MEMORANDUM

REGIONAL FLOOD CONTROL DISTRICT
FLOODPLAIN MANAGEMENT DIVISION

DATE: July 8, 2010

TO: Floodplain Management Division Staff

FROM: Eric Shepp, P.E., Division Manager
Floodplain Management Division

SUBJECT: Update to Special Study 10 – Lee Moore Wash Watershed

On November 2, 2009, the Chief Engineer approved the use of the floodplain delineations from the Lee Moore Wash Basin Management Study.

On June 11, 2010, the Board of Supervisors, sitting as the Board of Directors for the Flood Control District approved the entire Study, including the floodplain delineations, the Flow Corridors, and the Development Criteria.

Although additional work needs to be done to incorporate this Study into the Comprehensive Plan, the Boards approval allows us to replace the old Lee Moore Study (Sealed by Jim DeGrood on December 29, 1988) with this new information

This study has been included in the Special Studies GIS layer.

Please let me know if you have any questions.

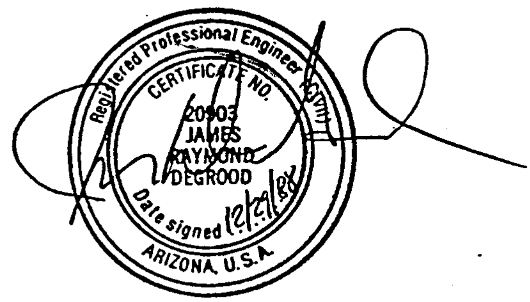
HYDROLOGIC INVESTIGATION FOR THE

LEE MOORE WASH WATERSHED,

Pima County, Arizona

Prepared for:
Pima County Department
of Transportation and
Flood Control District,
Planning Division

Principal Investigator:
Jonathan Fuller,
Principal Hydrologist



James R. DeGrood, P.E., Supervisor
Floodplain Management Section

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ABSTRACT

The base flood peak discharges for the Lee Moore Wash and its major tributaries, Gunnery Range Wash, Sycamore Canyon Wash, Fagan Wash, Cuprite Wash, Petty Ranch Wash, Flato Wash, and Summit Wash, as well as nearby Franco Wash were determined using the computer model HEC-1. 100-year peak discharges, at the Santa Cruz River, of 20900 cfs for the Lee Moore and 6400 cfs for Franco Wash were calculated. Runoff hydrographs were determined using USDA Soil Conservation Service techniques. Channel routings were performed using the Muskingum method. Reservoir and detention routings were not included as part of this analysis because none of the structures within the watershed are constructed to regulatory standards, or are associated with road design which is considered to be temporary.

Introduction

Increased development in the Santa Cruz floodplain between Lee Moore Wash and Old Nogales Highway has led to the need for determining the magnitude of the base flood for Lee Moore Wash and its major tributaries. The Lee Moore's major tributaries include Gunnery Range Wash, Sycamore Canyon Wash, Fagan Wash, Cuprite Wash, Petty Ranch Wash, Flato Wash, and Summit Wash. Franco Wash, while not physically part of the Lee Moore Wash watershed, is certainly part of a contiguous basin, particularly from a management standpoint. Therefore, Franco Wash has been included in this analysis.

At present, the tributary watersheds are largely undeveloped. However, construction of the new Sahuarita Road will open up the watershed to extensive development in the near future. Limited development has already occurred with the New Tucson and Corona De Tucson subdivisions in the upper Flato and Franco watersheds. Regulatory discharges and floodplain management policies should be established now, before extensive development begins.

Geography

Lee Moore Wash is so named from a point downstream of the confluence of Gunnery Range Wash, Sycamore Canyon Wash, Fagan Wash, and Cuprite Wash (See figure 1). Lee Moore Wash proper generally corresponds to the highly entrenched portion of the drainage system, most of which is located along the western side of Old Nogales Highway. Petty Ranch Wash joins the Lee Moore just upstream of Old Nogales Highway. Flato and Summit Washes cross Old Nogales Highway and the Southern Pacific Railroad and join Lee Moore Wash further downstream. For the purposes of this report, the entire watershed will be referred to as the Lee Moore, unless a specific tributary is being described.

