R-3

Reno Drainage Study

Preliminary Report: Analysis of Drainage Deficiency Areas Within the City Limits

Prepared for

The City of Reno

December 1984

Prepared by

WINZLER AND KELLY

consulting engineers

RENO DRAINAGE STUDY

PRELIMINARY REPORT

ANALYSIS OF DRAINAGE DEFICIENCY AREAS WITHIN THE CITY LIMITS

DECEMBER 1984

Prepared for:

City of Reno

Prepared by:

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INTRODUCTION

A. PROJECT BACKGROUND

The City of Reno, Nevada is located at the base of the eastern slope of the Sierra Nevada Mountain Range in the Truckee Meadows basin. The present population is approximately 101,000. Reno City limits encompasses approximately 28,200 acres and extends from approximately South McCarran Blvd. in the south to the Stead area in the north.

Perhaps the most significant hydrologic feature is the Truckee River that flows northeast out of Lake Tahoe, passing through the Reno-Sparks metropolitan areas before turning north to Pyramid Lake. The Truckee River has caused significant flooding in the past, though the flooding threat has been reduced by flood control dams in the upper reaches.

There have been numerous storm drainage reports (dating back to 1957) dealing not only with the Truckee River flood potential, but local drainage flood potential. Table 1 lists these various studies. In addition, there have been numerous smaller drainage studies completed for various subdivisions in the Reno area.

TABLE 1

STORM DRAINAGE REPORTS

A Master Plan Report on Storm Drainage and Sanitary Sewerage for the City of Reno, October 1957 - Clyde C. Kennedy.

An Addendum Report on Storm Drainage, August 1963 - Kennedy Engineers.

Flood Plain Information, Truckee River, Reno-Sparks-Truckee Meadows, Nevada, October 1970 - Department of the Army, Sacramento District, Corps of Engineers.

City of Reno In-house Storm Drain Deficiency Report, started 1976.

Truckee Meadows Investigation (Reno-Sparks Metropolitan Area) Nevada Plan for Channel Modifications - Truckee River - Twin Lakes Drive to U.S. Highway 395 (River Mile 55.12 to 50.49, March 1982 - Leeds, Hill and Jewett, Inc.

B. PRESENT PROJECT

Although a significant number of the proposed projects in the various drainage reports have been completed, there are still numerous isolated areas within the city where flooding continues to be a problem.

The City of Reno recently authorized a study that would review these various drainage deficiency areas in an attempt to define what the problem or problems are at the various locations. In addition, the City requested that the existing rainfall intensity duration-frequency curve for the Reno area developed in 1960 be updated. During the negotiations, it was decided that rainfall isopleth maps be developed in conjunction with the new rainfall intensity curves which would enhance the rainfall intensity accuracy for those areas not adjacent to the Reno-Cannon International Airport.

At the present time, twenty drainage deficiency areas have been identified, including the Stead area where the City of Reno has requested that a complete drainage report be prepared. Table 2 lists the various deficiency areas by priority. The original contract allowed for twenty-five deficiency areas to be analyzed so it is possible that the above table could be modified. Figure 1 is an enclosed City Street Map that identifies the twenty deficiency areas as to location.

TABLE 2

STORM DRAINAGE DEFICIENCY AREAS[1]

PRIORITY	LOCATION
1	Stead - including Stead Blvd. and Old State Complex (full drainage study)
2	Huffaker Hills Area
3	Harding and Gulling
4	Plumas Street near West Moana
5	Rewana Farms, north of Peckham
6	Market Street and Miami Way
7	Roberts Street near Yori Avenue (Libby C. Booth School)
8	Thomas Jefferson Drive and Aguila Avenue
9	Belford Road and Sharon Way
10	Second Street at the railroad crossing
11	Charles Drive - Clough Road area
12	Marsh Avenue and LaRue Avenue
13	Riverside Drive and Ralston Street
14	Lake Ridge Golf Course area
15	Panther Valley area
16	Longley Lane and McCarran Blvd.
17	University Drain at Longley Lane
18	Grant Drive and West Moana Lane
19	Parr Blvd. near Catron Drive
20	Dry Creek Drainage

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[1] Refer to Figure 1 for location of deficiency areas.

CHAPTER II

EXISTING AND PROJECTED STUDY AREA CHARACTERISTICS

A. INTRODUCTION

The intent of this chapter is to describe pertinent physical, demographic, environmental, and economic characteristics of the study area to provide a basis of development of the Reno Storm Drainage Report. Included are descriptions of the geographical setting, land use patterns, economic activity, population, and environmental setting within the study area.

B. GEOGRAPHICAL SETTING

1. TOPOGRAPHY

Reno is situated on the east side of the Sierra Nevada mountain range in a basin called the Truckee Meadows. The area generally slopes from west to east and from north to south. The downtown area is at approximately 4,500 feet while the Stead area to the north is approximately 5,000 feet elevation.

2. CLIMATE

The Reno area has a mild semi-arid climate. Temperatures range from a summer high in the low 90's to a winter low average of 18°F.

The average annual precipitation is only about 7¼ inches, although this average increases substantially closer to the Sierra Nevada Mountains in the west. The Truckee River flow is greatly affected by this much higher precipitation average and heavy snow pack to the west. The low annual rainfall can be deceiving in designing storm drainage systems as the storms that occur, particularly in the summer months, can be very intense.

The precipitation that occurs can be fit into two separate classes of storm events. During the winter months (from November through April) the rainfall events are generated by a frontal type storm event. During the summer months (from May through October) the rainfall events are generated from more localized convection or thunderstorm events.

3. NATURAL DRAINAGE SYSTEMS

The most significant natural drainage system within the study area is the Truckee River that traverses from west to east through the heart of the downtown area. The channel width varies between 125 feet and 200 feet and the channel bed slope averages approximately 0.1%. The channel banks and overbanks range from natural conditions to concrete flood walls.

There are numerous other creeks and ephemeral streams within the study area as well as several major irrigation ditches. Major drainages would include Steamboat Creek, Peavine Creek, Evans Creek, and Dry Creek.

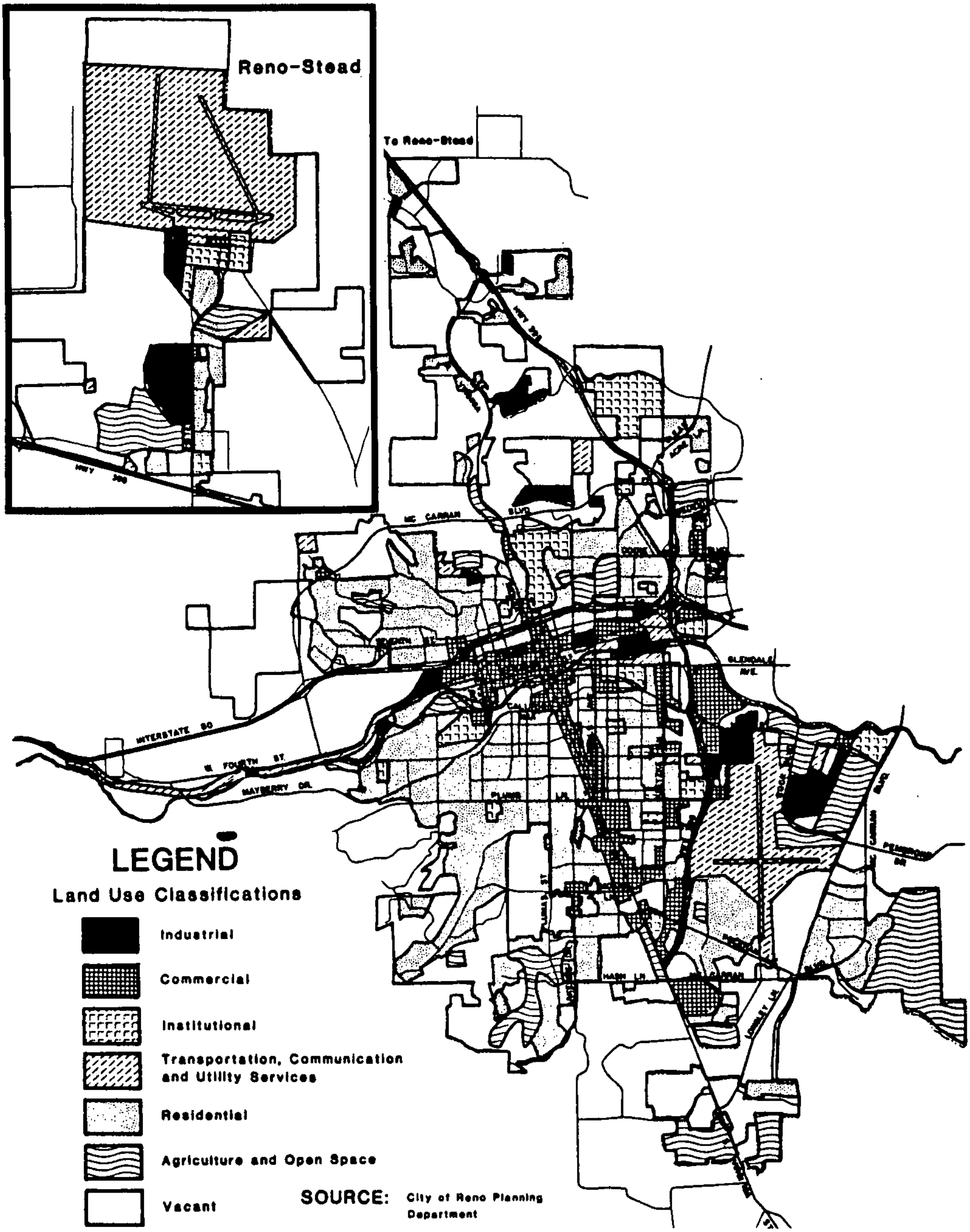
C. LAND USE

The predominant land uses within Reno (including the Reno-Stead area) are "vacant" and "residential", accounting for over 65% of the total 28,187 acres within the city boundary.

Figure 2 is a simplified version of the current Reno land use map. Table 3 taken from the Reno City Profile, A State-of-the-City Report, 1981-1982, presents the land use by city section.

City of Reno

Present Land Use Map



SOURCE: City of Reno Planning Department

Figure 2

TABLE 3

LAND USE, CITY OF RENO, SPRING 1981
(ACRES)

Area	Residential	Commercial	Industrial	Transportation	Communications & Utilities	Institutional	Open Space	Vacant	Total
Northwest	1,734 37.3%	185 4.0%	48 1.0%	325 7.0%	100 2.1%	83 1.8%	179 3.8%	2,001 43.0%	4,655 100%
Northeast	927 23.0%	249 6.1%	275 5.8%	448 11.1%	11 0.3%	585 14.5%	246 6.1%	1,295 32.1%	4,036 100%
Southwest	2,580 51.0%	224 4.4%	6 0.1%	88 1.8%	20 0.3%	127 2.5%	531 10.5%	1,489 29.4%	5,065 100%
Southeast	1,792 24.9%	763 10.6%	299 4.1%	1,125 15.6%	70 1.0%	271 3.8%	1,354 18.8%	1,528 21.2%	7,202 100%
City w/o Stead	7,033 33.5%	1,421 6.9%	628 3.0%	1,986 9.5%	201 0.9%	1,066 5.1%	2,310 11.0%	6,313 30.1%	20,958 100%
Stead	366 5.0%	12 0.1%	266 3.7%	1,350 18.7%	79 1.1%	122 1.7%	337 4.7%	4,697 65.0%	7,229 100%
City w/Stead	7,399 26.2%	1,433 5.1%	894 3.2%	3,336 11.8%	280 1.0%	1,188 4.2%	2,647 9.4%	11,010 39.1%	28,187 100%

The city has recently completed a Land Use/Transportation Master Plan. Figure 3 from this study is a proposed ultimate land use plan for the Reno area. There is a trend towards higher densities in the outlying areas. Much of the existing agricultural and open space land is slated for future residential development.

