storage below the normal water surface.

CAUTION: do not use the built in orifice equation in the HEC-1 model, errors can result. Build your own stage discharge table and input to the model.

2-205 GENERAL OUTLINE CHECKLIST FOR DRAINAGE REPORTS

Title: Preliminary or Final Drainage Report or Master Drainage Plan

1. Introduction
   - •Project Name
   - •Project Type
   - •Size
   - •Location

   - •Exhibit: Vicinity Map.

2. Objectives
   - •Describe the type of report and purpose: Preliminary, Final, Master Plan.

3. Description of Drainage Characteristics
   - •On-site Property.
     -Existing drainage network, patterns, and watershed boundaries
   - •Off-site Watersheds.
     -Existing conditions and characteristics.
     -Future planned conditions if different from existing.
   - •Off-site drainage network entering and leaving the project site.
   - •Relation to existing Master Plans and adjacent drainage plans above and below the project.
   - •Classification by the FIRM maps.

   - •Exhibits:
     Off-site Watershed Map:
     -USGS 7.5 min. quads and city 800 scale aerial photos.
     Existing On-site Drainage Map:
     -Include as a minimum City's existing drainage network 400 scale aerials and 100 scale 1ft. contour interval topographic map.

4. Proposed Drainage Plan
   •General description of proposed drainage system and components, including design criteria and probable effect on the existing upstream and downstream drainage system.
   - •Pre and post runoff characteristics at key concentration points.
   - •Stormwater storage requirements, volume required, volume provided, and location.
   - •Major drainage structures or special drainage facilities needed.
   - •Exhibits: Proposed On-site Drainage Plan:
     -Scale appropriate to type of drainage report and size of the project.
   - •Tables: Pre vs Post Development Peak Flows and Retention Volumes.

5. Data Analysis Methods
   - •Hydrologic procedures and assumptions.
   - •Hydraulic procedures, methods, and assumptions.
   - •Stormwater storage calculation methods and assumptions.

6. Summary and Recommendations (Optional)

7. References or Bibliography (Optional)

Appendix

Data and Calculations (as applicable)

- Peak Flow Calculations (figure 2.2-18 data records; or HEC-1 printouts)
- Channel Design Calculations
- Culvert Design Calculations
- Floodplain Calculations (Manning's or HEC-2 printouts)
- Storage Volume Calculations
- Retention/Detention Basin Inflow-Outflow Analysis and Design Calculations
- Street Capacity Calculations
- Curb Opening, Catch Basin Calculations
- Storm Drain Calculations
- Special Problem Calculations
- Sediment and Scour Calculations

Where applicable these additional sections may be required:

- Finished Floor Elevations
  - In relation to designated floodplains
  - In relation to natural ground elevation if not in floodplain
  - Basis for setting elevations
- Special Interim Measures
  - Construction Phasing
  - Erosion/Sediment Control Plan
- Discharge and Fill Permit Requirements
  (COE 404 Permit if filling or cutting below normal high water mark)

REFERENCES

Arizona Department of Water Resources, Engineering Division, Floodplain Management Section, "FLOOD HAZARD IDENTIFICATION FOR RIVERINE TYPE FLOODING IN ARIZONA," SSA-2-91 (Draft), Phoenix, 1990.

Arkell, E.E., and Richards, F., 1986, "SHORT DURATION RAINFALL RELATIONS FOR THE WESTERN UNITED STATES," Conference on climate and Water Management-A Critical Era and Conference on the Human Consequences of 1985's Climate, August 4-7, American Meteorological Society, pp. 136 - 141.

Boughton, Walter C., Kenneth G. Renard, and Jeffrey J. Stone, "FLOOD FREQUENCY ESTIMATES IN SOUTHEASTERN ARIZONA," Journal of Irrigation and Drainage Engineering, Vol. 113, No. 4, Nov., 1987, pp. 469-478.

City of Scottsdale, "THE FLOODPLAIN AND DRAINAGE ORDINANCE, SCOTTSDALE, AZ," City of Scottsdale, Chapter 37, Sup. No. 3, Code 1972§ 5-611; Ord. No. 1993, 2-29-88.

Dawdy, David R., "THE SORRY STATE OF FLOOD HYDROLOGY IN THE ARID SOUTHWEST," Hydraulics/Hydrology of Arid Lands, New York, N.Y., American Society of Civil Engineers, 1990, pp. 743 - 748.

DeVries, J.J., T.V. Hromadka II, "COMPARISON OF STREAMFLOW ROUTING PROCEDURES FOR HYDROLOGIC MODELS," Computational Hydrology 87, Mission Viejo, CA, Lighthouse Publications, 1987, pp. C-26 - C-33.

Flood Control District of Maricopa County, "EVALUATION OF HYDROLOGIC AND HYDRAULIC METHODS - PRELIMINARY DRAFT," Maricopa Co., AZ, Sept. 31, 1985.

Flood Control District of Maricopa County, "DRAINAGE REGULATION FOR THE UNINCORPORATED AREA OF MARICOPA COUNTY, ARIZONA, PHOENIX, AZ," Adopted 9-26-88, effective 10-5-88.

Flood Control District of Maricopa County, "FLOODPLAIN REGULATIONS FOR MARICOPA COUNTY, Adopted 8-4-86, Amended through 9-3-91.

Flood Control District of Maricopa County, "UNIFORM DRAINAGE POLICIES AND STANDARDS FOR MARICOPA COUNTY, AZ, PHOENIX, AZ," The FCDMD, Approved 4-20-87, Resolution FCD 87-7.

Hawkins, Richard H., "ASYMPTOTIC DETERMINATION OF CURVE NUMBERS FROM RAINFALL RUNOFF DATA," Watershed Planning and Analysis in Action, Durango, Colo., 1990, pp.67 - 76.

Hogan, Daniel H., "COMPUTER-ASSISTED FLOODPLAIN HYDROLOGY AND HYDRAULICS, New York, McGraw-Hill, Inc. 1989.

Hromadka II, T. V., "COMPLEX WATERSHED MODELS IN FLOOD CONTROL: QUESTIONS OF CREDIBILITY," Computational Hydrology 87, Mission Viejo, CA, Lighthouse Publications, 1987, pp. A-34 - A-37.

Kirpich, Z.P., "TIME OF CONCENTRATION OF SMALL AGRICULTURAL WATERSHEDS," Engineer's notebook, ASCE.

Miller, J.F., R. H. Frederick, and R.J. Tracey, "PRECIPITATION FREQUENCY ATLAS OF THE WESTERN UNITED STATES, VIII: ARIZONA: NOAA ATLAS 2," Silver Spring, Maryland, National Oceanic and Atmospheric Administration, 1973.

Osborn, Herbert B., and Kenneth G. Renard, "RAINFALL INTENSITIES FOR SOUTHEASTERN ARIZONA," Journal of Irrigation and Drainage Engineering, ASCE, Vol. 114, No. 1, Feb. 1988.

Reich, B.M., D.G. Renard and F.A. Lopez, "ALIGNMENT OF LARGE FLOOD PEAKS ON ARID WATERSHEDS," Hydraulics/Hydrology of Arid Lands, New York, N.Y. ASCE, 1990, pp. 477 - 482.

Sabol, George V., J.M. Rumann, Dave Khalili, and Stephen D. Waters, "DRAINAGE DESIGN MANUAL FOR MARICOPA COUNTY, ARIZONA, VOLUME I - HYDROLOGY," Special Projects Branch, Hydrology Division, Flood Control District of Maricopa County, Arizona, June 1, 1992.

U.S. Army Corps of Engineers, "HEC-1 FLOOD HYDROGRAPH PACKAGE USERS MANUAL," Davis, California, Hydrologic Engineering Center, September 1990.

U.S. Department of Agriculture, Soil Conservation Service, "URBAN HYDROLOGY FOR SMALL WATERSHEDS, TECHNICAL RELEASE 55, 2ND ED., 210-VI," Washington, D.C., Engineering Division, June 1986.

Ward, Robert L., "SENSITIVITY ANALYSIS OF REATA PASS HYDROLOGY SCOTTSDALE, ARIZONA, PHOENIX, AZ," Water Resources Associates, Inc., for the City of Scottsdale, Feb. 3, 1992.

Wisler, C.O., E.F. Brater, "HYDROLOGY," New York, John Wiley and Sons, Inc., 1967.

Wu, Jy S., Fred C.J. Wu, "APPLICATION OF MICROCOMPUTER PROGRAMS FOR PEAK DISCHARGE CALCULATION," Computational Hydrology 87, Mission Viejo, CA, Lighthouse Publications, 1987, pp. A-21 - A-24.

APPENDIX A

Steps for Determination of Precipitation Values for Various Durations and Return Periods.

Sheet 1 of 3

(Source: Addendum to "Hydrologic Design for Highway Drainage in Arizona," April 1975, and ADOT, April 17, 1987,

Step 1: From the precipitation maps, Figures 2.2-1 through 2.2-12, determine the precipitation values for the six and twenty four hour durations storms for return periods of 2, 5, 10, 25, 50, and 100 years. Tabulate these values in Table 1 in the column headed "Map Values."

Table 1

Return Period (Years)	Precipitaton Values (Inches)			
	6 hour duration		24 hour duration	
	Map Value	Corrected Value	Map Value	Corrected Value
2				
5				
10				
25				
50				
100				

NOTE: There is a possibility of making an error while reading the maps because: (1) a site is not easy to locate precisely on a series of 12 maps, (2) there may be some slight registration differences in printing, and (3) precise interpolation between isolines is difficult. In order to minimize any errors in reading the maps, these values should be plotted on the diagram "Precipitation Depth versus Return Period," Appendix A, Figure 1.

Step 2: Plot these values on the diagram "Precipitation Depth versus Return Period," Appendix A, Figure 1.

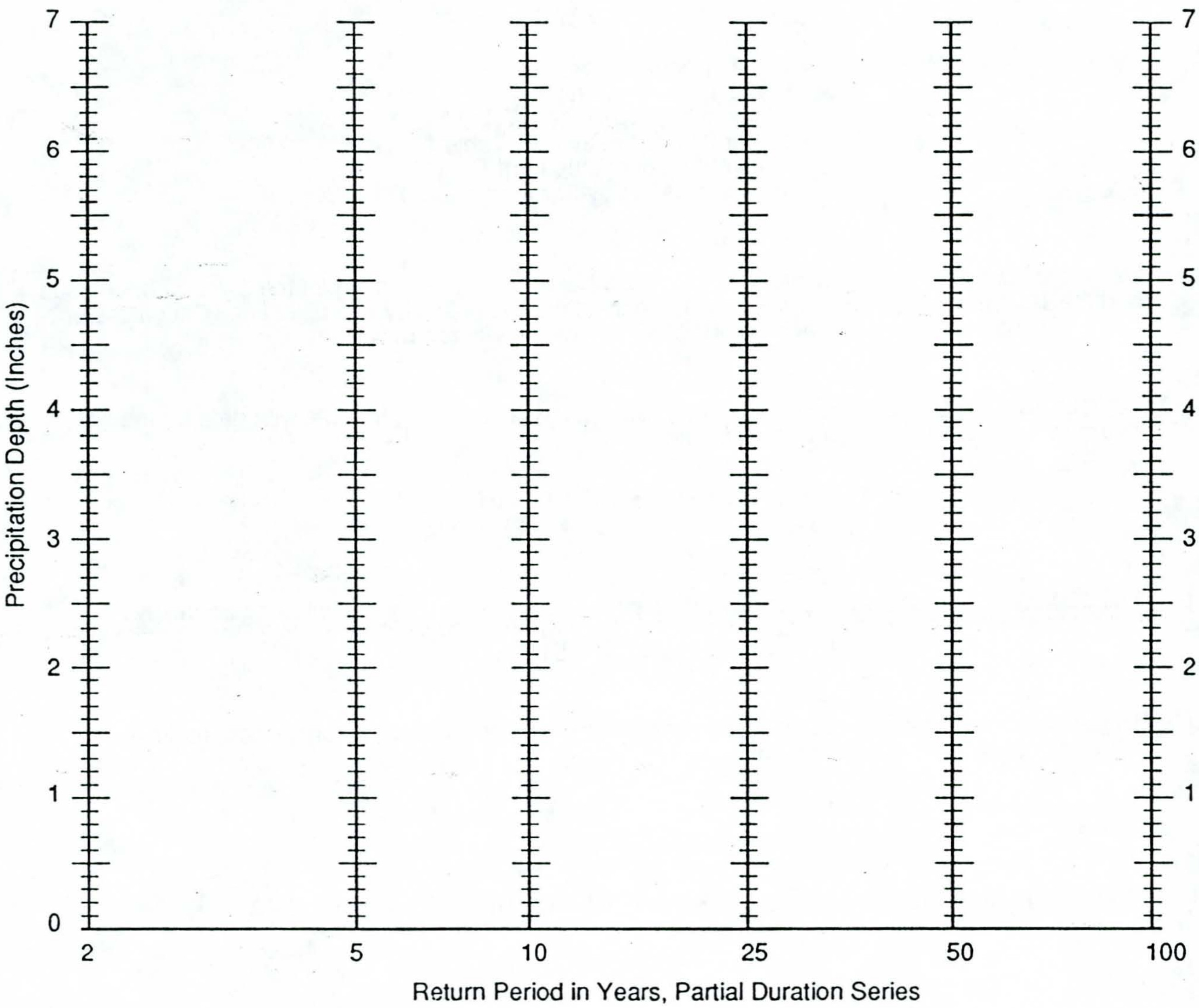
Step 3: Draw a line of best fit through the 6 hour precipitation values and another line through the 24 hour precipitation values.