The Lee Moore drains approximately 213 square miles of the north and northwestern slopes of the Santa Rita Mountains. Its watershed is bounded by Hughes Wash to the north, Interstate 10 to the northeast, Sonoita Highway to the east, Santa Rita Road to the south, and the Santa Cruz River to the west. The watershed ranges in elevation from 8175 feet at the summit of an unnamed promontory near Helvetia, to a low of 2560 feet at the confluence of the Lee Moore with the Santa Cruz River.

The lower reaches of the Lee Moore's tributaries make up the alluvial fan (technically, a bajada) of the Santa Rita Mountains. The upper portions of the basin are a pediment surface, as demonstrated by the presence of inselbergs, or isolated bedrock domes located down-fan from the mountain front, and by a

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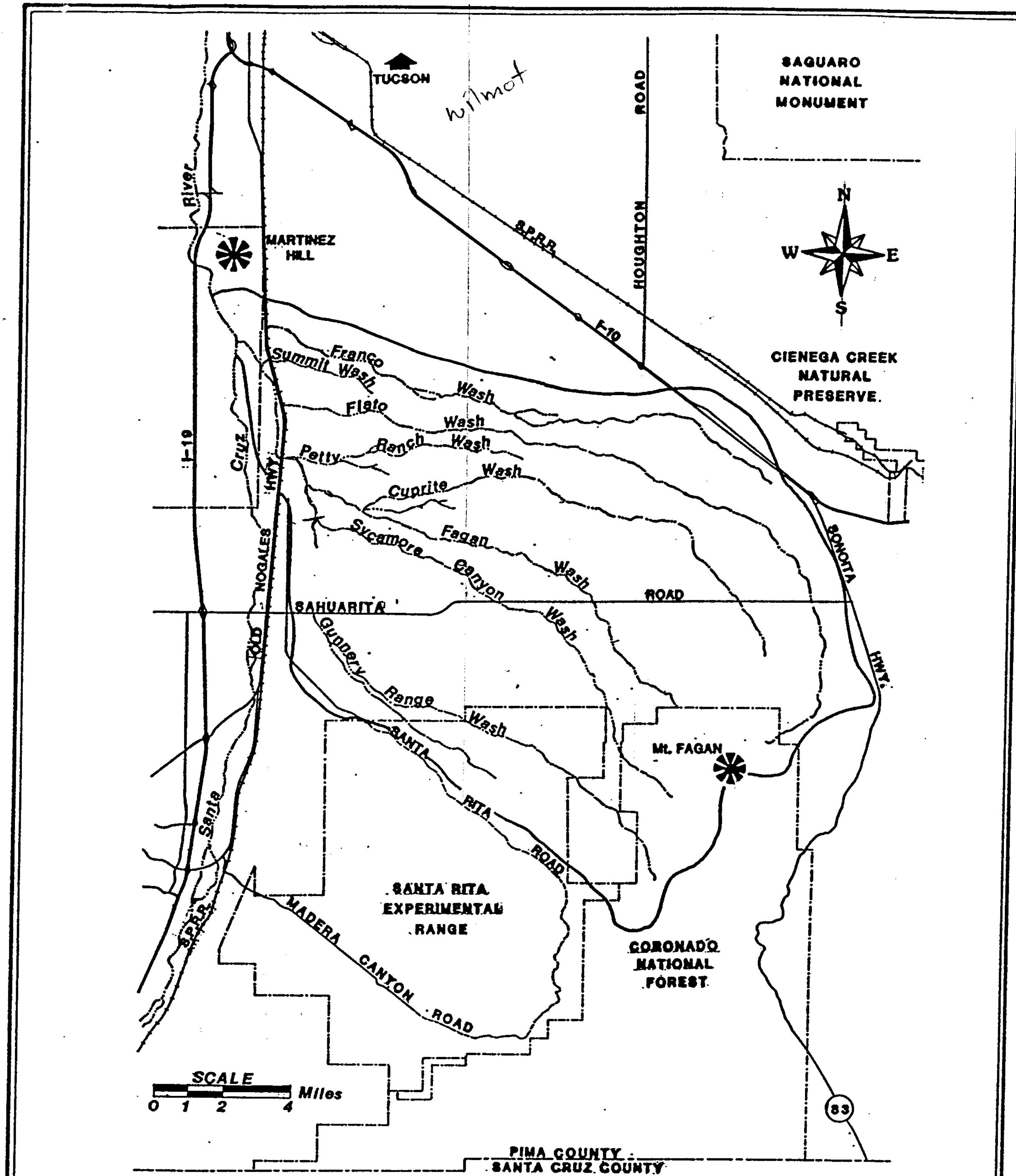

