LA-9445-PNTX-A

Los Alamos National Laboratory is operated by the University of California for the United States Department of Energy under contract W-7405-ENG-36.

Supplementary Documentation for an Environmental Impact Statement Regarding the Pantex Plant

Hydrologic Study for Pantex

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LA-9445-PNTX-A

Issued: December 1982

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HYDROLOGIC STUDY FOR PANTEX

by

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ABSTRACT

This report documents work performed in support of preparation of an Environmental Impact Statement (EIS) regarding the Department of Energy's Pantex Plant, near Amarillo, Texas. Drainage patterns and drainage diversion at the Pantex Plant and Texas Tech University Research Farm have been delineated. Rainfall-runoff relations for the 6- and 24-hour storms were investigated using historical data. Resultant flooding onsite from these storms was computed. Culvert sizes in Zones 11 and 12 were investigated to determine an adequate design size to carry storm water runoff. Erosion and soil loss rates were computed for wheat crops and native grasses and related to potential for contaminant transport.

I. INTRODUCTION

This report documents work performed in support of preparation of an Environmental Impact Statement (EIS) regarding the Department of Energy's (DOE) Pantex Plant, near Amarillo, Texas. The EIS addresses continuing nuclear weapons operations at Pantex and the construction of additional facilities to house those operations. The EIS was prepared in accordance with current regulations under the National Environmental Policy Act. Regulations of the Council on Environmental Quality (40 CFR 1500) require agencies to prepare a concise EIS with fewer than 300 pages for complex projects. This report was prepared by Los Alamos National Laboratory to document details of work performed and supplementary information considered during preparation of the Draft Environmental Impact Statement.

This report documents surface hydrologic studies performed for the Pantex Plant. The Pantex Plant, located approximately 16 miles (25 km) northeast of Amarillo, Texas, is situated in a semiarid climate. Precipitation is mainly in the form of spring and summer thundershowers, usually intense and of short duration. Therefore, this report addresses the possibility of flooding on a plant-wide scale and specifically for Zones 11 and 12. The effect flooding may have on plant activities is addressed and discussed. Chemical quality of the water is presented in Laseter (1982) and Purtymun (1982A).

English units have been used throughout this report because hydrologic measurements are typically reported in this system. For the reader's convenience, metric conversions are listed.

To convert	Multiply by	To obtain
Feet	0.3048	Meters
Acres	0.4047	Hectares
Cubic feet per second	0.0283	Cubic meters per second
Inches	0.0254	Meters
Tons per acre	224.15	Grams per square meter

II. DRAINAGE PATTERNS AND RAINFALL-RUNOFF RELATIONSHIPS

A. Delineation of Drainage Patterns on the Pantex Plant and Texas Tech University Research Farmlands

Surface drainage at the Pantex Plant and Texas Tech University Research Farm is shown in Fig. 1. As is common through much of the Texas Panhandle, surface drainage is into playa basins, which are closed drainage basins. This is in contrast to the development of stream drainage networks, which cover nearly all of the United States. For the most part, drainage on Pantex land remains within the plant boundaries. Drainage beyond the Pantex Plant boundaries occurs in Basin #1, where runoff from two north firing sites drains into a playa north of Farm Market Road 293. Basin #7 drains offsite to the south, into Seven Mile Basin, a large playa basin. Because of rerouted drainage in Zone 12, Basin #7 now consists of agricultural land only. Small portions of Basins #5, 6, and 9, as well as an unlabeled basin located west of Basin #2, also drain offsite of the Plant, but in all instances, these are perimeter portions of the Plant where land use is primarily agricultural or fallow and are not used in conjunction with Plant operations, Fig. 1.

There has been drainage diversion within the Plant. Area A (Fig. 1) has been rerouted to Playa Basin #1 through a system of culverts and open channels. Area B, also a built-up area, which was originally located within Basin #7, has been rerouted to the Texas Tech University Playa Basin through a culvert and open channel system. Adequate sizing of these culverts is discussed later in this report. Area C has been rerouted from drainage Basin #8 into Playa Basin #1, Fig. 1. Area D, which is primarily fallow land, has been routed to Playa Basin #2, Fig. 1.

Within the individual basins, there has been some minor rerouting through the use of drainage ditches. For example, in the eastern part of Basin #4, some natural drainage has been routed south before it flows into Playa Basin #1. This rerouting only lengthens the flow path and does not reroute the runoff into a different playa than it would go to otherwise. Similarly in Basin #1, runoff in the southern part of the basin has been rerouted into a ditch system, but it still flows into the playa associated with Basin #1 located north of Farm Market Road 293. Although the flow path is lengthened, the runoff is essentially not rerouted.

The Texas Tech University playa is connected by a pipeline to the Iowa Beef Packers Plant, which is located a few miles west of the Pantex Plant. Iowa Beef Packers uses this pipeline occasionally to discharge wastewater from its plant into the Texas Tech University playa for disposal, where it is used for irrigation on the Texas Tech Research Farm. This is the only known pipeline that has the capability of discharging wastes produced outside of plant boundaries into any playa basin on Pantex or the Texas Tech University property.

B. Rainfall at Pantex and Runoff into Playa Basins

This section investigates the volume of runoff produced from 6-hour and 24-hour storms at the Pantex Plant and adjoining Texas Tech Research Farm. The analysis employs the Soil Conservation Service (SCS) runoff curve number method for computing runoff from small agricultural watersheds and storm rainfall-intensity-frequency data from the US Weather Bureau's Technical Paper 40, a standard rainfall-intensity-frequency atlas (US Department of Commerce 1961). Recurrence intervals of 5, 10, 25, 50, and 100 years are investigated. A recurrence interval of 50 years, for example, means that this size storm will occur on the average of once every 50 years, or it may be interpreted to mean that the chance of occurrence of that size storm is 1 in 50 (0.02) in any one year.

The SCS method for estimating direct runoff from storm rainfall is based on a consolidation of methods used by SCS hydrologists over a period of about 30 years. It may be readily applied to ungauged watersheds. It assumes that runoff will begin some time after the rain accumulates, and that the double-mass line curves will become asymptotic to a straight line on arithmetic graph paper. Runoff is delayed until interception, infiltration and surface storage, or initial abstractions have all been satisfied. The rainfall-runoff relation is

$$Q = \frac{(P - 0.2S)^2}{P + 0.8S},$$

where P = storm runoff depth in inches,
S = potential maximum retention in inches, and
Q = computed direct runoff in inches.

The parameter S is related to the runoff curve number (a soil variable that is a measure of the soil's runoff potential) by

$$CN = \frac{1000}{S + 10},$$ where CN is the curve number.

Over 4000 soils in the United States and Puerto Rico have been assigned hydrologic classifications (Soil Conservation Service 1972). These classifications, ranging from A to D in order from low to high runoff potential, are then assigned a runoff curve number reflecting land use and antecedent soil moisture. Therefore, a rainfall intensity, a storm duration, and a curve number may be used collectively to predict a storm runoff volume.

Methodology

Rainfall amounts at Pantex are tabulated for 6- and 24-hour storms in Table I. These values are extrapolated directly from the figures in the rainfall-intensity-frequency atlas (US Department of Commerce 1961).

Curve numbers were selected according to land use and hydrologic soil group. All onsite soils are Pullman soils except for the playa bottoms, which are Randall soils (Jacquot 1962; Purtymun 1982B). Land use at Pantex and the Texas Tech University Research Farm was delineated through the use of aerial photographs of the area, Fig. 2. Composite curve numbers were developed using the methods described in the Soil Conservation Service National Engineering Handbook, Section 4, Hydrology (Soil Conservation Service 1972). These curve numbers, shown in Table II, were developed for Antecedent Moisture Conditions (AMC) I, II, and III. The antecedent moisture conditions relate to the runoff potential, where AMC III has the highest runoff potential as a result of the soils being saturated from previous rainfall, and AMC I has the lowest runoff potential. ACM II is the most commonly used moisture condition because it is the mean moisture between very wet and very dry (Table II).

Direct runoff was determined using Fig. 3. For a particular storm having an associated recurrence interval, runoff is estimated using the rainfall-runoff relation. This is the equivalent depth of runoff over the entire drainage basin.

Because it is assumed that all soils have at least some capacity for infiltration of precipitation, runoff is rarely 100% of rainfall. On an average, in the US only about 30% of the precipitation volume becomes runoff (Viessman 1977). This was not assumed to be the case for the playas, where all precipitation was considered to contribute to increased playa volume. This is because infiltration through the playas is minimal (Purtymun 1982B). Therefore, the runoff estimate is conservative in this aspect. For computation purposes, the basins were split into playa and nonplaya areas; the direct runoff was computed separately and then added. Runoff volumes were computed by multiplying the direct runoff by the basin and playa areas, which were determined by planimetry (Table III).

C. Flooding in the Playa Basins from the 6- and 24-Hour Design Storms

Using the volumes of runoff computed by the SCS method, the increase in playa surface area was computed to determine if any hazardous flooding would occur. This was performed for the 5-, 10-, 25-, 50-, and 100-year recurrence interval storms. For a 6-hour design storm, a recurrence interval of, for example, 100 years would correspond to the rainfall intensity of a 6-hour storm that would occur once on the average of every 100 years.

The increased submerged area, which was due to the direct runoff, was determined by calculating the volume contained within each successive playa contour. Each shaded playa area on the Fig. 1 map was assumed to be 2 feet deep. Where the contour interval is 5 feet (as it is in most instances), the increased volume can be schematically envisioned as described by a 5-foot depth and the corresponding surface area, Fig. 4.

The incremental volume was computed by conforming this irregularly shaped volume into an equivalent volume rectangle. This volume was added to the previous volume to obtain the new total volume (Table IV). These volumes contained within the contours are compared to the runoff volumes, Table III, to determine the extension of the playa's surface area that was due to rainfall events. Frequently, the runoff volume will fall between the volumes associated with two contour lines; in this instance, the outer (larger) contour was chosen.

The increase in submerged playa areas for each basin that would be due to these storms is shown by shaded areas, Fig. 5. These shaded areas represent the maximum area that is likely to be water covered resulting from a specified storm, because the larger contour was always selected. The only incidence of flooding on the plant site would be of some structures located in Basin #2 and at some formerly used buildings located on the Texas Tech University Research Farm in Basin #8, Fig. 6. Some flooding may affect offsite farm houses and buildings in Basins #1 and #9 as a result of storms that have a recurrence interval of 10 years or longer. Flooding on Basin #7 is not shown because runoff on the basin discharges through large (greater than 28-ft^2 cross-sectional area) culverts under US Highway 60 to Seven Mile Basin, a very large playa located south of US Highway 60. (Fig. 1).

Again, the projected surface volumes are conservative because it is likely that less area will be covered with water than indicated on Fig. 5. In the absence of more detailed topography for all the playas considered, this conservative approach was selected.

III. STUDY OF CULVERT CAPACITIES IN ZONES 11 AND 12

A. Zone 12

Zone 12 contains the highest concentration per unit area of buildings, walkways, barricades, and paved areas. Because of the relatively large amount of impervious area, adequate drainage from storm runoff is a necessity. A system of culverts and open channels has been superimposed on the natural drainage, rerouting most of the runoff and waste effluents from this area to Playa Basin #1. The remainder is conveyed to the Texas Tech University Playa Basin through a system of culverts and open channels. The culvert is the main structure that can limit the amount of discharge; as a result, a special study was made of the existing culvert network to see if the culverts were adequate in size to carry, at the minimum, the runoff from the 10-year storm.

A study was undertaken to determine an adequate design size of culverts to carry the 5-, 10-, 25-, 50-, and 100-year storm water runoff. After the sizes and locations of the culverts were field checked, the drainage area for each culvert was delineated. Design rainfall intensities were computed using both the Izzard and Kinematic wave formulas; then peak discharges were computed using the Rational Method. Where culverts emptied into downstream culvert drainage areas, peak discharges were summed. Culvert diameters were measured in the field and then used to compute peak discharge capacity; these diameters were compared with diameters required to contain the computed design flood discharges to determine their adequacy.

1. Computation of Peak Discharge. The location of most of the Zone 12 culverts is shown in Fig. 7. Delineation of drainage areas for individual culverts was made in accordance with local topography and in agreement with field inspection.

Peak discharges for storm recurrence intervals of 5-, 10-, 25-, 50-, and 100-year events were computed using the Rational Method:

$Q_p = ciA,$

where Q_p = peak discharge in cubic feet per second (cfs);
c = runoff coefficient (dimensionless);
i = average rainfall intensity in inches per hour (in./h) lasting for a critical period of time, t_c, and known as the time of concentration in hours; and
A = drainage area in acres.

Rainfall intensities were computed using two different formulas, the Izzard formula and the Kinematic wave formula, both of which are appropriate for urbanized (nonagricultural or developed) areas (Ragan 1972, Linsley 1972). In both instances, one solves for the time of concentration.

Power equations relating rainfall intensity to rainfall duration/time of concentration were developed from the intensity-duration-frequency curves developed for Amarillo (Fig. 8 and Table V). These equations are of the form $i = at^b$, where a and b are constants. The computed time of concentration is then substituted into the equation to determine the rainfall intensity.

Izzard's formula takes the form

$$t = \frac{41\ b\ L^{1/3}}{(c\ i\ )^{2/3}}, \quad \text{where} \quad iL < 500 \quad \text{and}$$

$$b = \frac{0.0007i + C_r}{s^{1/3}},$$

where t = duration in minutes (min),
i = rainfall intensity in inches per hour (in./h),
C_r = retardance coefficient,
s = dimensionless slope,
L = maximum flow length in feet (ft), and
c = runoff coefficient, same as in the Rational Method.

This formula applies to small plots without well-defined channels.

The Kinematic wave method, which was developed from the equations of continuity and momentum, takes the form

$$t = 56.271 \left(\frac{n}{s^{1/2}}\right)^{0.6} L^{0.6} \left(\frac{1}{ci}\right)^{0.4},$$

where t = time of concentration in seconds,
n = Manning n, a roughness coefficient,
s = dimensionless slope,
L = flow length in feet (ft),
c = runoff coefficient used in the Rational formula, and
i = rainfall intensity in inches/hour.

Runoff coefficients, c, were estimated using information derived from field inspection. Manning n's were similarly estimated, using a scheme assuming n = 0.10 for bare ground, and assigning n values for grasses using relationships between n values reported in the Chemicals, Runoff, and Erosion from Agricultural Management Systems (CREAMS) manual (Knisel 1980). The CREAMS manual documents a series of computer models simulating rainfall, runoff, and erosion (Foster 1980). A more detailed explanation of these models may be found later in this report.

Results of times of concentration, rainfall intensity, and peak discharge for Zone 12 are presented in Table VI. In many instances, the time of concentration and, therefore, peak discharge could not be computed using Izzard's formula, particularly for recurrence intervals of 10 years or greater. This is due to the failure of the $iL < 500$ test. In general, the peak discharges predicted using the Kinematic wave method tended to be larger than those predicted by the Izzard method. However, both methods produce discharges of comparable magnitudes. When a choice between the two discharges was available, the larger discharge was chosen with which to make other comparisons.

As a check to the Rational Method using the Izzard and Kinematic wave formulas, peak discharges for the 100-year recurrence interval were computed using a technique based on the Soil Conservation Service curve number method (Zeller 1979). Computed peak discharges from this method were larger than those computed by the Rational Method. Because the curve number method is based on data from the Midwest, which has different rainfall conditions than the semiarid Texas Panhandle, this result is to be expected. The predicted peak discharges from the two methods are of the same order of magnitude, and so, in this case, are considered to provide a reasonable check.

2. Size of Culverts to Carry Peak Discharge. The objective is to select a pipe diameter sufficiently large to carry the maximum peak discharge of a desired recurrence interval. Because a pipe under nonsubmerged inlet conditions will carry its maximum discharge when it is flowing slightly less than full (Chow 1959), it is appropriate to handle this as an open channel problem.

The Manning equation can be used as follows:

$$V = \frac{1.49}{n} R^{2/3} s^{1/2} , \qquad \text{(English units)}$$

where

V = velocity in feet per second (ft/s),

n = Manning's roughness coefficient,

R = hydraulic radius, defined as area/wetted perimeter, and

s = slope of pipe (dimensionless).

The hydraulic radius R for a circular pipe flowing nearly full can be determined.

$$R = \frac{\text{area}}{\text{wetted perimeter}} = \frac{\pi r^2}{2\pi r} = \frac{r}{2} , \quad \text{where} \quad r = \text{pipe radius} .$$

Substituting,

$$V = \frac{1.49}{n} \left(\frac{r}{2}\right)^{2/3} s^{1/2} .$$

Using the continuity equation,

$Q = AV = \pi r^2 V$, where Q = discharge and A = cross-sectional area, together with the Manning equation

$$Q = \frac{1.49}{n} \left(\frac{r}{2}\right)^{2/3} s^{1/2} \pi r^2$$

or

$$Q = \frac{1.49}{n} \frac{(r)^{8/3}}{(2)^{2/3}} s^{1/2} \pi .$$

At this point, the existing pipe radius may be substituted and the equation solved to find the largest discharge this particular pipe size may carry.

Or conversely, if design discharge is known, the pipe size may be sized by solving for r.

$$r = \left(\frac{0.34\ n\ Q}{s^{1/2}}\right)^{0.375} .$$

In some instances, culverts were not open to flow through their total diameter because of infilling by sediment and weeds, or by being crushed and deformed. A combination of the Manning equation and the continuity equation was again used, but this time, the hydraulic radius was computed assuming that the new shape of the culvert cross section was now elliptical rather than circular. Culverts were assumed to fall into this category if the actual diameter was less than 80% of the nominal diameter.

If the minor half axis is taken to be a, and the nominal radius to be r, then the discharge may be computed as follows:

$$Q = \frac{2.365}{n} \pi s^{1/2} a^{1/3} r^{2/3} (2r^2 - a^2)^{-1/6}. \quad \text{(English units)}$$

There are also a number of box or rectangular culverts in Zone 12. To calculate the peak discharge through these, the Manning equation and continuity equation are again employed. If the height of the box is L and the width W, then the hydraulic radius becomes LW/(2L + W) and the peak discharge is

$$Q = \frac{(LW)^{5/3}}{(2L + W)^{2/3}} \frac{1.49}{n} s^{1/2} .$$

Substituting for the measured actual diameters and the culvert slope, the resultant discharge may be compared to the discharge computed by the Rational Formula. The interflow connection between culverts is shown diagrammatically in Fig. 9, flow to Playa Basin #1 in Fig. 10; and the summed design discharges for these culverts are computed from the Rational Formula in Table VII. The maximum discharges for the culverts as limited by their diameter are tabulated in Table VIII.

3. Discussion. Nearly all the culverts in Zone 12 are adequate to carry the storm water runoff associated with the 100-year flood under non-submerged inlet conditions. A comparison of the summed design discharges (Table VII) with the maximum culvert discharges (Table VIII) shows that culverts 12-6 and 12-15 are inadequate in size to carry, under nonsubmerged inlet conditions, even Q_5, the storm water associated with the 5-year flood. Culvert 12-16 will carry only Q_5 under nonsubmerged inlet conditions, and probably no larger flood.

Culvert 12-6 is a very long (170.5-ft) culvert, which runs under a paved courtyard and walkway. It has at least 2 elbows, a 90° turn, and a drop box inlet at about the 2/3 point. These turns and inlet serve to increase the amount of head loss through the pipe. The maximum discharge that this culvert can convey is about 3 cfs, whereas the computed Q_5 for this culvert is 8.7 cfs. The maximum discharge was computed for a straight pipe; actual maximum discharge will, in fact, be less because of the additional head loss described above, which will serve to reduce the maximum discharge capacity.

Culverts 12-15 and 12-16 are culverts that drain under roads. Culvert 12-15 can convey up to 7 cfs, whereas the computed Q_5 is 11.9 cfs. Culvert 12-16 can convey a maximum discharge of 17.4 cfs. This maximum flow lies between a computed Q_5 of 15.3 cfs and Q_{10} of 20.3 cfs. If the storm runoff were to exceed the carrying capacity of the culverts, the additional flow would probably follow natural drainage patterns overland to the south, intersect other culverts or swales, and be conveyed to Playa Basin #1. This is where it would have gone had it been conveyed through culverts 12-15 and 12-16.

B. Zone 11

Zone 11 at the Pantex Plant is characterized by buildings, walkways, barricades, and paved surfaces. In contrast to Zone 12, the concentration of buildings and paved surfaces is not as great, and much of the zone is covered by open field. Natural drainage has been altered in much of the area by a system of culverts and open channels, although natural drainage over swales also occurs (Fig. 11). Drainage from Zone 11 is routed both to Playa Basin #1 and Playa Basin #2 (Fig. 10).

The methodology and computation techniques for determining the design discharges for the 5-, 10-, 25-, 50-, and 100-year storms using the Rational Method, the Izzard, and the Kinematic wave formulas for time of concentration are the same as for Zone 12 and have been described in the previous sections. Computations for time of concentration and peak discharge are shown in Table IX. Locations of the culverts are shown in Fig. 11 and their interflow connections, in Fig. 12. Maximum discharges as limited by culvert diameter are presented in Table X, and summed discharges are computed by the Rational Method in Table XI.

Although maximum discharge calculations were not prepared for every culvert in Zone 11, the main drainage culverts were covered. Comparing the results from Tables X and XI, the existing culverts appear to be adequately sized to convey even the 100-year flood event under nonsubmerged inlet conditions. There may be occurrences in some instances of relatively small localized ponding, but this problem is not expected to be either severe or troublesome.

IV. EROSION AND SEDIMENT MOVEMENT AS A RESULT OF RAINFALL RUNOFF

An analysis was undertaken to determine the amount of soil loss on the agricultural land at the Pantex Plant. Determination of the exact amount of soil loss is often imprecise, because the rate depends on many factors, such as rainfall intensity and volume, antecedent moisture conditions, type of vegetation, slope, soil characteristics, and land usage. Recognizing this limitation, any prediction of soil loss is made with the understanding of the uncertainties in the approach and margin of error.

Perhaps the most common method of estimating soil loss is by use of the Universal Soil Loss Equation (USLE) (Wischmeier 1978). An outgrowth of equations developed to predict soil loss in the corn belt about 1940, the USLE was developed by the Agricultural Research Service of the US Department of Agriculture in cooperation with Purdue University. Since then, the USLE has been improved to account for local rainfall characteristics, quantitative soil erodibility, and cropping and management effects. One of the major advantages of the USLE is that it is easy to use.

A relatively new model for predicting soil loss is CREAMS (Knisel 1980). It is a computer model tailored for field-sized plots and is capable, unlike the USLE, to evaluate sediment yield on a storm-by-storm basis. This model was developed by the US Department of Agriculture in 1980. CREAMS has the capability, in addition to its hydrology and sediment yield components, to model the movements of pesticides and nutrients. Soil loss at Pantex was computed using both the USLE and the CREAMS model. Movement of sediment into Playa Basin #1, which was considered to be a typical watershed in terms of slope, land use, and type of vegetation, was computed.

A. Methodology

The Universal Soil Loss Equation (Wischmeier 1978) is

$$A = R\ K\ L\ S\ C\ P,$$

where A = computed soil loss per unit area, in tons/acre/year,
R = rainfall and runoff factor,
K = soil erodibility factor, which is the soil loss rate per erosion index unit for a specified soil as measured on a uniform plot 72.6 feet long, of uniform 9% slope, continuously in clean tilled fallow,
L = slope length factor,
S = slope-steepness factor,
C = cover management factor, and
P = support practice factor.