Step 4: Tabulate the values represented by the lines of best fit, obtained in Step 3, in the column of Table 1 entitled "Corrected Value."

NOTE: The 1 hour precipitation value is needed to determine the 2 and 3 hour values as well as the 5, 10, 15, and 30 minute values.

APPENDIX A

Figure 1
Precipitation Depth Versus Return Period for Partial - Duration Series
Sheet 2 of 3
(Source: Addendum to "Hydrologic Design for Highway Drainage in Arizona," April 1975)



Project: ______________________ Station: ______________________

APPENDIX A

(Source: Addendum to "Hydrologic Design for Highway Drainage in Arizona," April 1975, and ADOT April 17, 1987)

Step 5: Using the 6 and 24 hour values for the 2 year and 100 year return periods, from Table 1 (corrected values), solve the following equations to determine the 1 hour values:

$$Y_2 = -0.011 + 0.942(X_1^2 / X_2)$$

$$Y_{100} = 0.494 + 0.755(X_3^2 / X_4)$$

Where: Y_2 = 2 year 1 hour value
Y_{100} = 100 year 1 hour value
X_1 = 2 year 6 hour value from Table 1
X_2 = 2 year 24 hour value from Table 1
X_3 = 100 year 6 hour value from Table 1
X_4 = 100 year 24 hour value from Table 1

Step 6: To determine 1 hour precipitation values for the other return periods, first plot the 2 year 1 hour value and the 100 year 1 hour value on Figure 1. Connect the two points by a straight line. The values on this line will give the 1 hour precipitation values for the various return periods.

Step 7: To determine the 2 and 3 hour precipitation values, use the following formula with data far the appropriate return period from Table 1 (corrected values):

$$P_{2\ hour} = 0.341\ (P_{6\ hour}) + 0.659\ (P_{1\ hour})$$
$$P_{3\ hour} = 0.569\ (P_{6\ hour}) + 0.431\ (P_{1\ hour})$$

Step 8: The 12 hour precipitation value for any return period is determined by the following equation:

$$P_{12hr} = 0.49\ P_{24\ hour} + 0.51\ P_{6\ hour}$$

Step 9: To determine precipitation values for durations less than 1 hour for any return period, multiply the 1 hour depth by the following ration:

Duration (minutes) :	5	10	15	30
Ratio to one hour*:	.34	.51	.62	.82

*From Arkell and Richards (1986) per FCDMC's Hydrology Manual (9-90)

APPENDIX B

SCS TR55's Time of Concentration and Travel Time.

Introduction

Travel time (T_t) is the time it takes water to travel from one location to another in a watershed. T_t is a component of time of concentration (T_c), which is the time for runoff to travel from the hydraulically most distant point of the watershed to a point of interest within the watershed. T_c is computed by summing all the travel times for consecutive components of the drainage conveyance system.

T_c influences the shape and peak of the runoff hydrograph. Urbanization usually decreases T_c, thereby increasing the peak discharge. But T_c can be increased as a result of (a) ponding behind small or inadequate drainage systems, including storm drain inlets and road culverts, or (b) reduction of land slope through grading.

Factors affecting time of concentration and travel time

Suface roughness
One of the most significant effects of urban development on flow velocity is less retardance to flow. That is, undeveloped areas with very slow and shallow overland flow through vegetation becomemodified by urban development: the flow is then delivered to streets, gutters, and storm sewers that transport runoff downstream more rapidly. Travel time through the watershed is generally decreased.

Channel shape and flow patterns
In small non-urban watersheds, much of the travel time results from overland flow in upstream areas. Typically, urbanization reduces overland flow lengths by conveying storm runoff into a channel as soon as possible. Since channel designs have efficient hydraulic characteristics, runoff flow velocity increases and travel time decreases.

Slope
Slopes may be increased or decreased by urbanization, depending on the extent of site grading or the extent to which storm sewers and street ditches are used in the design of the water management system. Slope will tend to increase when channels are straightened and decreased when overland flow is directed through storm sewers, street gutters, and diversions.

Computation of travel time and time of concentration

Water moves though a watershed as sheet flow, shallow concentrated flow, open channel flow, or some combination of these. The type that occurs is a function of the conveyance system and is best determined by field inspection.

Travel time (T_t) is the ratio of flow length to flow velocity:

$$T_t = \frac{L}{3600\ V} \quad \text{(Eq. \#1)}$$

Where:
T_t = travel time (hr.),
L = flow length (ft.),
V = average velocity (ft/s), and
3600 = coversion factor from seconds to hours.

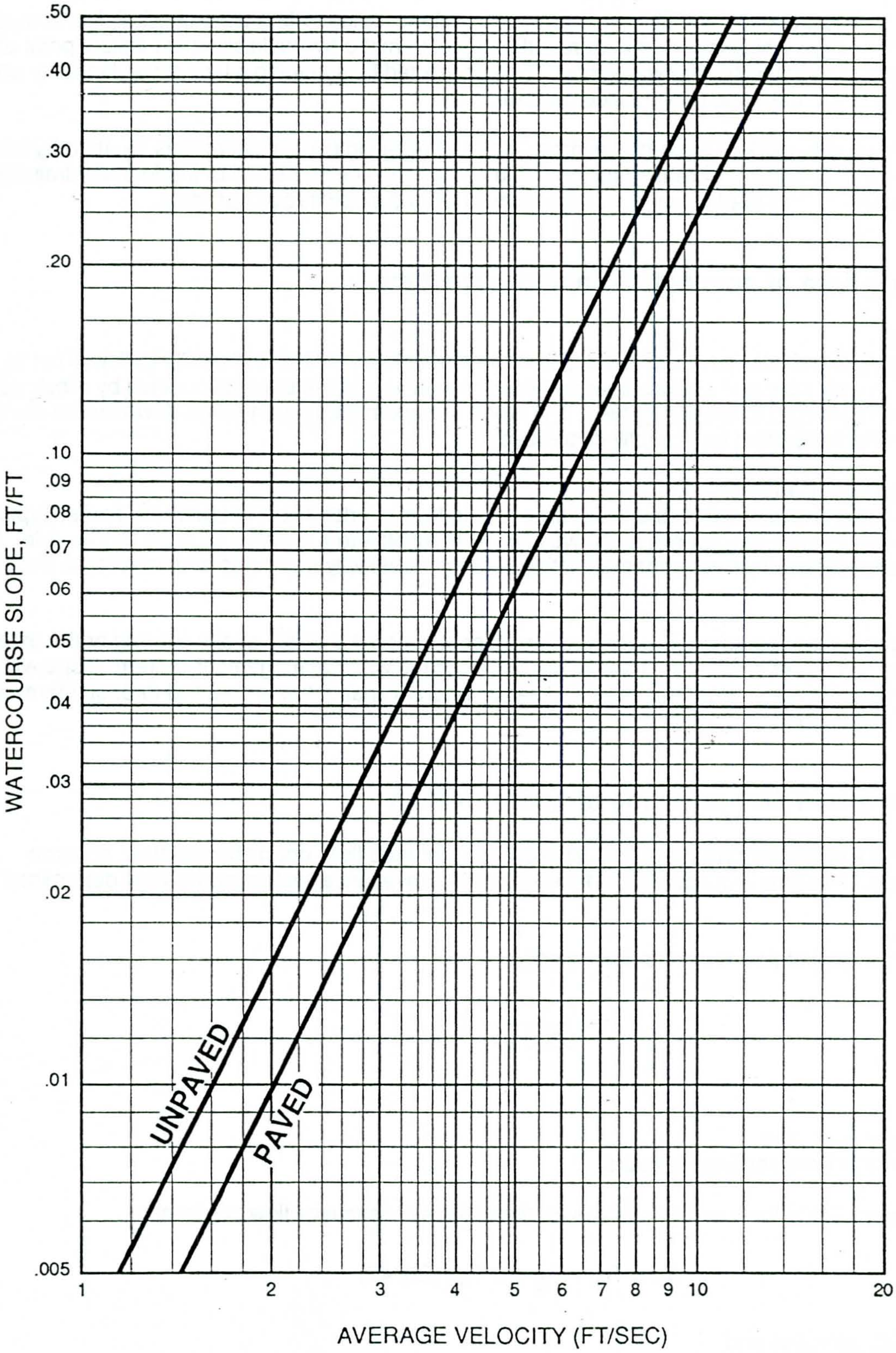
Time of concentration (T_c) is the sum ot T_t values for the various consecutive flow segments:

$$Tc = T_{t_1} + T_{t_2} + \ldots T_{t_m} \quad \text{(Eq. \#2)}$$

Where:
T_c = time of concentration (hr) and
m = number of flow segments.

APPENDIX B

Figure B-1
Average Velocity for Estimating Travel Time for shallow Concentrated Flow
Sheet 2 of 4



Source: TR-55, Fig. 3-1

APPENDIX B

SCS TR55's Time of Concentration and Travel Time.

Sheet Flow

Sheet flow is flow over plane surfaces. It usually occurs in the headwater of streams. With sheet flow, the friction value (Manning's n) is an effective roughness coefficient that includes the effect of raindrop impact; drag over the plane surface; obstacles such as litter, crop ridges, and rocks; and erosion and transportation of sediment. These n values are for very shallow flow depths of about 0.1 foot or so. The following table gives Manning's n values for sheet flow for various surface conditions.

Table B-1
Roughness coefficients (Manning's n) for sheet flow:

Surface Description	n[1]
Smooth surfaces (concrete, asphalt, gravel, or bare soil)	0.011
Fallow (no residue)	0.05
Cultivated soils:	
Residue cover ≤20%	0.06
Residue cover >20%	0.17
Range (natural)	0.13
Grass:	
Short grass prairie	0.15
Dense grasses[2]	0.24
Bermudagrass	0.41
Woods[3]:	
Light underbrush	0.40
Dense underbrush	0.80

[1]The n values are a composit of information compiled by Engman (1976)
[2]Includes species such as weeping lovegrass, bluegrass, buffalo grass, blue grama grass, and native grass mixtures
[3]When selecting n, consider cover to a height of about 0.1ft. This is the only part of the plant cover that will obstruct sheet flow.

For sheet flow of less than 300 feet, use Manning's kinematic solution (Overton and Meadows 1976) to compute T_t:

$$T_t = \frac{0.007\,(nL)^{0.8}}{(P_{10})^{0.5}\,(S)^{0.4}} \quad \text{(Eq. \#3)}$$

Where:
T_t = travel time (hr),
n = Manning's roughness coefficient (from Table B-1)
L = flow length (ft)
P_{10} = 10-year, 6 hour rainfall (in), and
S = slope of hydraulic grade line (land slope, ft/ft)

This simplified form of the Manning's kinematic solution is based on the following: (1) shallow steady uniform flow, (2) constant intensity of rainfall excess (that part of a rain available for runoff), (3) rainfall duration of 24 hours, and (4) minor effect of infiltration on travel time. (The above formula and assumptions were modified for use in Scottsdale based on: rainfall duration is 6 hours; and bankfull flow is a 10 year frequency event.)