FIGURE ONE
LEE MOORE WASH. LOCATION OF WATERSHED & MAJOR TRIBUTARIES

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prominent fault scarp located well away from the mountain front, as well as by the extreme degree of embayment of the tributary canyons. The upstream reaches of the tributaries are well defined, with large watershed divides, to approximately the Houghton Road alignment. (See figure 2.) Below the Houghton Road alignment, the tributaries are less well defined. Numerous breakouts and flow splits can be seen on aerial photographs, though the location of these diversions have not changed significantly over the last 15 years. Therefore, the lower watershed cannot be considered an active alluvial fan, but rather a dissected, inactive fan. Because of the lack of well defined subwatershed divides, discharge values for the lower reaches listed in the appendices of this report should be used with caution for design purposes.

Methodology

Watershed hydrology was modelled using the US Army Corps of Engineers hydrologic routing computer program HEC-1. The size of the basin (213 square miles) precluded using the Pima County Method, which is limited to basins less than 10 square miles. HEC-1 has been tested and accepted for use in Pima County. In order to provide continuity with the SCS-based Pima County Method, the SCS techniques were used within HEC-1 to estimate losses and determine the basin lag.

Precipitation depths were taken from the isohyetal maps printed in NOAA Atlas II. The 100-year rainfall depths for the 24-, 6-, and 1-hour storms were estimated using the procedure outlined in the Pima County Hydrology Manual. After the aerial reduction, the depths of the 24-, 6-, and 1-hour storms were determined to be 4.04, 2.99, 1.74 inches, respectively.

The standard SCS Type II rainfall distribution was used to model the 24- and 6-hour storms. Other rainfall distributions, including the SCS Type IIA and the City of Tucson design storm were also examined, but were found to be inappropriate, given the size of the Lee Moore watershed. The City of Tucson Design Storm distribution was utilized for the 1-hour storm. However, the 1-hour storm proved to be too short a duration for all but the smallest subwatersheds. However, discharge values determined using the 1-hour storm should be used as regulatory peak flows for the subwatersheds themselves.

Rainfall losses were estimated using SCS curve numbers. Curve numbers are a soil specific ratio of the amount of rainfall available for runoff. Curve number estimation included consideration of the "caliche" affect for the 1-hour storm simulation only. Because the caliche affect is thought to be due to rainfall intensity, it should not be considered when modelling