This future land use map will be used to develop the runoff coefficients "C" for the various drainages being analyzed.

D. ECONOMIC ACTIVITY

The gaming and tourist industry is the backbone of the Reno economy. However, there has been a push to diversify the economic base and the wholesale trade and manufacturing sectors have shown dramatic growth over the last several years. On the whole, Reno is faring much better economically than other cities in the west.

E. POPULATION

Mirroring the expanding economic growth, the population growth has shown a steady increase over the last decade. Census figures of 1980 indicate a population of 100,756 in Reno, indicating a 35% increase in population from 1970 to 1980. This is, however, significantly lower than the 60% growth rate that occurred within Washoe County over the same ten year period. A major reason for this difference has been a growth boom in the outlying areas outside the city corporate limits, due in large part to a migration out of the city limits.

This population growth has meant significant new construction within the past decade with an associated increase in drainage problems, especially in the outlying areas of the city where new subdivisions are springing up.

Future Land Use Map

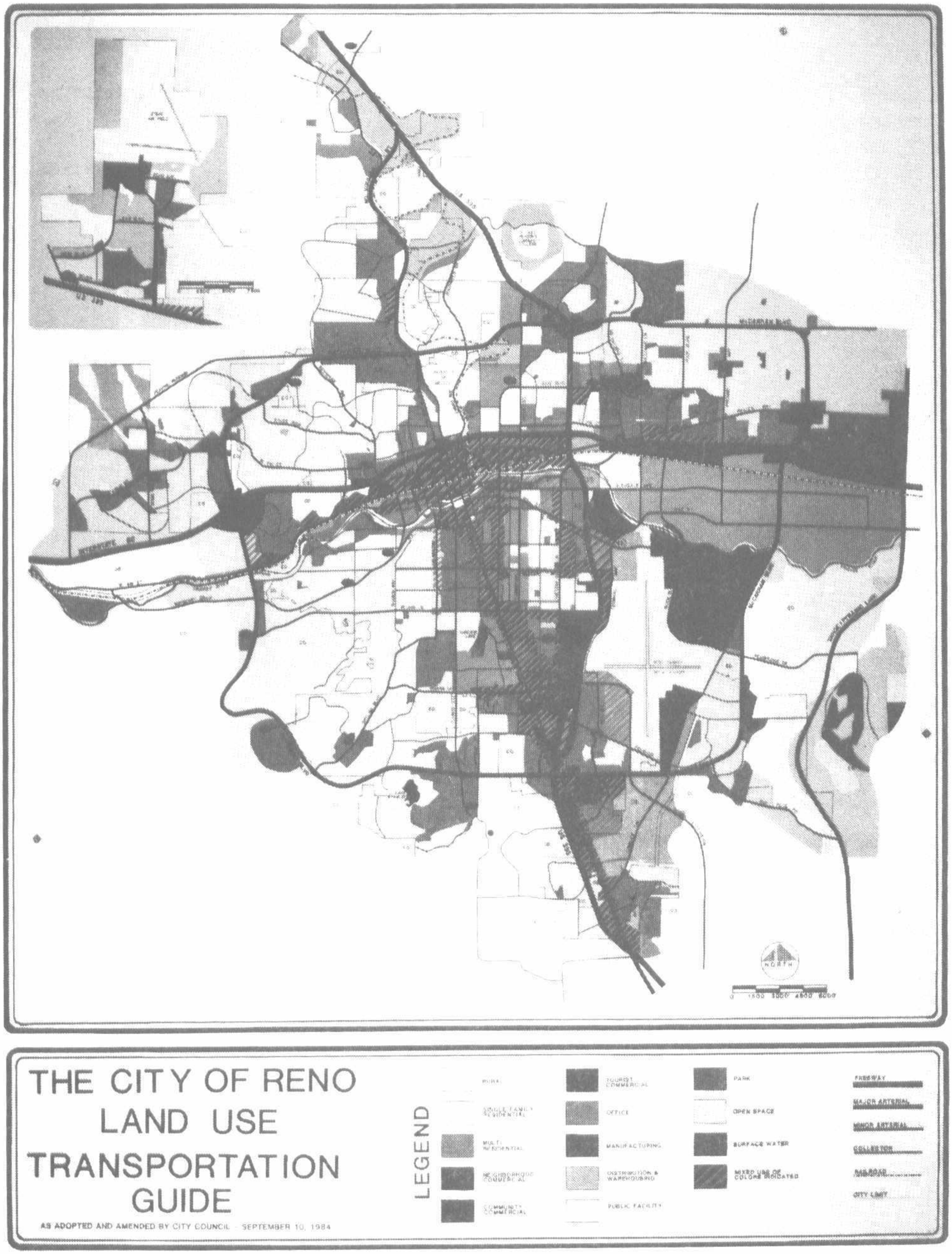


Figure 3

The major growth-restricting factor for the Reno area is the limited water supply. The ultimate city population is estimated at 175,000, based on this predicted available water supply.

F. ENVIRONMENTAL SETTING

1. PHYSICAL CHARACTERISTICS

The physical characteristics of the project area have been discussed in detail in previous sections of this chapter.

2. BIOTIC ENVIRONMENT

The major portion of the undeveloped property in the study area can be characterized as a semi-arid high-altitude desert community. There is little vegetation in the surrounding undeveloped areas and runoff can be expected to be relatively rapid, especially during the intense convection storm events of summer. Significant erosion can occur during this time, compounding the drainage problems by siltation of channels and pipes.

CHAPTER III

DESIGN CONSIDERATIONS

A. INTRODUCTION

One of the principal purposes of this study is to develop criteria applicable to the design of drainage facilities. This chapter reviews existing data including design reports, mapping and planning documents, and rainfall records to establish pertinent design criteria.

B. LAND USE CLASSIFICATIONS

1. EXISTING LAND USE

The existing land use within the Reno area is characteristic of a developing urban center surrounded by residential development (refer to Chapter II, Figure 2). The outlying areas are generally undeveloped open spaces or parks.

2. FUTURE LAND USE

Future land use should follow the recently developed land use plan (refer to Chapter II, Figure 3) with a trend toward increasing densities as development warrants.

C. STORM DRAINAGE SYSTEM

The city has storm drainage mapping that is relatively up to date. There are several areas where the existing facilities are inadequate, especially when considering future growth.

Part of the scope of this study is to field verify the existing storm drainage structures at the various drainage deficiency areas. Initial field work at some of these areas have shown that siltation can be a significant problem. It is possible that some of the storm drainage facilities are adequately sized if they were kept clear of silt and rubbish. Perhaps a much more rigorous storm drainage inspection/maintenance program will be required to keep the drains open, thereby averting potential flooding problems.

D. HYDROLOGY - HYDRAULICS CONSIDERATIONS

1. HYDRAULIC DESIGN

The city has a policy requiring design of the majority of storm water facilities to pass 5-year return frequency storm flows. Major drainage facilities, where the drainage basin is 100 acres or greater, are sized to pass 100-year return frequency storm flows. Although the ordinance does not state it specifically, it is recommended that storm drains sized for 5-year storm events be sized to pass these flows with no static head. This will allow additional flows to pass with some head for storm events exceeding the 5-year return frequency.

The Federal Emergency Management Agency (FEMA) has a set of minimum standards for development in the flood plain. No development is allowed in the actual floodway, which is the channel of a stream plus any adjacent flood plain areas that must be kept free of encroachment in order that a 100-year flood may be carried without substantial increases in flood height. In addition, any development in the floodway fringes cannot cause more than a one foot rise in flood heights and any such development must be at least one foot above the 100-year flood elevations.

2. RATIONAL METHOD

The Rational Method is the most used method in this country for computing quantities of storm water runoff. It allows consideration of local conditions and relates runoff directly to rainfall by the following equation:

$Q = cia$

where: Q = peak runoff rate in cubic feet per second

c = runoff coefficient which is actually the ratio of the peak runoff rate for particular surface types and permeabilities to the average rainfall rate for a period known as the time of concentration.

i = average rainfall intensity in inches per hour for a period equal to the time of concentration.

a = drainage area in acres

3. RUNOFF COEFFICIENT

The proper selection of runoff coefficient "c" is critical for storm water runoff computations. It is dependent on a number of factors including slope condition and imperviousness of the surface, as well as the degree of saturation.

The expected land use can greatly affect the amount of runoff which will significantly increase with increased development. After discussions with City staff, values of the runoff coefficient "c" were developed based on the present and future Reno Land Use Maps for the area as shown on Figures 2 and 3. They are listed in Table 4.

TABLE 4

RUNOFF COEFFICIENTS "C"

Land Use Type	Runoff Coefficient "C"
Rural	0.25-0.35
Single Family Residential	0.45-0.55
Multi-residential	0.60-0.70
Neighborhood Commercial	0.85
Community Commercial	0.85
Tourist Commercial	0.85
Office	0.85
Manufacturing	0.85-0.90
Distribution and Warehousing	0.85-0.90
Public Facility	0.50-0.85
Park	0.25
Open Space	0.20-0.30

These values are somewhat conservative when used for entire areas, as it assumes maximum build-out in all these areas. Substantial portions of rural and low density areas may not develop to full potential. However, it is difficult to determine where growth will or will not develop, and costs of storm water drainage systems are very expensive. Thus, it is generally preferable to size the system for maximum development rather than having to upsize the system later.

The City Ordinance generally does not allow increased runoff from that already existing for new developments. All additional runoff generated from increased development must be kept on site by the use of on-site storage. This is especially true if the increased runoff would exceed the existing downstream storm drainage facilities capacity.

However, exceptions have been allowed in the past. Thus, it is recommended that a more detailed hydraulic study be required for the individual drainage systems at the design or predesign stage. At this time the actual zoning or land use for the area in question should be re-evaluated to arrive at an acceptable runoff coefficient "c". This report will consider two cases. Case I assumes that additional runoff will be kept on site. This case will use Figure 2, the present land use map, to develop runoff coefficients. Case II assumes that additional runoff will be allowed and maximum development will take place. This case will use Figure 3, the future land use map, to develop runoff coefficients.

4. RAINFALL INTENSITY AND DURATION

An accurate measurement of rainfall intensity and duration "i" is necessary to determine storm water flows for a particular area.

The existing rainfall intensity-duration-frequency (IDF) curves for the Reno area were developed in 1960 and are based on rainfall records through 1939.

One of the major tasks of this study is to develop new rainfall IDF curves based on more updated data that is available.