Shallow concentrated flow

After a maximum of 300 feet, sheet flow usually becomes shallow concentrated flow. The average velocity for this flow can be determined from Figure B-1, in which average velocity is a function of watercourse slope and type of channel. Tillage can affect the direction of shallow concentrated flow. Flow may not always be directly down the watershed slope if tillage runs across the slope.

After determining average velocity in Figure B-1, use equation #1 to estimate travel time for the shallow concentrated flow segment.

Open channels

Open channels are assumed to begin where surveyed cross section information has been obtained, where channels are visible on aerial photographs, or where blue lines (indicating streams) appear on United States Geological Survey (USGS) quadrangle sheets. Manning's equation or water surface profile information can be used to estimate average flow velocity. Average flow velocity is usally determined for bank-full elevation (assume 10 year frequency event in Arizona desert).

APPENDIX B

SCS TR55's Time of Concentration and Travel Time.
Sheet 4 of 4

Manning's equation is:

$$V = \frac{1.49 r^{2/3} s^{1/2}}{n} \quad \text{(Eq.\#4)}$$

Where:
- V = average velocity (ft/s)
- r = hydraulic radius (ft) and is equal to a/p_w
- a = cross sectional flow area (ft^2)
- p_w = wetted perimeter (ft)
- s = slope of the hydraulic grade line (channel slope, ft/ft)
- n = Manning's roughness coefficient for open channel flow

Manning's n values for open channel flow can be obtained from standard textbooks such as Chow (1959) or Linsley et al. (1982). After average velocity is computed using equation #4, T_t for the channel segment can be estimated using equation #1.

Reservoirs or lakes

Sometimes it is necessary to estimate the velocity of flow through a reservoir or lake at the outlet of a watershed. This travel time is normally very small and can be assumed as zero.

Limitations

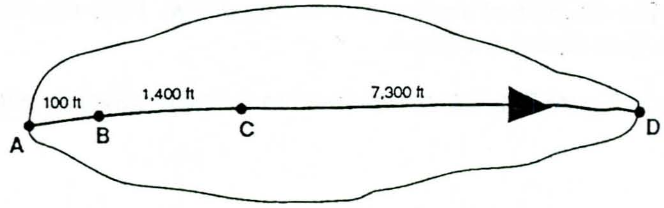
- Manning's kinematic solution should not be used for sheet flow longer than 300 feet. Equation #3 was developed for use with the four standard rainfall intensity-duration relationships (used in TR-55).

- In watersheds with storm sewers, carefully identify the appropriate hydraulic flow path to estimate T_c. Storm sewers generally handle only a small portion of a large event. The rest of the peak flow travels by streets, lawns, and so on, to the outlet. Consult a standard hydraulics textbook to determine average velocity in pipes for either pressure or nonpressure flow.

- The minimum T_c used in TR-55 is 0.1 hour.

Example

The sketch below shows a sample watershed. The problem is to compute T_c at the outlet of the watershed (point D). All three types of flow (overland sheet flow, shallow concentrated flow, and channel flow) occur from the hydraulically most distant point (A) to the point of interest (D). To compute T_c, first determine T_t for each segment, then sum all three T_t's to obtain the watershed or sub-area T_c.