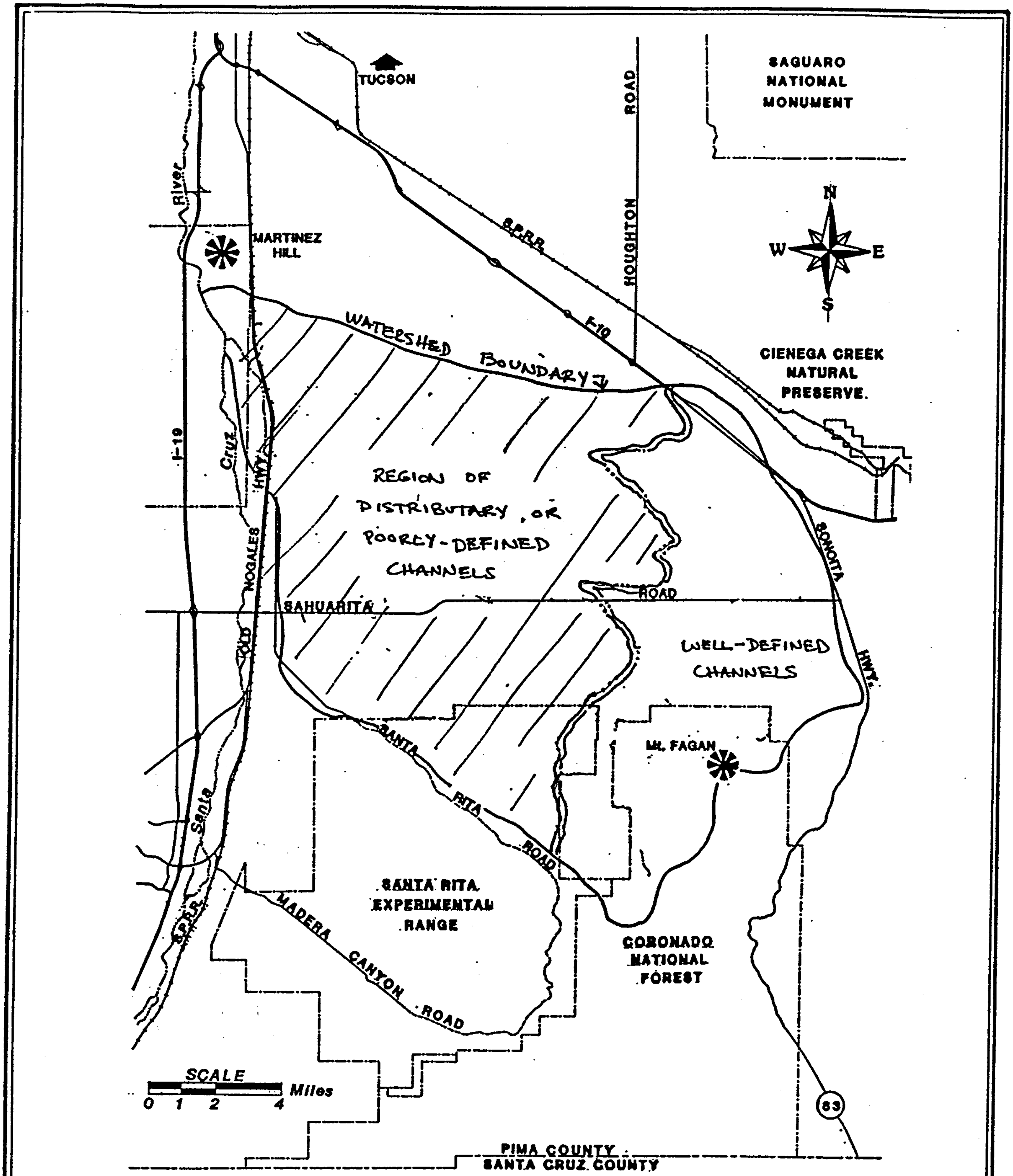

FIGURE TWO

LEE MOORE WASH : AREAS OF POORLY DEFINED WASH, ALLUVIAL FAN REACHES, OR DISTRIBUTARY CHANNELS.