Each of these variables is evaluated for the particular field, through information on the soil type, crop management and field practices, and field slope.

The CREAMS Model (Knisel 1980, Foster 1981, Lane 1981) is designed to simulate rainfall, runoff, erosion, and movement of pesticides and nutrients. It is designed to operate on both storm-by-storm and annual basis, unlike the USLE. For this application, only the hydrology and erosion components of the model were used. Information from USGS topographic maps, USLE parameter information, and crop and precipitation data measured at the US Department of Agriculture's Agricultural Research Station at Bushland, Texas, were used for input information. Guidance on parameter selection is found in the CREAMS manual (Foster 1980).

B. Results

The soil loss rate for a wheat crop using the USLE was 0.5 - 0.7 tons/acre annually. The variability comes from the choice of the rainfall runoff factor and cover management factor.

An average soil loss rate using the CREAMS model on a wheat crop is shown in Table XII. The watershed was subdivided and the soil loss was computed on each subwatershed area. Each value represents the average of 20 years of rainfall-runoff-erosion simulation. Soil loss rates were also computed for native grasses using leaf area indices from a similar prairie (Knight 1973).

C. Discussion

There is a great deal of similarity between the soil loss rates predicted by both the USLE and CREAMS for the wheat crop. In particular, the values of 0.38, 0.52, and 0.39 tons/acre should be compared to the USLE values because these are all overland flow simulations.

The CREAMS soil loss rates for the southwest and north subwatersheds are larger in all instances because these subbasins have an active channel component. This channel serves to move soil through and out of the subbasin faster. There is no comparable analogy to this type of sediment movement in the USLE.

Table XII also points out that areas with native grasses, such as buffalo grass and blue grama, which are indigenous to the region, probably produce less sediment than from areas with a wheat crop. Usual farm practices at the Pantex plant include leaving a wheat stubble residue, or plowing the residue under while the field remains unused during all of middle-to-late summer. This is in contrast to native grasses, which are growing during this period, which also happens to coincide with Amarillo's rainfall pattern (predominant precipitation period from May through August). Therefore, the native grasses are still growing during the period of greatest runoff and sediment transport potential and would be expected to produce less sediment yield than a plowed-but-unplanted field. This has implications if land management practices were to be evaluated in terms of contaminant transport. This exercise concludes that land retained in native grasses provides less potential for lateral movement of contaminants that would adsorb and travel with soil particles than would land planted in a wheat crop at the Pantex location.

V. SUMMARY AND CONCLUSIONS

Surface drainage on Pantex land and the Texas Tech University Research Farm is into playa basins. For the most part, drainage remains within the plant boundaries. There has been diversion of drainage from one playa basin to another.

Rainfall and the volume of runoff produced from the 6- and 24-hour storms were investigated using historical data. The Soil Conservation Service's runoff curve number method was used to compute runoff and the resulting volume of water conveyed to the playa basins to determine the extent of flooding. The only incidence of flooding on the plant site would be some structures in Basin #2 and some abandoned buildings on the Texas Tech University Research Farm. There may also be some flooding of offsite farmhouses and buildings located north and west of Pantex.

Optimal culvert sizes in Zone 11 and Zone 12 to convey storm runoff from design storms of recurrence intervals of 5, 10, 25, 50, and 100 years were computed using a combination of the Izzard or the Kinematic wave formulas for the time of concentration, the Manning equation, and the Rational Formula. In Zone 11, all the culverts considered were adequately sized to carry the 100-year flood event under nonsubmerged inlet conditions. In Zone 12, all but three culverts will carry the storm water runoff associated with the 100-year flood under nonsubmerged conditions.

Soil loss was computed over Drainage Basin #4 using the Universal Soil Loss Equation and the CREAMS model. Calculations were made both for a wheat crop and for native grasses. The CREAMS model predicted an average soil loss on a field planted in wheat between 0.3 and 1.0 ton /acre annually for overland flow, which agrees well with the amount predicted by the Universal Soil Loss Equation. The amount of soil loss effectively doubles when runoff is combined overland-channel flow.

Soil loss was also computed using the CREAMS model on fields of native grasses. Soil loss rates are around 0.2 to 0.6 tons/acre annually, lower than for a wheat crop.

Therefore, at the Pantex location, land retained in native grasses provides less potential for lateral movement of contaminants that would adsorb and travel with soil particles than would land planted in a wheat crop.

ACKNOWLEDGMENTS

The authors wish to thank Howard Kirkpatrick of Mason and Hanger-Silas Mason Company, Inc., for his field assistance; and Ron Davis and O. R. Jones of the US Department of Agriculture's Conservation and Production Research Laboratory at Bushland, Texas, for their generous sharing of data.

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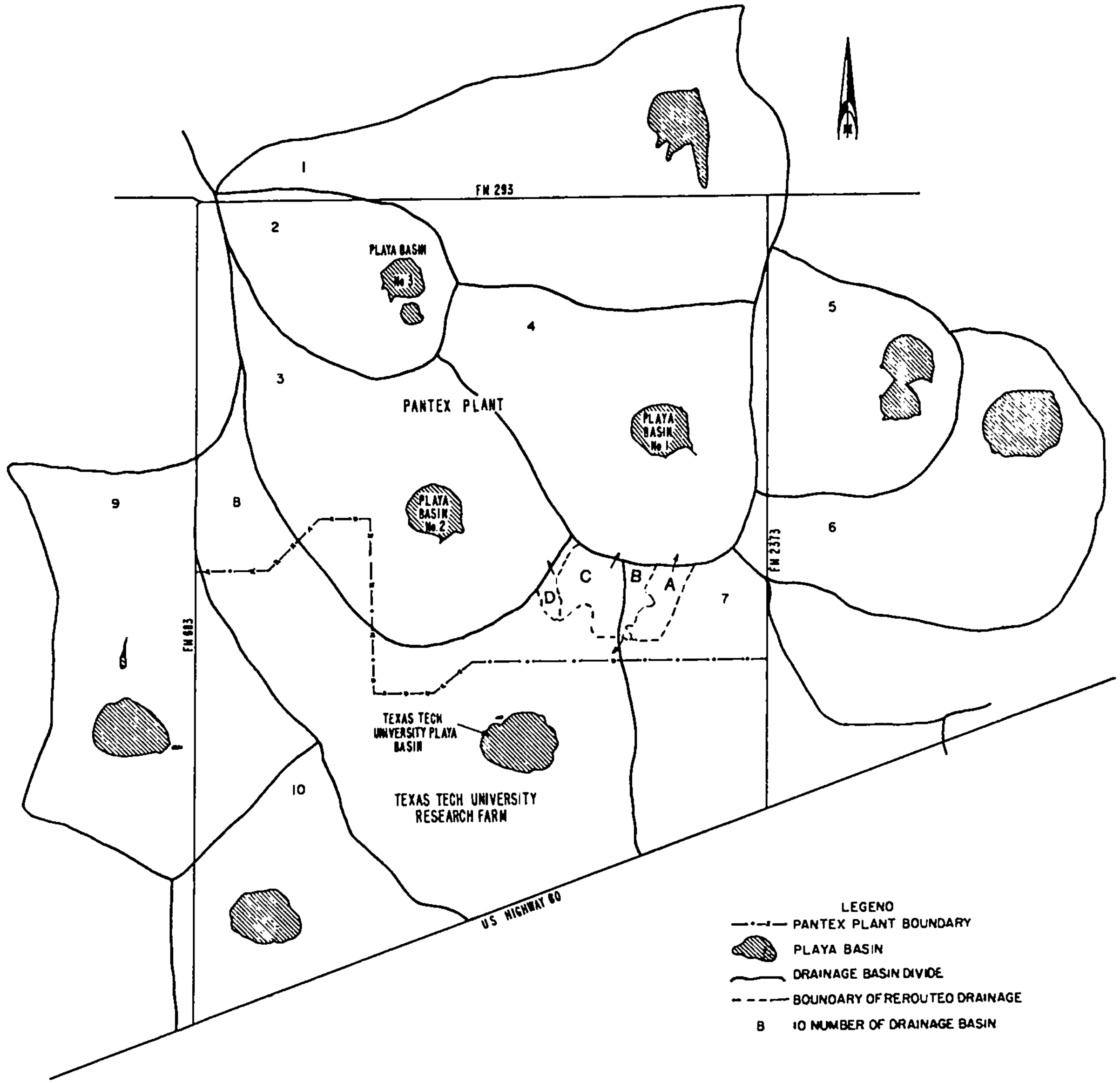


Fig. 1. Surface drainage at the Pantex Plant and Texas Tech University Research Farm.

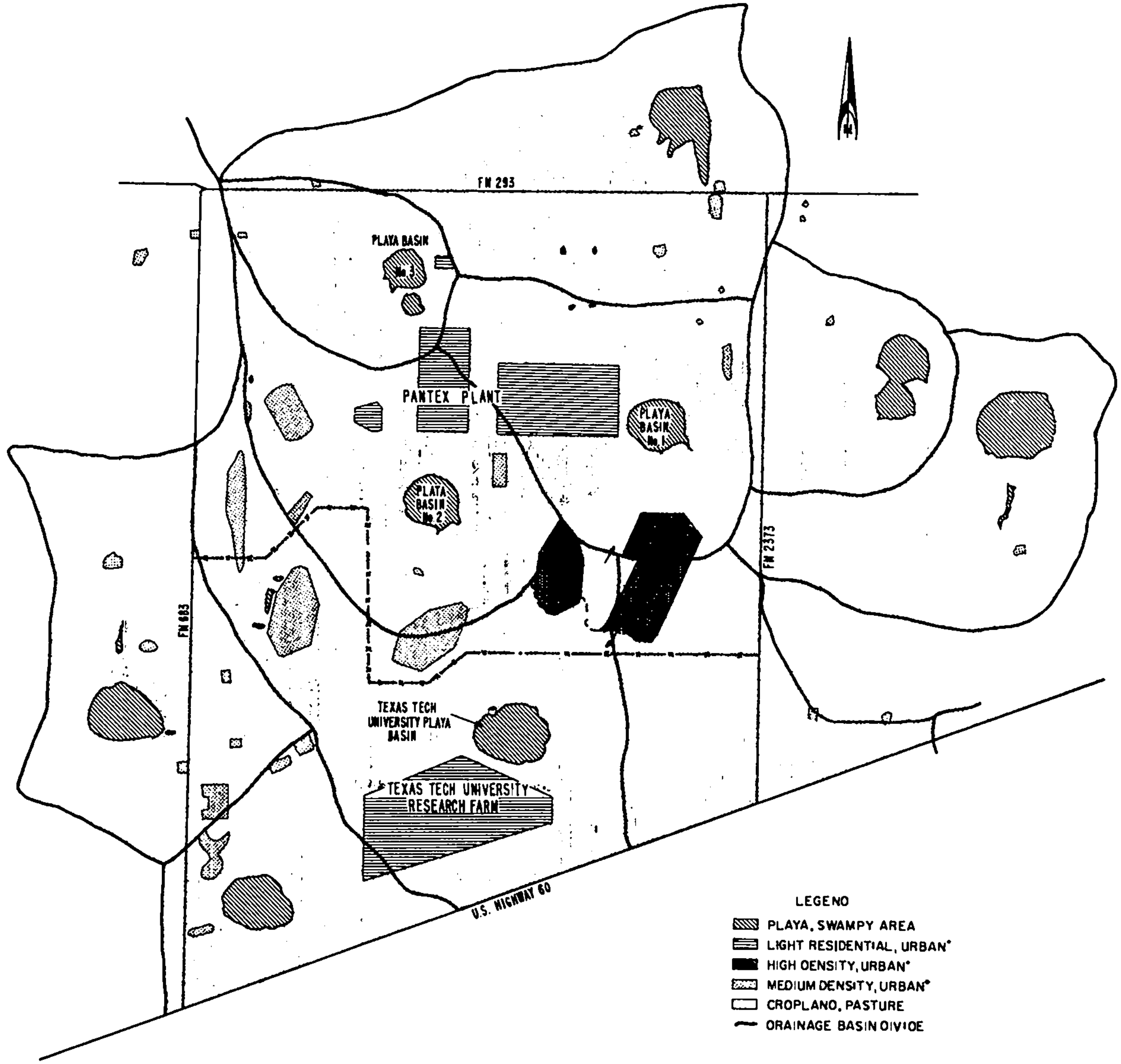


Fig. 2. Land use at the Pantex Plant and Texas Tech University Research Farm.

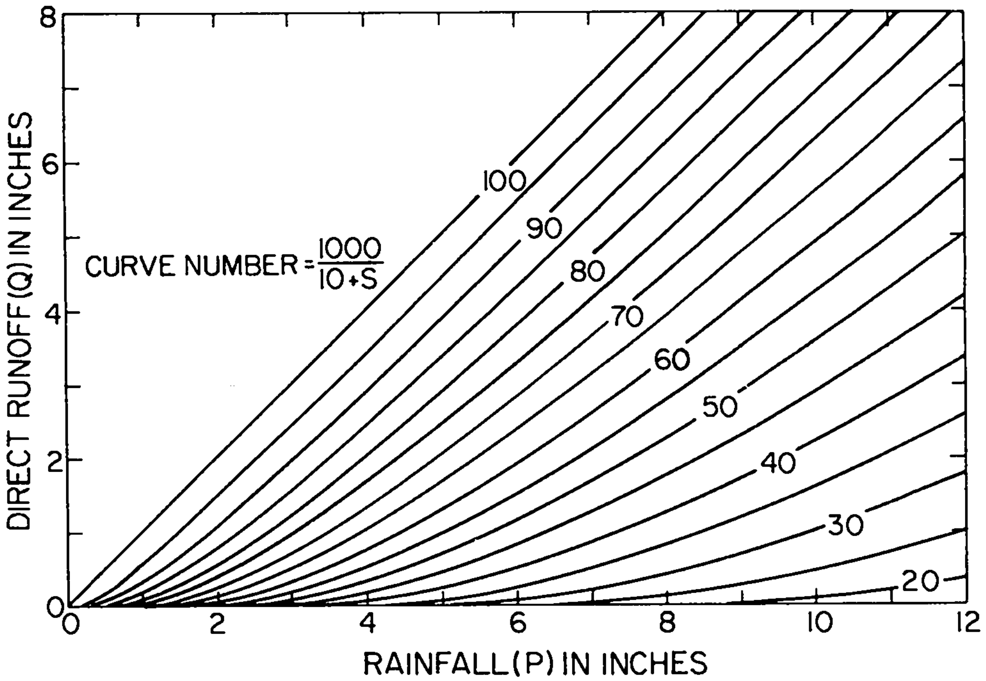


Fig. 3. Graphic solution of the runoff equation.

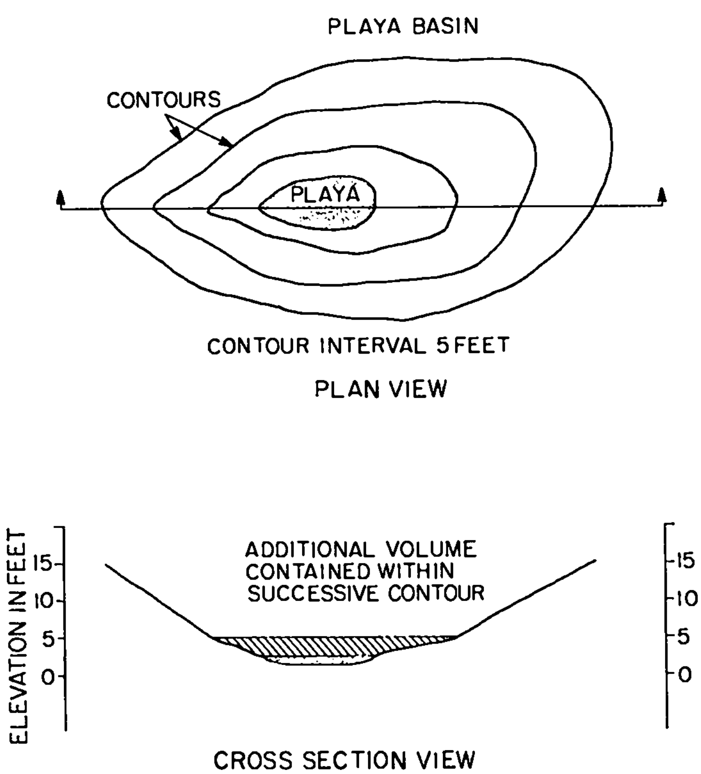


Fig. 4. Playa basin volume.

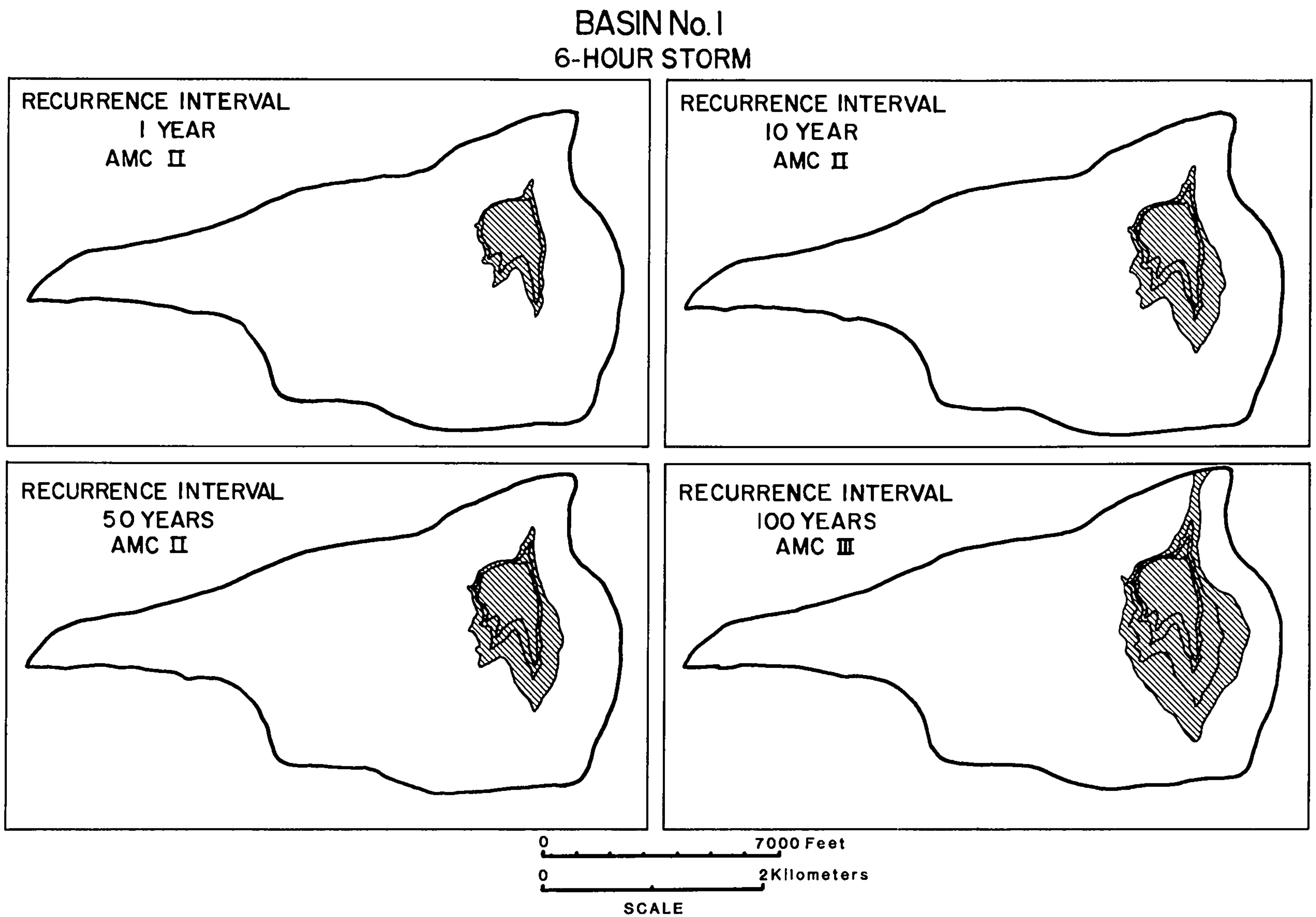
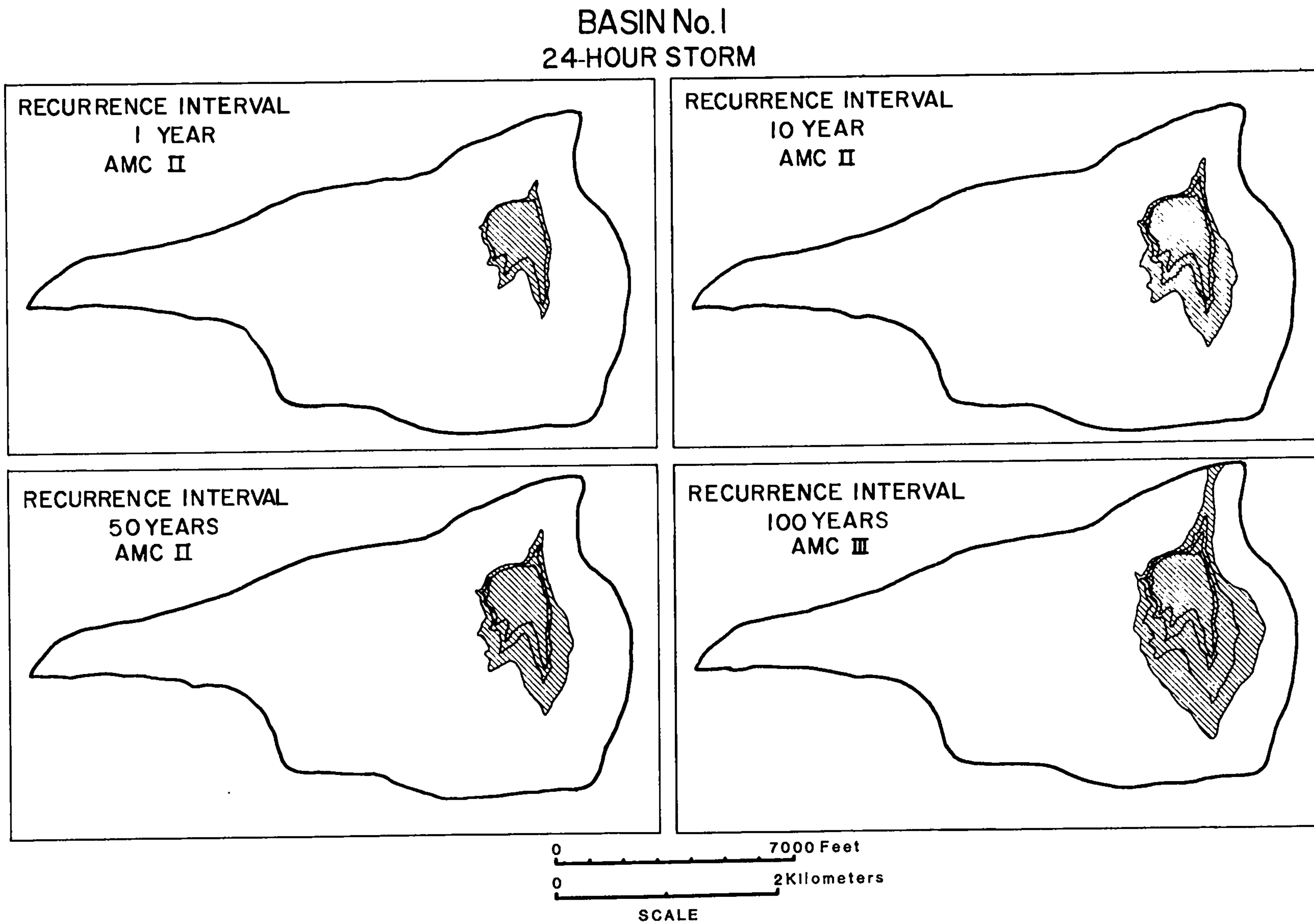