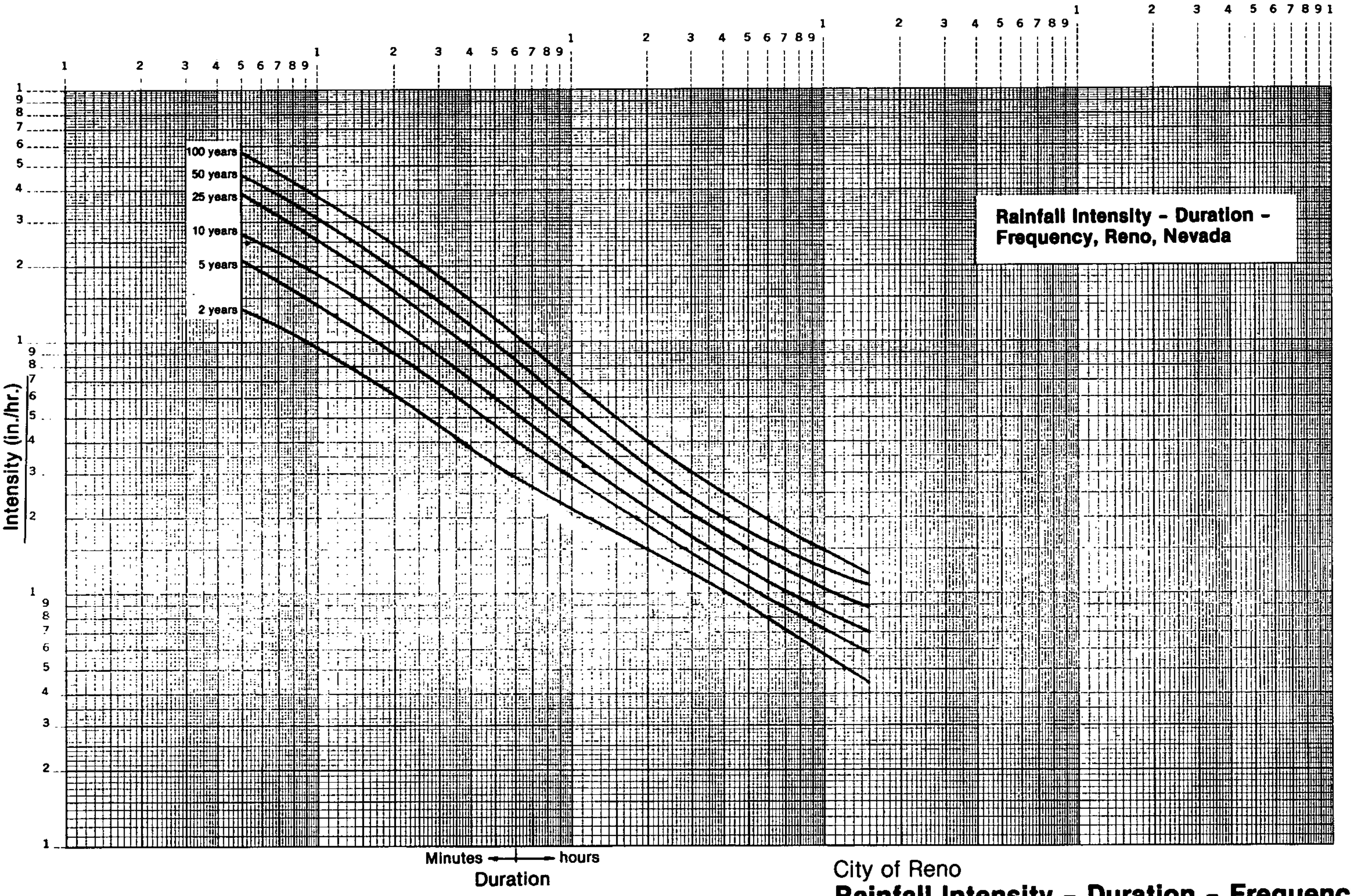
In addition, the scope of work includes the analysis of spatial variation of rainfall in the study area. This requires developing rainfall isopleth maps for both the summer and winter seasons, based upon available rain gauging stations in the area.

Three sources of rainfall information were analyzed in developing the rainfall IDF curves. These are:

1) National Weather Service, "Technical Paper No. 40," 1964
2) NOAA "Rainfall Atlas 2 - Volume Vii," 1972
3) Analysis of raw precipitation data from the National Weather Service Climatic Center in Asheville, North Carolina for the Reno-Cannon Airport from 1952 to 1983.

Rainfall IDF curves were developed from each individual source of information (refer to Figures A-1, A-2, and A-3 in the Appendix). An interesting point to note is that, generally, the longer the data base used, the lower the rainfall IDF curves become.

After careful analysis it was decided that the curve based strictly on rainfall records at the Cannon Airport (Figure 4) combined with the use of the rainfall isopleth maps would present the most accurate rainfall intensity records for the various drainages in the study area. It should be noted that the data presented is recommended for use only within the study area. Use of the rainfall IDF curves for areas outside the study area should be done so with caution and careful engineering judgment.



City of Reno

Rainfall Intensity - Duration - Frequency Curves for General Reno Area

Based on Rainfall Data from Cannon Airport Gaging Station

Figure 4

The rainfall isopleth maps are based on nine unofficial gauging stations in the area that have daily rainfall information available for use. These stations are located at Dickerson Road, Royal Drive, Upper Skyline, Ganser, La Veaga Court, Verdi, Sparks Fire Station, Sierra Sage Road, and Christmas Tree.

Each rainfall event at every location was compared and a ratio computed to the corresponding values recorded by the local weather service station at the Reno Cannon Airport. The summer season was assumed to extend from May through October and the winter season was assumed to extend from November through April. The two rainfall isopleth maps are shown as Figures 5 and 6.

2,000-scale overlays of these isopleth maps have been completed to be used in conjunction with the standard 7.5 minute topographic quadrangle maps of the Reno area.

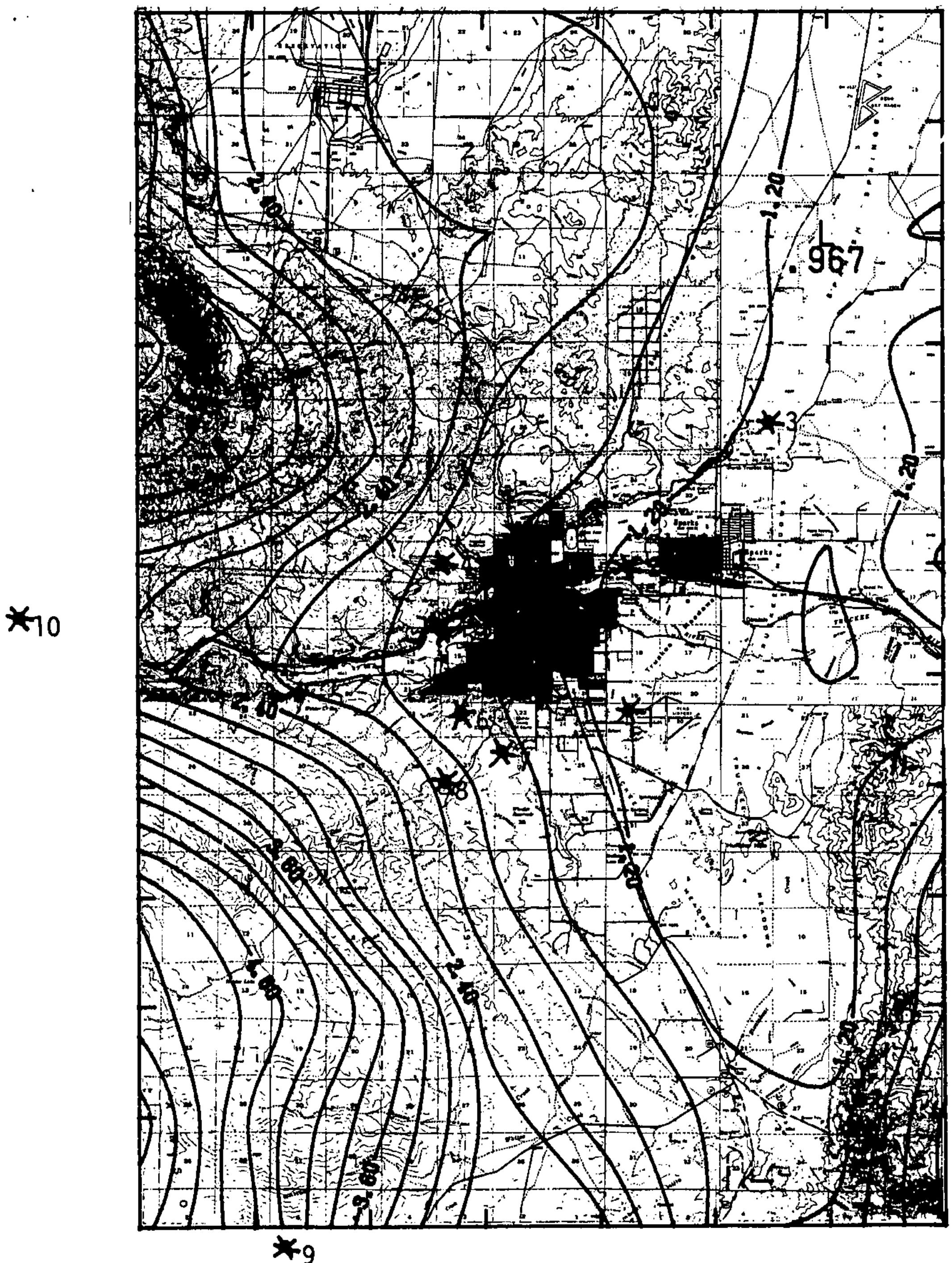
Figure 7 describes the use of the rainfall isopleth maps for a typical drainage area. Basically the drainage area is divided into subareas, each corresponding to the area under a particular isopleth range. A weighted average is obtained and this average is multiplied by the rainfall intensity taken from the rainfall IDF curve for the Reno-Cannon Airport to derive a modified rainfall intensity for the drainage basin in question.

In using these rainfall isopleth maps, it is recommended that a rainfall intensity correction factor be calculated for both the summer and the winter season. The highest correction factor should be used in calculating the rainfall intensity to be used in the Rational Formula.

For additional information on the development of the rainfall IDF curves and the rainfall isopleth maps, please refer to the report prepared by Dr. Tung of the University of Nevada-Reno, appended to this report.