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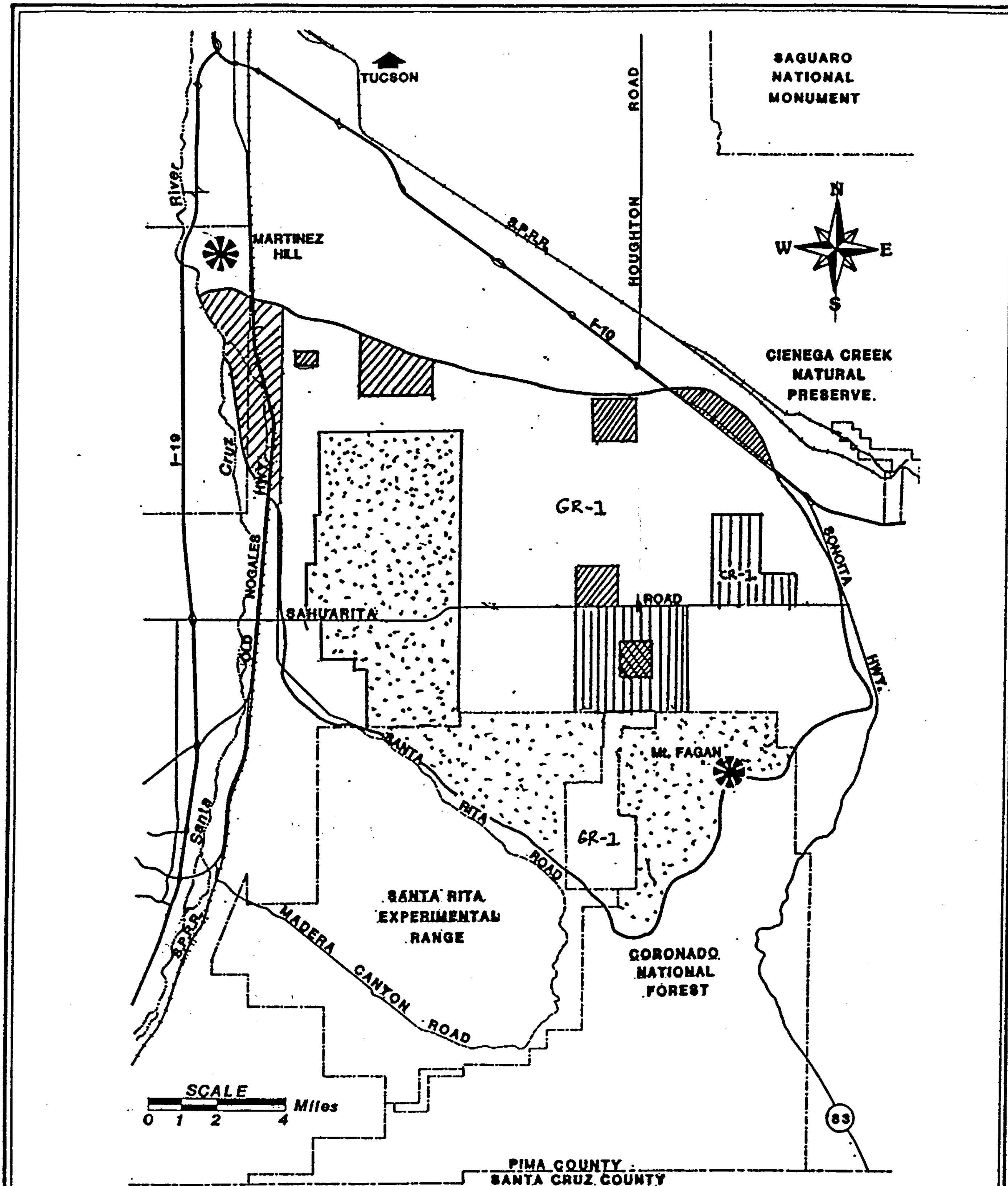
storms with sufficient duration to reduce the intensity to less than 0.88 inches/hour. Such is the case for the 6- and 24-hour events. Soils data was obtained from the revised SCS soils maps and from the soils data published in the Pima County Hydrology Manual. Vegetative cover type and density were determined by examining aerial photographs and by field checking.

Physical watershed characteristics were determined from published and field data. Slope was measured from 15-minute USGS topographic maps. Basin length and length to center of gravity were measured from large scale aerial photographs (1972 U-2 photos). Land use (percent imperviousness and basin factor) variables were based on future build-out at existing zoning (See figure 3). Subwatersheds were delineated on the 1972 aerials, and were verified with 1984 aerial photographs and by field checking. Figure 4 shows subwatershed delineation used in the HEC-1 model.

Each of the subwatersheds was rated using the Pima County Method. The time of concentration determined by this method was transformed to the SCS hydrograph parameter "lag", and was entered into the HEC-1 model for the one-hour storm. However, the lag calculated by the Pima County Method was determined to be inappropriate for the 24-hour storm. Therefore, equation 15.4 in the SCS National Engineering Handbook (Section 4) was used to determine lag. Regression analysis was used to check the consistency of the lag calculated by equation 15.4, and anomalous values were revised.