Fig. 5. Submerged playa basin areas for the 6- and 24-hour storm.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AMC II
RECURRENCE INTERVAL
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AMC II
RECURRENCE INTERVAL
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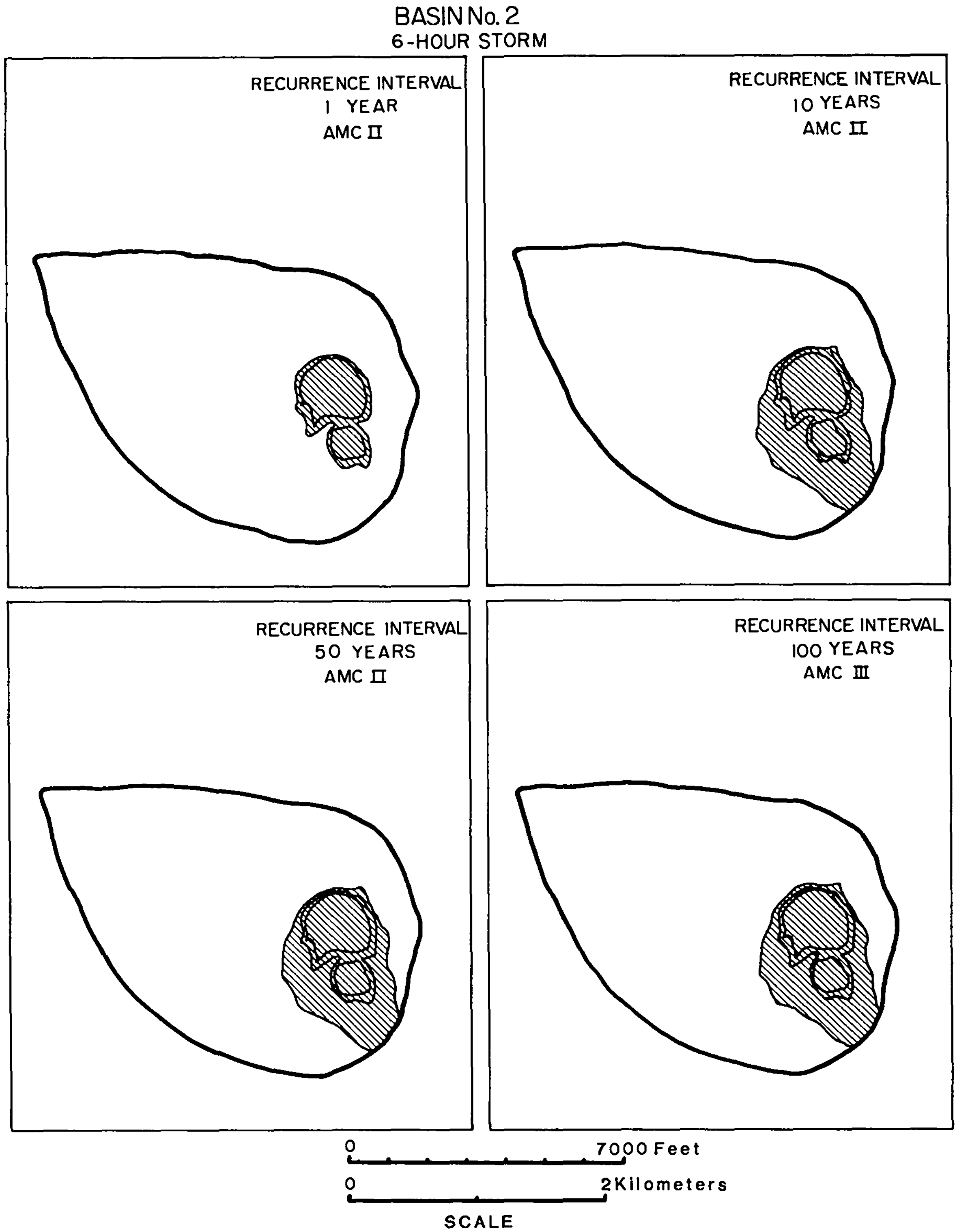
AMC II
RECURRENCE INTERVAL
IOO YEARS
AMC III
0
7000 Feet
0
2 Kilometers
SCALE

Fig. 5. (cont)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AMC II
RECURRENCE INTERVAL
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AMC II
RECURRENCE INTERVAL
100 YEARS
AMC III
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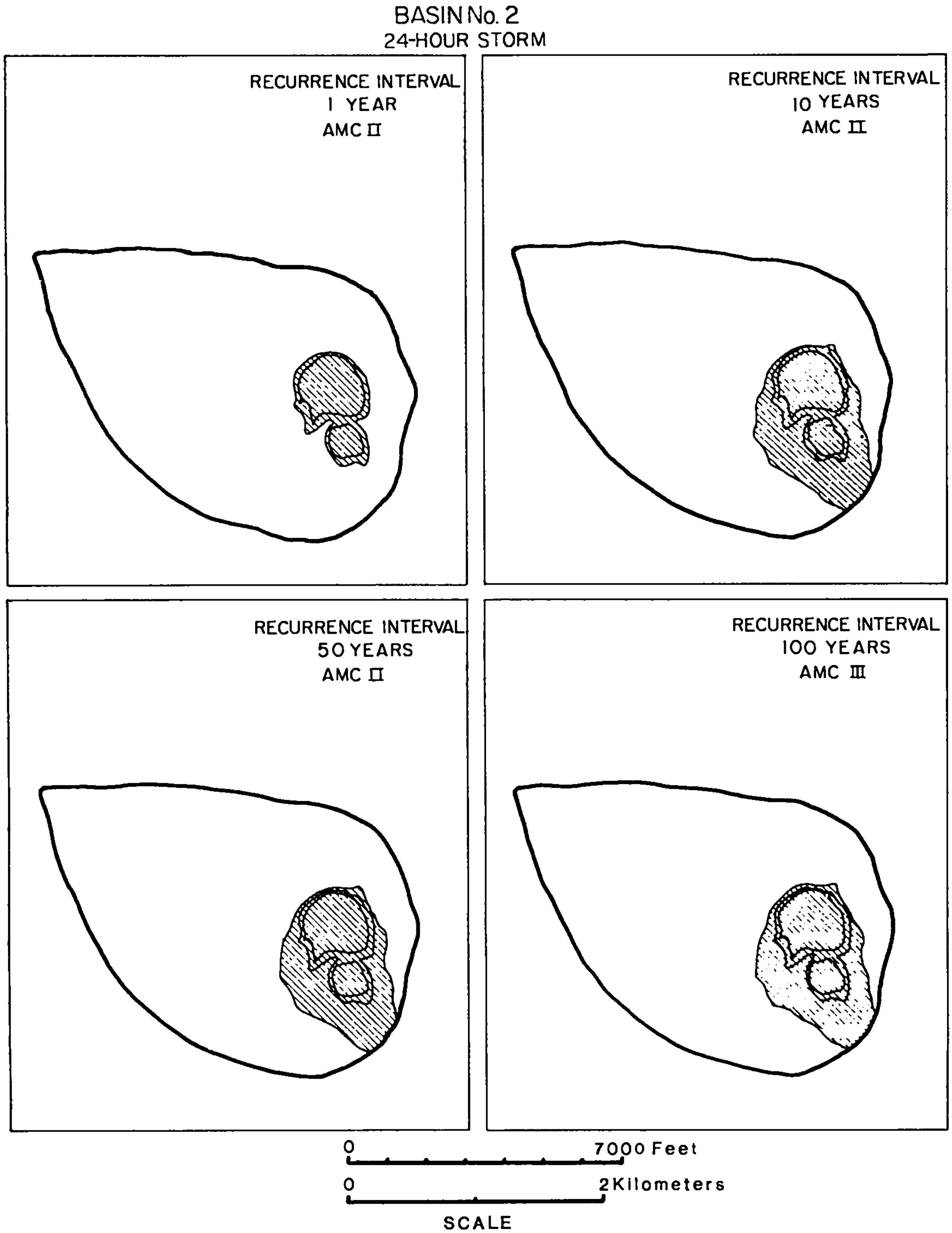
7000 Feet
0
2 Kilometers
SCALE

Fig. 5. (cont)



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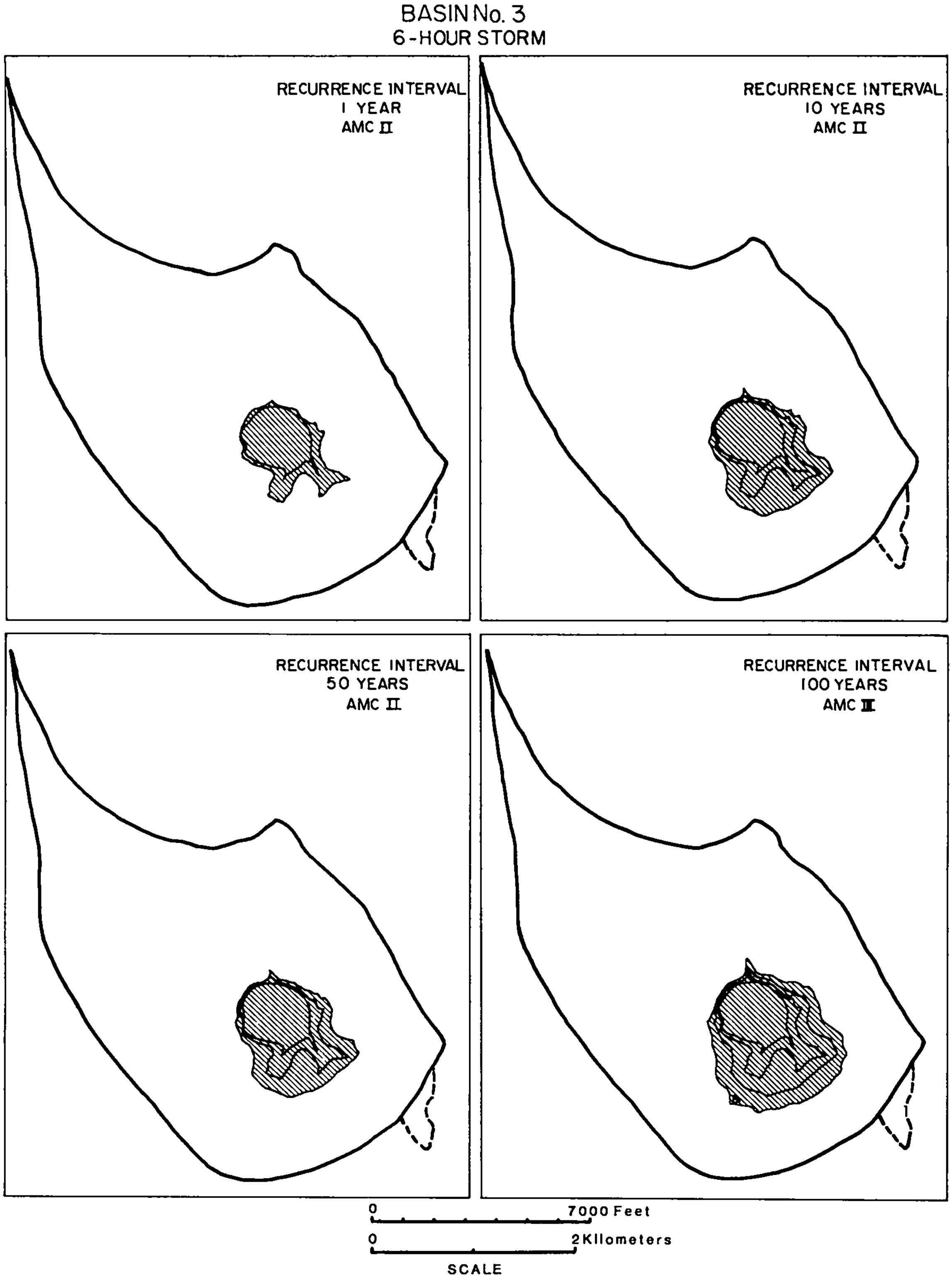
AMC II
RECURRENCE INTERVAL
10 YEARS
AMC II
RECURRENCE INTERVAL
50 YEARS
AMC II
RECURRENCE INTERVAL
100 YEARS
AMC III
0
7000 Feet
0
2 Kilometers
SCALE

Fig. 5. (cont)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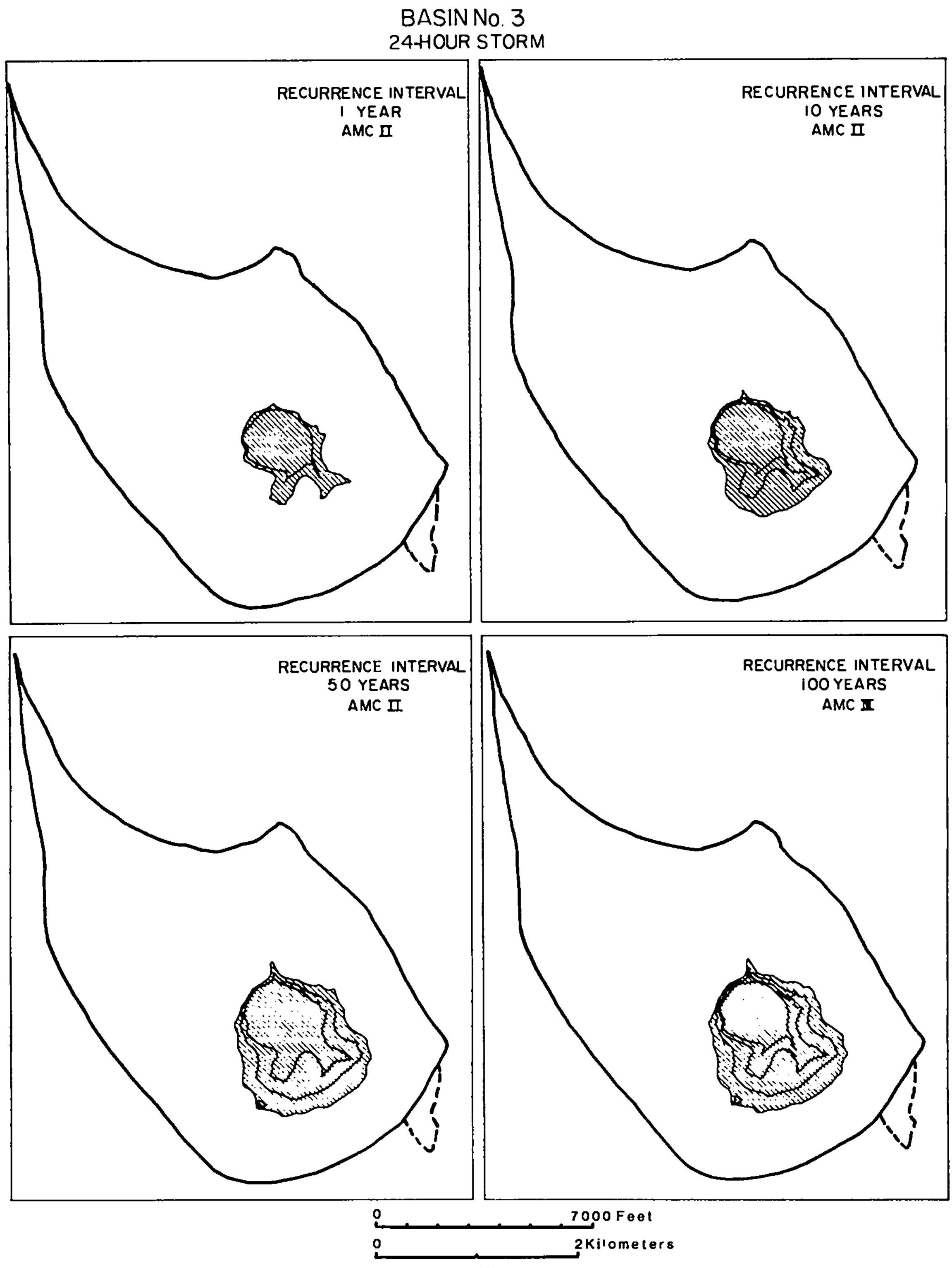
AMC II
RECURRENCE INTERVAL
100 YEARS
AMC II
0
7000 Feet
0
2 Kilometers
SCALE

Fig. 5. (cont)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RECURRENCE INTERVAL
100 YEARS
AMC II
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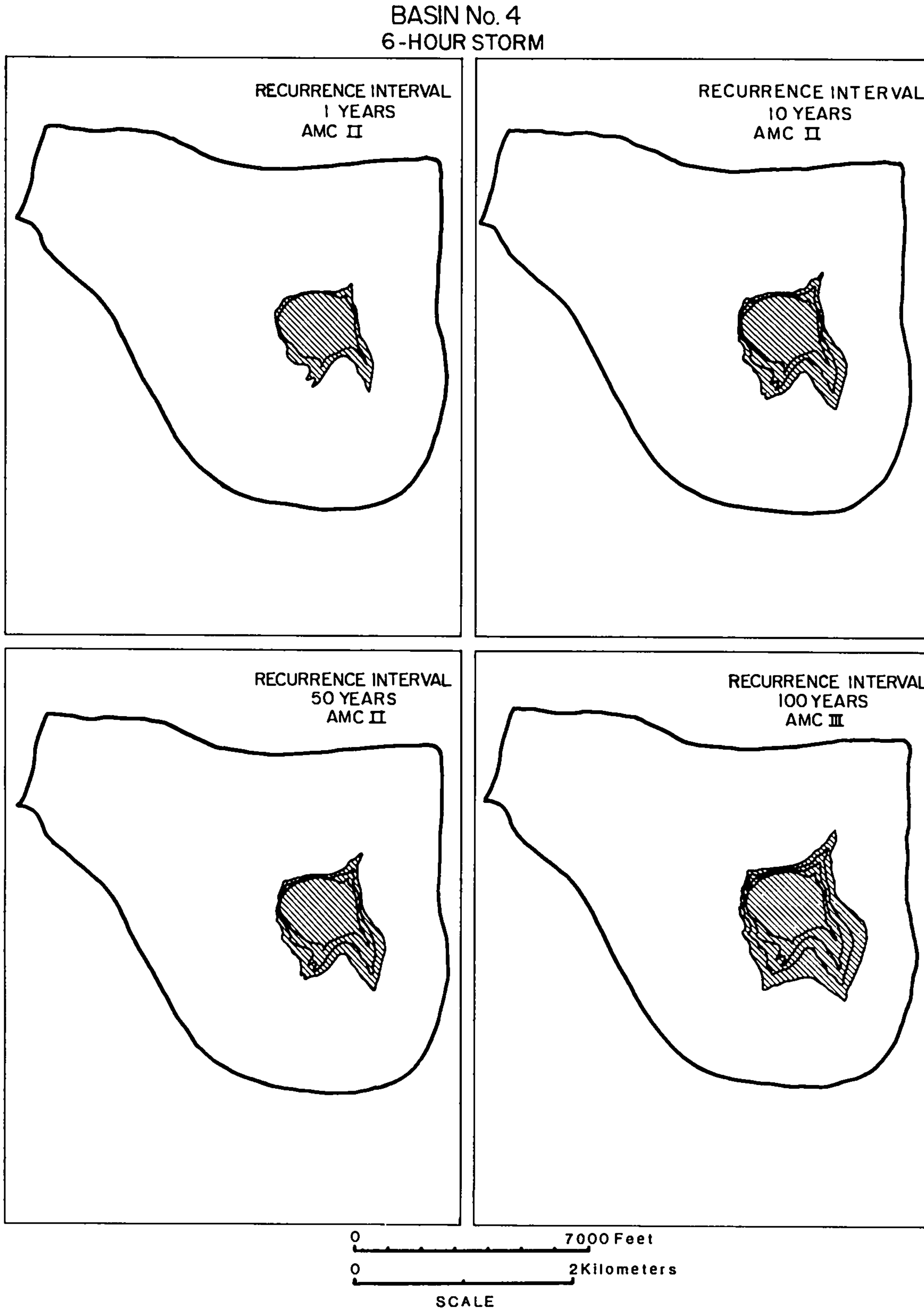
0
2 Kilometers
SCALE

Fig. 5. (cont)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AMC II
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RECURRENCE INTERVAL
100 YEARS
AMC III
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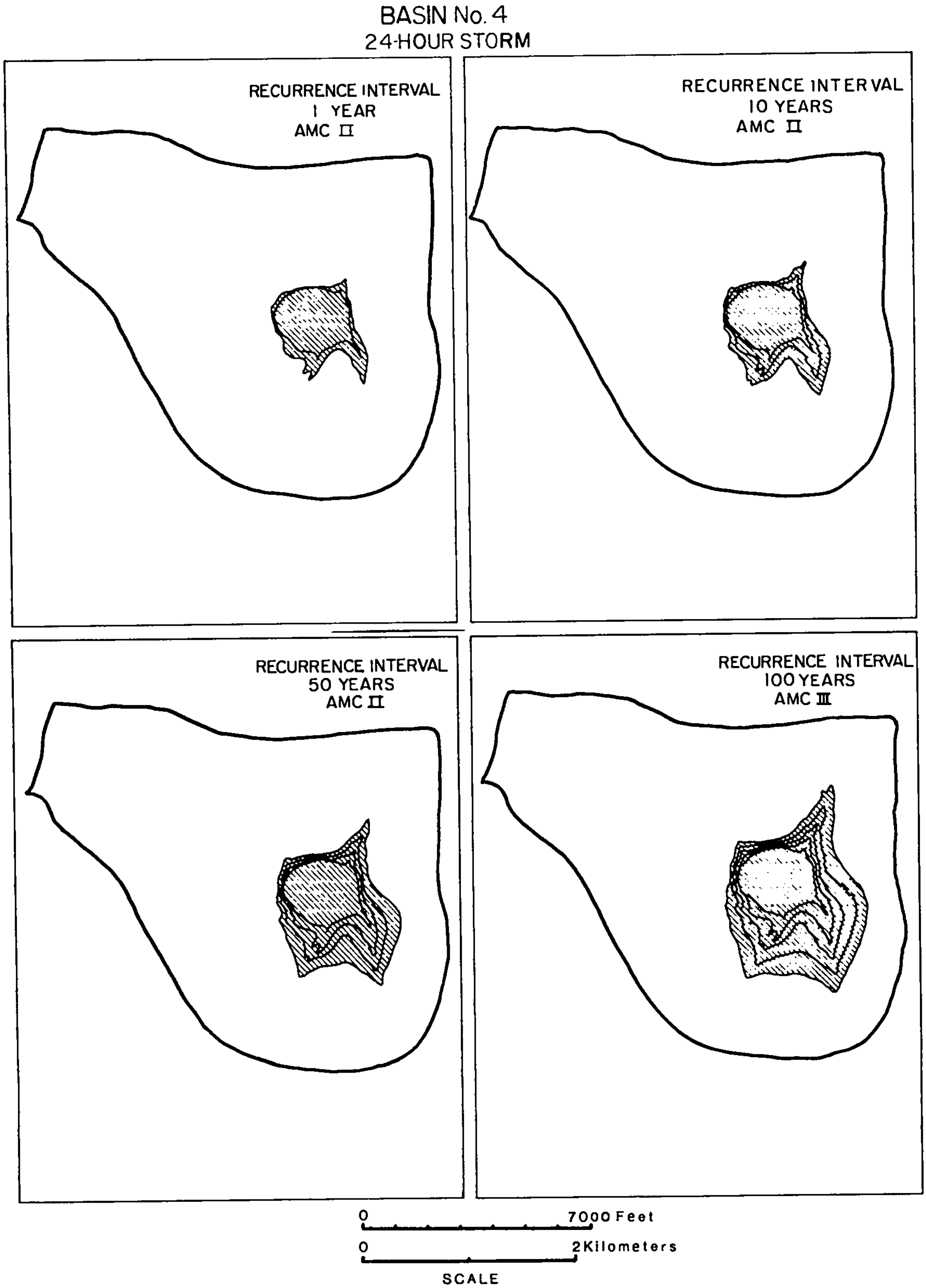
7000 Feet
0
2 Kilometers
SCALE