City of Reno

Rainfall Isopleth Map for Wet Season November to April



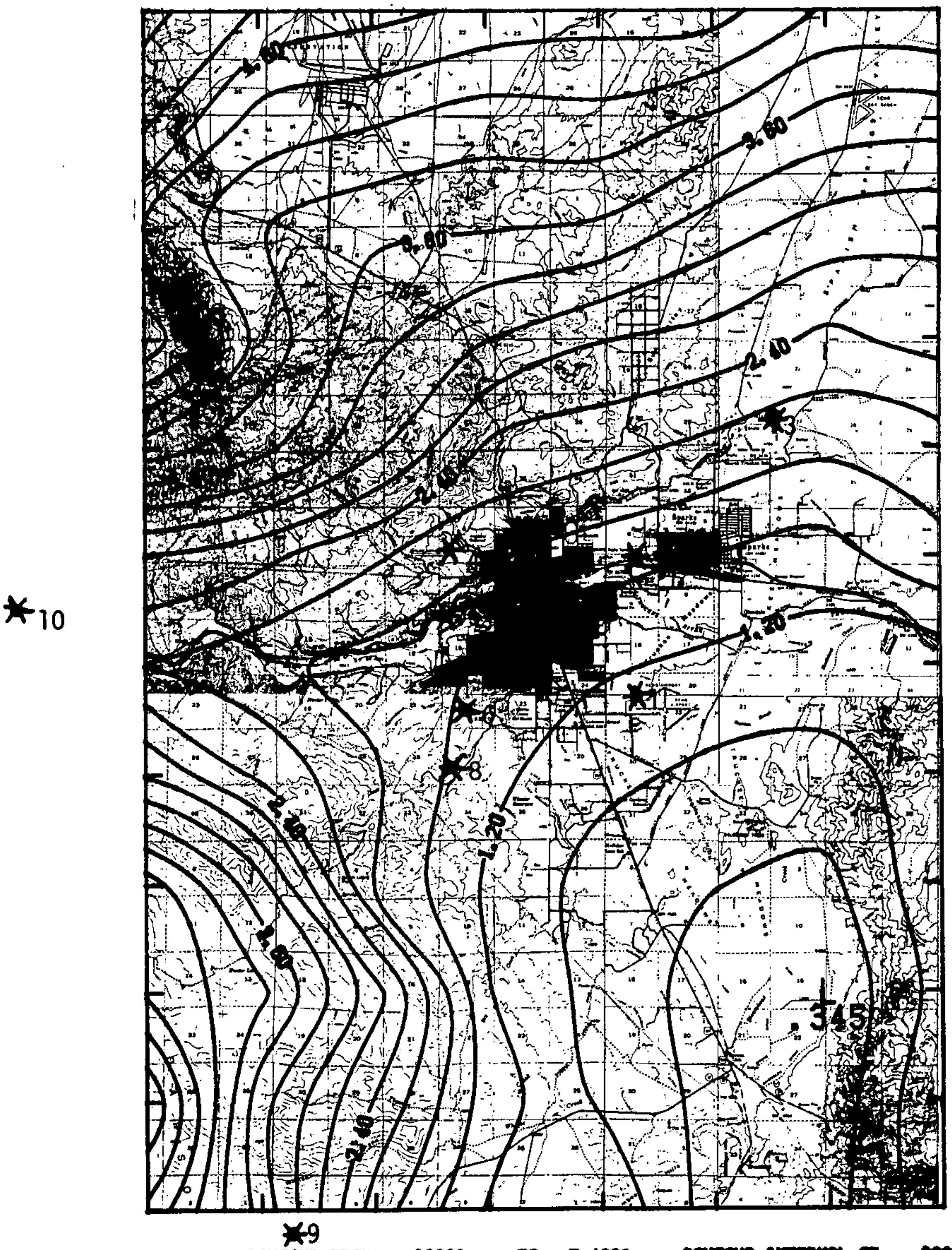
1. Cannon Airport
2. Sparks Fire Station
3. La Veaga Ct.
4. Royal Dr.
5. Dickerson Rd.
6. Ganser
7. Sierra Sage Ln.
8. Upper Skyline
9. Christmas Tree
10. Verdi

CONTOUR FROM .60000 TO 6.0000 CONTOUR INTERVAL OF .60000 PT(3,3)= 4.0878

Figure 5

City of Reno

Rainfall Isopleth Map for Dry Season May to October



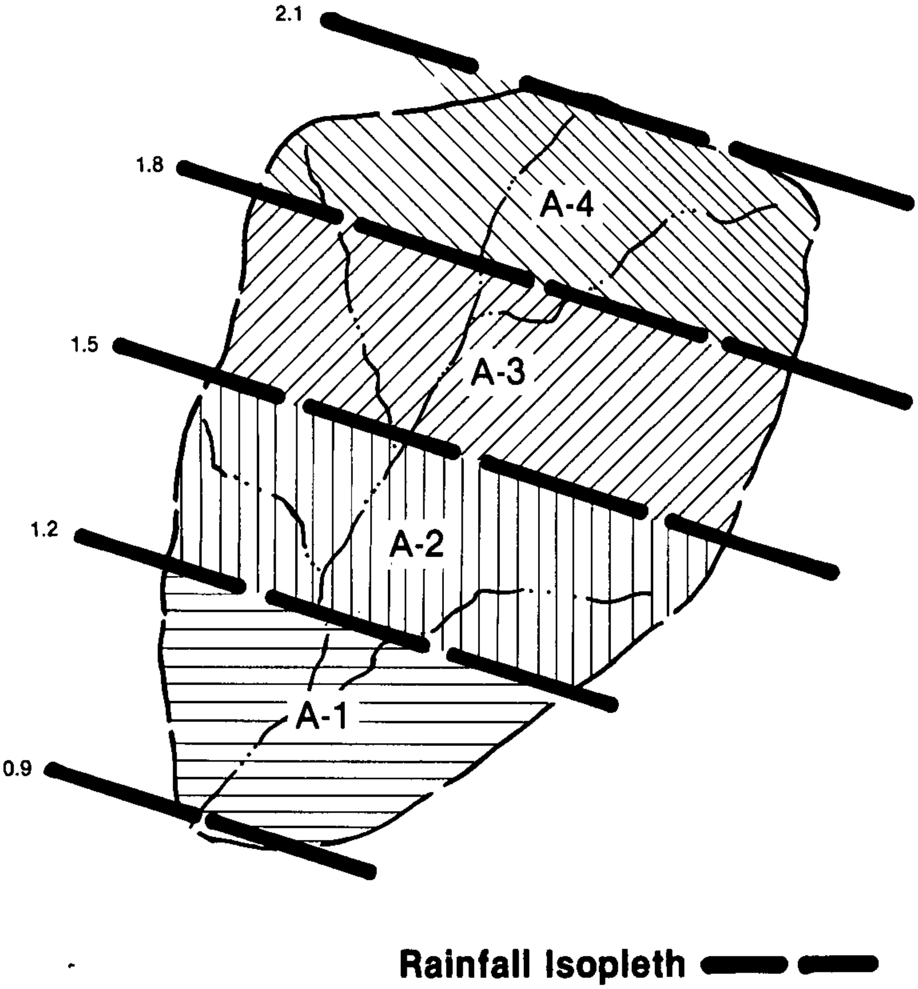
CONTOUR FROM .30000 TO 5.4000 CONTOUR INTERVAL OF .30000 PT(3,3)= 2.8281

1. Cannon Airport
2. Sparks Fire Station
3. La Veaga Ct.
4. Royal Dr.
5. Dickerson Rd.
6. Ganser
7. Sierra Sage Ln.
8. Upper Skyline
9. Christmas Tree
10. Verdi

Figure 8

City of Reno

Rainfall Isopleth Map Usage (Typical Example)



Rainfall Intensity Correction Factor =

$$\frac{\mathbf{A\text{-}1}\left(\frac{0.9+1.2}{2}\right) + \mathbf{A\text{-}2}\left(\frac{1.2+1.5}{2}\right) + \mathbf{A\text{-}3}\left(\frac{1.5+1.8}{2}\right) + \mathbf{A\text{-}4}\left(\frac{1.8+2.1}{2}\right)}{\mathrm{A_{TOTAL}}}$$

NOTE: This modified rainfall intensity factor is multiplied by the rainfall intensity value from the Cannon Airport Curves

5. TIME OF CONCENTRATION

The time of concentration, "t_c", is defined as the flow time from the most remote point in the drainage area to the point in question. It is composed of two parts, inlet time and conduit travel time. Inlet time consists of the time required for water to flow overland from the most remote point in the watershed to a defined channel such as a street gutter plus the gutter flow time to the first inlet. The time of concentration is affected by several factors such as steepness of terrain, vegetation or land cover, and existing soil moisture conditions.

Inlet time in this study for unimproved areas is determined using average overland velocities shown on Figure 8. (From SCS "Urban Hydrology for Small Watersheds", T.R. 55). Inlet time for improved areas can vary widely and accurate values are difficult to obtain. Values between 5 and 30 minutes are normally used. Design inlet times from 5 to 15 minutes are used for developed areas with steep slopes or closely spaced inlets. Ten (10) to fifteen (15) minute periods are common for similar areas with flatter slopes and for areas with widely spaced inlets and/or very gentle slopes, inlet times of 20 to 30 minutes are normally used.

It is recommended that a minimum inlet time of 10 minutes be adopted by the City in this and future runoff analyses. A five minute time of concentration is unreasonable except for very small drainages and will give exceedingly high runoff valves that field analysis does not support.

E. ANALYSIS OF DRAINAGE DEFICIENCY AREAS

The third phase of this project is PROBLEM IDENTIFICATION. As is stated in Chapter I, twenty potential drainage deficiency areas have been identified by City staff for review.