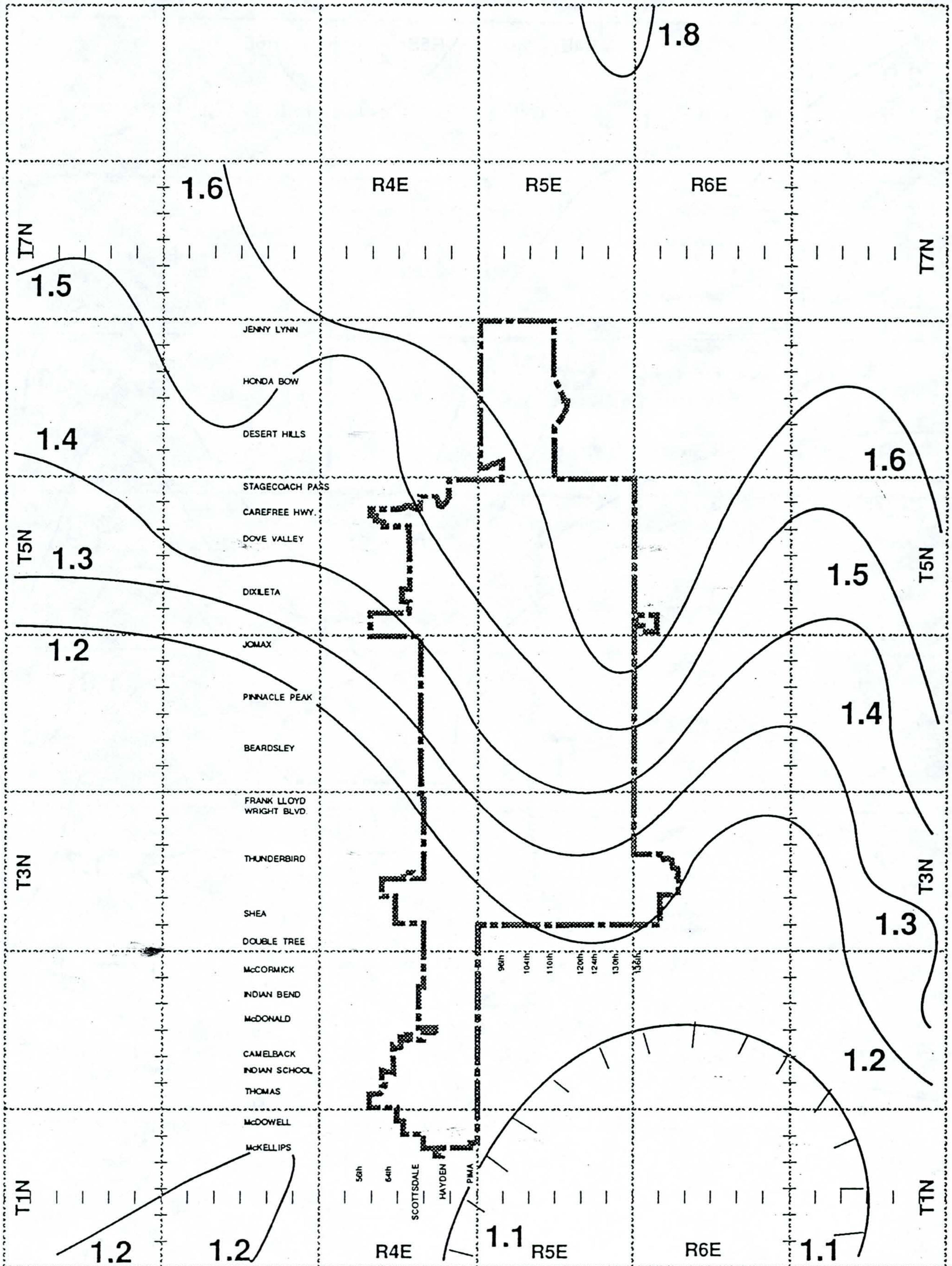


FIGURE 2.2-1

Isopluvials 2 Year 6 Hour Precipitation in Inches

Rainfall Data From NOAA Atlas 2, Vol. VIII

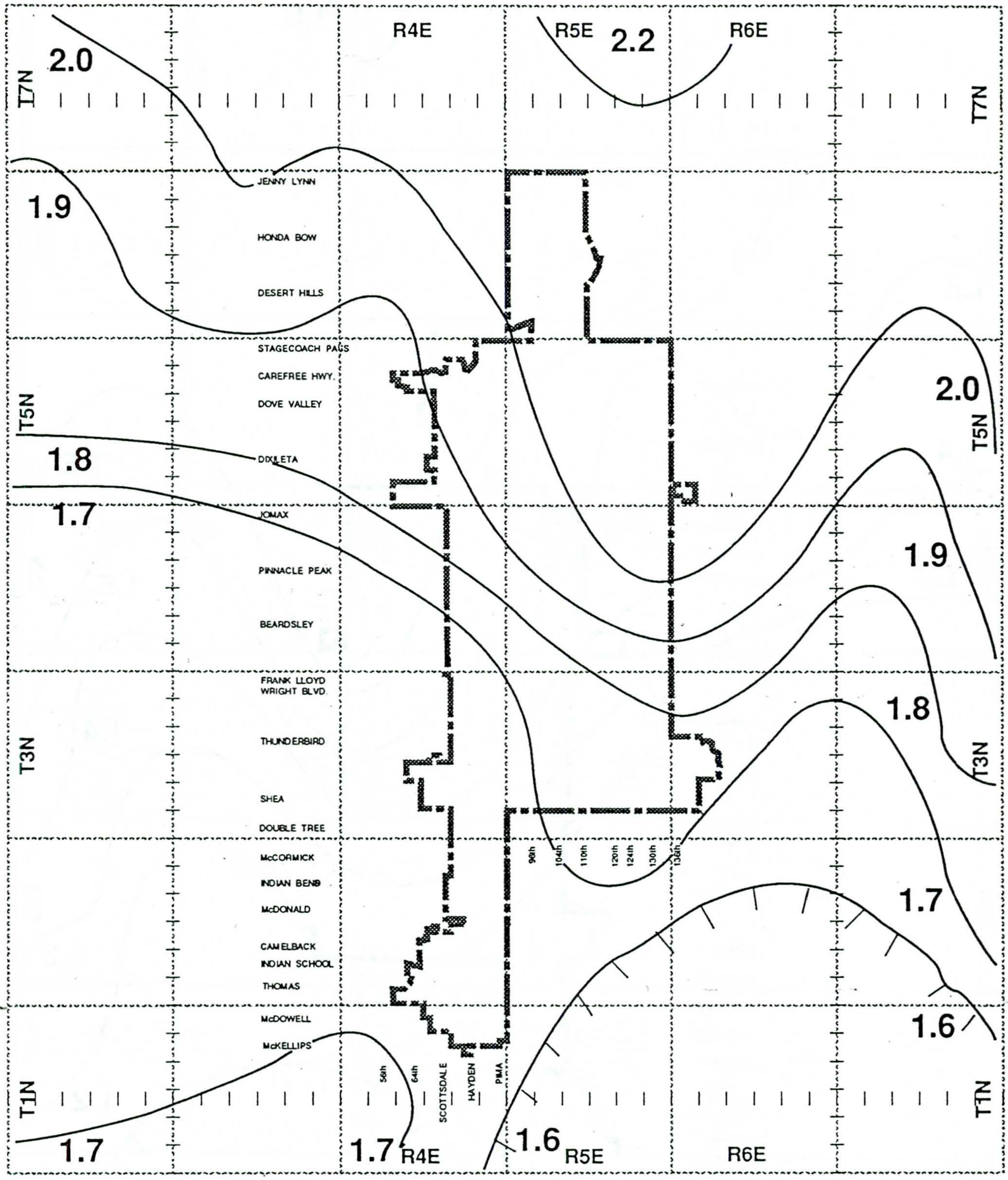


FIGURE 2.2-2

Isopluvials 5 Year 6 Hour Precipitation in Inches

Rainfall Data From NOAA Atlas 2, Vol. VIII

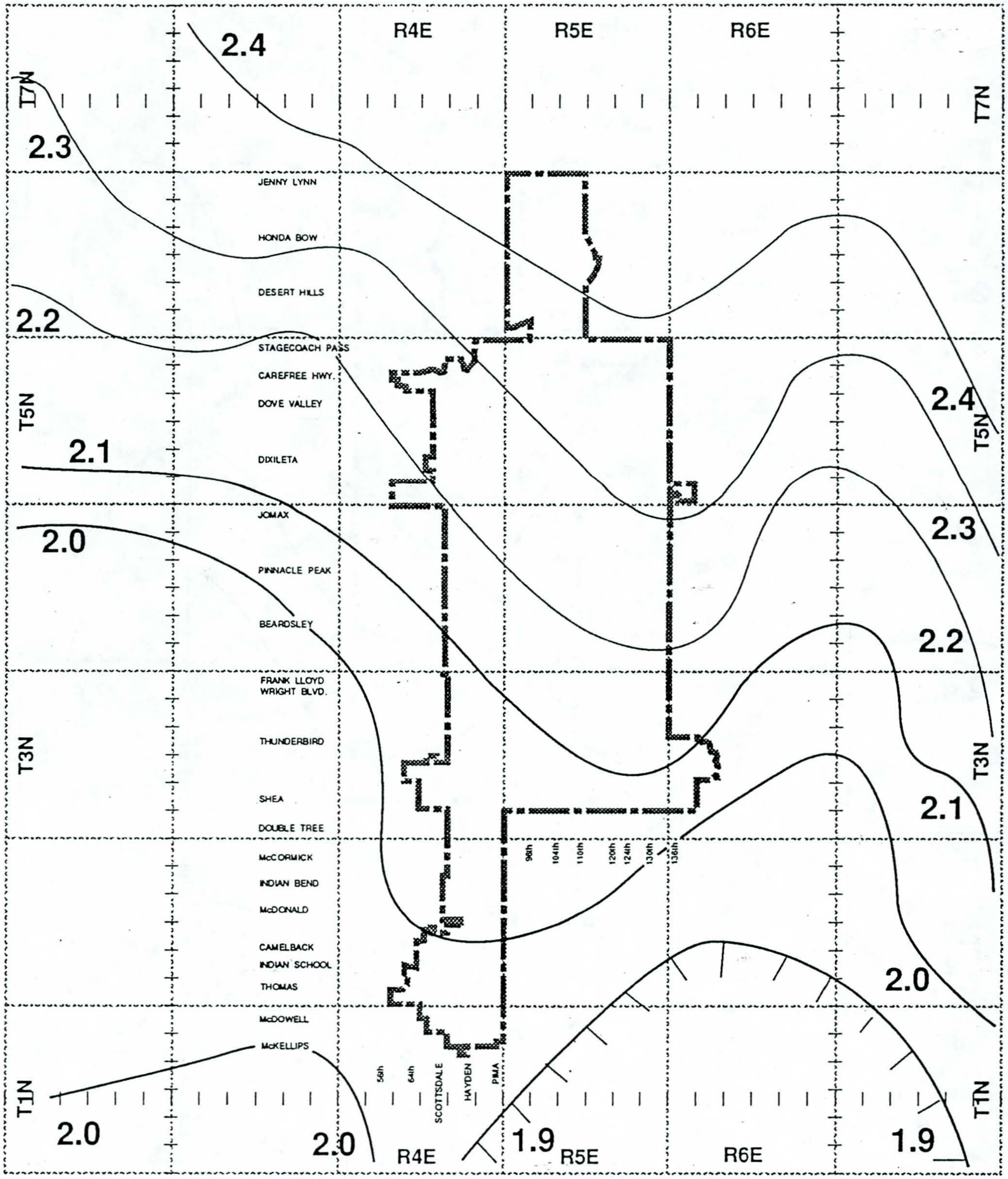


FIGURE 2.2-3

Isopluvials 10 Year 6 Hour Precipitation in Inches

Rainfall Data From NOAA Atlas 2, Vol. VIII

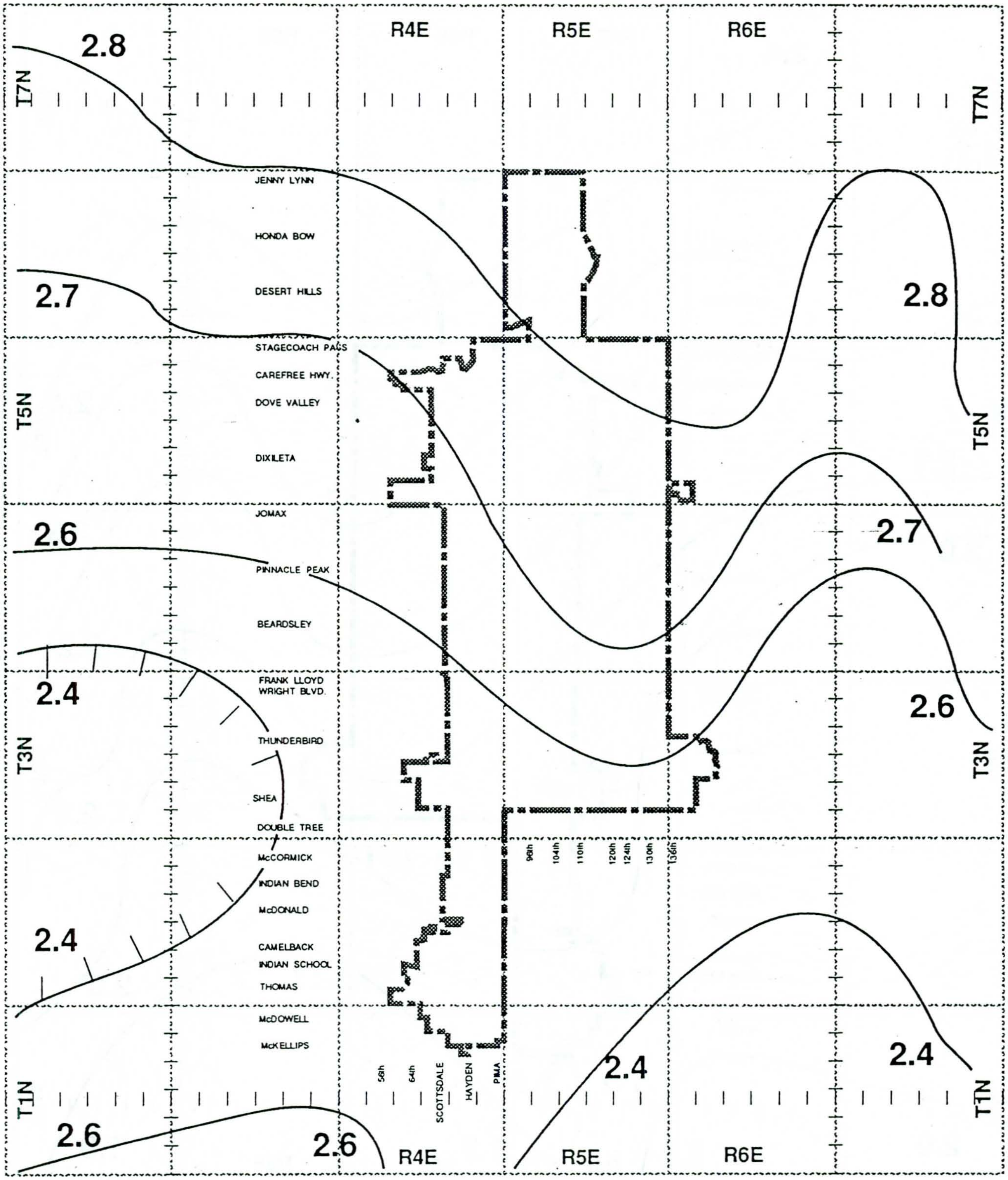


FIGURE 2.2-4

Isopluvials 25 Year 6 Hour Precipitation in Inches

Rainfall Data From NOAA Atlas 2, Vol. VIII

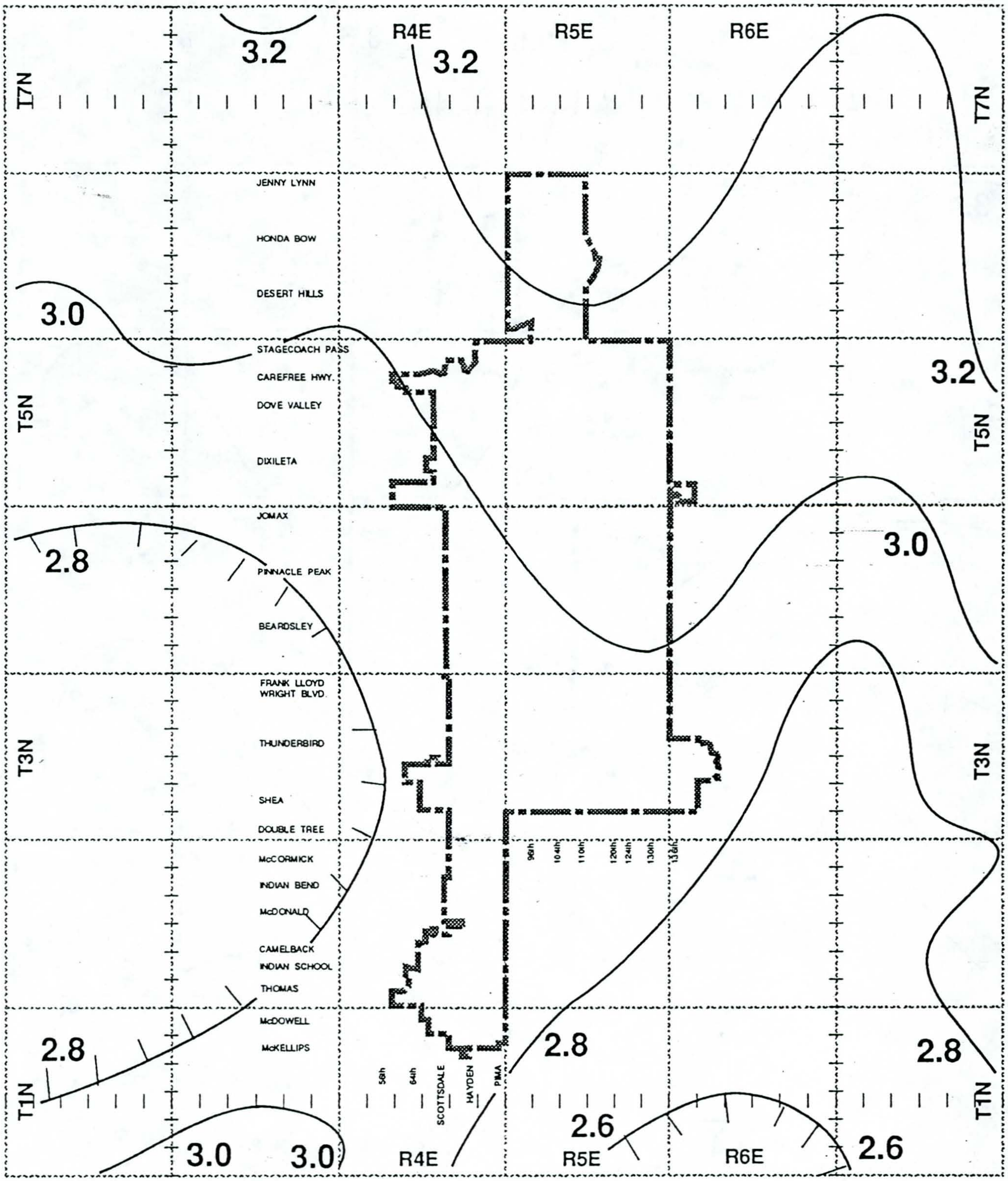


FIGURE 2.2-5

Isopluvials 50 Year 6 Hour Precipitation in Inches