HEC-1 generated hydrographs were routed downstream using the Muskingum method. Muskingum routing was chosen due to the lack of accurate topographic information and geometric continuity within routing reaches, as is required for kinematic or storage routing techniques. Routing parameters varied from x = .1 (maximum attenuation) for wide shallow reaches in the alluvial fan portions of the basin , to x = .4 for entrenched high-velocity reaches which would cause little attenuation of the flood peak. Manning's ratings of the routing reaches were performed, using approximated cross sections, to determine the average channel velocity in order to determine Muskingum's "k". Topographic data for the Manning's ratings were obtained from field investigation and examination of aerial photography. Discharge estimates for the Manning's sections were taken from the Pima County Method peaks for the subwatersheds referred to earlier.



LEE MOORE WASH
EXISTING ZONING MAP

(diagonal hatch)	CI, TR
(vertical lines)	CR-1
(cross hatch)	CR-2
(blank)	GR-1
(stipple)	Range land or forest

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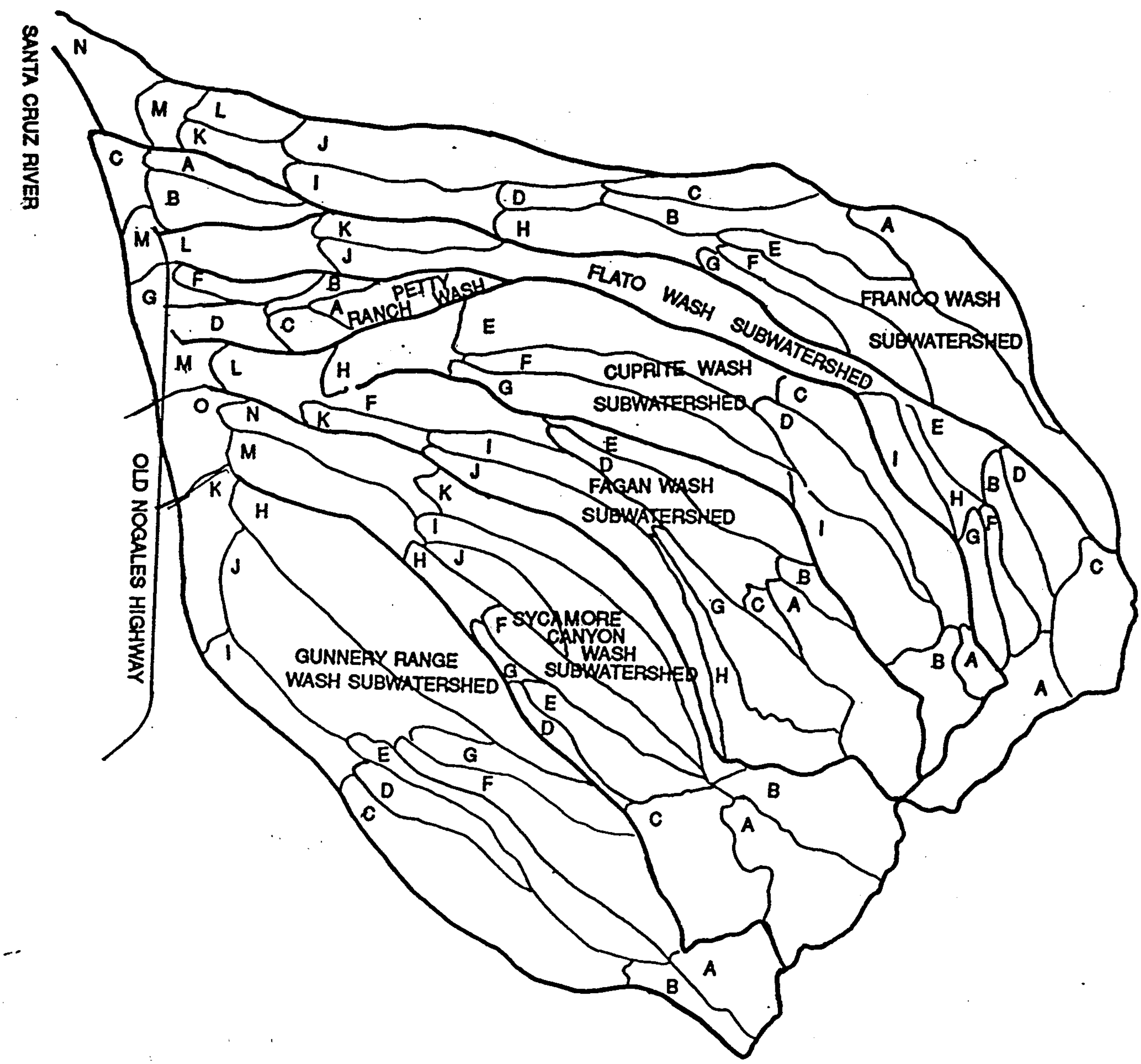