City of Reno

Average Velocities for Estimating Travel for Overland Flow

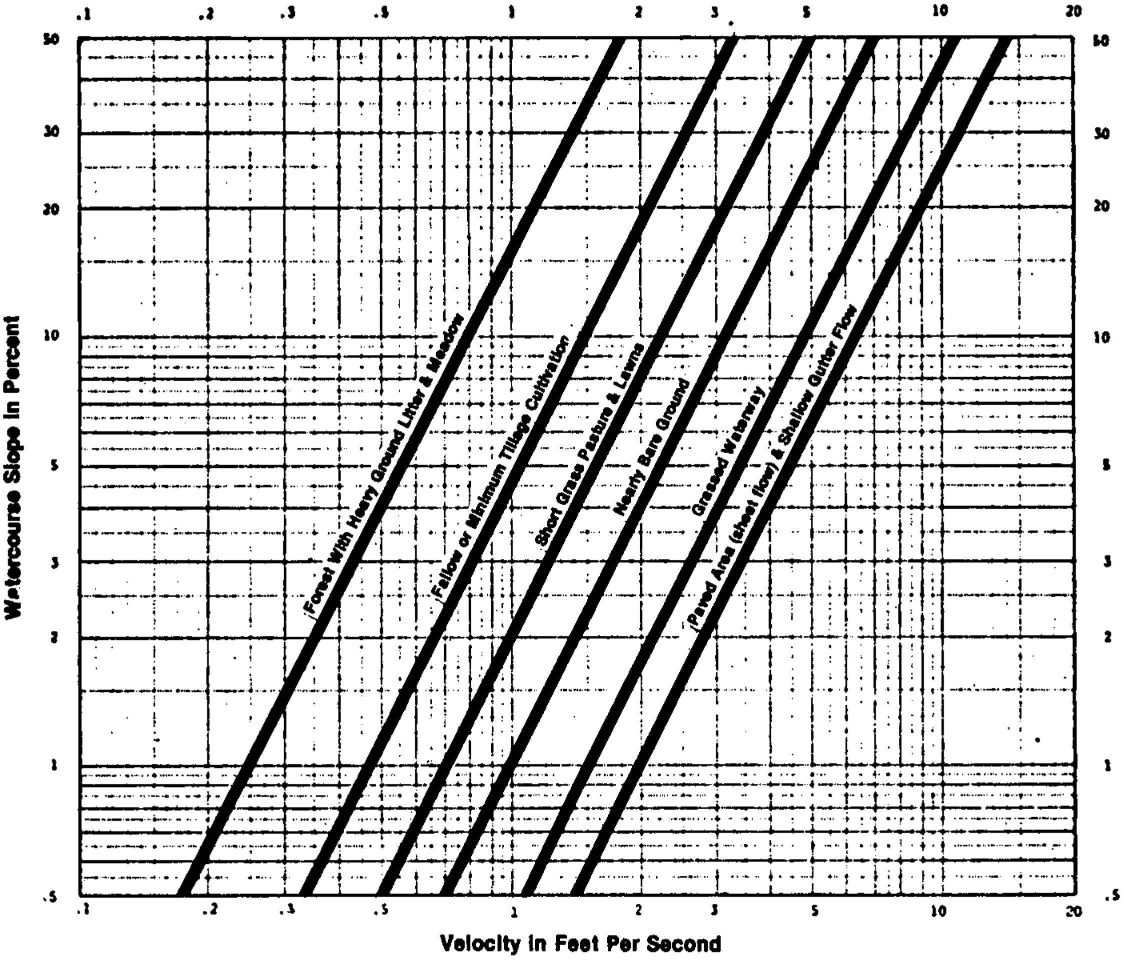


Figure 8

We propose to analyze these deficiency areas in the following manner: The existing storm drainage facilities will be plotted on 500 scale mapping available from Washoe County Department of Comprehensive Planning (formerly Regional Administrative Planning Agency) and will be field verified. Generally the flooding will occur at a particular node such as a culvert crossing. The drainage basin that contributes to a particular node will be identified. This drainage basin will be broken into sub-areas if required, each corresponding to the proposed land use (refer to Figures 2 and 3). Each land use has a runoff coefficient "C" assigned to it. A weighted average "C" will be calculated for the particular drainage basin.

A time of concentration "t_c" will be calculated as described in Section III-D-5 above. From this time of concentration, a rainfall intensity can be obtained from the rainfall IDF curve for the Reno-Cannon Airport. A modified rainfall intensity will be derived using the rainfall isopleth maps as described in Section III-D-4.

With this information, storm runoff flows for a five year return frequency storm (Q_5) and a one-hundred year return frequency storm (Q_{100}) can be calculated. These flows will be compared with the existing storm drainage node capacity to determine if the existing system is undersized. If the system is adequately sized, but flooding still occurs, attempts will be made to pinpoint where the problem may be, such as excessive siltation or poor inlet configuration.

A mini-report will be prepared for each individual drainage deficiency area describing the procedure taken, and including mapping identifying the contributing drainage area.

APPENDIX

DEVELOPMENT OF UPDATED RAINFALL INTENSITY DURATION FREQUENCY CURVES AND RAINFALL ISOPLETH MAPS FOR THE RENO AREA

OCTOBER 1984

Prepared by:

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Winzler and Kelly

PROBLEM STATEMENT

Reliable quantification of hydrologic events is an essential step for designing, planning, and evaluating any water resources sytem. Basic hydrologic information required for the design, analysis, and evaluation of storm drainage systems is the rainfall intensity - duration - frequency (IDF) curves. Under the context of a storm drain deficiency study, accurate rainfall IDF curves are needed to assess the performance capability of the existing system or subsystems.

The rainfall IDF curves currently used by the City of Reno were developed by Kennedy Engineers in 1964. More rainfall data have been collected by the National Weather Service (NWS) at the Cannon Airport Station since that time. To include an additional twenty years or so of records in rainfall IDF analysis would greatly increase the accuracy of IDF curves for the area.

SCOPE OF STUDY

The scope of this part of the study is to update the existing rainfall IDF curves at Reno Cannon Airport with additional rainfall records. In addition, the scope of this work includes the analysis of spatial variation of rainfall around the Reno area including the Stead Air Force Base region. Rainfall isopleth maps for both summer and winter will be developed based upon available rain gauging stations in the area.

PHASES OF STUDY

Phase 1 - Updating IDF Curves

This phase is divided into three tasks.

(Task 1A) Review of Relevant Precipitation Information -

Several sources for developing the rainfall IDF information are available through the National Weather Service (NWS) and National Oceanographic and Atmospheric Administration (NOAA) publications. It is the objective of this task to research and extract information from publications such as the "NWS - Technical Paper 40" and "NOAA Nevada Rainfall Atlas 2."

(Task 1B) Analysis of Raw Precipitation Data -

The information required for deriving rainfall IDF curves is the maximum precipitation depth of different durations. For a storm drainage study, the rainfall durations commonly used are 5 minutes, 10 minutes, 15 minutes, 30 minutes, 1 hour, 2 hours, and 3 hours. The maximum rainfall depths of those durations have been extracted by the NWS Reno Airport Station since 1974. Therefore, analysis of raw precipitation data in the form of precipitation mass curves for all storm events occurring before 1973 is needed.

(Task 1C) Frequency Analysis of Rainfall Data -

After Task 1B is completed, a statistical frequency analysis of the extracted maximum rainfall intensity of various durations will be performed. The results of this analysis along with the IDF information obtained from Task 1A are combined to produce the final rainfall IDF curves for the area in the vicinity of the Reno airport.

Phase 2 - <u>Developing Rainfall Isopleth Maps for the Reno Area Including the Stead Air Force Base Region</u>

(Task 2A) Analysis of Spatial Variation of Rainfall -

Rainfall data are obtained from as many rain gauging stations in the area as possible. A number of storms from both winter and summer will be selected where information is available. The purpose of this task is to analyze the spatial variation of rainfall intensity around the Reno area because the topography of the area varies significantly.

(Task 2B) Development of Rainfall Isopleth -

This would be the final product of this phase of the study. The rainfall isopleth maps developed would reflect the general trend of the rainfall pattern around the area. The rainfall isopleth maps will be used in conjunction with the rainfall IDF curves developed in Phase 1 for the Reno Airport to assess the rainfall intensity at various parts of the City.

APPROACHES

Phase 1 - Updating IDF Curves

(Task 1A) Review of Relevant Precipitation Information -

We began our analysis by researching the relevant rainfall publications already in circulation. Two major sources that contain information for rainfall IDF derivations were compiled in this task:

1. National Weather Service, "Technical Paper No. 40," 1964,
2. National Oceanographic and Atmospheric Administration, "Rainfall Atlas 2 - Vol. VII," 1972.

From these two sources, interpolation following the procedures described in the publications was used to obtain all available point rainfall intensity information for the Reno airport. Extraction of information from NWS Technical Publication No. 40 is straightforward and the results are shown in Table 1 and the corresponding IDF curves are shown in Figure A-1.

To obtain rainfall depths for 6 and 24 hour durations and other durations for return periods between 2 and 100 years is also straightforward when the NOAA Rainfall Atlas 2 is used. However, rainfall depths of any return periods with a duration shorter than 6 hours require an estimation of a 1 hour rainfall depth which is computable by the regression equations. In the NOAA Rainfall Atlas 2, Reno is located close to the boundary that separates regions 2 and 4 of different climatic and geographic characteristics and each of the regions has its own regression equations of different accuracies for computing a 1 hour rainfall depth. Therefore, the 1 hour rainfall depth for the Reno airport is derived by computing the weighted average of 1 hour rainfall depths from regions 2 and 4 with the weighting factor determined by the relative accuracy of the regression equations for the two regions. The rainfall IDF information for the Reno airport derived from the NOAA Rainfall Atlas 2, Vol. VII is shown in Table 2 as well as Figure A-2.

TABLE 1. RAINFALL IDF INFORMATION FOR RENO AIRPORT FROM NWS TECHNICAL PUBLICATION 40, 1964

Return Period (Years)	Duration (Minutes)							
	5	10	15	30	60	120	180	1440
2	1.55	1.20	1.01	0.70	0.42	0.30	0.27	0.07
5	2.26	1.74	1.47	1.02	0.66	0.40	0.33	0.10
10	2.80	2.15	1.81	1.26	0.80	0.50	0.40	0.12
25	3.11	2.39	2.02	1.40	0.90	0.63	0.50	0.13
50	3.69	2.84	2.39	1.66	1.10	0.71	0.57	0.14
100	4.22	3.25	2.74	1.90	1.20	0.75	0.65	0.17

TABLE 2. RAINFALL IDF INFORMATION FOR RENO AIRPORT FROM NOAA RAINFALL ATLAS 2, VOL. VII, 1972

Return Period (Years)	Duration (Minutes)							
	5	10	15	30	60	120	180	1440
2	1.50	1.16	0.98	0.68	0.43	0.25	0.18	0.05
5	2.09	1.62	1.37	0.95	0.60	0.37	0.26	0.06
10	2.61	2.03	1.71	1.19	0.75	0.44	0.33	0.07
25	3.06	2.38	2.01	1.39	0.88	0.52	0.39	0.09
50	3.48	2.70	2.28	1.58	1.00	0.59	0.42	0.10
100	4.11	3.19	2.69	1.86	1.18	0.65	0.49	0.11