Fig. 5. (cont)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RECURRENCE INTERVAL
100 YEARS
AMC III
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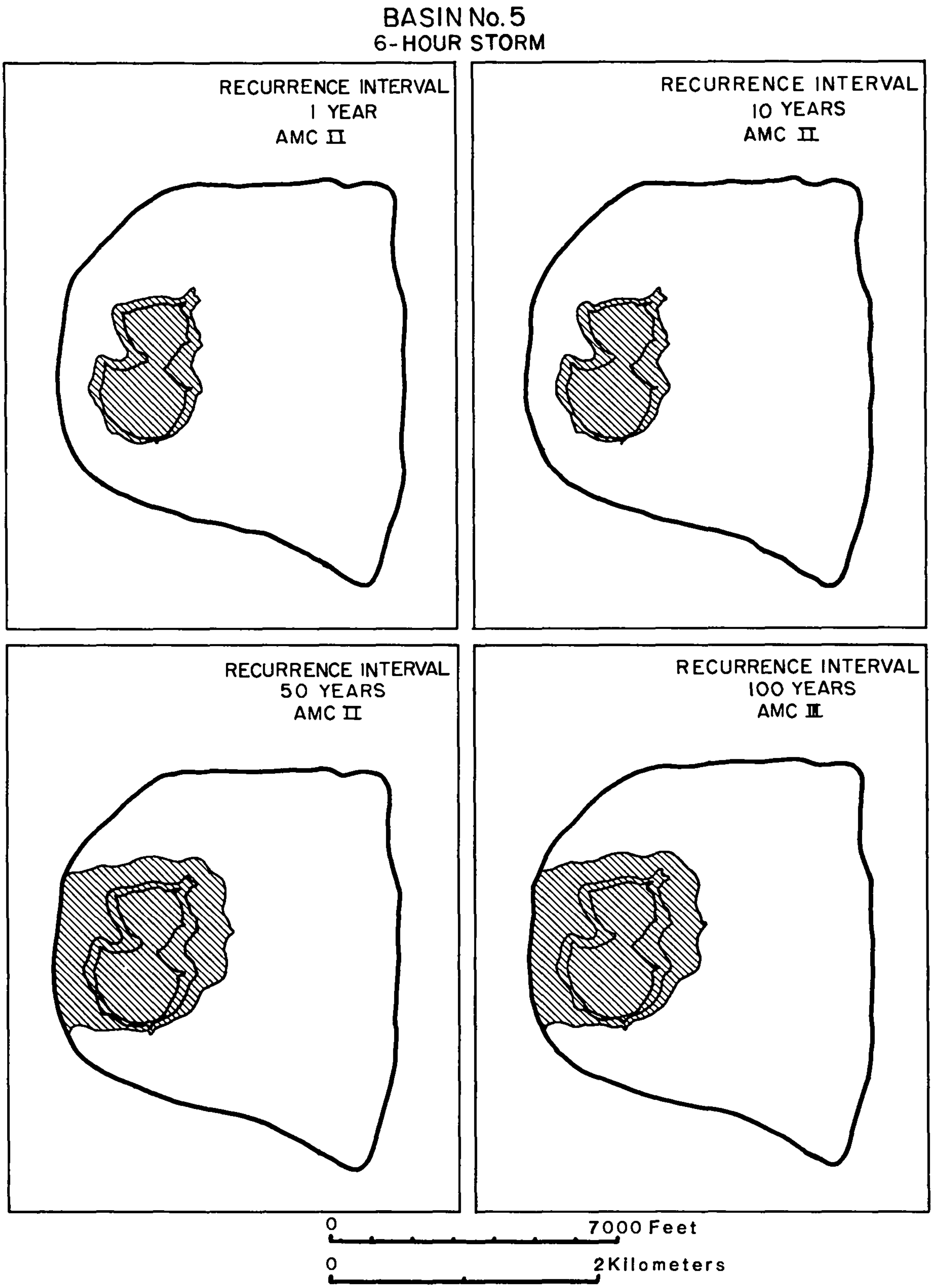
7000 Feet
0
2 Kilometers
SCALE

Fig. 5. (cont)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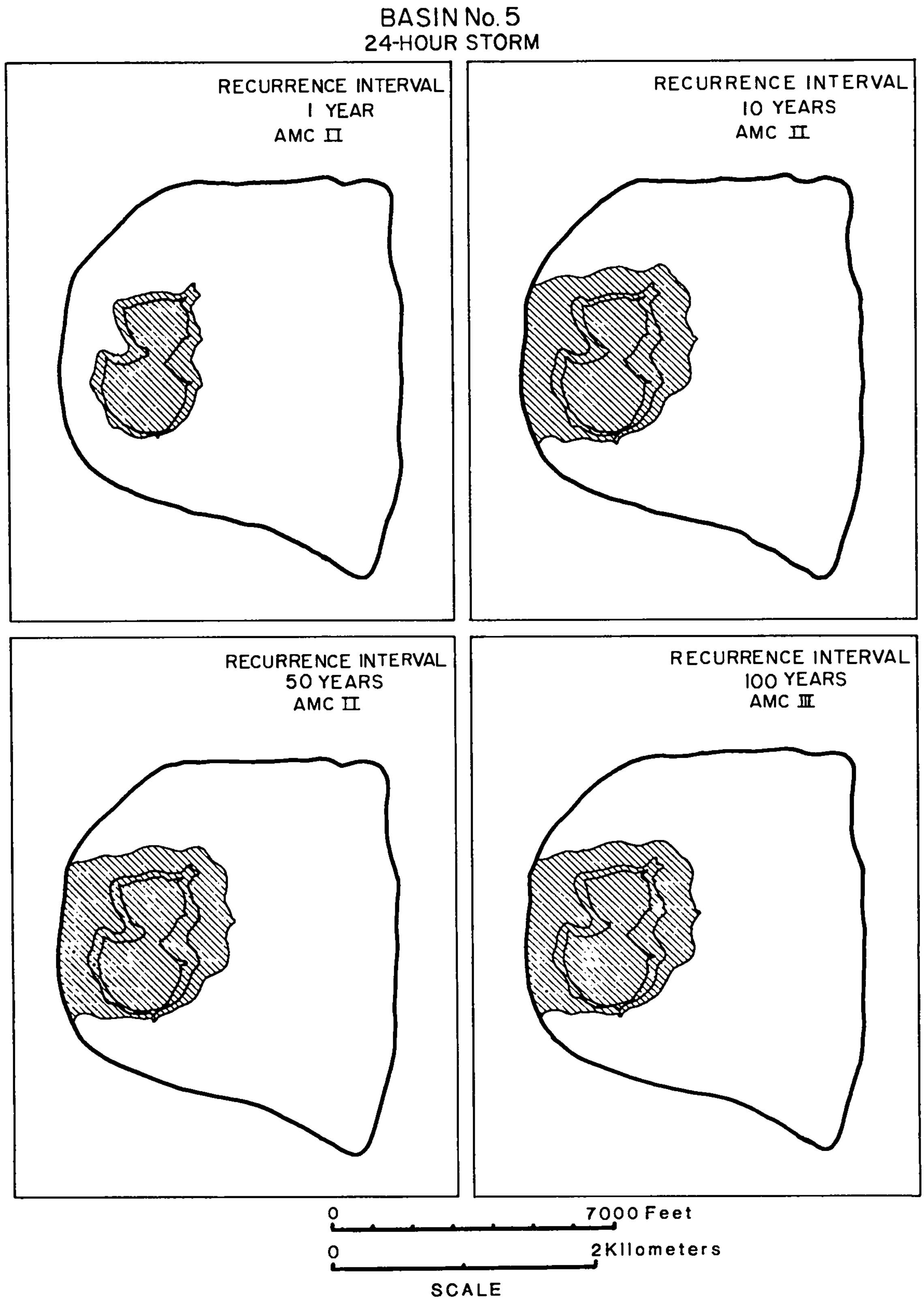
RECURRENCE INTERVAL
10 YEARS
AMC II
RECURRENCE INTERVAL
50 YEARS
AMC II
RECURRENCE INTERVAL
100 YEARS
AMC III
0
7000 Feet
0
2 Kilometers
SCALE

Fig. 5. (cont)



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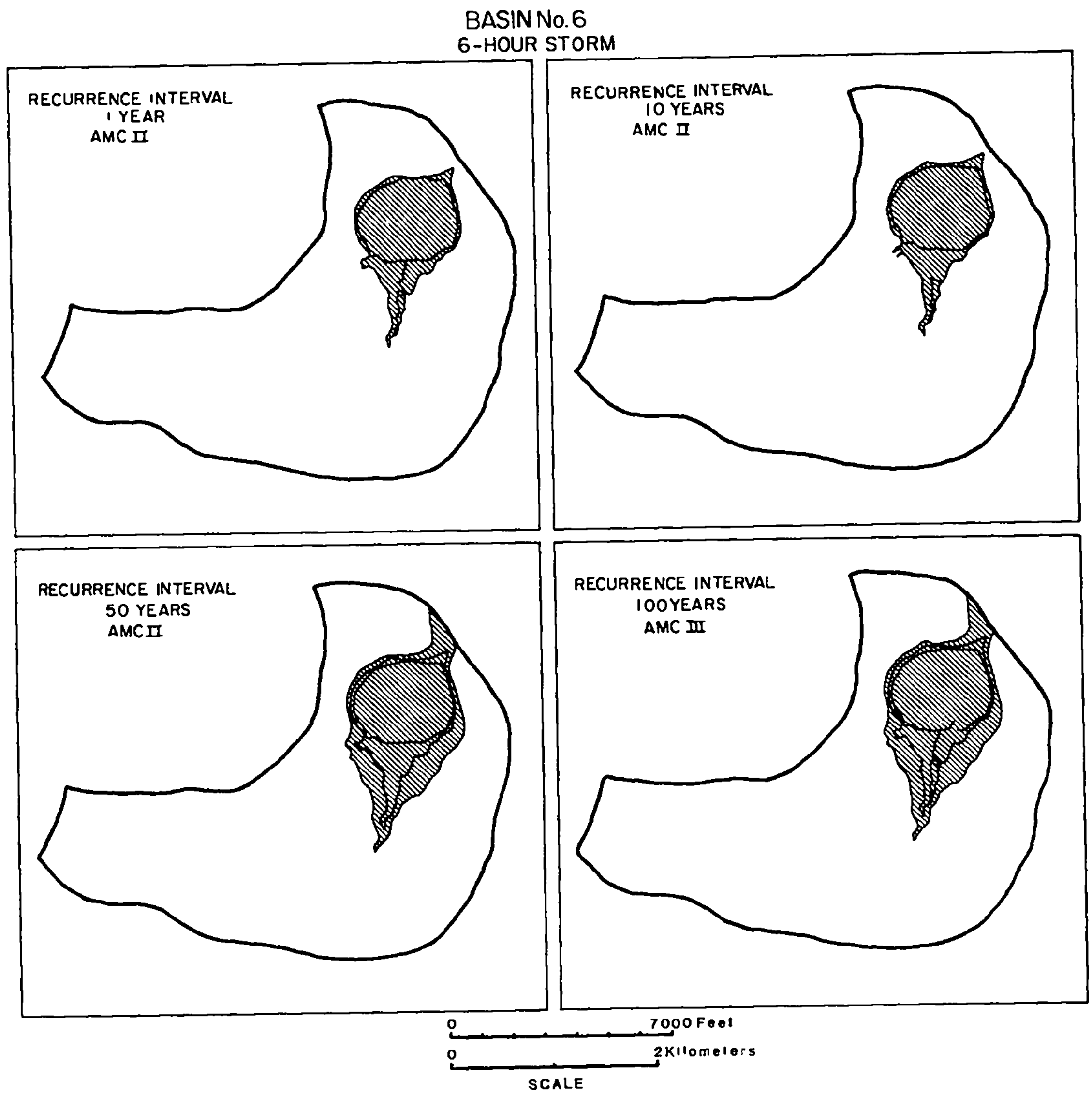
AMC II
RECURRENCE INTERVAL
10 YEARS
AMC II
RECURRENCE INTERVAL
50 YEARS
AMC II
RECURRENCE INTERVAL
100 YEARS
AMC III
0
7000 Feet
0
2 Kilometers
SCALE

Fig. 5. (cont)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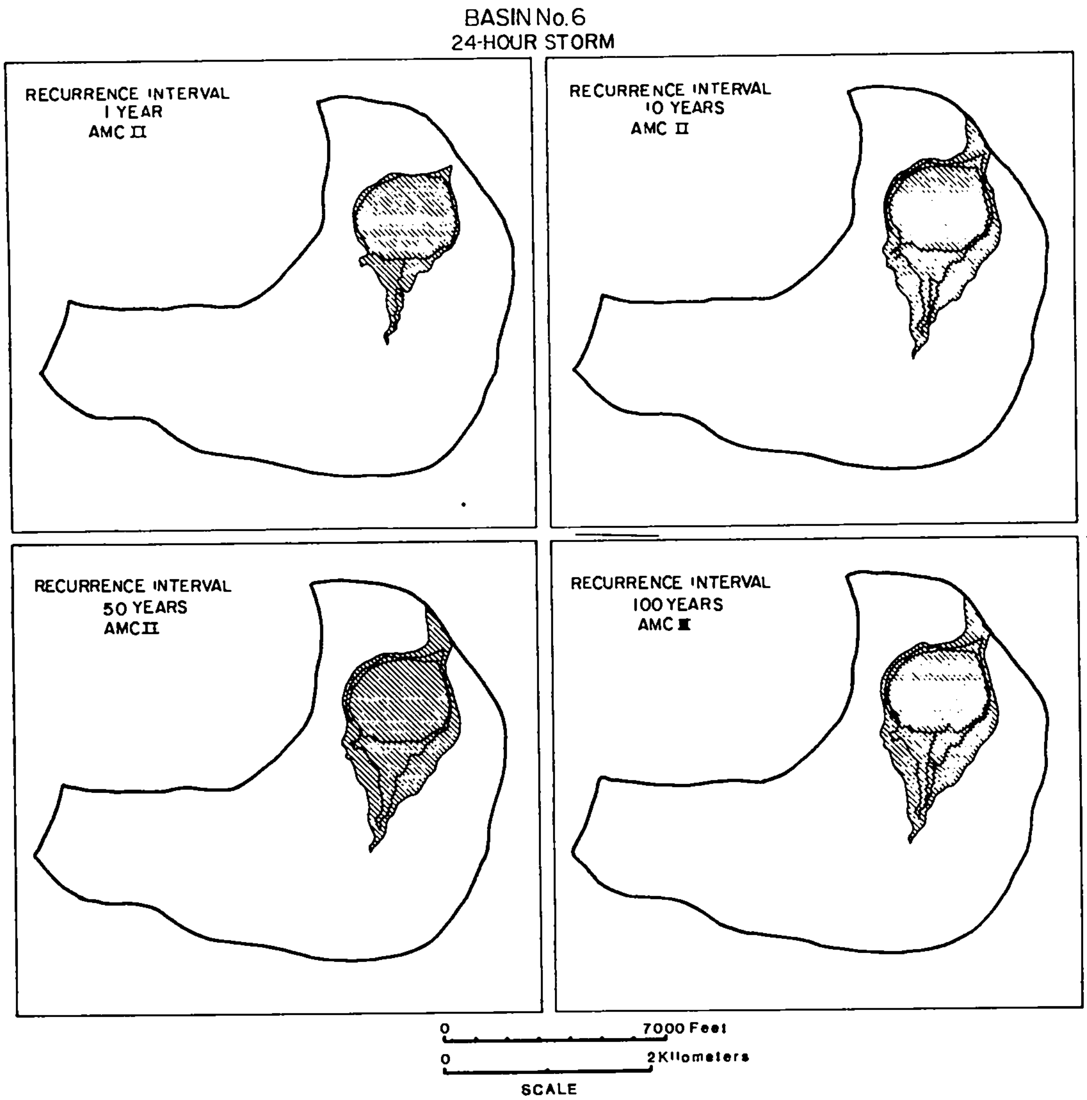
RECURRENCE INTERVAL
10 YEARS
AMC II
RECURRENCE INTERVAL
50 YEARS
AMC II
RECURRENCE INTERVAL
100 YEARS
AMC III
0
7000 Feet
0
2 Kilometers
SCALE

Fig. 5. (cont)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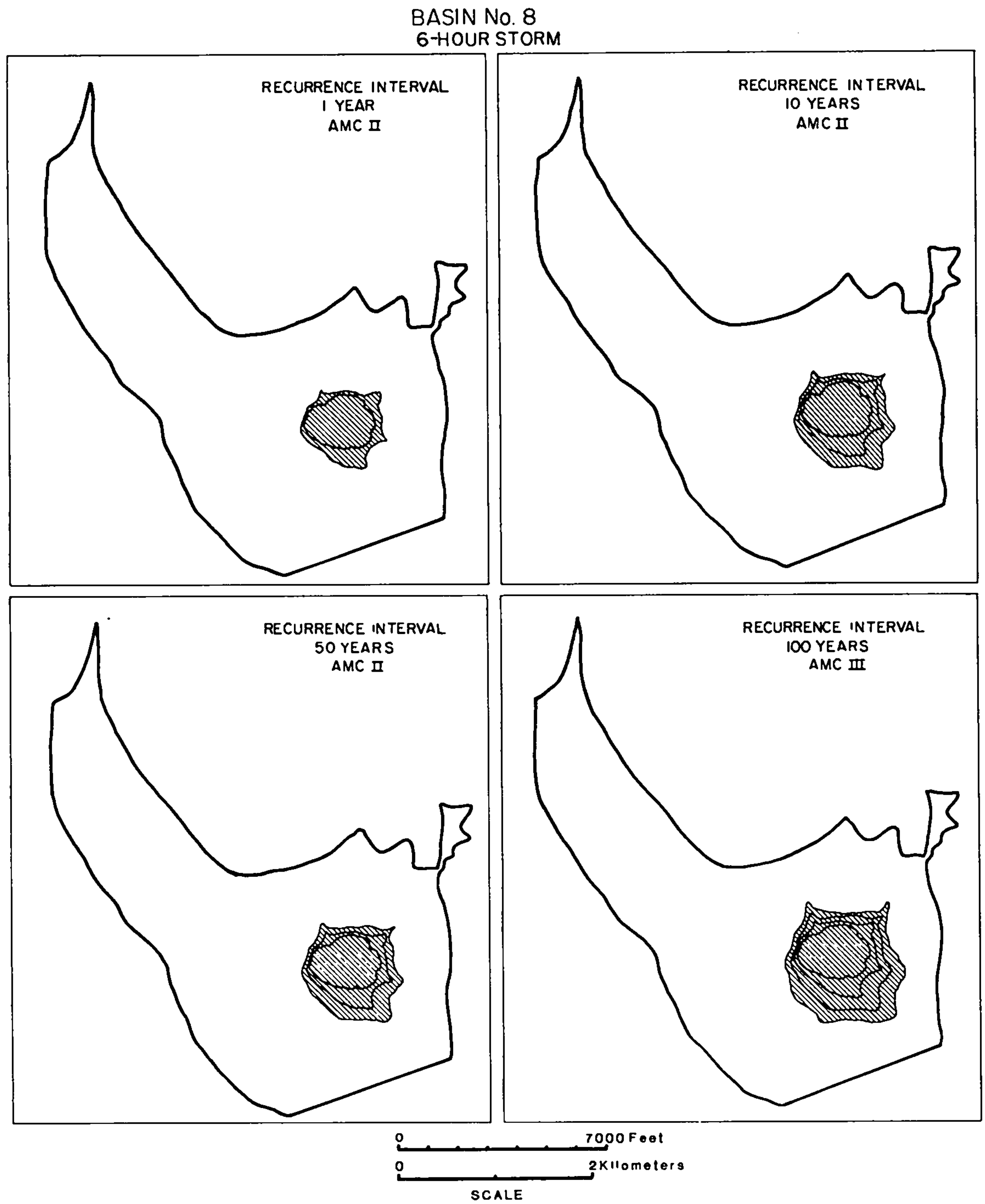
AMC II
RECURRENCE INTERVAL
10 YEARS
AMC II
RECURRENCE INTERVAL
50 YEARS
AMC II
RECURRENCE INTERVAL
100 YEARS
AMC III
0
7000 Feet
0
2 Kilometers
SCALE