Figure 4. LEE MOORE WASH AND FRANCO WASH SUBWATERSHED DELINEATION USED IN THE HEC-1MODEL

Results

Peak discharges for key points in the watershed are listed in Table 1. A complete listing of the peak discharges, flow volumes, and print-outs of the hydrographs are included in Appendix One. Peak discharge determinations using the Pima County Method can be found in the major wash file under Lee Moore Wash. Peak discharge estimates from other studies, using other method are shown in Table 2.

TABLE ONE.
Peak Discharges for the Lee Moore Wash Watershed, from HEC-1.

Concentration Point (Subwatersheds, at Lee Moore)	Rainfall Duration P-24 Qp	Tp	P-6 Qp	Tp	P-1 Qp	Tp
Gunnery Range	5736	15.2	3974	6.2	2682	3.0
Sycamore Canyon	7793	15.0	6101	6.0	3136	2.7
Fagan (includes Cuprite)	7817	15.5	5855	6.5	3126	3.2
Cuprite (at Fagan)	3171	15.0	2566	6.2	1385	3.5
Petty Ranch	1103	14.5	863	5.5	783	1.3
Flato	2652	17.2	1576	8.0	586	2.3
Summit	1096	14.3	932	5.3	874	1.8
Franco (at Santa Cruz)	6388	16.5	5220	7.3	2651	2.0
Lee Moore Wash						
-below Gunnery	5207	15.7	3463	6.7	2145	3.5
-below Sycamore	12554	15.3	9164	6.2	4832	3.3
-below Fagan	19814	15.5	14521	6.5	7382	3.3
-below Petty Ranch	19711	15.8	14167	6.7	6402	3.5
-below Flato	20164	16.2	14369	7.0	6278	3.7
-below Summit	20866	16.2	15002	6.8	6487	3.5

⇑ use these discharges for Q_{100}

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TABLE TWO

Peak Discharges (cfs) for Lee Moore Wash Determined by Other Studies.

Wash Name	Hydrologic Method Regression Equation PCDOT	USGS	PCDOT Method (Subdivision files)	RAINFLO (Ponce)
Gunnery Range	21654	10862	no data available	
Sycamore Cyn	20542	10430	" "	"
Fagan	18686	9690	" "	"
Cuprite	17209	9085	" "	"
Petty Ranch	7322	4542	" "	"
Flato	17756	9311	2640	-
Summit	4124	2796	5865	-
Lee Moore	43162	18048	9477	24485
Franco	19847	10155	-	4988

Discussion

The peak discharges for the 24-hour storm listed in Table One should be adopted as the base flood peak discharges for Lee Moore Wash and its major tributaries. The 24-hour Type II storm is the most appropriate storm distribution and duration for the watershed. Given the size of the basin, the time to peak at the outlet, and likelihood of shorter duration storm covering the entire basin, the 24-hour event provides the most conservative, reasonable estimate of expected flow rates.