Rainfall Data From NOAA Atlas 2, Vol. VIII

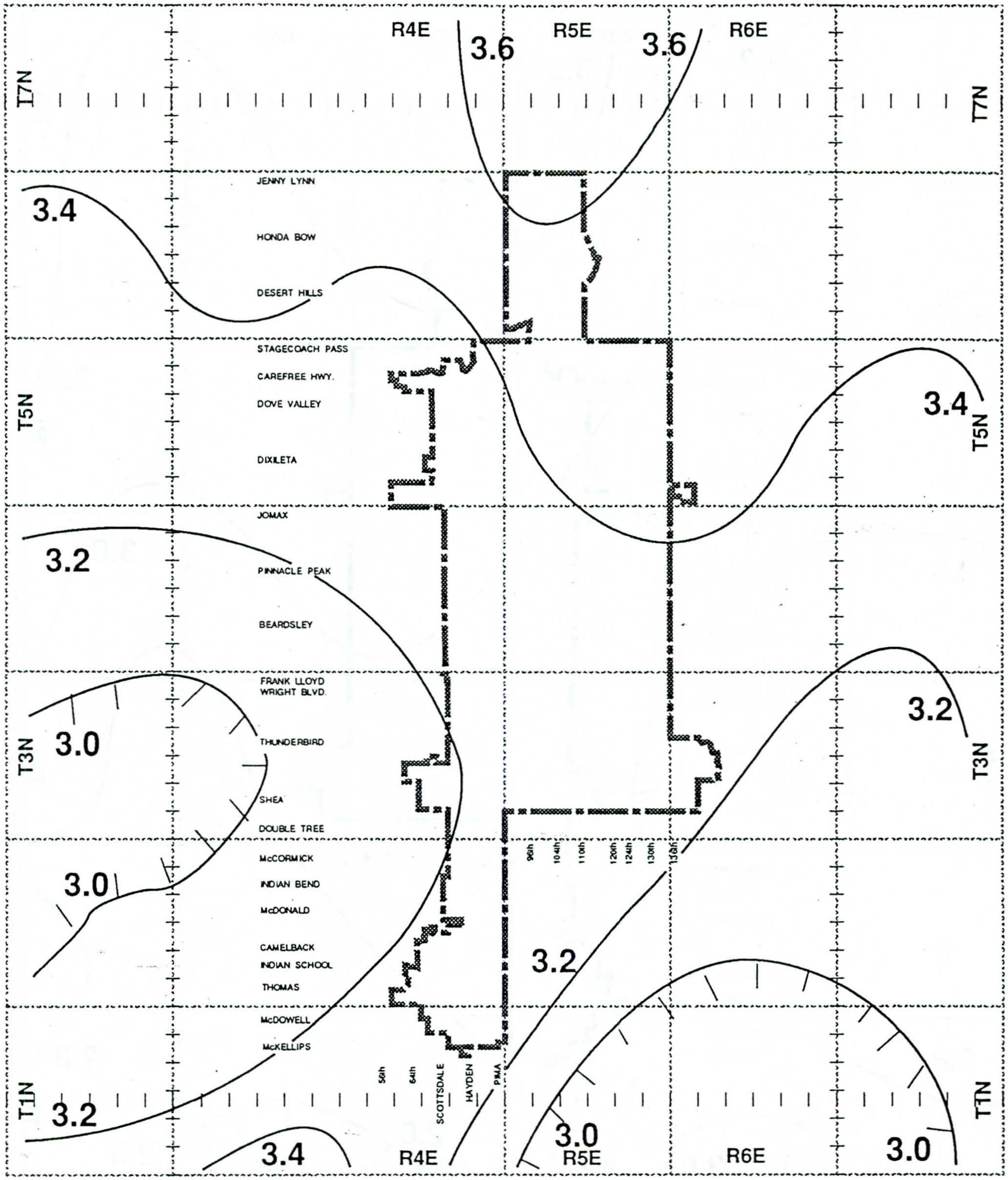


FIGURE 2.2-6

Isopluvials 100 Year 6 Hour Precipitation in Inches

Rainfall Data From NOAA Atlas 2, Vol. VIII

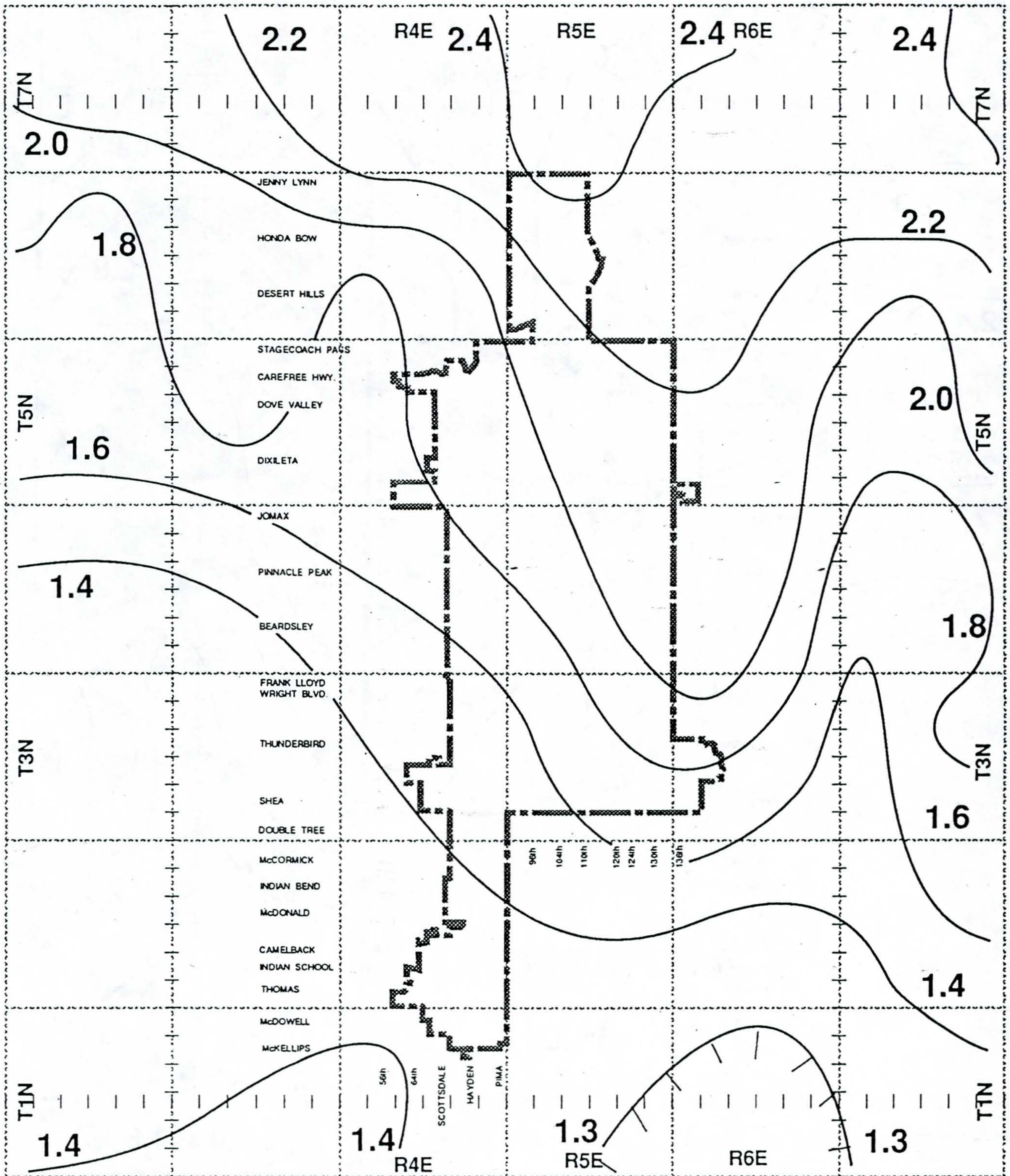


FIGURE 2.2-7

Isopluvials 2 Year 24 Hour Precipitation in Inches

Rainfall Data From NOAA Atlas 2, Vol. VIII

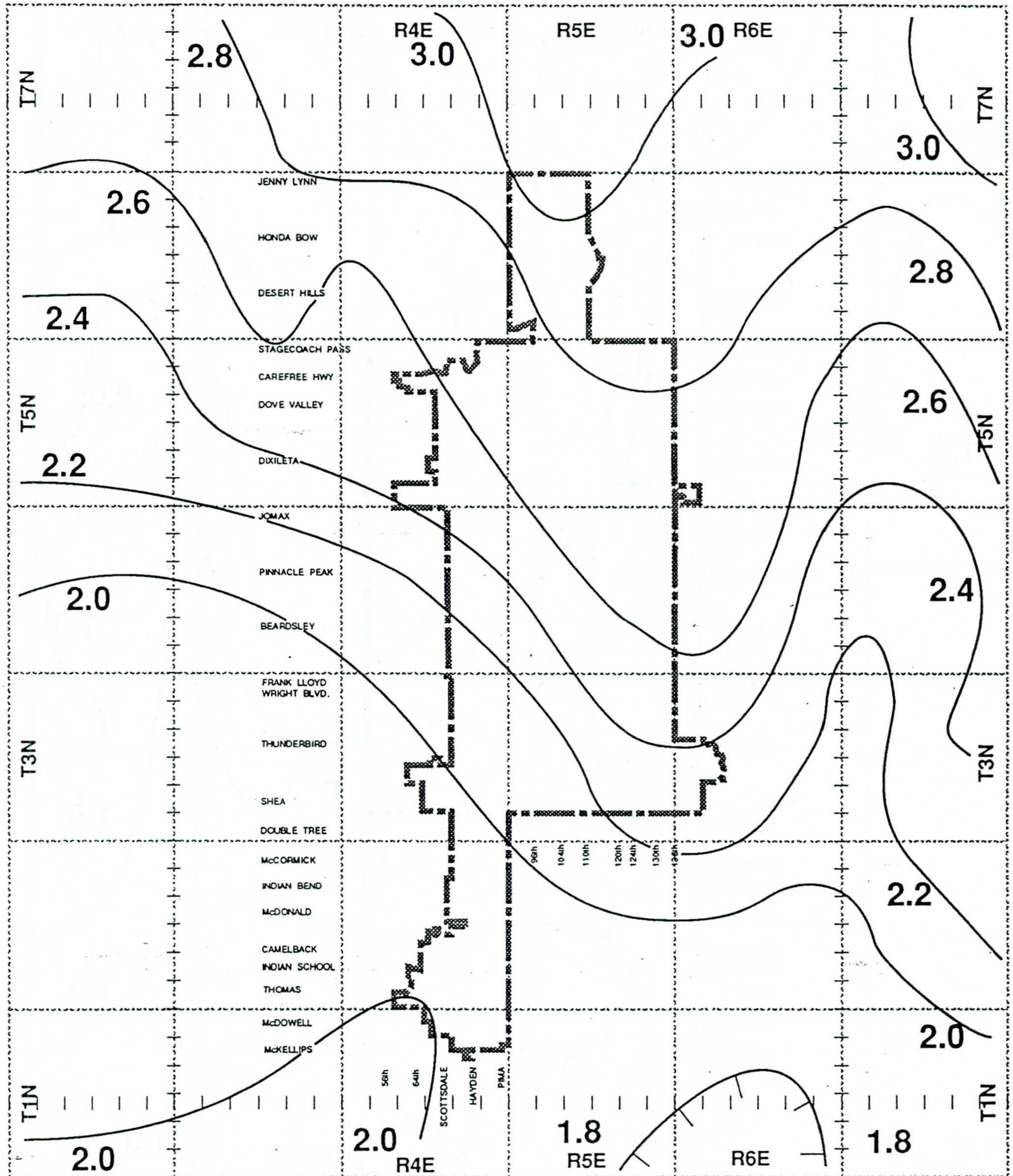


FIGURE 2.2-8

Isopluvials 5 Year 24 Hour Precipitation in Inches

Rainfall Data From NOAA Atlas 2, Vol. VIII

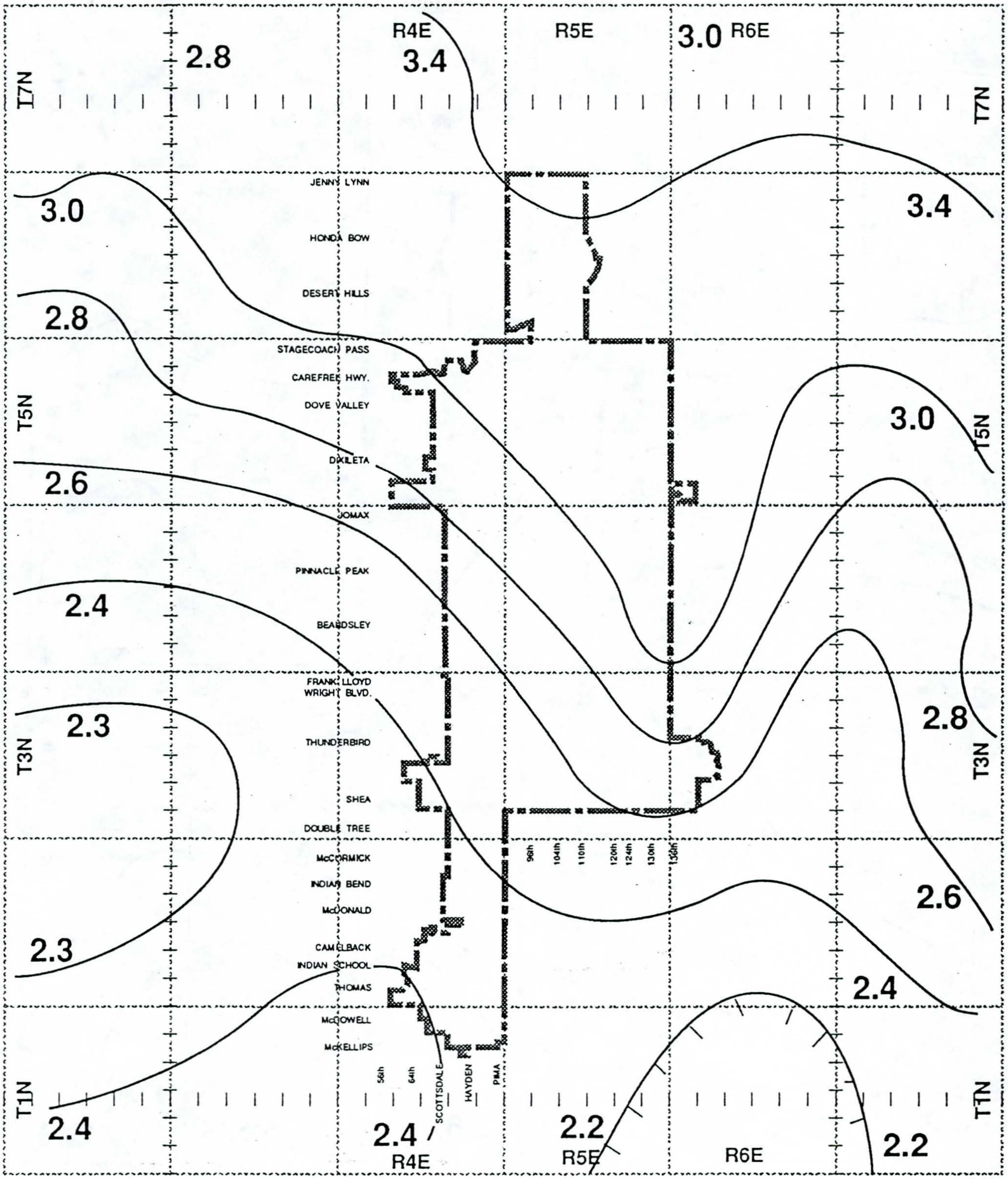


FIGURE 2.2-9

Isopluvials 10 Year 24 Hour Precipitation in Inches

Rainfall Data From NOAA Atlas 2, Vol. VIII

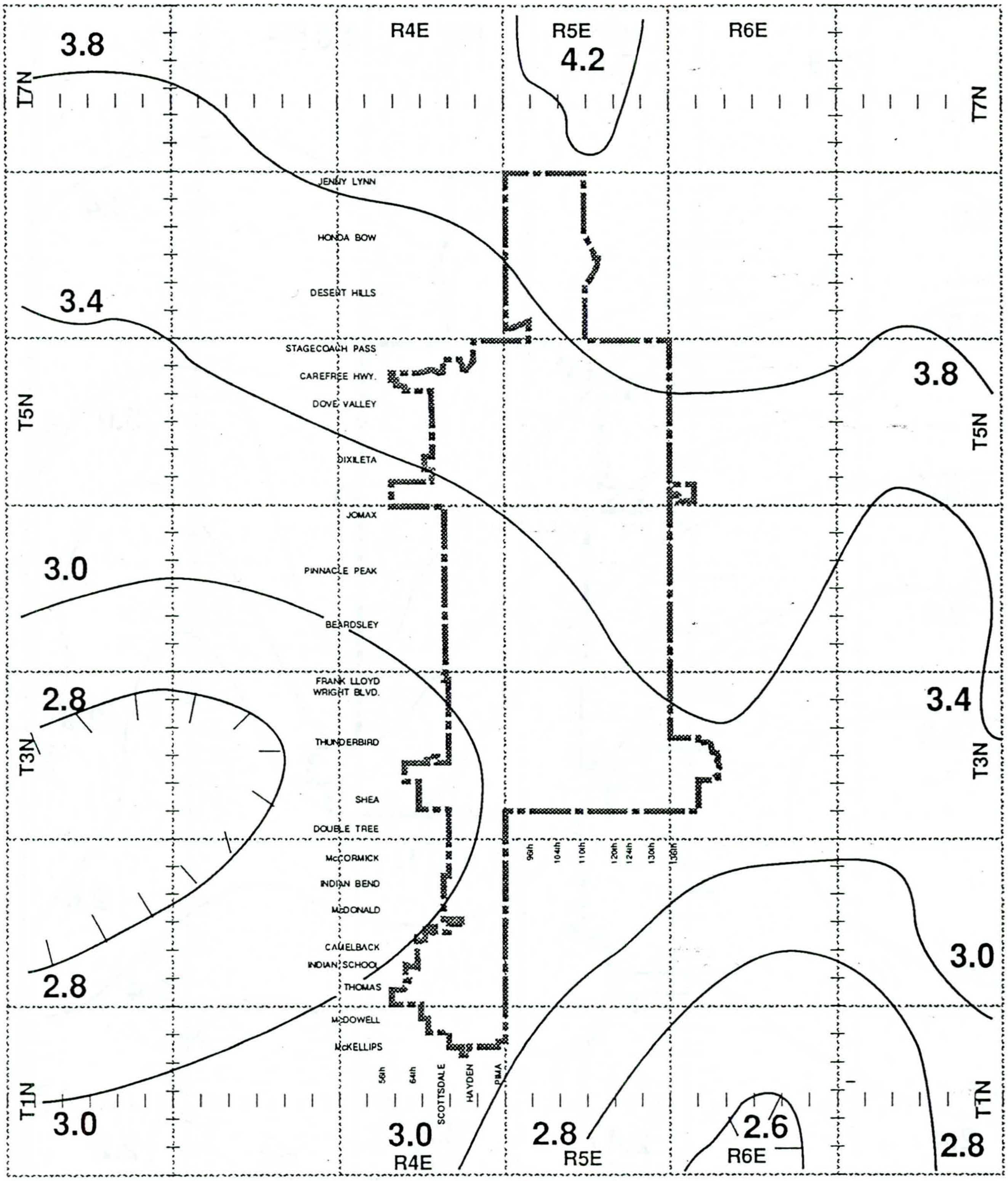


FIGURE 2.2-10

Isopluvials 25 Year 24 Hour Precipitation in Inches