Fig. 5. (cont)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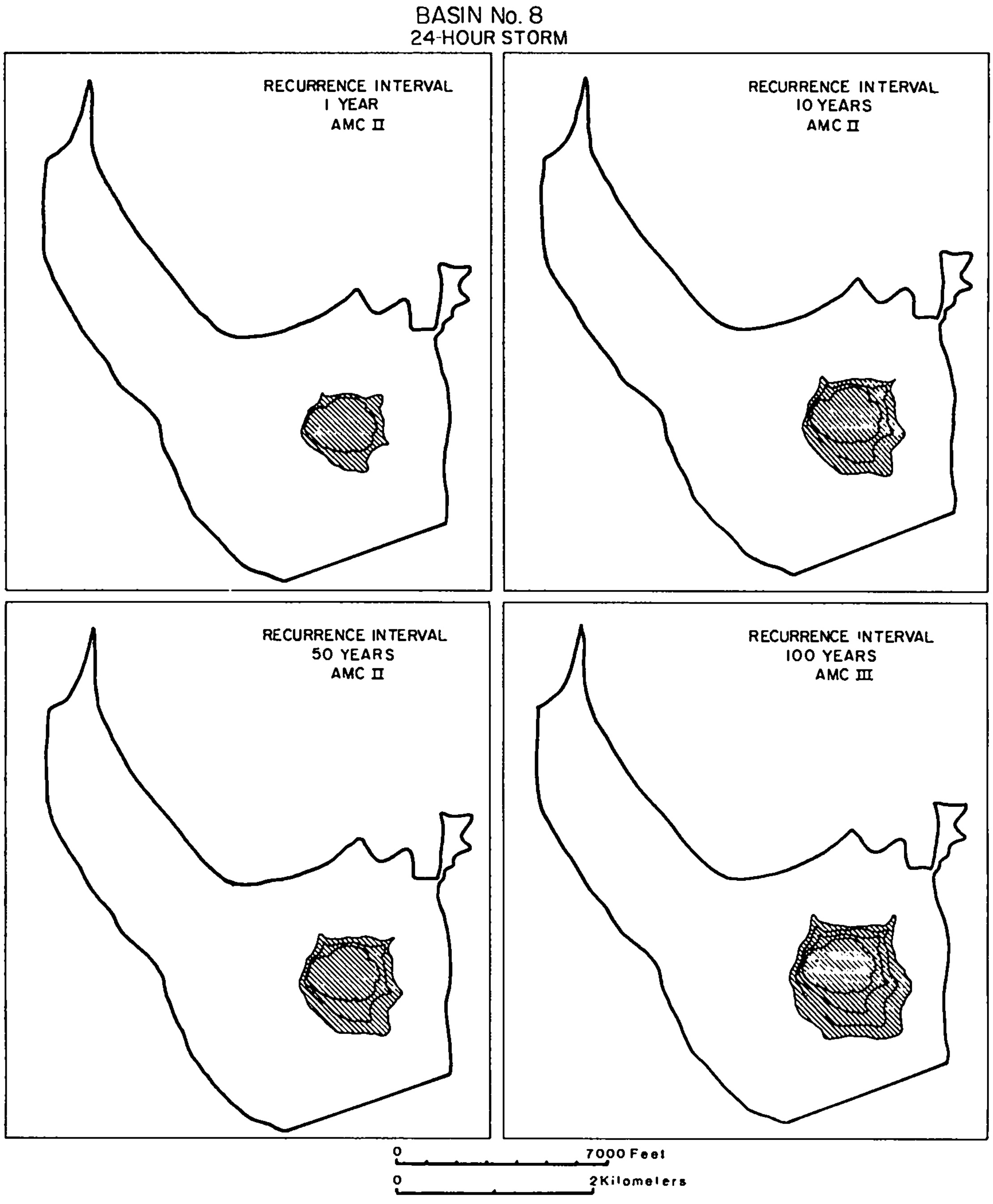
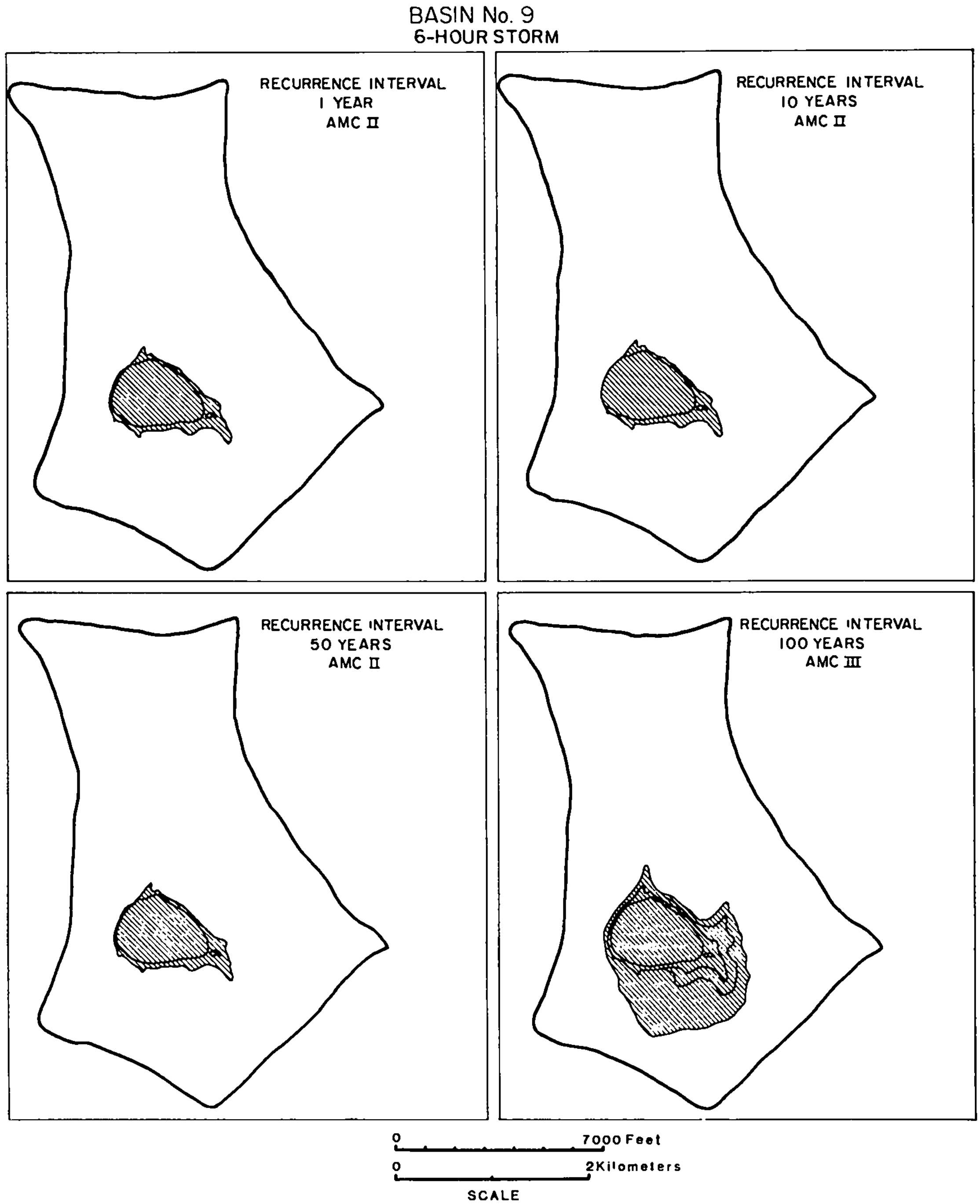
RECURRENCE INTERVAL
10 YEARS
AMC II
RECURRENCE INTERVAL
50 YEARS
AMC II
RECURRENCE INTERVAL
100 YEARS
AMC III
0
7000 Feet
0
2 Kilometers
SCALE

Fig. 5. (cont)



BASIN No. 8
24-HOUR STORM
RECURRENCE INTERVAL
I YEAR
AMC II
RECURRENCE INTERVAL
10 YEARS
AMC II
RECURRENCE INTERVAL
50 YEARS
AMC II
RECURRENCE INTERVAL
100 YEARS
AMC III
0 7000 Feet
0 2 Kilometers
SCALE

Fig. 5. (cont)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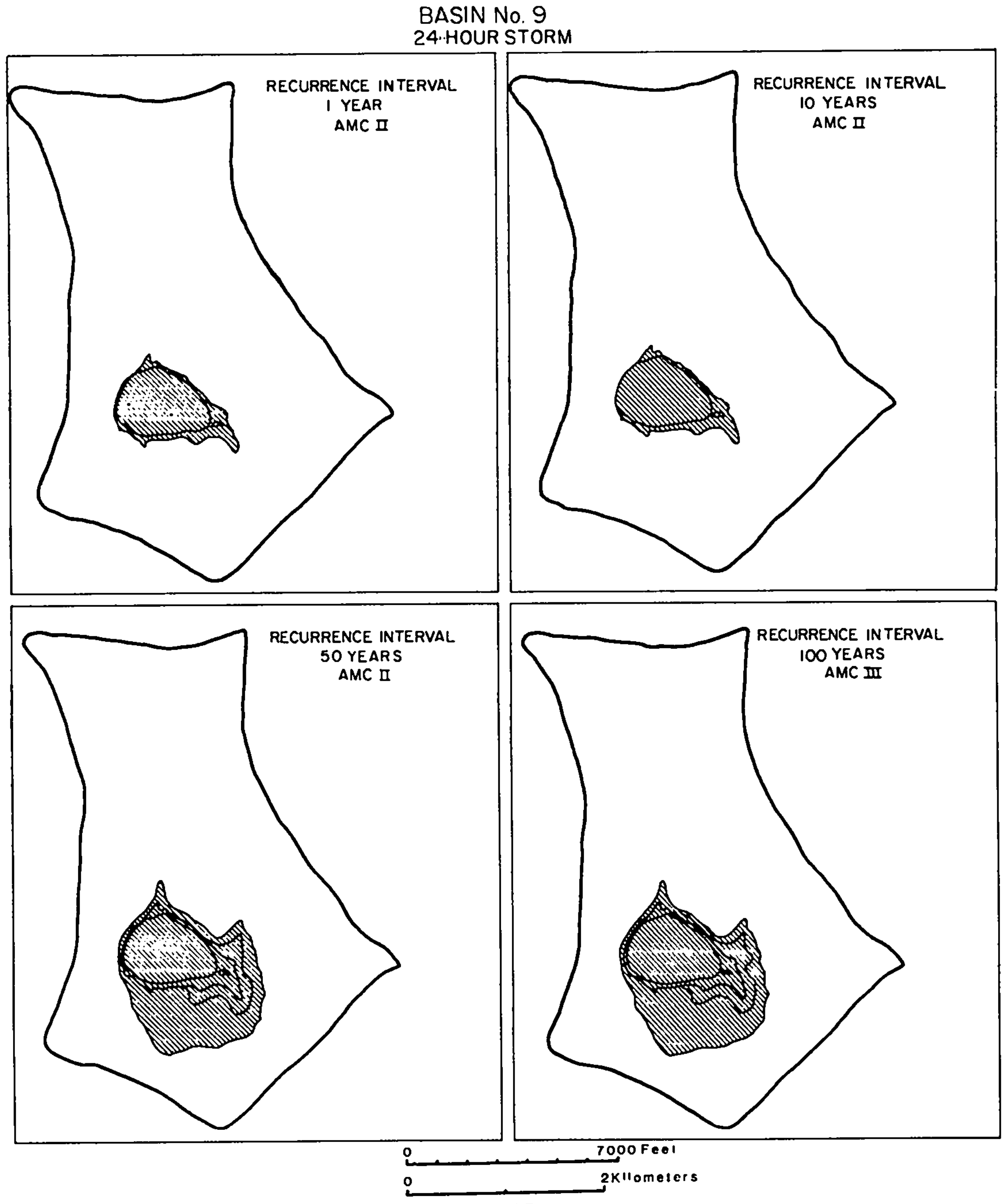
RECURRENCE INTERVAL
10 YEARS
AMC II
RECURRENCE INTERVAL
50 YEARS
AMC II
RECURRENCE INTERVAL
100 YEARS
AMC III
0
7000 Feet
0
2 Kilometers
SCALE

Fig. 5. (cont)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10 YEARS
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100 YEARS
AMC III
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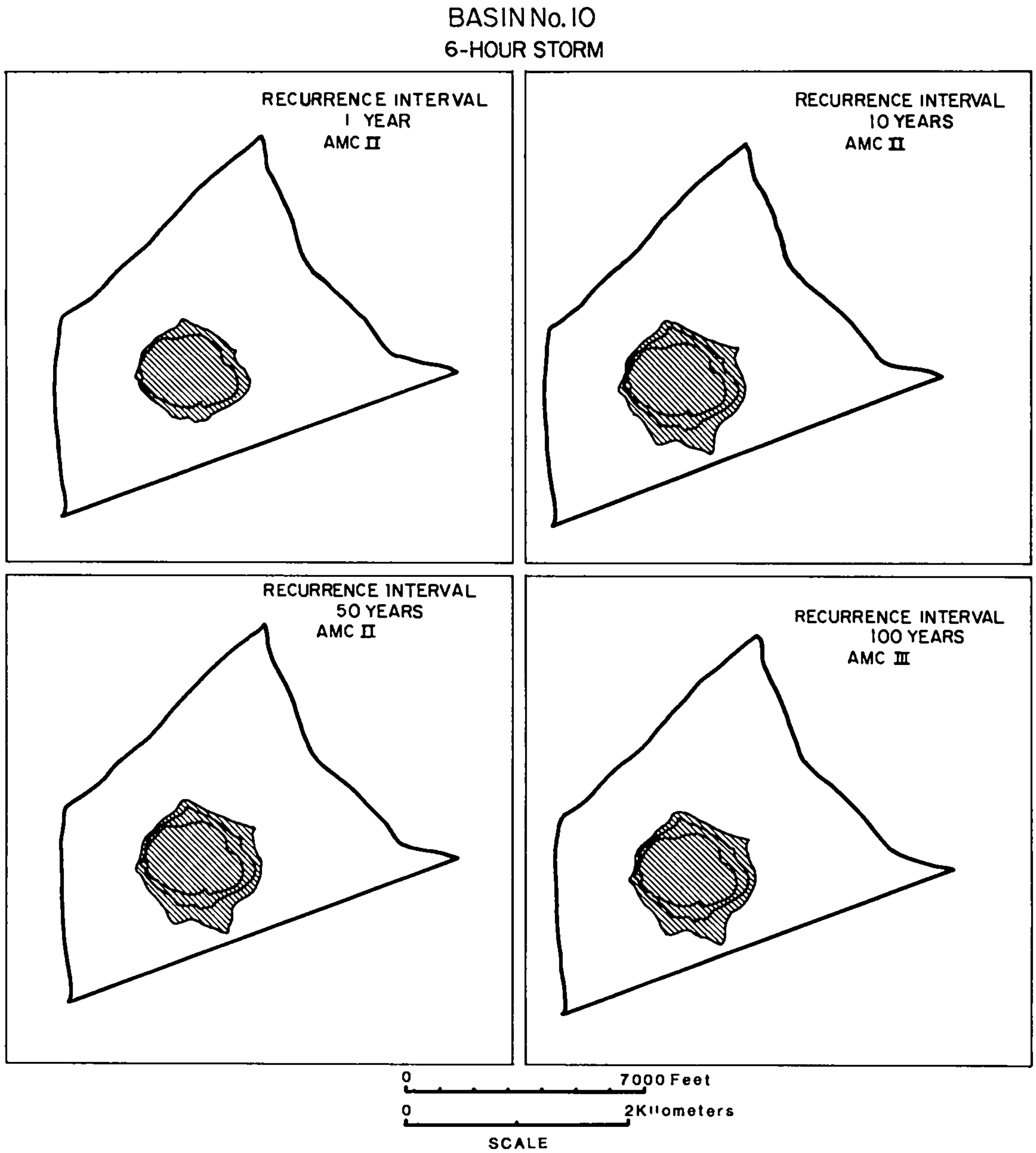
SCALE

Fig. 5. (cont)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AMC II
RECURRENCE INTERVAL
10 YEARS
AMC II
RECURRENCE INTERVAL
50 YEARS
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RECURRENCE INTERVAL
100 YEARS
AMC III
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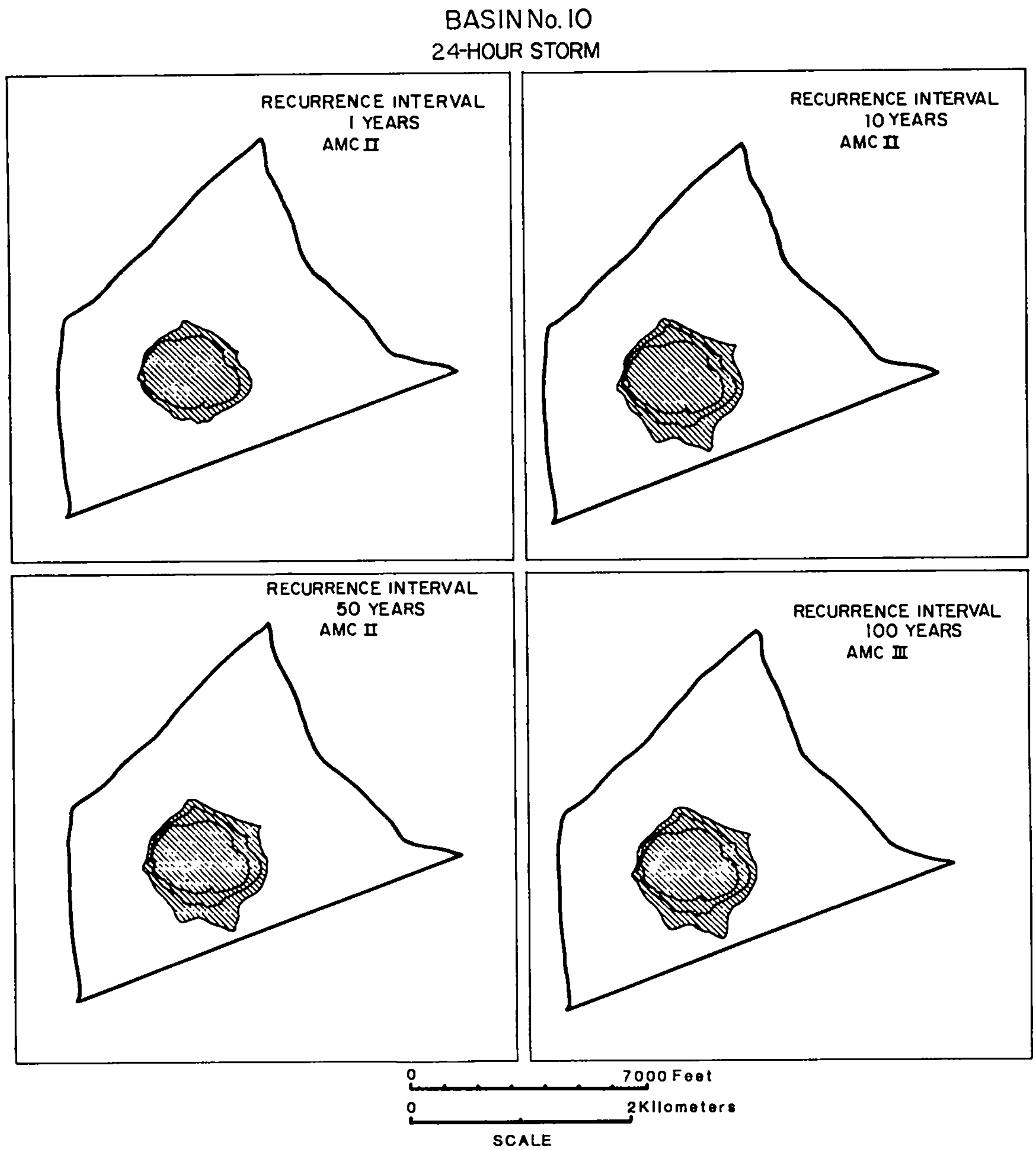
7000 Feet
0
2Kilometers
SCALE

Fig. 5. (cont)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RECURRENCE INTERVAL
10 YEARS
AMC II
RECURRENCE INTERVAL
50 YEARS
AMC II
RECURRENCE INTERVAL
100 YEARS
AMC III
0
7000 Feet
0
2 Kilometers
SCALE

Fig. 5. (cont)

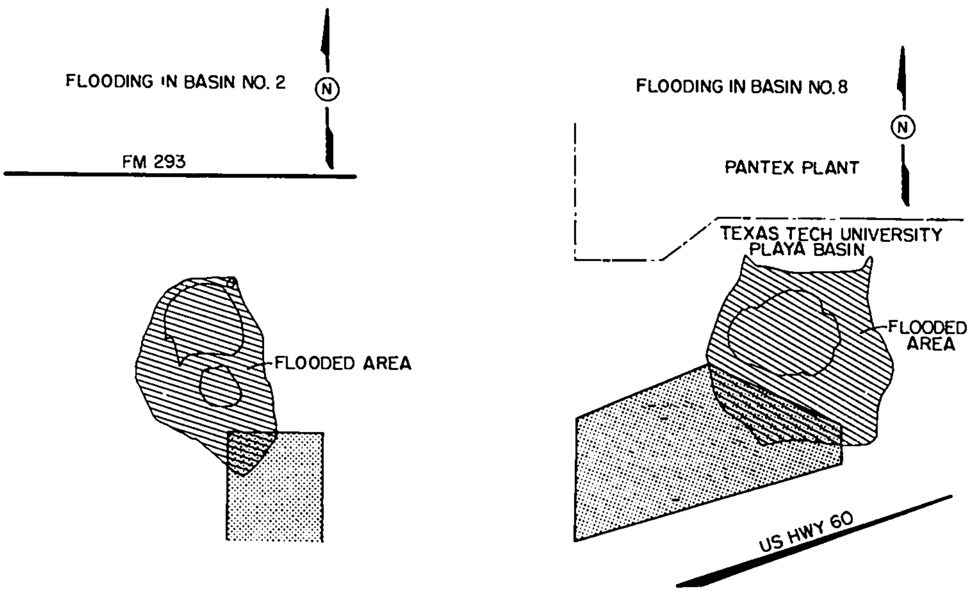


Fig. 6. Flooding of buildings due to the 6- and 24-hour storms.