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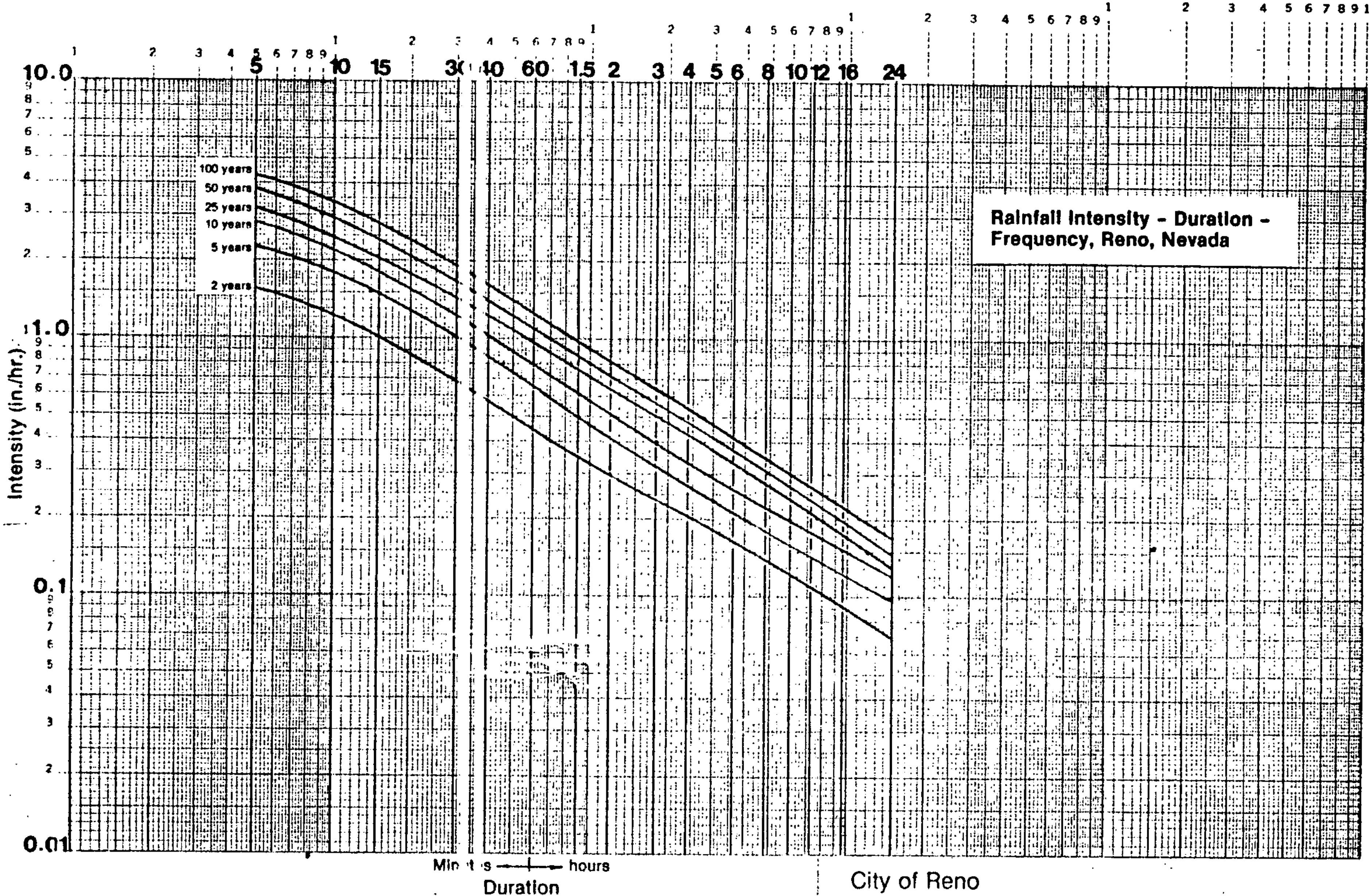
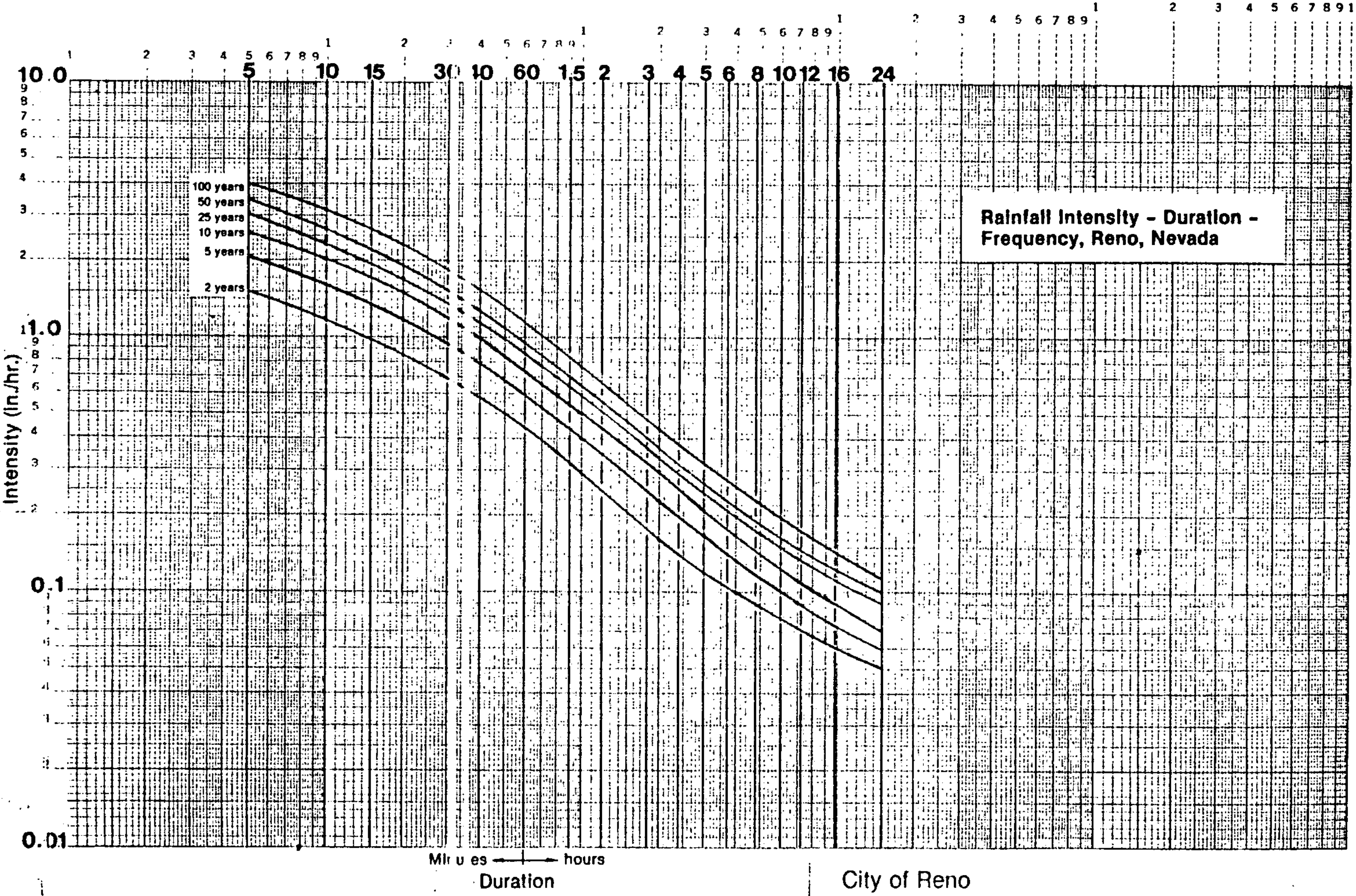


City of Reno

Rainfall Intensity - Duration - Frequency Curves for General Reno Area

Based on NWS Technical Paper No. 40 (1964)

Figure A-1



City of Reno

Rainfall Intensity - Duration - Frequency Curves for General Reno Area

Based on NOAA Atlas II (1972)

Figure A-2

Task 1B) Analysis of Raw Precipitation Data -

The raw precipitation data were obtained from the National Weather Service Climatic Center in Asheville, North Carolina, in the form of microfilms of the recorded weighting rain gauge charts at the Reno airport. These charts are the rainfall mass curves showing the time history of the accumulative rainfall depth during storm events. All storm events which occurred in the period 1952-1972 were carefully screened, and those significant events were selected for further analysis.Principally, at least one storm event per month was selected for the analysis unless nothing had happened in the month.

A computerized digitizing device was used to convert the rain chart information to form the data base into a rectangular coordinate system. This was accomplished by dividing each mass curve selected for the analysis into enough points that a straight line approximation between said points could be used to describe the shape of the mass curves. The digitizing pad then allowed us to assign rectangular coordinates to these points on the mass curves. The problem that arose in the digitization was that the original rain charts were plotted on an obscure coordinate system in which the ordinates are semicircular and the abscissas are linear. Thus, the digitized points from the original rain charts were not based upon a true rectangular coordinate system. A computer program was written to correct this geometric problem, and all the data points were converted to a true rectangular coordinate assignment.

Finally, having the data points correctly aligned, a computer program using the random search technique was developed to search for the maximum rainfall depth of different durations for all storm events considered in each calendar year. Knowing the change in depth and time, intensities were then calculated; and the maximum values for each of the prescribed durations could be obtained for each year of records. The series so obtained is called the annual maximum series. In this study, the annual maximum series of rainfall intensity of various durations for the frequency analysis were extracted from 1952 to 1983.

(Task 1C) Frequency Analysis of Rainfall Data -

The statistical frequency analysis was performed considering three types of distributions: log-normal, extreme value type I, and log-Pearson type III distributions. The general frequency analysis equation can be written as

$$X_{d,T} = \bar{X}_d + K_T S_d$$

where $X_{d,T}$ is the rainfall intensity value for a given duration, d, having a return period of T years. $\bar{X}_d$ and S_d are the mean and standard deviation of the rainfall intensity for any given duration, and K_T is the frequency factor corresponding to T-year return period dependent upon the type of distribution considered. The frequency analysis was performed using the annual maximum series obtained earlier to produce rainfall intensity values for the durations and return periods specified in the study.

An important question in the hydrologic frequency analysis that should be addressed is the assessment of the underlying distribution which describes the random occurrence of the hydrologic process. In rainfall frequency analysis, the extreme type I distribution is commonly used. However, in this study, the extreme type I distribution does not closely fit the annual maximum rainfall intensity series. Therefore, the annual maximum rainfall intensity series of different durations were fitted using log-normal and log-Pearson type II as well as type I distributions. It was found that there is no single distribution function universally superior for all cases. As a result, it was decided to use a weighted average of rainfall intensities obtained from using the three distributions. The weighting factors were determined based upon the relative accuracy of curve fittings in the frequency analysis. The results of rainfall intensity frequency analysis on the annual maximum rainfall series for various durations are given in Table 3. Because it is a common practice to express rainfall IDF information using the partial duration series, the frequency analysis results derived from the annual maximum series were converted to the partial duration series; and the results are given in the last column of Table 3 and the associated IDF curves are plotted in Figure A-3.

TABLE 3(a) RESULTS OF RAINFALL INTENSITY FREQUECY ANALYSIS FOR STORMS WITH 5 MINUTES DURATION

	Annual Maximum				Partial Duration
Return Period	Log-Normal	Log-Pearson III	Extreme Type I	Weighted Average	Weighted Average
2	1.10	1.10	1.23	1.10	1.32
5	1.99	1.99	2.14	1.99	2.09
10	2.71	2.72	2.74	2.72	2.75
25	3.77	3.80	3.51	3.78	3.80
50	4.67	4.72	4.07	4.69	4.69
100	5.66	5.74	4.63	5.69	5.69
Weighting Factor	0.49	0.50	0.01		

TABLE 3(b) RESULTS OF RAINFALL INTENSITY FREQUECY ANALYSIS FOR STORMS WITH 10 MINUTES DURATION

	Annual Maximum				Partial Duration
Return Period	Log-Normal	Log-Pearson III	Extreme Type I	Weighted Average	Weighted Average
2	0.83	0.83	0.90	0.83	1.00
5	1.42	1.42	1.49	1.42	1.50
10	1.88	1.89	1.88	1.89	1.92
25	2.54	2.57	2.37	2.55	2.55
50	3.09	3.13	2.73	3.11	3.11
100	3.67	3.74	3.10	3.70	3.70
Weighting Factor	0.49	0.50	0.01		

TABLE 3(c) RESULTS OF RAINFALL INTENSITY FREQUECY ANALYSIS FOR STORMS WITH 15 MINUTES DURATION

	Annual Maximum				Partial Duration
Return Period	Log-Normal	Log-Pearson III	Extreme Type I	Weighted Average	Weighted Average
2	0.64	0.62	0.69	0.63	0.75
5	1.07	1.06	1.15	1.06	1.11
10	1.40	1.43	1.46	1.42	1.43
25	1.87	2.00	1.85	1.95	1.95
50	2.25	2.52	2.14	2.41	2.41
100	2.67	3.11	2.43	2.93	2.93
Weighting Factor	0.39	0.60	0.01		