Rainfall Data From NOAA Atlas 2, Vol. VIII

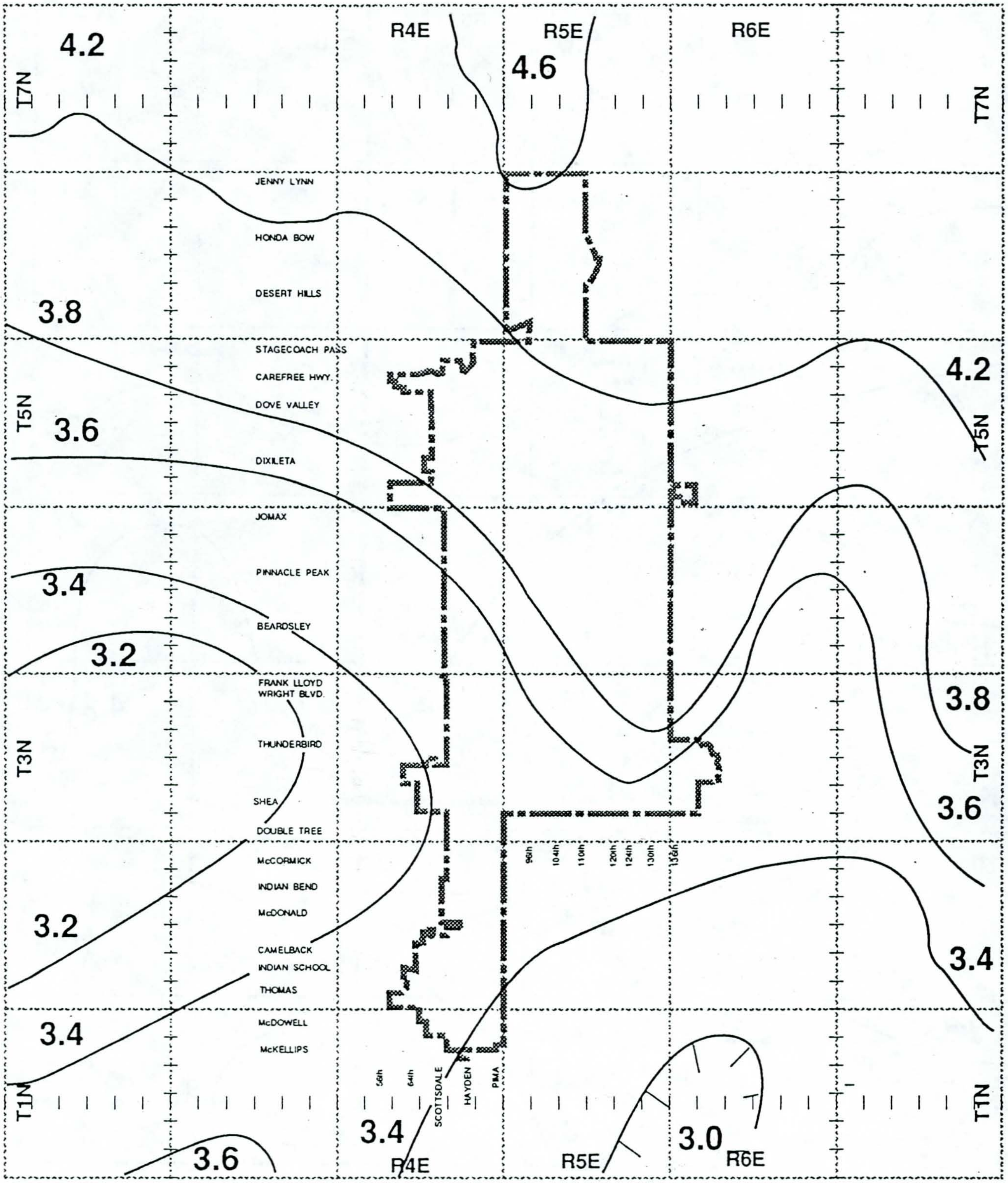


FIGURE 2.2-11

Isopluvials 50 Year 24 Hour Precipitation in Inches

Rainfall Data From NOAA Atlas 2, Vol. VIII

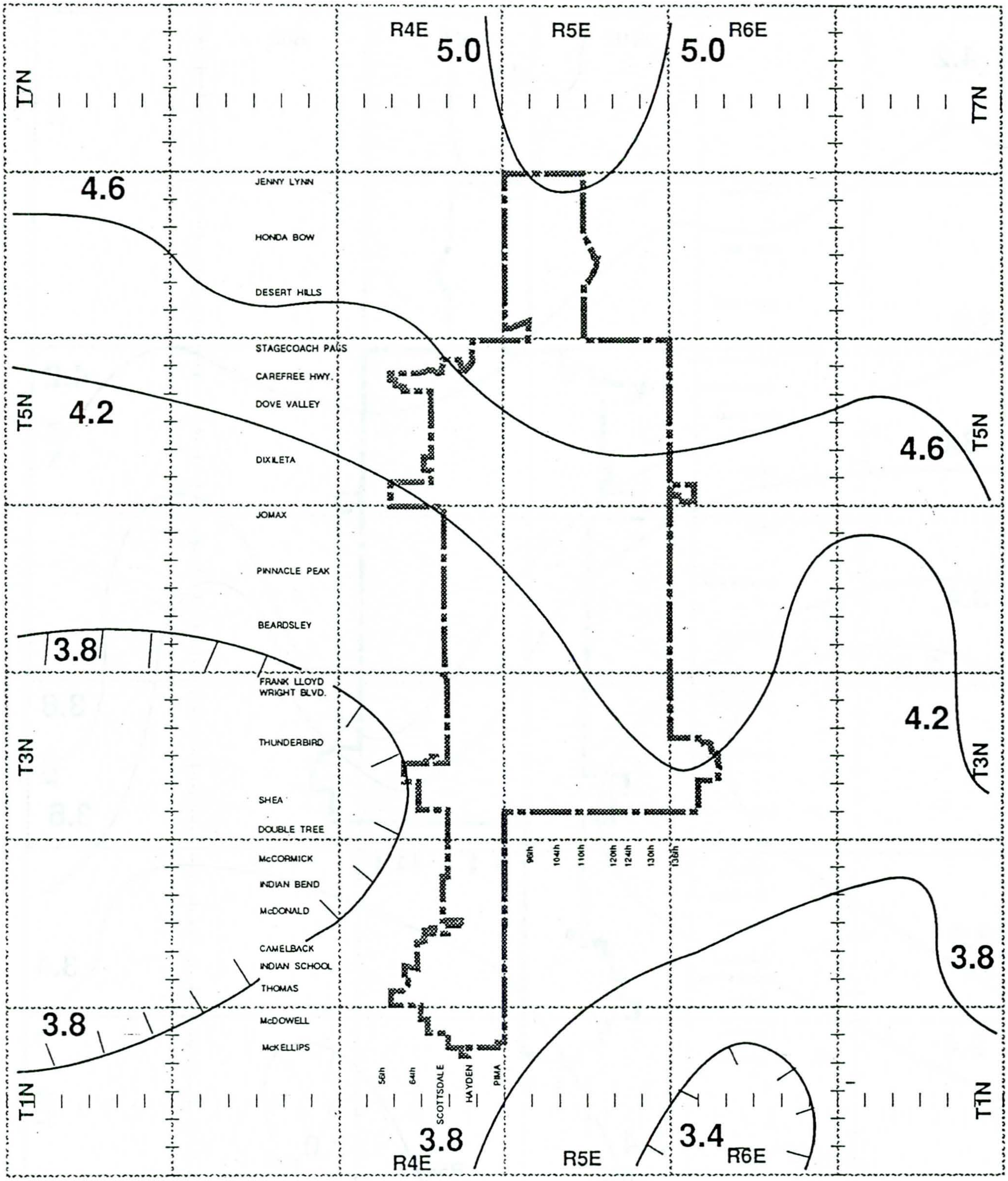


FIGURE 2.2-12

Isopluvials 100 Year 24 Hour Precipitation in Inches

Rainfall Data From NOAA Atlas 2, Vol. VIII

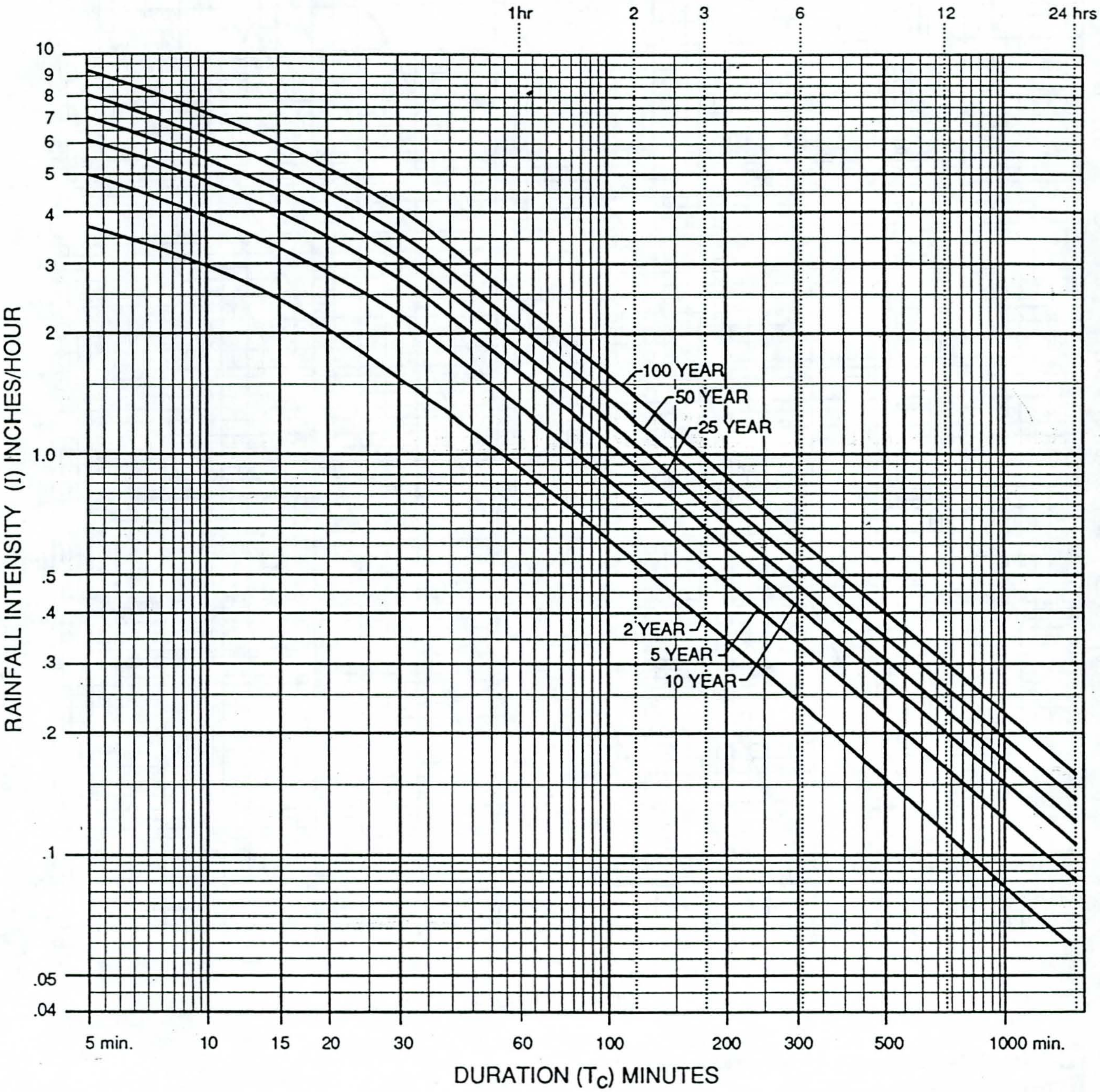
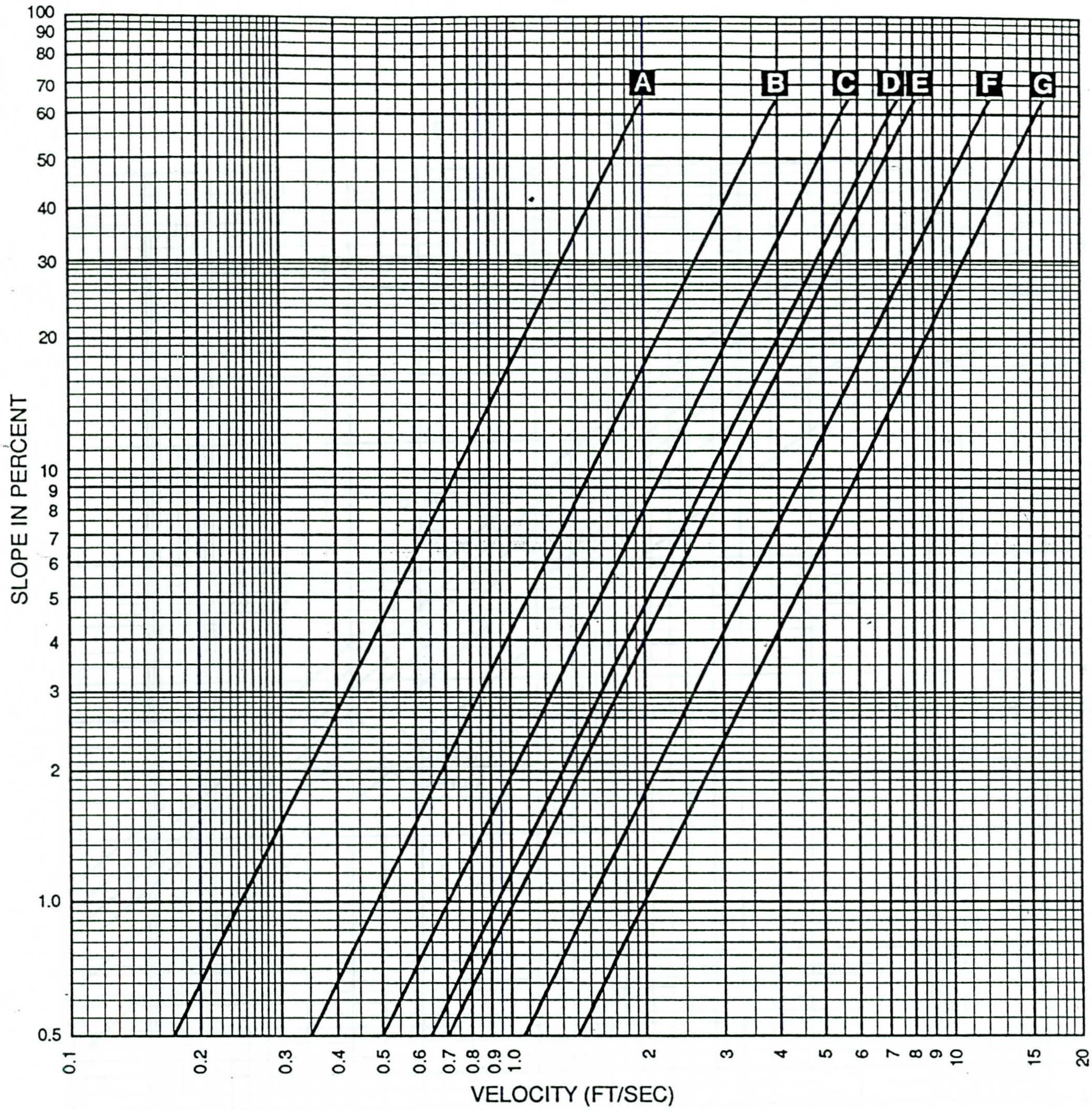


FIGURE 2.2-13

Rainfall Intensity (I) Values for Use in Rational Method

Source: Hydrologic Design Manual for Maricopa County



A Forest with heavy ground litter & hay meadow (overland flow)

B Trash fallow or minimum tillage cultivation; contour or strip cropped & woodland (overland flow)