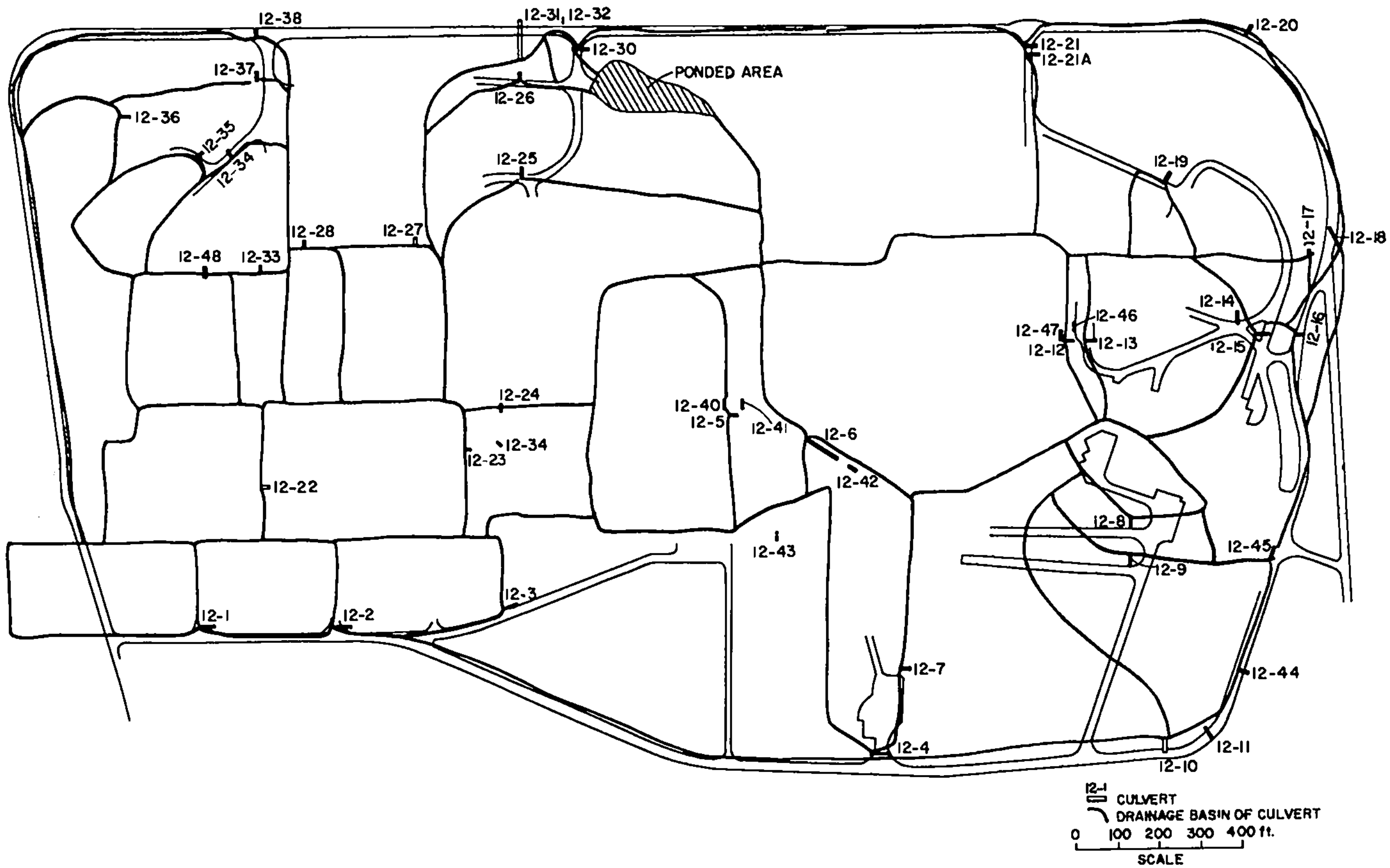
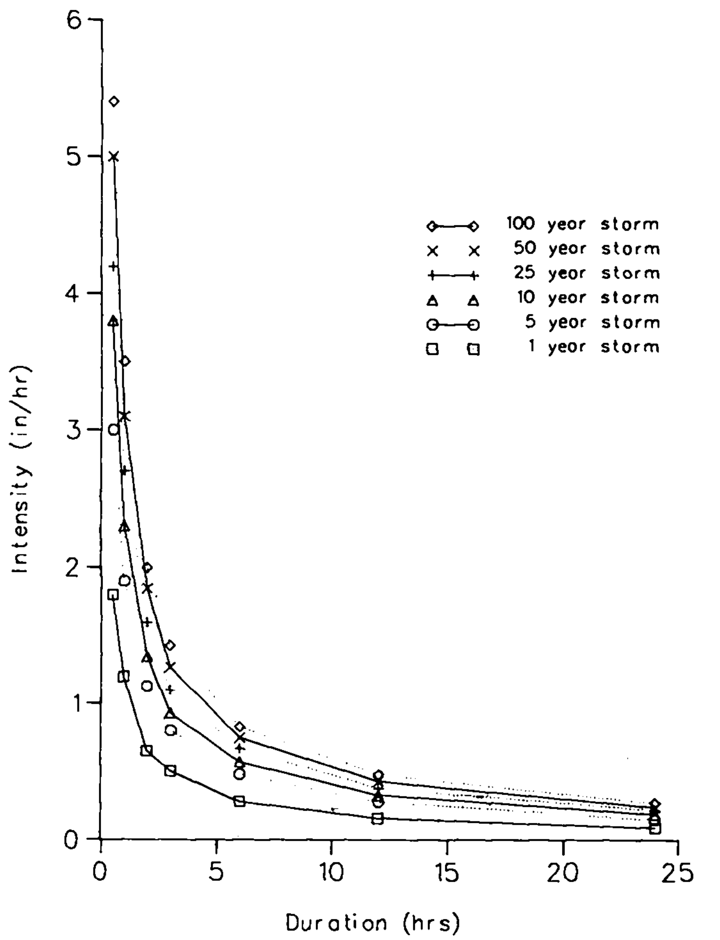


Fig. 7. Location of culverts in Zone 12.



*ref. U.S. Dept. of Commerce, Technical Paper No.40, "Rainfall Frequency Atlas of the U.S. for Durations from 30 Minutes to 24 Hours and Periods from 1 to 100 Years," 1961.

Fig. 8. Intensity-duration-frequency curves for Pantex.

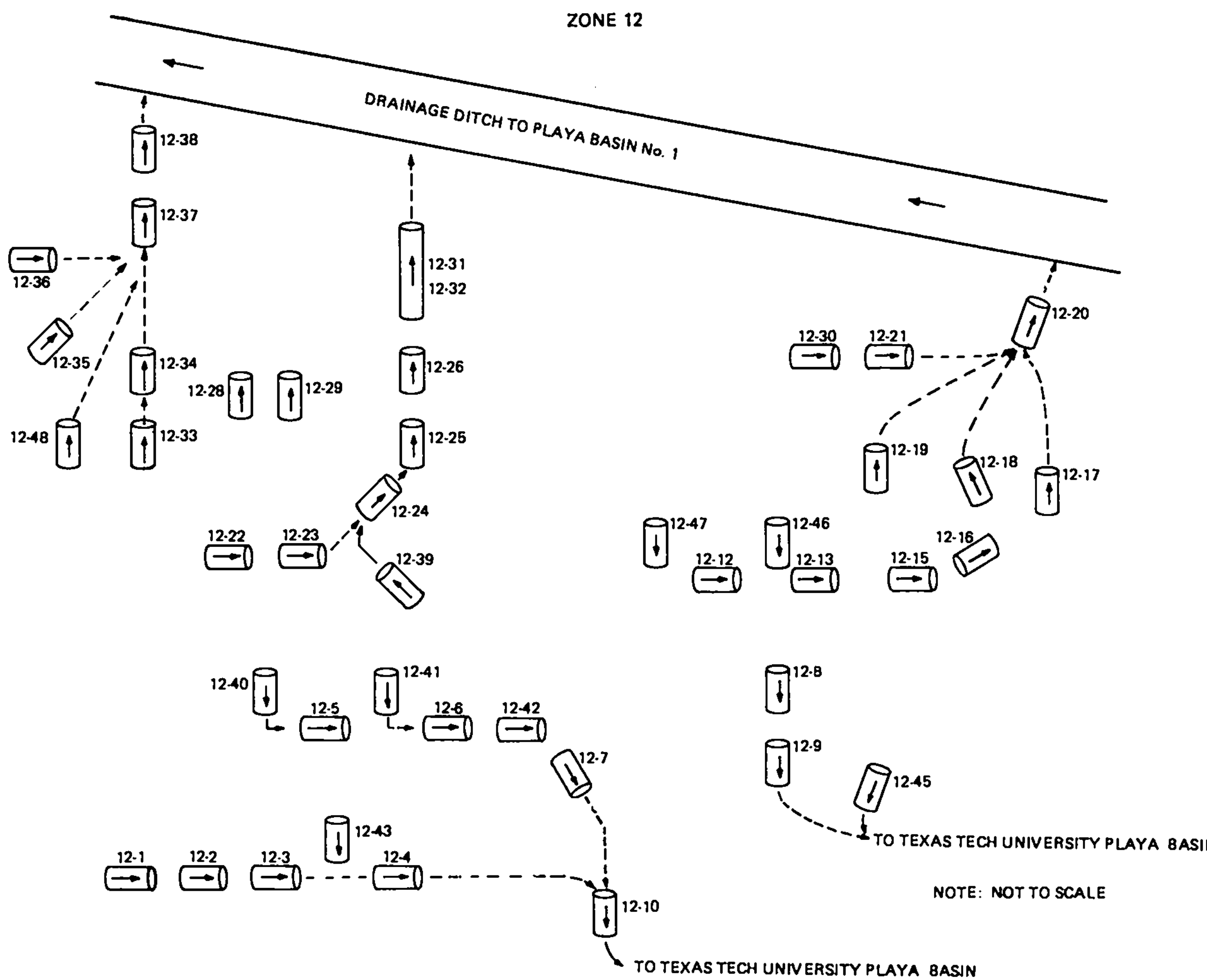


Fig. 9. Interflow connection of culverts in Zone 12.

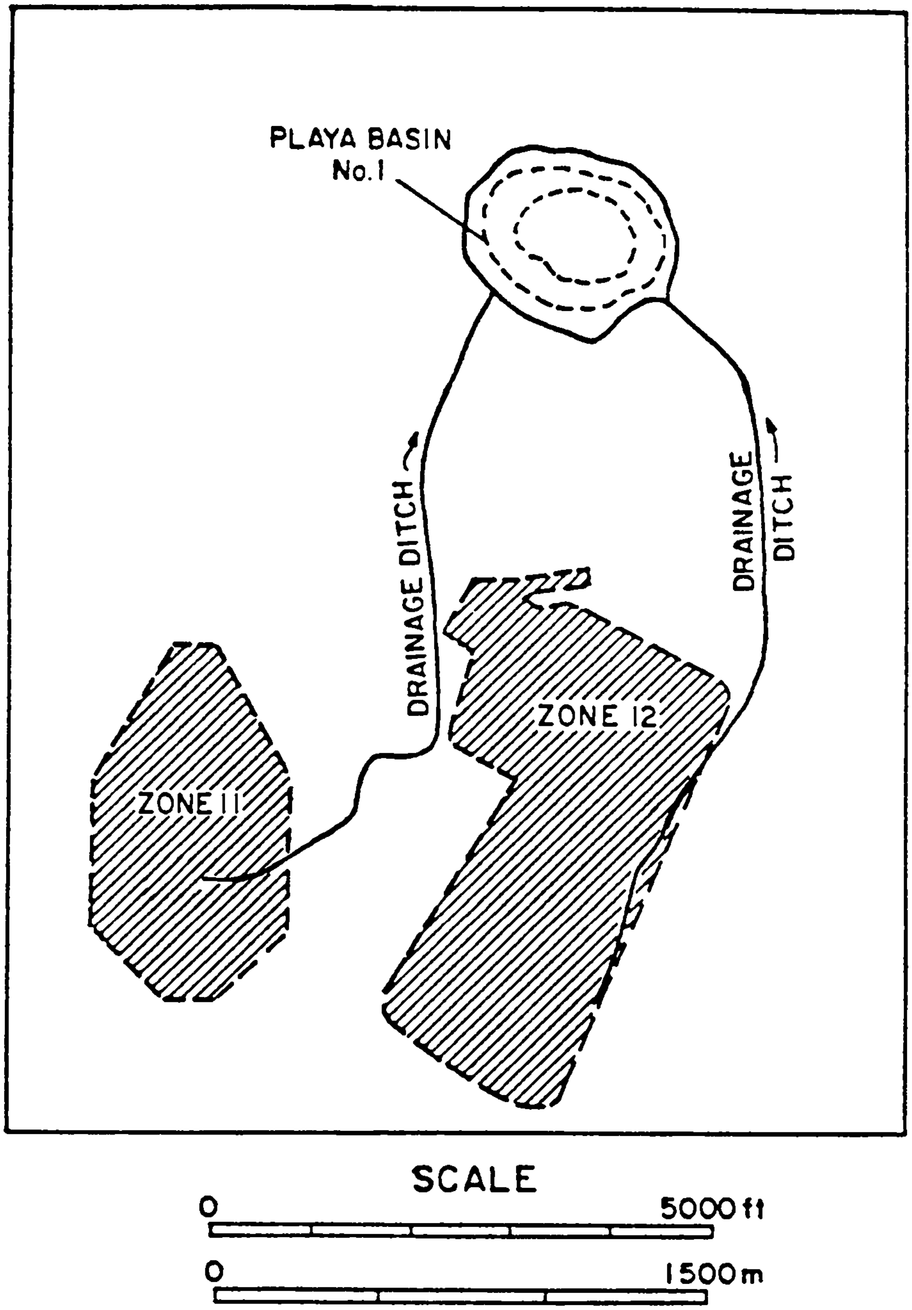


Fig. 10. Ditch system to Playa Basin #1.

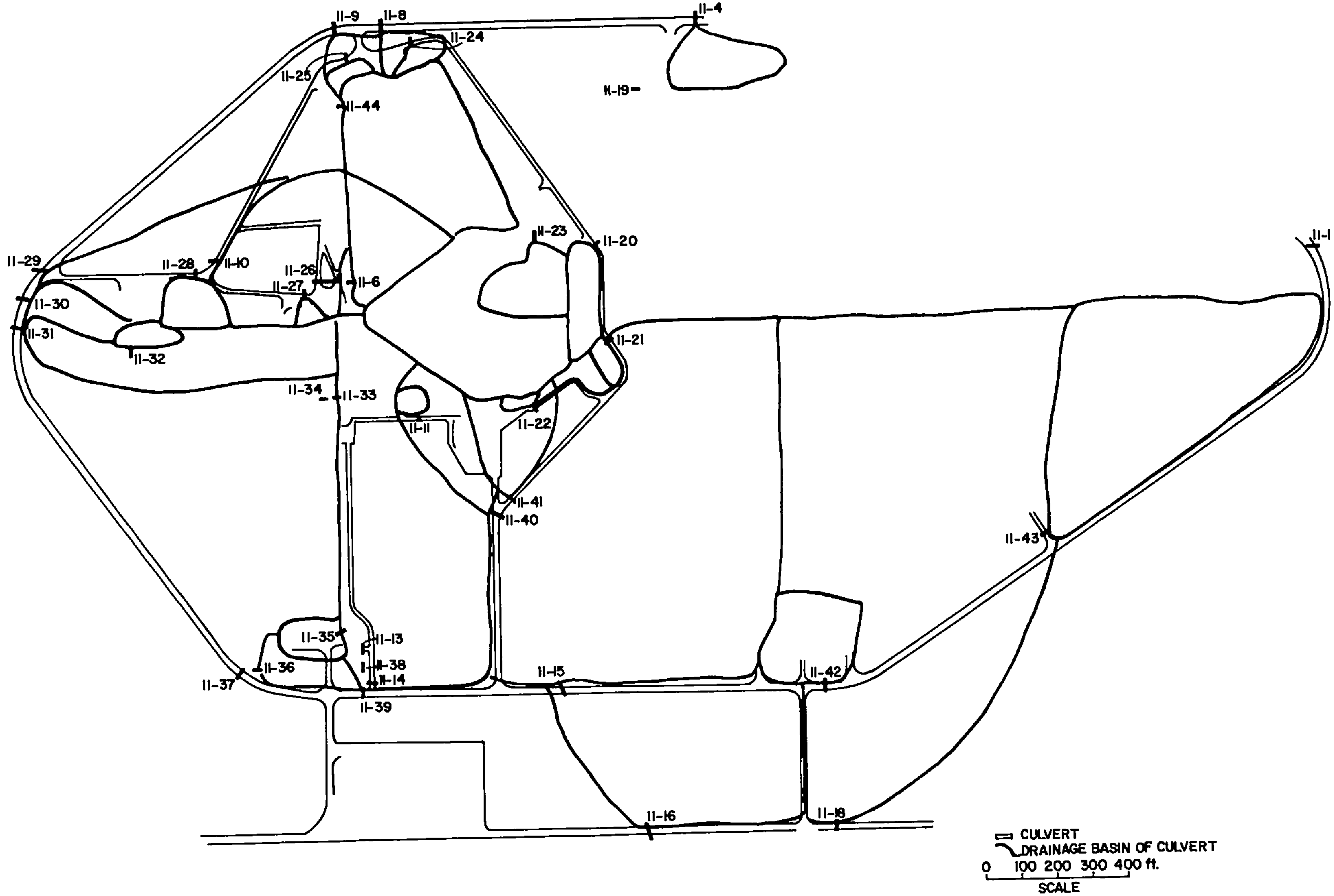


Fig. 11. Location of culverts in Zone 11.

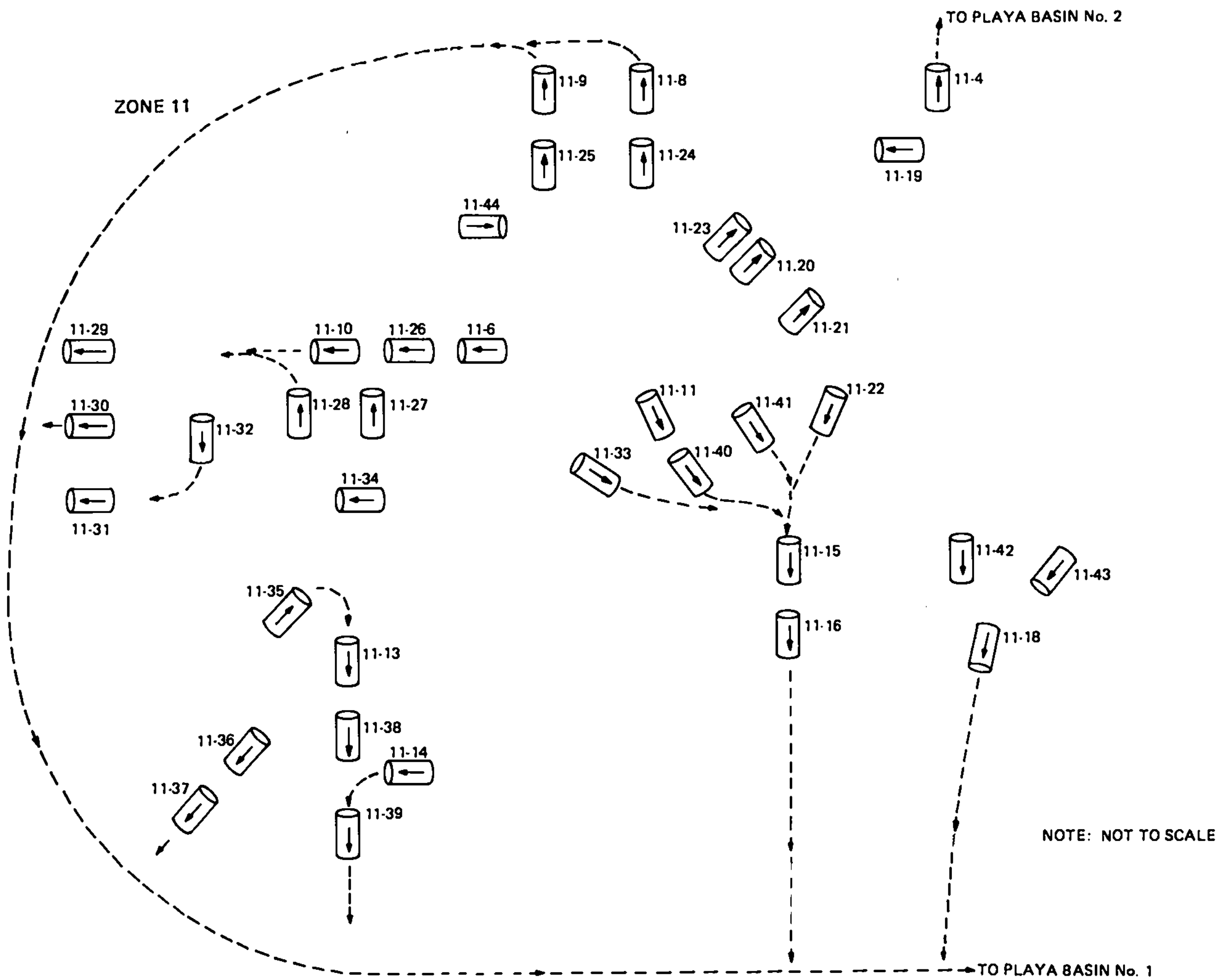


Fig. 12. Interflow connection of culverts in Zone 11.

TABLE I

RAINFALL INTENSITIES FOR AMARILLO, TEXAS

6-Hour Storm		24-Hour Storm	
Recurrence Interval (yr)	Amount (in.)	Recurrence Interval (yr)	Amount (in.)
5	2.9	5	3.7
10	3.4	10	4.5
25	4.0	25	5.3
50	4.5	50	5.8
100	5.0	100	6.5

TABLE II

CURVE NUMBERS FOR PANTEX BASINS

Basin No.	Area (Acre)	CN AMC II	CN AMC I	CN AMC III
1	3441	86	72	94
2	1182	86	72	94
3	2493	87	73	95
4	2577	87	73	95
5	1503	87	73	95
6	2200	87	73	95
7	1186	86	72	94
8	3780	87	73	95
9	2720	87	73	95
10	1422	87	73	95

TABLE III

RUNOFF VOLUMES INTO PLAYA BASINS

6-Hour Storm

Frequency	Rainfall (in.)	Playa Area (Acre)	Runoff Volume (Acre-ft) AMC II	AMC I	AMC III
Basin No. 1	Area = 3326 Acre				
5 yr	2.9	115	471	236	665
10 yr	3.4		587	337	809
25 yr	4.0		745	440	967
50 yr	4.5		875	542	1110
100 yr	5.0		1004	658	1254
Basin No. 2	Area = 1119 Acre				
5 yr	2.9	63	164	85	230
10 yr	3.4		204	116	279
25 yr	4.0		259	156	333
50 yr	4.5		303	191	378
100 yr	5.0		348	231	432
Basin No. 3	Area = 2411 Acre				
5 yr	2.9	82	341	170	482
10 yr	3.4		425	234	586
25 yr	4.0		540	319	700
50 yr	4.5		634	392	794
100 yr	5.0		727	476	908
Basin No. 4	Area = 2488 Acre				
5 yr	2.9	89	353	177	498
10 yr	3.4		440	243	606
25 yr	4.0		558	330	724
50 yr	4.5		655	407	821
100 yr	5.0		752	493	939

TABLE III (cont)

6-Hour Storm (cont)

Frequency	Rainfall (in.)	Playa Area (Acre)	Runoff Volume (Acre-ft) AMC II	AMC I	AMC III
Basin No. 5	Area = 1392 Acre				
5 yr	2.9	111	212	114	294
10 yr	3.4		263	153	356
25 yr	4.0		333	205	426
50 yr	4.5		390	250	482
100 yr	5.0		446	301	551
Basin No. 6	Area = 2043 Acre				
5 yr	2.9	157	310	166	430
10 yr	3.4		385	223	521
25 yr	4.0		486	299	623
50 yr	4.5		570	365	706
100 yr	5.0		653	440	806
Basin No. 7	Area = 1186 Acre				
5 yr	2.9	0	158	74	227
10 yr	3.4		198	104	277
25 yr	4.0		252	143	331
50 yr	4.5		296	178	376
100 yr	5.0		341	217	430
Basin No. 8	Area = 3653 Acre				
5 yr	2.9	127	518	259	731
10 yr	3.4		645	356	888
25 yr	4.0		817	484	1062
50 yr	4.5		961	596	1204
100 yr	5.0		1103	723	1377
Basin No. 9	Area = 2596 Acre				
5 yr	2.9	124	376	192	528
10 yr	3.4		468	262	641
25 yr	4.0		593	355	766
50 yr	4.5		696	436	869
100 yr	5.0		798	528	993

TABLE III (cont)

6-Hour Storm (cont)

Frequency	Rainfall (in.)	Playa Area (Acre)	Runoff Volume (Acre-ft) AMC II	AMC I	AMC III
Basin No. 10	Area = 1314 Acre				
5 yr	2.9	108	201	108	278
10 yr	3.4		250	146	337
25 yr	4.0		315	195	403
50 yr	4.5		369	238	457
100 yr	5.0		423	286	521

24-Hour Storm

Frequency	Rainfall (in.)	Playa Area (Acre)	AMC II	AMC I	AMC III
Basin No. 1	Area = 3326 Acre				
5 yr	3.7	115	673	396	895
10 yr	4.5		875	542	1096
25 yr	5.3		1090	716	1326
50 yr	5.8		1234	832	1469
100 yr	6.5		1420	1005	1670
Basin No. 2	Area = 1119 Acre				
5 yr	3.7	63	234	141	308
10 yr	4.5		303	191	378
25 yr	5.3		378	252	457
50 yr	5.8		427	292	506
100 yr	6.5		491	351	575
Basin No. 3	Area = 2411 Acre				
5 yr	3.7	82	487	286	648
10 yr	4.5		634	392	794
25 yr	5.3		790	518	960
50 yr	5.8		894	602	1064
100 yr	6.5		1029	728	1210
Basin No. 4	Area = 2488 Acre				
5 yr	3.7	89	504	297	670
10 yr	4.5		655	407	821
25 yr	5.3		817	537	993
50 yr	5.8		924	624	1100
100 yr	6.5		1064	753	1251

TABLE III (cont)

24-Hour Storm (cont)

Frequency	Rainfall (in.)	Playa Area (Acre)	Runoff Volume (Acre-ft) AMC II	AMC I	AMC III
Basin No. 5	Area = 1392 Acre				
5 yr	3.7	111	301	185	394
10 yr	4.5		390	251	483
25 yr	5.3		484	328	583
50 yr	5.8		547	379	646
100 yr	6.5		629	455	733
Basin No. 6	Area = 2043 Acre				
5 yr	3.7	157	440	270	576
10 yr	4.5		570	365	706
25 yr	5.3		708	478	852
50 yr	5.8		799	553	944
100 yr	6.5		919	664	1072
Basin No. 7	Area = 1186 Acre				
5 yr	3.7	0	227	128	306
10 yr	4.5		296	178	376
25 yr	5.3		371	237	455
50 yr	5.8		420	277	504
100 yr	6.5		484	336	573
Basin No. 8	Area = 3653 Acre				
5 yr	3.7	127	739	435	983
10 yr	4.5		961	596	1204
25 yr	5.3		787	1198	1456
50 yr	5.8		1355	914	1614
100 yr	6.5		1560	1104	1834
Basin No. 9	Area = 2596 Acre				
5 yr	3.7	124	536	319	709
10 yr	4.5		696	436	867
25 yr	5.3		866	574	1050
50 yr	5.8		979	666	1163
100 yr	6.5		1127	803	1322

TABLE III (cont)

24-Hour Storm (cont)

Frequency	Rainfall (in.)	Playa Area (Acre)	Runoff Volume (Acre-ft) AMC II	AMC I	AMC III
Basin No. 10	Area = 1314 Acre				
5 yr	3.7	108	285	176	373
10 yr	4.5		369	238	457
25 yr	5.3		458	310	551
50 yr	5.8		518	359	611
100 yr	6.5		595	431	694

TABLE IV

VOLUMES ENCLOSED BY CONTOURS IN PLAYA BASINS

	Contour	Volume (acre-ft)
Basin #1	3520	361.25
	3525	1252.
	3530	2200.
Basin #2	3560	188.75
	3565	710.
Basin #3	3520	266.25
	3525	877.5
	3530	1362.5
Basin #4	3515	267.5
	3520	767.5
	3525	1120.
	3530	1635.
Basin #5	3505	356.25
	3510	1337.5
Basin #6	3490	480.
	3495	1440.
Basin #8	3500	428.75
	3505	1355.
	3510	2035.
Basin #9	3510	722.5
	3520	2900.
Basin #10	3500	327.5
	3505	932.5

TABLE V

RAINFALL INTENSITY AS A FUNCTION OF RAINFALL DURATION

Recurrence Interval (Year)	Power Equation
5	$i = 44.150\ t^{-0.773}$
10	$i = 54.166\ t^{-0.776}$
25	$i = 61.174\ t^{-0.771}$
50	$i = 77.005\ t^{-0.789}$
100	$i = 82.389\ t^{-0.783}$

where i = rainfall intensity in inches/hour and t = duration in minutes.