TABLE 3(d) RESULTS OF RAINFALL INTENSITY FREQUECY ANALYSIS FOR STORMS WITH 30 MINUTES DURATION

	Annual Maximum				Partial Duration
Return Period	Log-Normal	Log-Pearson III	Extreme Type I	Weighted Average	Weighted Average
2	0.41	0.38	0.43	0.39	0.46
5	0.65	0.63	0.71	0.64	0.68
10	0.83	0.85	0.90	0.84	0.86
25	1.07	1.22	1.14	1.17	1.17
50	1.27	1.57	1.32	1.47	1.47
100	1.48	1.99	1.50	1.83	1.83
Weighting Factor	0.31	0.68	0.01		

TABLE 3(e) RESULTS OF RAINFALL INTENSITY FREQUECY ANALYSIS FOR STORMS WITH 60 MINUTES DURATION

	Annual Maximum				Partial Duration
Return Period	Log-Normal	Log-Pearson III	Extreme Type I	Weighted Average	Weighted Average
2	0.27	0.25	0.28	0.26	0.29
5	0.40	0.39	0.45	0.39	0.40
10	0.50	0.51	0.56	0.51	0.51
25	0.62	0.71	0.70	0.68	0.68
50	0.71	0.91	0.80	0.85	0.85
100	0.81	1.16	0.91	1.04	1.04
Weighting Factor	0.31	0.67	0.02		

TABLE 3(f) RESULTS OF RAINFALL INTENSITY FREQUECY ANALYSIS FOR STORMS WITH 120 MINUTES DURATION

	Annual Maximum				Partial Duration
Return Period	Log-Normal	Log-Pearson III	Extreme Type I	Weighted Average	Weighted Average
2	0.19	0.17	0.19	0.18	0.196
5	0.26	0.25	0.28	0.25	0.260
10	0.31	0.32	0.34	0.31	0.31
25	0.37	0.43	0.42	0.41	0.41
50	0.42	0.53	0.48	0.49	0.49
100	0.47	0.66	0.54	0.59	0.59
Weighting Factor	0.33	0.64	0.03		

TABLE 3(g) RESULTS OF RAINFALL INTENSITY FREQUECY ANALYSIS
FOR STORMS WITH 180 MINUTES DURATION

Return Period	Annual Maximum				Partial Duration
	Log-Normal	Log-Pearson III	Extreme Type I	Weighted Average	Weighted Average
2	0.15	0.14	0.15	0.15	0.165
5	0.20	0.20	0.21	0.20	0.210
10	0.24	0.24	0.25	0.24	0.245
25	0.28	0.31	0.30	0.30	0.30
50	0.31	0.37	0.34	0.35	0.35
100	0.35	0.40	0.38	0.40	0.40
Weighting Factor	0.33	0.65	0.02		

TABLE 3(h) RESULTS OF RAINFALL INTENSITY FREQUENCY ANALYSIS
FOR STORMS WITH 24 HOURS DURATION

Return Period	Annual Maximum				Partial Duration
	Log-Normal	Log-Pearson III	Extreme Type I	Weighted Average	Weighted Average
2	0.041	0.039	0.037	0.039	0.045
5	0.058	0.057	0.054	0.057	0.059
10	0.070	0.072	0.065	0.071	0.071
25	0.085	0.093	0.079	0.089	0.089
50	0.096	0.112	0.090	0.105	0.105
100	0.107	0.134	0.100	0.123	0.123
Weighting Factor	0.30	0.60	0.10		

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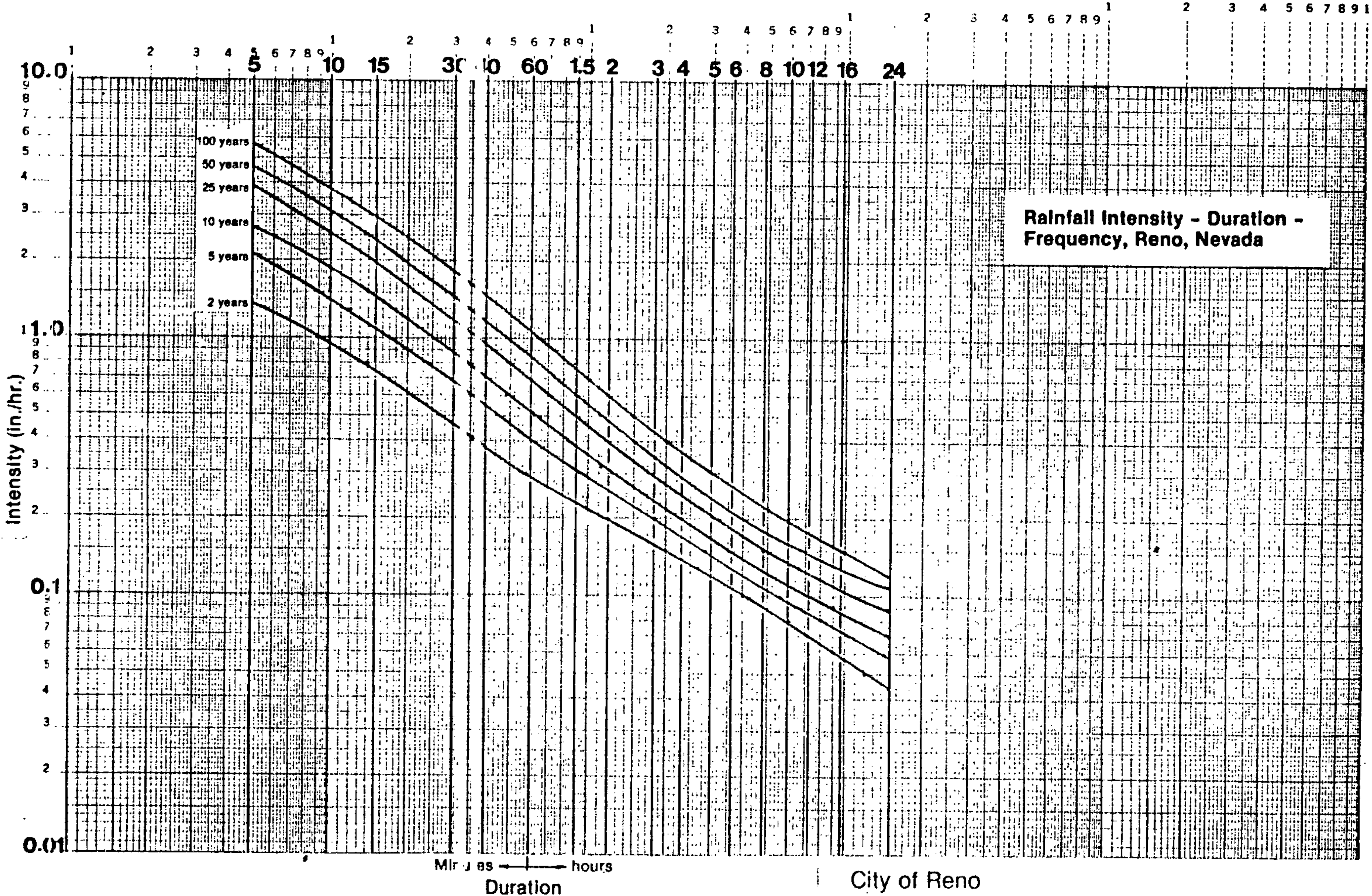


City of Reno

Rainfall Intensity - Duration - Frequency Curves for General Reno Area

Based on Rainfall Data from Cannon Airport Gauging Station

Figure A-3

Phase 2: Development of Rainfall Isopleth Map

(Task 2A) Analysis of Spatial Variation of Precipitation -

Attempts were made to obtain rainfall data from as many rain gauging stations in the area as possible. A list of rain gauging stations in the Great Basin is compiled by John James, the State climatologist. There are about twelve unofficial stations in the list that are located within or near the study area. However, only nine of them have daily rainfall information available for use; they are located at Dickerson Road, Royal Drive, Upper Skyline, Ganser, La Veaga Ct., Verdi, Sparks Fire Station, Sierra Sage Road, and Christmas Tree. It is unfortunate that we were unable to locate any retrievable rainfall information related to the Air Force Base at Stead, Nevada.

The rainfall events that occurred during each year were separated into two seasons. Those occurring from November to April were considered to be generated by frontal type storm events, and those from May to October were considered to be from convection or "thunderstorm" type events. Each recorded event at every location was compared and a ratio computed to the corresponding values recorded by the local weather service station at Reno Cannon Airport. Then the ratios were categorized into the corresponding wet (frontal) or dry (thunderstorm) seasons for each of the nine locations. Both the concurrent monthly maximum daily rainfall and the monthly total rainfall were used to calculate the ratio with respect to the record at the Reno Cannon Airport. To develop the rainfall isopleth maps for both dry and wet seasons, the averages of the ratio in each station were computed and used. The values of average ratio, the number of months used in its computation, and some statistics are shown in Table 5a for the monthly maximum daily rainfall and in Table 5b for the monthly total rainfall.

As can be expected, the values of standard deviation for the dry season in most stations is larger than that of the wet season because most storm events occurring in the dry season are of the convection type. Variability of the ratio in any given station using the monthly maximum daily rainfall is generally higher than that using the monthly total rainfall. However, the mean values of the ratio based on either the monthly maximum daily rainfall or the monthly total rainfall do not differ significantly. As a result, the average of the two ratios was used for the development of rainfall isopleth maps.

TABLE 5a. RATIO OF MONTHLY MAXIMUM DAILY RAINFALL TO RENO CANNON AIRPORT STATION

Station Name	Season	No. of Records	Average Ratio	Standard Deviation
Sparks Fire Station	Wet	43	1.16	0.62
	Dry	34	1.72	2.02
La Veaga Court	Wet	10	1.04	0.42
	Dry	9	2.01	1.94
Royal Drive	Wet*	--	----	----
	Dry*	--	----	----
Dickerson Road	Wet	44	1.45	0.63
	Dry	36	1.46	0.83
Ganser	Wet	24	1.92	1.31
	Dry	17	1.38	0.74
Sierra Sage	Wet	6	1.54	0.61
	Dry*	--	----	----
Upper Skyline	Wet	18	2.34	1.71
	Dry	14	1.48	0.92
Christmas Tree	Wet	40	4.53	4.32
	Dry	32	3.35	3.26
Verdi	Wet	6	3.27	1.86
	Dry	2	2.48	2.34

*Information not available

TABLE 5b. RATIO OF MONTHLY TOTAL RAINFALL TO RENO CANNON AIRPORT STATION

Station Name	Season	No. of Records	Average Ratio	Standard Deviation
Sparks Fire Station	Wet	43	1.03	0.38
	Dry	34	1.58	1.44
La Veaga Court	Wet	10	1.06	0.47
	Dry	9	1.66	0.95
Royal Drive	Wet	6	1.30	0.18
	Dry	6	3.10	3.43
Dickerson Road	Wet	44	1.43	0.44
	Dry	36	1.54	0.71
Ganser	Wet	24	1.64	0.51
	Dry	17	1.41	0.57
Sierra Sage	Wet	6	1.51	0.18
	Dry*	--	----	----
Upper Skyline	Wet	18	2.04	0.78
	Dry	14	1.49	0.88
Christmas Tree	Wet	40	4.96	3.58
	Dry	32	3.59	2.80
Verdi	Wet	6	3.87	1.64
	Dry	2	2.91	1.55

*Information not available

(Task 2B) Development of Rainfall Isopleth Maps-

The average values of the mean ratios obtained from the monthly maximum daily rainfall and the monthly total rainfall for each station listed in Table 5 were used to develop rainfall isopleth maps for both the dry and wet seasons. The isopleth maps prepared cover an area between 39° 21' - 39° 40' in latitude and 119° 40' - 119° 56' in longitude. The total plane area is approximately 77 square miles.