C Short grass pasture (overland flow)

D Cultivated, straight row (overland flow)

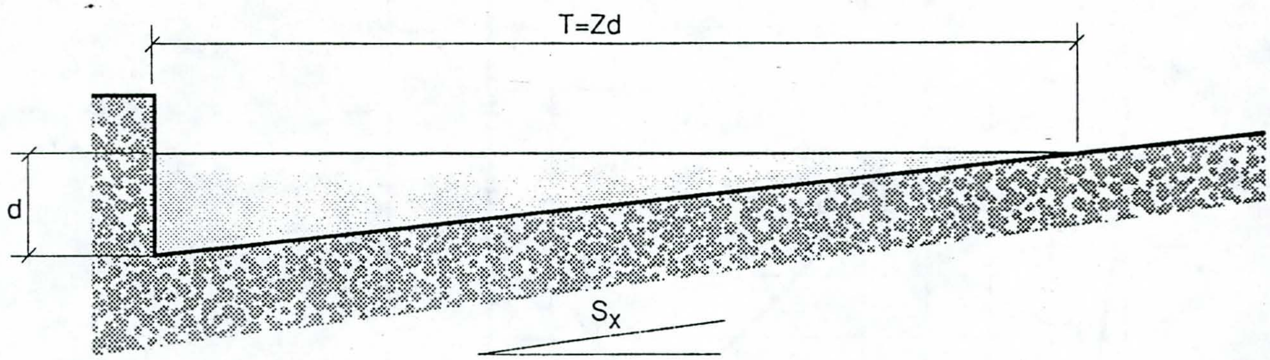
E Nearly bare and untilled (overland flow); alluvial fans western mountain regions

F Grassed waterway

G Paved area (sheet flow); small upland gullies

FIGURE 2.2-14

Overland Flow Velocities for Upland Method of Estimating T_C



$$Q=\left(\frac{0.56}{n}\right)S_x^{1.67}S^{0.5}T^{2.67*}$$

Where:

Q = Rate of discharge in cubic feet per second.

n = Manning's channel roughness coefficient.

S_x = Cross slope of gutter.

S = Longitudinal slope of gutter in feet per second.

T = Top width of water surface in feet.

d = depth of flow at curb in feet.

Z = Reciprocal of the cross slope T/d.