TABLE VI
PEAK DISCHARGE COMPUTATIONS FOR ZONE 12

Culvert Location	Area Drained by (ft^2)	Area Drained (acres)	Slope (ft/ft)	Maximum Flow Length(ft)	Runoff Coeff. c	Manning n	T 5-yr (min) I	T 5-yr (min) K	i 5-yr (in./hr) I	i 5-yr (in./hr) K	Q 5-yr (cfs) I	Q 5-yr (cfs) K
12-1	97 078	2.23		660	0.6	0.115	-	73.3	-	1.60	-	2.14
12-2	73 449	1.69		550	0.3	0.12	-	97.0	-	1.28	-	0.65
12-3	85 230	1.96		610	0.35	0.12	-	97.1	-	1.28	-	0.88
12-4	407 315	9.35		1410	0.4	0.125	-	192.8	-	0.76	-	2.83
12-5	187 134	4.30		410	0.6	0.12	-	50.3	-	2.14	-	5.51
12-6	72 850	1.67		240	0.6	0.115	-	30.5	-	3.15	-	3.15
12-7	126 298	2.90		600	0.7	0.115	-	61.7	-	1.82	-	3.70
12-8	44 762	1.03		240	0.65	0.12	-	30.2	-	3.17	-	2.12
12-9	39 570	0.91		230	0.6	0.12	-	30.5	-	3.15	-	1.72
12-10	268 737	6.17		910	0.35	0.12	-	137.4	-	0.98	-	2.12
12-11												
12-12	373 369	8.57		700	0.6	0.125	-	83.0	-	1.45	-	7.46
12-13	17 372	0.40		210	0.6	0.12	-	28.1	-	3.35	-	0.80
12-14												
12-15	137 414	3.15		500	0.6	0.115	-	57.6	-	1.92	-	3.63
12-16	112 487	2.58		490	0.65	0.115	-	54.0	-	2.02	-	3.39
12-17	26 617	0.61		430	0.3	0.12	-	78.4	-	1.52	-	0.28
12-18	28 122	0.65		320	0.3	0.12	86	60.6	1.41	1.85	0.27	0.36
12-19	22 597	0.52		180	0.4	0.12	39	31.1	2.59	3.10	0.54	0.64
12-20	338 059	7.76		550	0.4	0.135	-	91.0	-	1.35	-	4.19
12-21	397 531	9.13		1030	0.5	0.12	-	124.5	-	1.06	-	4.84
12-22	114 916	2.64		380	0.6	0.115	-	45.4	-	2.31	-	3.66
12-23	152 256	3.50		580	0.5	0.12	-	75.6	-	1.56	-	2.73
12-24	78 641	1.81		340	0.4	0.115	-	52.1	-	2.08	-	1.50
12-25	253 255	5.81	0.003	600	0.6	0.115	-	67.5	-	1.70	-	5.93
12-26	174 720	4.01		450	0.4	0.12	-	69.0	-	1.67	-	2.68
12-27												
12-28	50 170	1.15		350	0.6	0.115	-	42.3	-	2.44	-	1.69
12-29	87 992	2.02		500	0.5	0.115	-	64.0	-	1.77	-	1.79
12-30	10 284	0.24		110	0.5	0.115	21	17.2	4.27	4.90	0.51	0.59
12-31	19 902	0.46		250	0.5	0.11	-	33.7	-	2.91	-	0.67
12-32												
12-33	37 873	0.87		300	0.7	0.115	-	33.8	-	2.90	-	1.77
12-34	79 573	1.83		320	0.3	0.12	86	60.6	1.41	1.85	0.77	1.01
12-35	50 320	1.16		330	0.3	0.12	88	62.3	1.38	1.81	0.48	0.63
12-36	146 665	3.37		1170	0.3	0.12	-	187.0	-	0.77	-	0.78
12-37	67 592	1.55		440	0.4	0.12	-	67.7	-	1.70	-	1.05
12-38	82 535	1.89		700	0.2	0.13	259	162.2	0.60	0.86	0.23	0.33
12-39												
12-40												
12-41												
12-42												
12-43												
12-44												
12-45	159 545	3.66		1040	0.65	0.14	-	123.3	-	1.07	-	2.54
12-46												
12-47												
12-48	79 648	1.83		450	0.5	0.12	-	60.6	-	1.85	-	1.69
12-49												
12-6A												
Ponded Area	20 833	0.48		200	0.5	0.115	-	28.9	-	3.28	-	0.79
Const. E of 12-28/29	161 708	3.71		400	0.55	0.12	-	51.8	-	2.09	-	4.26

I = Izzard's Formula; K = Kinematic Wave Formula; C_r = 0.025; Discharge computed by the Rational Formula Q = CiA. Those culverts for which information is not presented were either missing, filled, crushed, or combined with another culvert.

TABLE VI (cont)

Culvert Location	T 10-yr (min)		i 10-yr (in./hr)		Q 10-yr (cfs)		T 25-yr (min)		i 25-yr (in./hr)		Q 25-yr (cfs)	
	I	K	I	K	I	K	I	K	I	K	I	K
12-1	-	65.1	-	2.12	-	2.84	-	60.3	-	2.59	-	3.47
12-2	-	86.1	-	1.71	-	0.86	-	79.8	-	2.09	-	1.06
12-3	-	86.2	-	1.71	-	1.17	-	79.8	-	2.09	-	1.43
12-4	-	171.2	-	1.00	-	3.74	-	158.4	-	1.23	-	4.61
12-5	-	44.6	-	2.84	-	7.33	-	41.4	-	3.46	-	8.94
12-6	-	27.0	-	4.20	-	4.20	-	25.1	-	5.10	-	5.11
12-7	-	54.8	-	2.42	-	4.92	-	50.8	-	2.96	-	6.01
12-8	-	26.8	-	4.23	-	2.83	-	24.8	-	5.14	-	3.44
12-9	-	27.0	-	4.20	-	2.29	-	25.1	-	5.10	-	2.78
12-10	-	122.0	-	1.30	-	2.81	-	113.0	-	1.60	-	3.45
12-11												
12-12	-	73.6	-	1.93	-	9.91	-	68.2	-	2.36	-	12.12
12-13	-	25.0	-	4.46	-	1.07	-	23.2	-	5.42	-	1.30
12-14												
12-15	-	51.1	-	2.56	-	4.84	-	47.4	-	3.12	-	5.90
12-16	-	47.9	-	2.69	-	4.51	-	44.5	-	3.28	-	5.50
12-17	-	69.5	-	2.02	-	0.37	-	64.4	-	2.46	-	0.45
12-18	-	53.8	-	2.46	-	0.48	-	49.9	-	3.00	-	0.59
12-19	-	27.6	-	4.13	-	0.86	-	25.6	-	5.02	-	1.04
12-20	-	80.8	-	1.79	-	5.57	-	74.8	-	2.20	-	6.82
12-21	-	110.5	-	1.41	-	6.42	-	102.3	-	1.72	-	7.88
12-22	-	40.3	-	3.08	-	4.88	-	37.4	-	3.75	-	5.94
12-23	-	67.1	-	2.07	-	3.63	-	62.2	-	2.53	-	4.43
12-24	-	46.2	-	2.76	-	2.00	-	42.9	-	3.37	-	2.44
12-25	-	59.9	-	2.26	-	7.88	-	55.5	-	2.76	-	9.64
12-26	-	61.2	-	2.22	-	3.57	-	56.8	-	2.72	-	4.36
12-27												
12-28	-	37.5	-	3.25	-	2.24	-	34.8	-	3.96	-	2.73
12-29	-	56.8	-	2.36	-	2.38	-	52.7	-	2.88	-	2.91
12-30	-	15.2	-	6.54	-	0.78	-	14.2	-	7.92	-	0.95
12-31	-	29.9	-	3.88	-	0.89	-	27.8	-	4.71	-	1.08
12-32												
12-33	-	30.0	-	3.87	-	2.36	-	27.8	-	4.71	-	2.87
12-34	-	53.8	-	2.46	-	1.35	-	49.9	-	3.00	-	1.65
12-35	-	55.2	-	2.41	-	0.84	-	51.2	-	2.94	-	1.02
12-36	-	166.0	-	1.02	-	1.04	-	153.6	-	1.26	-	1.28
12-37	-	60.0	-	2.26	-	1.40	-	55.7	-	2.76	-	1.71
12-38	-	144.0	-	1.14	-	0.43	-	133.3	-	1.41	-	0.53
12-39												
12-40												
12-41												
12-42												
12-43												
12-44												
12-45	-	109.5	-	1.42	-	3.37	-	101.4	-	1.74	-	4.14
12-46												
12-47												
12-48	-	53.8	-	2.46	-	2.25	-	49.9	-	3.00	-	2.75
12-49												
12-6A												
Ponded Area	-	25.6	-	4.37	-	1.05	-	23.8	-	5.31	-	1.28
Const. E of 12-28/29		45.9	-	2.78	-	5.67	-	42.6	-	3.39	-	6.92

I = Izzard's Formula C_r = 0.025
K = Kinematic Wave Formula
Discharges computed by the Rational Formula A = CiA

TABLE VI (cont)

Culvert Location	T 50-yr (min)		i 50-yr (in./hr)		Q 50-yr (cfs)		T 100-yr (min)		i 100-yr (in./hr)		Q 100-yr (cfs)	
	I	K	I	K	I	K	I	K	I	K	I	K
12-1	-	55.0	-	3.26	-	4.36	-	52.2	-	3.73	-	4.98
12-2	-	73.0	-	2.61	-	1.32	-	69.1	-	2.99	-	1.52
12-3	-	73.0	-	2.61	-	1.79	-	69.2	-	2.99	-	2.05
12-4	-	145.9	-	1.51	-	5.65	-	137.9	-	1.74	-	6.51
12-5	-	37.6	-	4.40	-	11.36	-	35.7	-	5.01	-	12.93
12-6	-	22.7	-	6.56	-	6.58	-	21.6	-	7.44	-	7.46
12-7	-	46.2	-	3.74	-	7.59	-	43.9	-	4.27	-	8.66
12-8	-	22.4	-	6.61	-	4.43	-	21.4	-	7.50	-	5.02
12-9	-	22.7	-	6.56	-	3.58	-	21.6	-	7.44	-	4.06
12-10	-	103.7	-	1.98	-	4.27	-	98.1	-	2.27	-	4.91
12-11												
12-12	-	62.3	-	2.96	-	15.20	-	59.1	-	3.38	-	17.38
12-13	-	20.9	-	6.99	-	1.68	-	19.9	-	7.92	-	1.90
12-14												
12-15	-	43.1	-	3.95	-	7.47	-	40.9	-	4.50	-	8.51
12-16	-	40.4	-	4.16	-	6.97	-	38.4	-	4.74	-	7.94
12-17	-	58.8	-	3.09	-	0.57	-	55.8	-	3.54	-	0.65
12-18	-	45.4	-	3.80	-	0.74	-	43.1	-	4.33	-	0.84
12-19	-	23.2	-	6.45	-	1.34	-	22.0	-	7.32	-	1.52
12-20	-	68.4	-	2.75	-	8.52	-	64.8	-	3.14	-	9.76
12-21	-	93.8	-	2.14	-	9.77	-	88.8	-	2.46	-	11.21
12-22	-	33.9	-	4.78	-	7.57	-	32.2	-	5.44	-	8.61
12-23	-	56.7	-	3.18	-	5.57	-	53.8	-	3.64	-	6.37
12-24	-	39.0	-	4.28	-	3.10	-	37.0	-	4.88	-	3.53
12-25	-	50.6	-	3.48	-	12.14	-	48.0	-	3.98	-	13.86
12-26	-	51.7	-	3.42	-	5.49	-	49.1	-	3.91	-	6.27
12-27												
12-28	-	31.5	-	5.06	-	3.49	-	30.0	-	5.75	-	3.97
12-29	-	48.0	-	3.63	-	3.67	-	45.5	-	4.14	-	4.19
12-30	-	12.7	-	10.35	-	1.24	-	12.1	-	11.68	-	1.40
12-31	-	25.1	-	6.05	-	1.39	-	23.9	-	6.87	-	1.58
12-32												
12-33	-	25.2	-	6.04	-	3.68	-	23.9	-	6.85	-	4.17
12-34	-	45.4	-	3.80	-	2.08	-	43.1	-	4.33	-	2.38
12-35	-	46.6	-	3.72	-	1.29	-	44.2	-	4.24	-	1.48
12-36	-	141.4	-	1.55	-	1.56	-	133.7	-	1.78	-	1.80
12-37	-	50.7	-	3.48	-	2.16	-	48.1	-	3.97	-	2.46
12-38	-	122.5	-	1.73	-	0.66	-	115.9	-	1.99	-	0.75
12-39												
12-40												
12-41												
12-42												
12-43												
12-44												
12-45	-	92.9	-	2.16	-	5.13	-	88.0	-	2.48	-	5.89
12-46												
12-47												
12-48	-	45.4	-	3.79	-	3.47	-	43.1	-	4.33	-	3.96
12-49												
12-6A												
Ponded Area	-	21.5	-	6.85	-	1.64	-	20.4	-	7.76	-	1.86
Const. E of 12-28/29	-	38.7	-	4.30	-	8.78	-	36.8	-	4.90	-	10.00

I = Izzard's Formula $C_r = 0.025$
K = Kinematic Wave Formula
Discharges computed by the Rational Formula Q = CiA

TABLE VII

SUMMED DESIGN DISCHARGES FOR ZONE 12 - RATIONAL METHOD

Culvert Location	Q 5-yr (cfs)	Q 10-yr (cfs)	Q 25-yr (cfs)	Q 50-yr (cfs)	Q 100-yr (cfs)
12-1	2.14	2.84	3.47	4.36	4.98
12-2	2.79	3.70	4.53	5.69	6.50
12-3	3.67	4.87	5.96	7.48	8.55
12-4	6.50	8.62	10.57	13.12	15.06
12-5	5.51	7.33	8.94	11.36	12.93
12-6	8.66	11.54	14.05	17.93	20.39
12-7	12.36	16.46	20.06	25.52	29.05
12-8	2.12	2.83	3.44	4.43	5.02
12-9	3.84	5.12	6.22	8.01	9.08
12-10	20.98	27.89	34.08	42.92	49.01
12-11	-	-	-	-	-
12-12	7.46	9.91	12.12	15.20	17.38
12-13	8.26	10.98	13.43	16.87	19.28
12-14	-	-	-	-	-
12-15	11.90	15.82	19.33	24.34	27.80
12-16	15.29	20.32	24.83	31.31	35.74
12-17	15.56	20.69	25.28	31.88	36.39
12-18	0.36	0.48	0.59	0.74	0.84
12-19	0.64	0.86	1.04	1.34	1.52
12-20	22.00	29.23	35.73	44.97	51.36
12-21	5.43	7.20	8.83	11.01	12.61
12-22	3.66	4.88	5.94	7.57	8.61
12-23	6.39	8.50	10.38	13.14	14.98
12-24	7.89	10.50	12.82	16.24	18.51
12-25	13.83	18.39	22.45	28.38	32.37
12-26	16.51	21.96	26.81	33.87	38.64
12-27	-	-	-	-	-
12-28	1.69	2.24	2.73	3.49	3.97
12-29	1.79	2.38	2.91	3.67	4.19
12-30	0.59	0.78	0.95	1.24	1.40
12-31	17.18	22.85	27.90	35.26	40.22
12-32	-	-	-	-	-
12-33	1.77	2.36	2.87	3.68	4.17
12-34	2.78	3.71	4.52	5.76	6.55
12-35	0.63	0.84	1.02	1.29	1.48
12-36	0.78	1.04	1.28	1.56	1.80
12-37	5.89	7.83	9.56	12.09	13.79

TABLE VII (cont)

Culvert Location	Q 5-yr (cfs)	Q 10-yr (cfs)	Q 25-yr (cfs)	Q 50-yr (cfs)	Q 100-yr (cfs)
12-38	6.22	8.26	10.09	12.75	14.54
12-39	-	-	-	-	-
12-40	-	-	-	-	-
12-41	-	-	-	-	-
12-42	-	-	-	-	-
12-43	-	-	-	-	-
12-44	-	-	-	-	-
12-45	2.54	3.37	4.14	5.13	5.89
12-46	-	-	-	-	-
12-47	-	-	-	-	-
12-48	1.69	2.25	2.75	3.47	3.96
12-49	-	-	-	-	-
12-6A	-	-	-	-	-
Ponded Area	0.79	1.05	1.28	1.64	1.86
Const. E of 12-28/29	4.26	5.67	6.92	8.78	10.00

TABLE VIII

MAXIMUM DISCHARGE OF CULVERTS - ZONE 12

Culvert Location	Culvert Length(ft)	Change in Elevation (ft)	Slope ( )	Material	Manning n	Diameter (ft) Nominal	Actual	Comments	Discharge Formula Used	Maximum Q (cfs)
12-1	30.25	0.27	0.0089	r. conc.	0.013	1.50	1.25	Weeds. silt	Radial	38.8
12-2	30.25	0.12	0.004	r. conc.	0.013	1.42	1.31	Weeds, silt	Radial	29.5
12-3	32.25	0.25	0.0078	r. conc.	0.013	1.50	1.46	Small amt. silt, weeds	Radial	55.0
12-4	In construction area - missing									
12-5	30.5	0.80	0.0262	c. metal	0.030	1.25	1.00	Weeds	Radial	15.9
12-6	170.5	0.03	0.0002	c. metal	0.024	1.25	1.25		Radial	3.2
12-7	101.5	1.31	0.0129	c. metal	0.024	1.50	1.50	Double	Radial	82.3
12-8	51.75	0.34	0.0066	c. metal	0.030	2.50	2.17		Radial	63.0
12-9	40.33	0.35	0.0087	c. metal	0.030	2.50	1.17		Elliptical	30.0
12-10	45	0.09	0.002	c. metal	0.024	2.50	2.50	Double	Radial	126.5
12-11	Not found during field check.									
12-12	33.75	0.62	0.0184	c. metal	0.030	1.33	0.67	Bent end	Elliptical	29.5
12-13	-	-	-	c. metal	0.030	1.33	0.75	Bent end		-
12-14	57.83	0.06	0.001	c. metal	1.030	1.50	1.08		Elliptical	8.6
12-15	64.83	0.05	0.0008	c. metal	0.024	1.00	1.00	Double	Radical	7.0
12-16	60	0.30	0.005	c. metal	0.024	1.00	1.00	Double	Radial	17.4
12-17	79.33	0.80	0.0101	r. conc.	0.013	2.00	1.08.1.25	Double	Elliptical	139.9
12-18	33.42	0.40	0.012	c. metal	0.030	1.50	1.00		Elliptical	28.8
12-19	69.83	0.42	0.006	r. conc.	0.013	2.00	1.42		Elliptical	58.6
12-20	52.42	0.11	0.0021	r. conc.	0.013	2.00	1.50,1.67	Double	Ellip/Rad	76.4
12-21	53	0.20	0.0038	r. conc.	0.011	1.50	1.50		Radial	48.7
12-22	29.75	0.70	0.0235	c. metal	0.030	1.50	1.00		Elliptical	40.4
12-23	29.67	0.02	0.0007	r. conc.	0.014	2.00	1.17	Standing water	Elliptical	17.1
12-24	24.25	0.08	0.0033	r. conc.	0.014	2.00	1.17	Standing water	Elliptical	37.2
12-25	35.75	0.34	0.0095	r. conc.	0.013	1.50	1.25		Radial	40.1
12-26	41	0.83	0.0202	r. conc.	0.011	1.50	1.50		Radial	112.3
12-27	22	0.21	0.0095	c. metal	0.030	1.17	0.92		Elliptical	23.4
12-28	25	0.28	0.0112	r. conc.	0.013	1.50	1.25x2.41 high		Rectangular	22.9
12-29	43	0.32	0.0074	r. conc.	0.010	2.0	2.0		Radial	161.1
12-30	40.08	0.13	0.0032	r. conc.	0.014	1.50	0.67		Elliptical	27.3
12-31	101.75	0.47	0.0046	Smooth conc.	0.010	2.00	2.00	trash rack	Radial	127.0
12-32	An extension of 12-31									
12-33	14	0.15	0.0107	Concrete box	0.011		2.5x1.5		Rectangular	36.4
12-34	30.17	0.21	0.007	Steel	0.012	1.67	1.50		Radial	60.6
12-35	60.25	0.47	0.0078	c. metal	0.030	2.00	1.75		Radial	38.6
12-36	39.75	1.02	0.0257	r. conc.	0.013	1.33	0.75		Elliptical	84.0
12-37	65.25	0.62	0.0095	r. conc.	0.011	2.00	2.00	Double	Radial	331.8
12-38	52.5	0.34	0.0065	r. conc.	0.011	2.00	2.00	Double	Radial	274.5
12-39	-	-	-	c. metal	0.030	1.50	1.25	Weeds		-

Note: Those culverts for which information is not presented were either missing, filled, crushed, or combined with another culvert.