In view of sparseness of data points with variable degrees of accuracy, it is felt that the use of an elaborate mapping technique is not necessary. The technique used for assessing the general spatial trend of rainfall is called the trend surface analysis. The trend surface analysis is a simple technique which relates the variable of interest (rainfall ratio in this case) to geographical coordinates such as (X,Y,Z) in which X and Y are plane coordinates of the data points with respect to a predetermined origin and Z can be the elevation of the observation point. A number of trend surface equations were examined and the corresponding maps drawn. It is felt that the following two trend surface equations might adequately describe the general spatial variation of rainfall around the Reno area.

(1) For the wet season:

$$R = -13.87 - 1.85X^{1/4} + 19.25Z^{1/4} \qquad (\text{Z in miles})$$

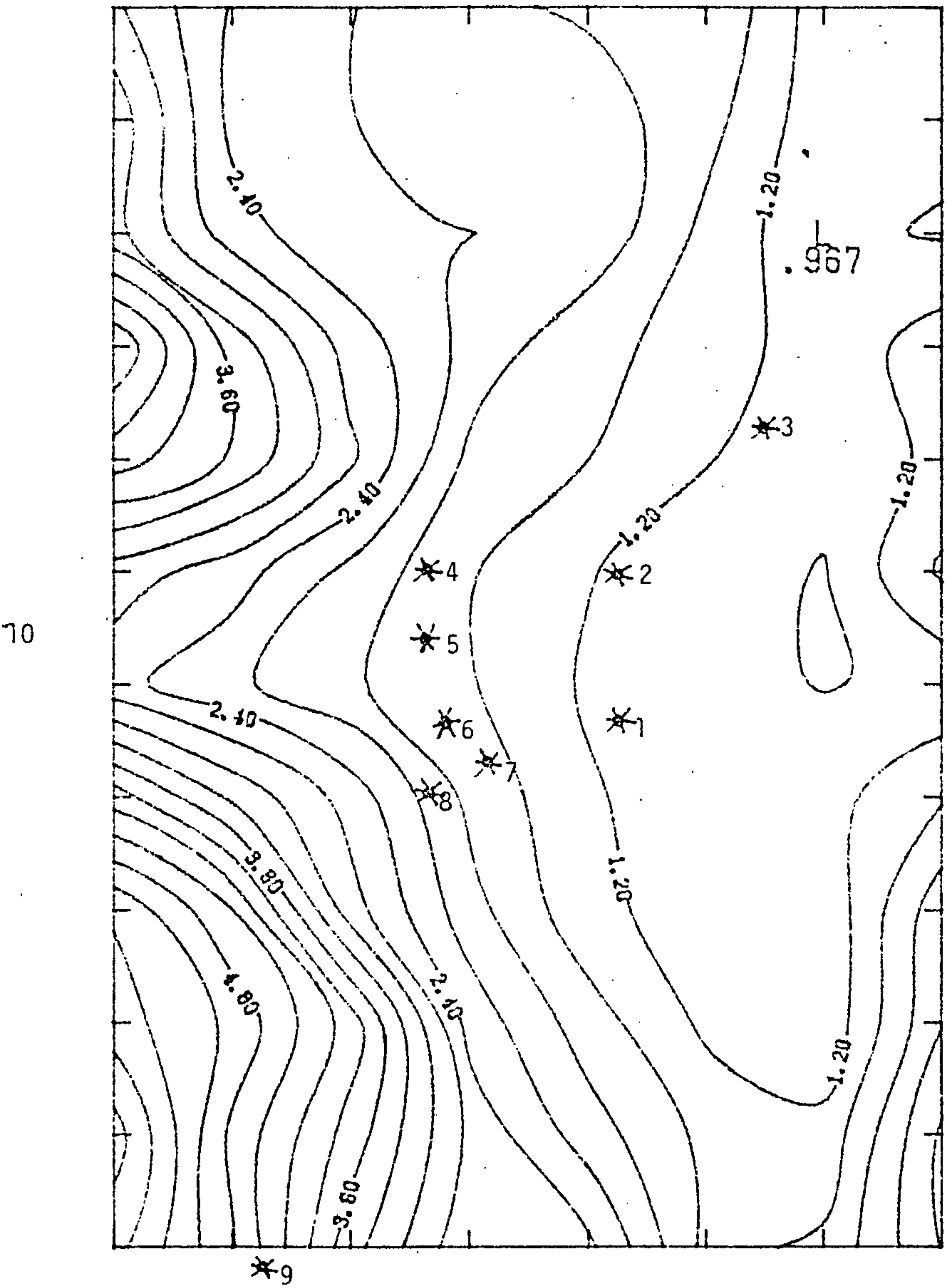
(2) For the dry season:

$$R = 0.5455 - 0.3983X^{1/2} + 7.511 \times 10^{-3} Y^2 + 5175 \times 10^{-8} \qquad (\text{Z in feet})$$

Where R is the ratio of rainfall depth at any location with coordinate (X,Y,Z) to the rainfall depth at the Reno Cannon Airport station, X and Y are plane distances in miles along east-west and south-north directions, respectively, and Z is the elevation. (Note that the X,Y coordinate plane origin is at the lower left hand corner of the map.)

As can be seen, the equation derived for the wet season does not include a term of Y. This implies that, during the wet season in winter, the frontal type of storm generally covers large areas and does not produce noticeable differences in rainfall depth along the north-south direction. Rainfall depth tends to become large as elevation gets higher as shown by a positive sign associated with the Z term. The negative sign associated with the X term indicates that the rainfall depth decreases as the point of interest moves from west to east. The contour maps for both the wet and dry seasons around the Reno area are shown in Figures A-4 and A-5, respectively.

WET SEASON (NOVEMBER - APRIL)

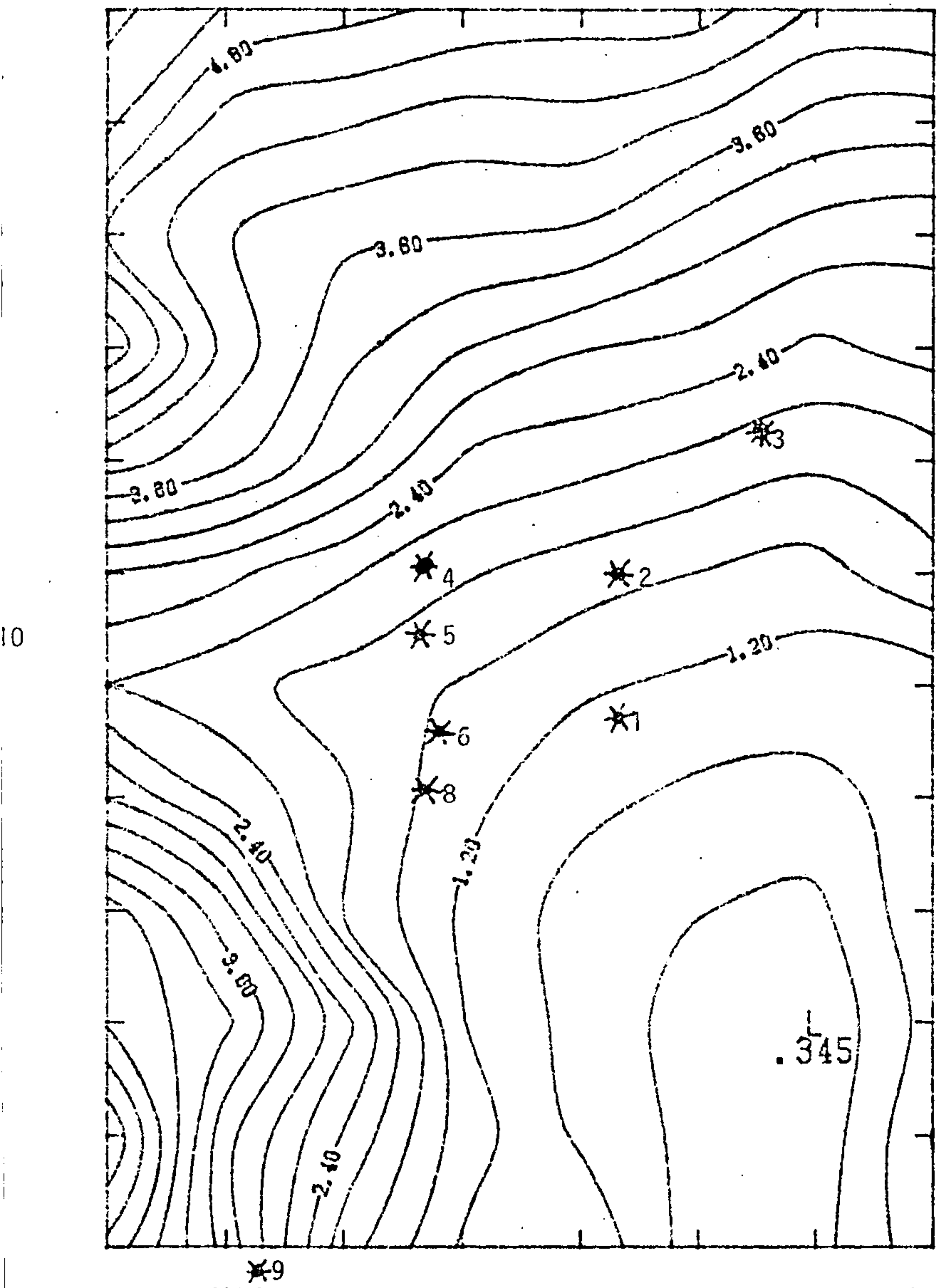


1 - Cannon Airport
2 - Sparks Fire Sta.
3 - La Veaga Ct.
4 - Royal Dr.
5 - Dickerson Rd.
6 - Ganser
7 - Sierra Sage Ln.
8 - Upper Skyline
9 - Chrismas Tree
10 - Verdi

CONTOUR FROM .60000 TO 6.0000 CONTOUR INTERVAL OF .60000 PT(3,3)= 4.0678

Figure A-4

DRY SEASON (MAY - OCTOBER)



1 - Cannon Airport

2 - Sparks Fire Sta.

3 - La Veaga Ct.

4 - Royal Dr.

5 - Dickerson Rd.

6 - Ganser

8 - Upper Skyline

9 - Chrismas Tree

10 - Verdi

CONTOUR FROM .30000 TO 5.4000 CONTOUR INTERVAL OF .30000 PT(3,3)= 2.8291

Figure A-5