Since V=Q/A and $A=\frac{Zd^2}{2}$:

$$V=\left(\frac{1.12}{n}\right)S^{0.5}d^{0.67}\ \text{fps}^*$$

If n=0.013 (which is typical for concrete gutters):

$$V= 86\ S^{0.5}d^{0.67*}$$

If d=6" (0.5') when n=0.013:

$$V= 54\ S^{0.5*}$$

If d=4" (0.33') when n=0.013:

$$V= 41\ S^{0.5*}$$

*Does not apply when depth of water is above the top of curb

FIGURE 2.2-15

Flow Velocities in Street Gutters

(Source: Hydraulic Engineering Circular No. 12, U.S. Department of Transportation)

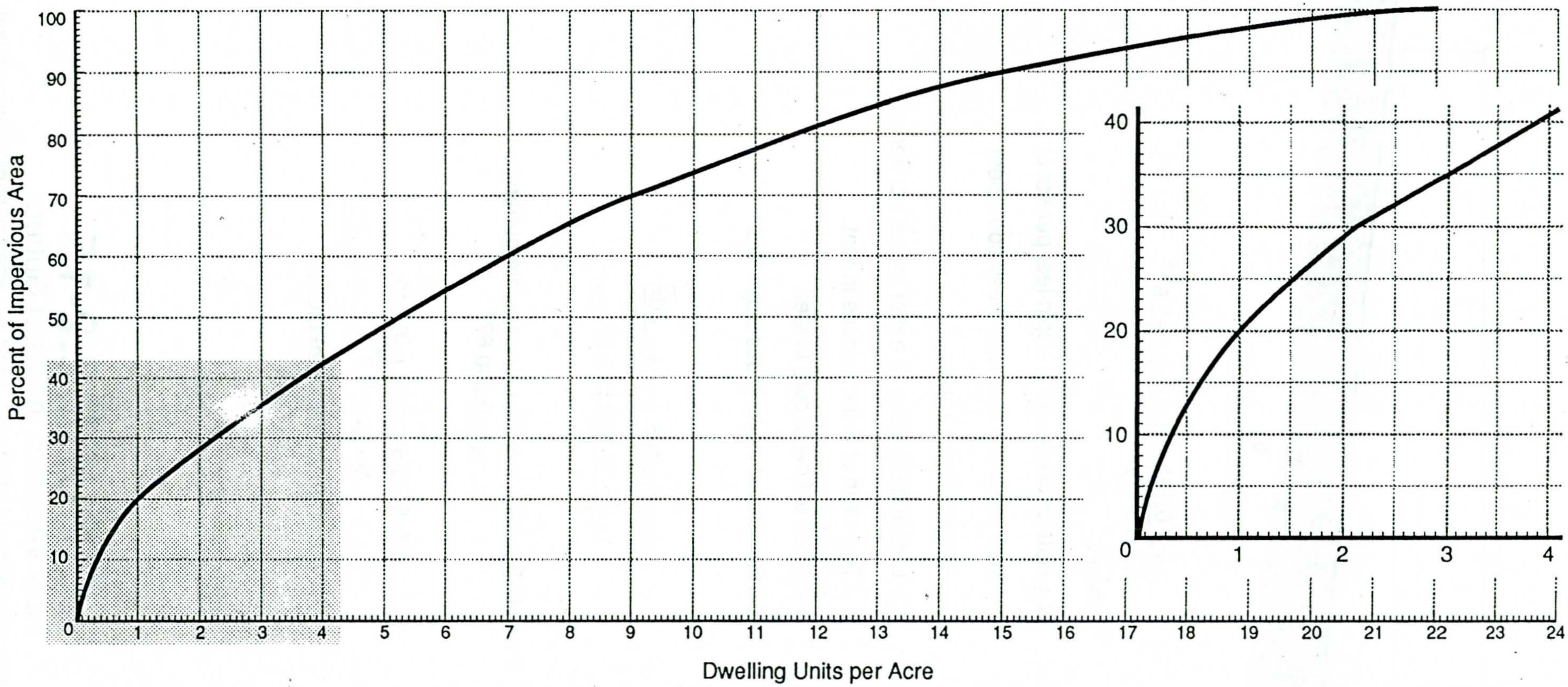


FIGURE 2.2-16

Percent of Impervious Area vs. Dwelling Density

ıveloped by Water Resources Associates, Inc. from data in Table 2.2a of TR-55, ı Hydrology For Small Watersheds, and from discussions with Scottsdale city s

Runoff Coefficients

Land Use	"C" Value Hydrologic Soil Group B	C	D
Composite Area-wide Values			
Commercial and industrial areas:	0.90		
Residential areas-single family (average lot size):			
R1-1-190:	0.33	0.50	0.58
R1-130:	0.35	0.51	0.59
R1-170:	0.37	0.52	0.60
R1-43:	0.38	0.55	0.61
R1-35 (35,000 sq. ft./lot):	0.40	0.56	0.62
R1-18 (18,000 sq. ft./lot):	0.43	0.58	0.64
R1-10 (10,000 sq. ft./lot):	0.47	0.62	0.67
R1-7 (7,000 sq. ft./lot):	0.51	0.64	0.70
Townhouses (R-2, R-4):	0.63	0.74	0.78
Apartments and condominiums (R-3, R-5):	0.76	0.83	0.87
Specific Surface Type Values			
Paved streets or parking lot (concrete or asphalt), roofs, dirveways, etc.	0.95		
Lawns, golf courses, and parks (grassed areas):	0.33	0.56	0.66
Undisturbed natural desert or desert landscaping (no impervious weed barrier):	0.31	0.48	0.56
Desert landscaping (with impervious weed barrier)	0.83	0.83	0.83
Mountain terrain - slopes greater than 10%:	0.70	0.70	0.70
Agricultural areas (Flood Irrigated Fields):	0.20	0.20	0.20

FIGURE 2.2-17

Runoff Coefficients (C) for use with the Rational Formula

CITY OF SCOTTSDALE

HYDROLOGIC DESIGN DATA RECORD
RATIONAL METHOD

LOCATION DATA

PROJECT: ______________________ CONCENTRATION POINT: ______________________

LOCATION: ____

PROJECT NO.: ______________________ STATION: ______________________

NAME OF STREAM/WATERSHED: ____

DESIGN DATA

DESIGN FREQUENCY:		2	5	10	25	50	100	YEARS
DRAINAGE AREA:	A1							ACRES
	A2							ACRES
	A3							ACRES
	TOTAL (A)							ACRES
DRAINAGE LENGTH:								FEET
ELEVATION:								
TOP OF DRAINAGE AREA:								FEET
AT STRUCTURE								FEET
DRAINAGE AREA SLOPE:								PERCENT
HYDROLOGIC SOIL GROUP:								

DESIGN COMPUTATIONS

FREQUENCY FACTOR (F):		1.00	1.00	1.00	1.10	1.20	1.25	
TIME OF CONCENTRATION:	T_c							MINUTES
RAINFALL INTENSITY (I):								INCHES/HOUR (Figure 2.2-13)
RUNOFF COEFFICIENT (C):	C1							
	C2							
	C3							
WEIGHTED RUNOFF COEFFICIENT (C_W):	C_W							
PEAK DISCHARGE $Q_p = C_W IA(F)$:								cfs

COMPUTED BY: ______________________ DATE: ______________

CHECKED BY: ______________________ DATE: ______________

FIGURE 2.2-18
Hydrologic Design Data Record

Runoff Curve Numbers for Urban Areas[1]

Cover type and hydrologic condition	Average % Impervious Area[2]	Curve numbers for hydrologic soil group A	B	C	D
Fully developed urban areas with vegetation established					
Open space (lawns, parks, golf courses, cemeteries, etc.)[3]:					
Poor condition (grass cover less that 50%)		68	79	86	89
Fair condition (grass cover 50-75%)		49	69	79	84
Good condition (grass cover greater than 75%)		39	61	74	80
Impervious areas:					
Paved parking lots, roads, driveways, etc. (excld. right-of-way)		98	98	98	98
Steets and roads:					
Paved; curbs and storm sewer (excld. right-of-way)		98	98	98	98
Paved; open dithces (including right-of-way)		83	89	92	93
Gravel (including right-of-way)		76	85	89	91
Dirt (including right-of-way)		72	82	87	89
Western desert urban areas:					
Natural desert landscaping (pervious areas only)[4]		63	77	85	88
Artificial desert landscaping (impervious weed barrier, desert shrub with 1 to 2-inch sand or gravel mulch and basin borders)		96	96	96	96
Urban districts:					
Commercial and business	85	Not Applicable in Scottsdale			
Industrial	85				
Townhouse, duplexes	65				
Multi-Family	85				
Residential districts by average lot size: (See Figure 2.2-16)					
Developing Urban Areas					
Newly graded areas (pervious areas only, no vegetation)[5]:		77	86	91	94

[1]Average runoff condition, and $I_a = 0.2S$; Table 2-2a, 210-VI-TR55, Second Ed., June 1986.

[2]The average percent impervious area shown was used to develop the compsite CN's. Other assumptions are as follows: impervious areas are directly connected to the drainage system, impervious areas have a CN of 98, and pervious areas are considered equivalent to open space in good hydrologic condition (not applicable in Scottsdale).

[3]CN's shown are equaivalent to those of pasture. Composite CN's may be computed for other combinations of open space cover type.

[4]Composite CN's for natural desert landscaping should be computed based on the impervious area percentage (CN = 98) and the pervious area CN. The pervious area CN's are assumed equivalent to desert shrub in poor hydrologic condition.

[5]Composite CN's to use for the design of temporary measures during grading and construction shoud be computed based on the degree of development (impervious area percentage) and the CN's for the newly graded pervious areas.

FIGURE 2.2-19

Runoff Curve Numbers for Urban Areas[1]

Runoff Curve Numbers for Arid and Semiarid Rangelands[1]

Cover type and hydrologic condition	Hydrologic Condition[2]	Curve numbers for hydrologic soil group			
		A	B	C	D
Herbaceous - mixture of grass, weeds, and low-growing brush, with brush the minor element.	Poor		80	87	93
	Fair		71	81	89
	Good		62	74	85
Oak-aspen - mountain brush mixture of oak brush, aspen, mountain mahogany, bitter brush, maple, and other brush.	Poor		66	74	79
	Fair		48	57	63
	Good		30	41	48
Pinyon-juniper - pinyon, juniper, or both; grass understory.	Poor		75	85	89
	Fair		58	73	80
	Good		41	61	71
Sagebrush with grass understory.	Poor		67	80	85
	Fair		51	63	70
	Good		35	47	55
Desert shrub - major plants include saltbush, greasewood, creosotebush, blackbrush, bursage, palo verde, mequite, and cactus.	Poor	63	77	85	88
	Fair	55	72	81	86
	Good	49	68	79	84

[1]Average runoff condition, and $I_a = 0.2S$; Table 2-2d, 210-VI-TR55, Second Ed., June 1986.
[2]Poor: <30% ground cover (litter, grass, and brush overstory).
Fair: 30 to 70% ground cover (not applicable in Scottsdale)
Good: >70% ground cover (not applicable in Scottsdale).
[3]Curve Numbers for group A have been developed only for desert shrub.

FIGURE 2.2-20

Runoff Curve Numbers for Arid and Semiarid Rangelands[1]

CN for Condition II	CN for Condition I	CN for Condition III	CN for Condition II	CN for Condition I	CN for Condition III
100	100	100	54	34	73
99	97	100	53	33	72
98	94	99	52	32	71
97	91	99	51	31	70
96	89	99	50	31	70
95	87	98	49	30	69
94	85	98	48	29	68
93	83	98	47	28	67
92	81	97	46	27	66
91	81	97	45	26	65
90	78	96	44	25	64
89	76	96	43	25	63
88	75	95	42	24	62
87	73	95	41	23	61
86	72	94	40	22	60
85	70	94	39	21	59
84	68	93	38	21	58
83	67	93	37	20	57
82	66	92	36	19	56
81	64	92	35	18	55
80	63	91	34	18	54
79	62	91	33	17	53
78	60	90	32	16	52
77	59	89	31	16	51
76	58	89	30	15	50
75	57	88			
74	55	88	25	12	43
73	54	87	20	9	37
72	53	87	15	6	30
71	52	86	10	4	22
70	51	86	5	2	13
69	50	85	0	0	0
68	48	84			
67	47	84			
66	46	83			
65	45	82			
64	44	82			
63	43	81			
62	42	80			
61	41	79			
60	40	78			
59	39	78			
58	38	77			
57	37	76			
56	36	75			
55	35	75			

FIGURE 2.2-21

Curve Numbers (CN) for Antecedent Moisture Conditions I, II, and III