TABLE VIII (cont)

Culvert Location	Culvert Length	Change in Elevation (ft)	Slope ( )	Material	Manning n	Diameter (ft) Nominal	Actual	Comments	Discharge Formula Used	Peak Q (cfs)
12-40	42.33	0.19	0.0045	c. metal	0.030	1.25	0.96	Weeds	Elliptical	16.7
12-41	42.33	0.08	0.0019	c. metal	0.030	1.25	0.71		Elliptical	9.5
12-42	-	-	-	c. metal	0.024	1.00		Bent end	-	-
12-43	20	0.24	0.012	r. conc.	0.013	2.00	1.04		Elliptical	72.9
12-44	60	0.63	0.0105	c. metal	0.030	2.00	1.33		Elliptical	32.7
12-45	60.33	0.44	0.0073	c. metal	0.024	1.50	1.50		Radial	31.0
12-46	-	-	-	c. metal	0.024	2.00	2.00			
12-47	-	-	-	r. conc.	0.013	1.50	1.25x2.17 high			
12-48	14	0.14	0.01	r. conc. box	0.014	1.17	0.58		Elliptical	42.5
12-49	Not open			r. conc.	-	1.17	0	Double		
12-50	43.5	0.08	0.0018	c. metal	0.028	1.25	1.25		Radial	8.1
12-51	43.5	0.06	0.0014	c. metal	0.028	1.25	1.25		Radial	7.1
12-21A	44	0.48	0.0109	r. conc.	0.012	1.5	1.5		Radial	75.6
12-29A	56	0.20	0.0036	r. conc.	0.010	2.0	2.0		Radial	112.3

TABLE IX

PEAK DISCHARGE COMPUTATIONS FOR ZONE 11

Culvert Location	Area Drained (ft^2)	Area Drained (acres)	Slope (ft/ft)	Maximum Flow Length(ft)	Runoff Coeff. c	Manning n	T 5-yr (min) I	T 5-yr (min) K	i 5-yr (in./hr) I	i 5-yr (in./hr) K	Q 5-yr (cfs) I	Q 5-yr (cfs) K
11-1												
11-2												
11-3												
11-4	40 633	0.93	0.003	270	0.3	0.17	112	71	1.15	1.64	0.32	0.46
11-5												
11-6	59 008	1.35	0.003	310	0.2	0.09	215	58	0.69	1.91	0.19	0.52
11-7												
11-8	10 577	0.24	0.003	160	0.5	0.10	39	21	2.61	4.18	0.31	0.50
11-9	12 878	0.30	0.003	120	0.3	0.11	64	24	1.77	3.79	0.16	0.34
11-10	123 471	2.83	0.003	400	0.25	0.13	189	88	0.77	1.39	0.54	0.98
11-11	5 790	0.13	0.002	70	0.8	0.03	15	3	5.39	17.63	0.56	1.83
11-12												
11-13												
11-14												
11-15	701 715	16.11	0.003	1175	0.2	0.18	538	338	0.34	0.49	1.10	1.58
11-16	257 066	5.90	0.003	600	0.2	0.18	339	188	0.49	0.77	0.58	0.91
11-17												
11-18	854 021	19.61	0.001	1560	0.25	0.20	1024	670	0.21	0.29	1.03	1.42
11-19												
11-20	26 341	0.60	0.003	320	0.7	0.09	-	29	-	3.28	-	1.38
11-21	7 397	0.17	0.003	150	0.8	0.05	-	8	-	8.59	-	1.17
11-22	3 615	0.08	0.003	90	0.7	0.09	16	10	5.08	7.68	0.28	0.43
11-23	38 557	0.89	0.003	210	0.3	0.10	94	36	1.31	2.77	0.35	0.74
11-24	7 196	0.17	0.003	100	0.35	0.08	46	14	2.30	5.68	0.14	0.34
11-25	7 330	0.17	0.003	90	0.25	0.09	68	17	1.70	4.85	0.07	0.21
11-26	6 259	0.14	0.003	100	0.5	0.10	28	14	3.36	5.74	0.24	0.40
11-27	4 251	0.10	0.003	80	0.7	0.05	15	5	5.40	12.34	0.38	0.86
11-28	21 756	0.50	0.003	170	0.4	0.10	55	25	2.00	3.64	0.40	0.73
11-29	95 758	2.20	0.006	700	0.4	0.15	-	91	-	1.35	-	1.19
11-30	23 094	0.53	0.006	270	0.4	0.17	-	44	-	2.36	-	0.50
11-31	130 081	2.99	0.006	850	0.25	0.15	317	141	0.51	0.96	0.38	0.72
11-32	11 146	0.26	0.006	130	0.8	0.03	-	3	-	16.82	-	3.50
11-33												
11-34												
11-35	19 003	0.44	0.006	160	0.7	0.07	-	9	-	7.80	-	2.40
11-36	25 705	0.59	0.006	250	0.25	0.13	85	43	1.43	2.41	0.21	0.36
11-37												
11-38												
11-39	314 116	7.21	0.006	1020	0.25	0.17	-	185	-	0.78	-	1.41
11-40	51 535	1.18	0.003	450	0.5	0.13	-	65	-	1.75	-	1.03
11-41	45 687	1.05	0.003	325	0.5	0.09	-	36	-	2.79	-	1.46
11-42	59 242	1.36	0.003	280	0.45	0.12	66	43	1.74	2.42	1.06	1.48
11-43	306 125	7.03	0.001	1000	0.25	0.19	755	436	0.26	0.40	0.46	0.71
11-44	147 536	3.39	0.003	600	0.40	0.06	-	49	-	2.20	-	2.98

I = Izzard's Formula
K = Kinematic Wave Formula
C_r = 0.030

Note: Those culverts for which information is not presented were either missing, filled, crushed, or combined with another culvert.

TABLE IX (cont)

Culvert Location	T 10-yr (min)		i 10-yr (in/hr)		Q 10-yr (cfs)		T 25-yr (min)		i 25-yr (in./hr)		Q 25-yr (cfs)	
	I	K	I	K	I	K	I	K	I	K	I	K
11-1												
11-2												
11-3												
11-4	86	63	1.71	2.18	0.48	0.61	-	58	-	2.66	-	0.74
11-5												
11-6	166	52	1.03	2.54	0.28	0.69	136	48	1.39	3.10	0.38	0.84
11-7												
11-8	-	19	-	5.59	-	0.67	-	17	-	6.77	-	0.81
11-9	49	21	2.63	5.05	0.24	0.46	41	20	3.52	6.13	0.32	0.55
11-10	145	78	1.14	1.85	0.81	1.31	-	72	-	2.26	-	1.60
11-11	-	3	-	23.68	-	2.46	-	3	-	28.37	-	2.95
11-12												
11-13												
11-14												
11-15	-	300	-	0.65	-	2.09	-	277	-	0.80	-	2.58
11-16	262	167	0.72	1.02	0.85	1.20	-	155	-	1.26	-	1.48
11-17												
11-18	795	596	0.30	0.38	1.47	1.87	-	550	-	0.47	-	2.31
11-19												
11-20	-	26	-	4.37	-	1.84	-	24	-	5.31	-	2.23
11-21	-	7	-	11.50	-	1.56	-	7	-	13.86	-	1.89
11-22	-	9	-	10.29	-	0.58	-	8	-	12.41	-	0.70
11-23	72	32	1.95	3.70	0.52	0.99	-	30	-	4.50	-	1.20
11-24	35	13	3.43	7.60	0.20	0.45	-	12	4.57	9.18	0.27	0.55
11-25	52	15	2.53	6.47	0.11	0.28	43	14	3.38	7.84	0.14	0.33
11-26	-	12	-	7.67	-	0.54	-	12	-	9.28	-	0.65
11-27	-	5	-	16.56	-	1.16	-	4	-	19.89	-	1.39
11-28	-	22	-	4.85	-	0.97	-	21	-	5.89	-	1.18
11-29	-	81	-	1.79	-	1.58	-	75	-	2.20	-	1.93
11-30	-	39	-	3.14	-	0.66	-	36	-	3.82	-	0.81
11-31	-	126	-	1.27	-	0.95	-	116	-	1.56	-	1.17
11-32	-	3	-	22.60	-	4.70	-	3	-	27.08	-	5.63
11-33												
11-34												
11-35	-	8	-	10.44	-	3.22	-	8	-	12.60	-	3.88
11-36	-	38	-	3.20	-	0.47	-	36	-	3.90	-	0.58
11-37												
11-38												
11-39	-	164	-	1.04	-	1.87	-	152	-	1.27	-	2.30
11-40	-	58	-	2.33	-	1.37	-	53	-	2.84	-	1.68
11-41	-	32	-	3.72	-	1.95	-	29	-	4.52	-	2.38
11-42	-	38	-	3.23	-	1.98	-	35	-	3.93	-	2.41
11-43	585	387	0.39	0.53	0.69	0.94	-	357	-	0.66	-	1.16
11-44	-	43	-	2.92	-	3.96	-	40	-	3.56	-	4.83

I = Izzard's Formula
K = Kinematic Wave Formula
C_r = 0.030

Note: Those culverts for which information is not presented were either missing, filled, crushed, or combined with another culvert.

TABLE IX (cont)

Culvert Location	T 50-yr (min) I	T 50-yr (min) K	i 50-yr (in./hr) I	i 50-yr (in./hr) K	Q 50-yr (cfs) I	Q 50-yr (cfs) K	T 100-yr (min) I	T 100-yr (min) K	i 100-yr (in./hr) I	i 100-yr (in./hr) K	Q 100-yr (cfs) I	Q 100-yr (cfs) K
11-1												
11-2												
11-3												
11-4	-	53	-	3.35	-	0.94	-	50	-	3.83	-	1.07
11-5												
11-6	-	43	-	3.93	-	1.06	-	41	-	4.48	-	1.21
11-7												
11-8	-	16	-	8.80	-	1.06	-	15	-	9.94	-	1.19
11-9	-	18	-	7.94	-	0.72	-	17	-	8.99	-	0.81
11-10	-	66	-	2.83	-	2.00	-	62	-	3.24	-	2.29
11-11	-	2	-	38.69	-	4.02	-	2	-	43.02	-	4.47
11-12												
11-13												
11-14												
11-15	-	257	-	0.97	-	3.12	-	242	-	1.12	-	3.61
11-16	-	142	-	1.54	-	1.82	-	135	-	1.77	-	2.09
11-17												
11-18	-	513	-	0.56	-	2.74	-	482	-	0.65	-	3.20
11-19												
11-20	-	21	-	6.84	-	2.87	-	20	-	7.76	-	3.26
11-21	-	6	-	18.46	-	2.51	-	6	-	20.69	-	2.81
11-22	-	7	-	16.46	-	0.92	-	7	-	18.47	-	1.03
11-23	-	27	-	5.76	-	1.54	-	25	-	6.54	-	1.75
11-24	-	10	-	12.06	-	0.72	-	10	-	13.58	-	0.81
11-25	34	13	4.76	10.24	0.20	0.44	-	12	-	11.55	-	0.49
11-26	-	10	-	12.18	-	0.85	-	10	-	13.72	-	0.96
11-27	-	4	-	26.81	-	1.88	-	4	-	29.92	-	2.10
11-28	-	19	-	7.61	-	1.52	-	18	-	8.62	-	1.72
11-29	-	68	-	2.75	-	2.42	-	65	-	3.14	-	2.77
11-30	-	33	-	4.87	-	1.03	-	31	-	5.54	-	1.17
11-31	-	107	-	1.93	-	1.44	-	101	-	2.22	-	1.66
11-32	-	3	-	36.87	-	7.67	-	2	-	41.02	-	8.53
11-33												
11-34												
11-35	-	7	-	16.71	-	5.15	-	7	-	18.76	-	5.78
11-36	-	32	-	4.98	-	0.73	-	31	-	5.66	-	0.84
11-37												
11-38												
11-39	-	140	-	1.56	-	2.82	-	132	-	1.80	-	3.24
11-40	-	49	-	3.59	-	2.12	-	46	-	4.10	-	2.42
11-41	-	27	-	5.80	-	3.04	-	25	-	6.58	-	3.46
11-42	-	32	-	5.02	-	3.07	-	30	-	5.71	-	3.49
11-43	-	332	-	0.79	-	1.39	-	313	-	0.92	-	1.61
11-44	-	36	-	4.53	-	6.14	-	34	-	5.16	-	6.99

I = Izzard's Formula
K = Kinematic Wave Formula
C_r = 0.030

TABLE X

MAXIMUM DISCHARGES OF CULVERTS - ZONE 11

Culvert Location	Culvert Length (ft)	Change in Elevation (ft)	Slope ( )	Material	Manning n	Diameter(ft) Nominal	Actual	Comments	Discharge Formula Used	Maximum Q (cfs)
11-1				Concrete	0.014	1.5	.50			
11-2	Missing									
11-3	Missing									
11-4				Concrete	0.014	2.0	0.83			
11-5	Missing									
11-6	10.00	0.17	0.0170	C. metal	0.030	2.5	0.92		Elliptical	24.2
11-7	Missing									
11-8				Concrete	0.014	1.0	0.67			
11-9	48.5	0.3	0.0062	Concrete	0.013	1.0	0.92		Radial	2.8
11-10				Concrete	0.013	1.0, 1.04	0.96, 0.83	Double		
11-11	24.25	0.29	0.0120	Concrete	0.013	1.25	0.96		Elliptical	39.6
11-12	Missing									
11-13				C. metal	0.028	1.0	0.58			
11-14				C. metal	0.030	2.5	1.25	Oval		
11-15	54.25	0.07	0.0013	Concrete	0.014	1.67	1.0	Double	Elliptical	26.3 total
11-16	Not measured									
11-17	Missing			Concrete						
11-18				Concrete	0.014,0.011	1.58,1.50,1.50	1.08,1.5	Triple		
					0.011		1.5			
11-19				Concrete	0.013	1.25	1.17			
11-20				C. metal	0.028	1.0	0.58			
11-21				C. metal	0.028	1.0	0.75			
11-22				Concrete	0.014	1.5	0.46			
11-23	60.00	0.09	0.0015	C. metal	0.030	2.5	1.42	Smashed	Elliptical	8.5
11-24				Concrete	0.013	1.25	0.88			
11-25				Concrete	0.014	1.25 (?)	0.63			
11-26				C. metal	0.030	1.0	0.5			
11-27				Concrete	0.014	1.25	0.67			
11-28	20.17	0.21	0.0104	Concrete	0.013	1.25	1.17		Radial	6.6
11-29	77.00	0.77	0.0100	C. metal	0.030	2.5	1.17	Egg shaped Crushed ends	Elliptical	20.3
11-30	57.00	0.46	0.0081	Concrete	0.013	1.5	1.25		Radial	9.5
11-31				Concrete	0.013	1.5	1.42			
11-32				C. metal	0.030	1.0	0.54			
11-33				Concrete	0.014	1.17	0.63	Double		
					0.013	1.25	1.17			
11-34				Concrete	0.014	1.67	0.67			
11-35				Steel	0.017	1.0	0.42			
11-36	20.25	0.14	0.0069	Concrete	0.011	1.5	1.5		Radial	10.3
11-37	60.58	0.62	0.0102	Concrete	0.013	1.5	1.33		Radial	10.6
11-38				C. metal	0.024	1.0	1.0			
11-39	56.58	0.66	0.0177	Concrete	0.013	2.0	1.83, 1.75	Double	Radial, Radial	49.1 total
11-40				Concrete	0.013	1.5	0.96			
11-41				Concrete	0.013	1.0	0.71			
11-42	56.58	0.45	0.0080	Concrete	0.013	1.5	1.25		Radial	9.4
11-43				Concrete	0.013	1.5	1.33			
11-44				V. Clay	0.017	0.67	0.33	Broken		

TABLE XI

SUMMED DESIGN DISCHARGES FOR ZONE 11 - RATIONAL METHOD

Culvert Location	Q 5-yr (cfs)	Q 10-yr (cfs))	Q 25-yr (cfs)	Q 50-yr (cfs)	Q 100-yr (cfs)
11-1	-	-	-	-	-
11-2	-	-	-	-	-
11-3	-	-	-	-	-
11-4	0.46	0.61	0.74	0.94	1.07
11-5	-	-	-	-	-
11-6	0.52	0.69	0.84	1.06	1.21
11-7	-	-	-	-	-
11-8	0.84	1.12	1.36	1.77	2.00
11-9	0.55	0.73	0.88	1.15	1.30
11-10	2.76	3.69	4.48	5.79	6.55
11-11	1.83	2.46	2.95	4.02	4.47
11-12	-	-	-	-	-
11-13	-	-	-	-	-
11-14	-	-	-	-	-
11-15	6.34	8.45	10.28	13.22	14.99
11-16	7.25	9.66	11.76	15.04	17.08
11-17	-	-	-	-	-
11-18	3.61	4.78	5.88	7.20	8.30
11-19	-	-	-	-	-
11-20	1.38	1.84	2.23	2.87	3.26
11-21	1.17	1.56	1.89	2.51	2.81
11-22	0.43	0.58	0.70	0.92	1.03
11-23	0.74	0.99	1.20	1.54	1.75
11-24	0.34	0.45	0.55	0.72	0.81
11-25	0.21	0.28	0.33	0.44	0.49
11-26	0.92	1.22	1.49	1.91	2.17
11-27	0.86	1.16	1.39	1.88	2.10
11-28	0.73	0.97	1.18	1.52	1.72
11-29	4.68	6.24	7.59	9.73	11.04
11-30	0.50	0.66	0.81	1.03	1.17
11-31	4.22	5.65	6.80	9.12	10.19
11-32	3.50	4.70	5.63	7.67	8.53
11-33	-	-	-	-	-
11-34	-	-	-	-	-
11-35	2.40	3.22	3.88	5.15	5.78
11-36	0.36	0.47	0.58	0.73	0.84
11-37	-	-	-	-	-
11-38	-	-	-	-	-
11-39	3.81	5.08	6.18	7.96	9.02
11-40	2.87	3.84	4.63	6.14	6.89
11-41	1.46	1.95	2.38	3.04	3.46
11-42	1.48	1.98	2.41	3.07	3.49
11-43	0.71	0.94	1.16	1.39	1.61
11-44	2.98	3.96	4.83	6.14	6.99

TABLE XII

SOIL LOSS RATES ON PLAYA BASIN #1
(Tons/Acre Annually)

Subwatershed Basin	East	West	Southwest	Southeast	North
Wheat crop	0.38	0.52	1.05	0.39	1.00
Native grasses	0.21	0.24	0.48	0.33	0.62

Printed in the United States of America
Available from
National Technical Information Service
US Department of Commerce
5285 Port Royal Road
Springfield, VA 22161

Microfiche (A01)

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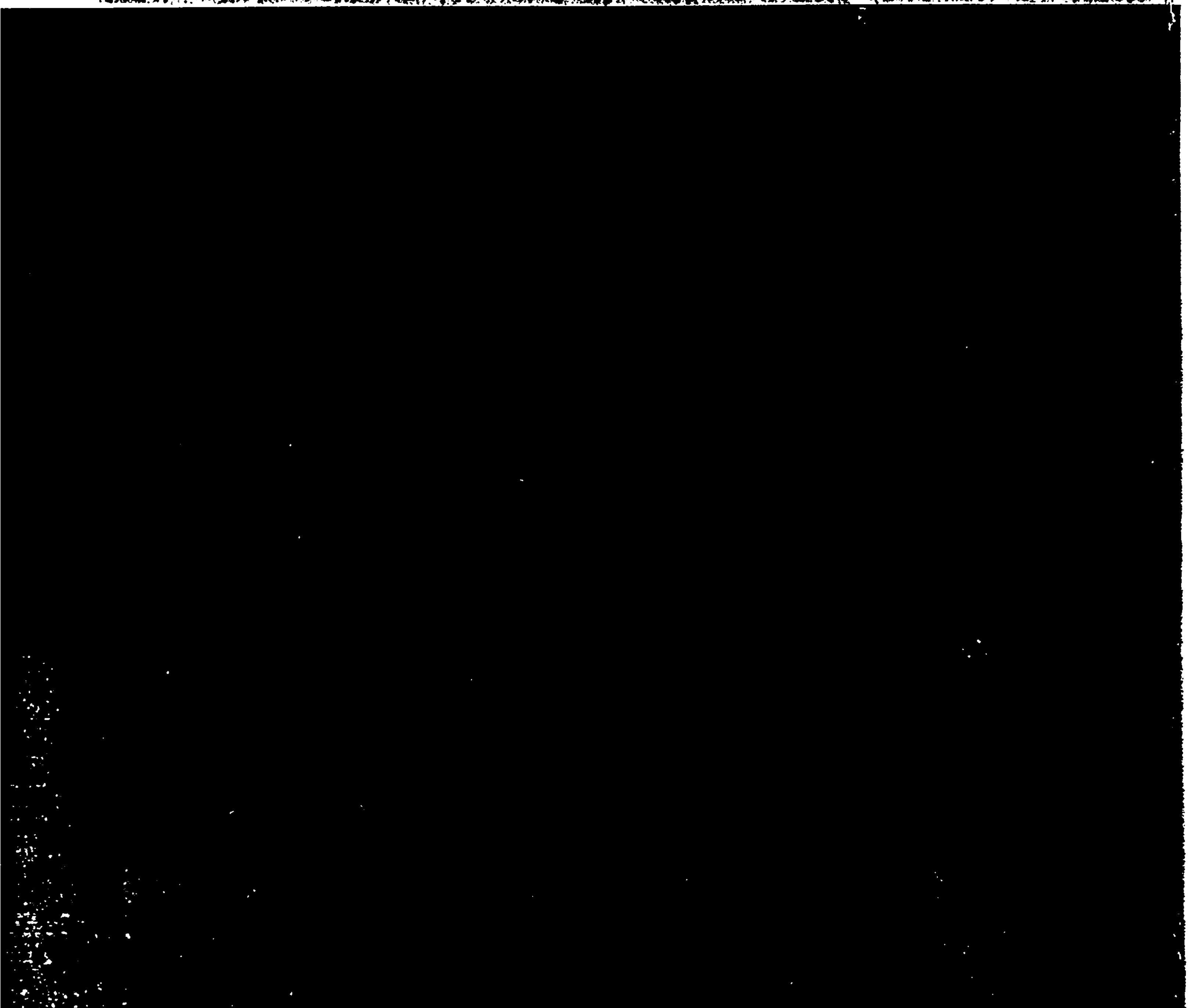
*Contact NTIS for a price quote.



Los Alamos