The discharges listed in Table 1 were calculated for maximum development allowed under existing zoning. However, even though future conditions were modelled, the likelihood of increased land use density due to rezoning is high once Sahuarita Road is improved. A preliminary investigation indicates that the base flood discharge could be as high as 60000 cfs at the confluence of the Lee Moore and the Santa Cruz if the existing natural channels were replaced by lined channels. The loss of attenuation and infiltration would almost triple the peak flow rate. The 60000 cfs estimate does not consider increased runoff due to greater imperviousness. Future studies should attempt to better quantify possible increases in runoff due to development.

Peak discharge rates shown in Table 2 were included for comparison only. The PCDOT area-discharge regression is not normally applied to watersheds larger than 2000 acres. The USGS regression equation was developed for long, linear watersheds. As all of the major subwatersheds are long and linear, it is interesting to note that the discharges determined by the USGS equation are similar, though somewhat higher than, the peak rates for the 24-hour storm determined using the HEC-1 model.

The peak discharges calculated by consulting engineers for proposed development along Flato and Summit Washes which used the Pima County Method were not accepted, although the subdivisions with which they are associated were later approved. The peak flow rate for Lee Moore Wash was accepted by the County review agency, but is clearly inaccurate. The basin area was underestimated by 30000 acres, and other parameters are equally suspect. Further, the Pima County Method, as noted earlier, was not intended for use on watersheds larger than 10 square miles.

Discharges listed under Ponce's RAINFLO model were determined by modifying Ponce's input code, requesting output for the Sycamore Canyon (Lee Moore) and Franco subwatersheds. Ponce's study was focused on the Santa Cruz and therefore had insufficient detail to accurately predict base flood peaks on the Lee Moore's tributaries. The peak runoff rates determined using HEC-1 are within about 1000 cfs of Ponce's values.

Although this report does not attempt to map the floodplain of the Lee Moore and its major tributaries, a generalized description of flood prone areas follows. The alluvial fan portion (Figure 3) of watershed should be considered as entirely floodprone, due to the potential for migrating flow paths, channel avulsion, and undersized channels. In particular, the area immediately upstream of the Southern Pacific Railroad is subject to a special flood hazard due to the undersized culverts under the railroad and under Old Nogales Highway. Areas within the alluvial fan portion of the watershed should not be considered flood-free without a detailed hydraulic analysis which considers backwater affects. Within the remainder of the watershed, the floodplain is restricted to the near channel overbanks.

Lee Moore Wash, downstream of Old Nogales Highway, has capacity for the entire calculated base flood peak discharge through much of its length. However, the channel has become entrenched to depths of up to 20 feet in this reach. Therefore, while not subject to inundation by floodwater, near channel areas are extremely vulnerable to channel bank erosion hazards. These hazards include back bank erosion, piping, and bank collapse. The entrenched channel is formed in Santa Cruz floodplain silts, which are easily eroded when saturated. Elsewhere within the watershed, erosion hazards are slight to normal, as natural flow paths are wide and shallow with extensive vegetative growth on the overbanks.

Basin Management Policies

The following policies should be formally adopted for the Lee Moore Watershed:

1. The 24-hour peak discharges listed in Table 1 should be adopted as the base flood peak rates.

2. The 1-hour peak discharges for the tributary subwatersheds (see figure 4) calculated using the HEC-1 model, as listed in Appendix 3 and 4 should be adopted as interim regulatory values until more detailed analyses are completed, or until land use and zoning changes.

3. The alluvial fan portion of the watershed should be designated a critical basin due to the presence of severely undersized culverts which cause extensive backwater ponding above the SPRR grade, and undersized channels on the alluvial fan itself.

4. Regional sites for retention/detention structures should be selected prior to urbanization of the basin and the

consequent increase in land values. Multiple use basins which allow ranching uses, in addition to recreation, etc. should be considered.

5. A special erosion hazard setback of 500 feet from the outside bank of channel bends for curvilinear reaches (250 feet for straight reaches) of the entrenched portion of Lee Moore Wash should be adopted. Structural approaches to erosion protection should be discouraged, and if allowed, should include an analysis of long term degradation.

6. Culverts under the railroad and Old Nogales Highway should be targeted for improvement as development increases in the area. Old Nogales Highway at Summit Wash and Flato Wash is in danger of failure due in part to culvert design and in part to long term channel degradation.

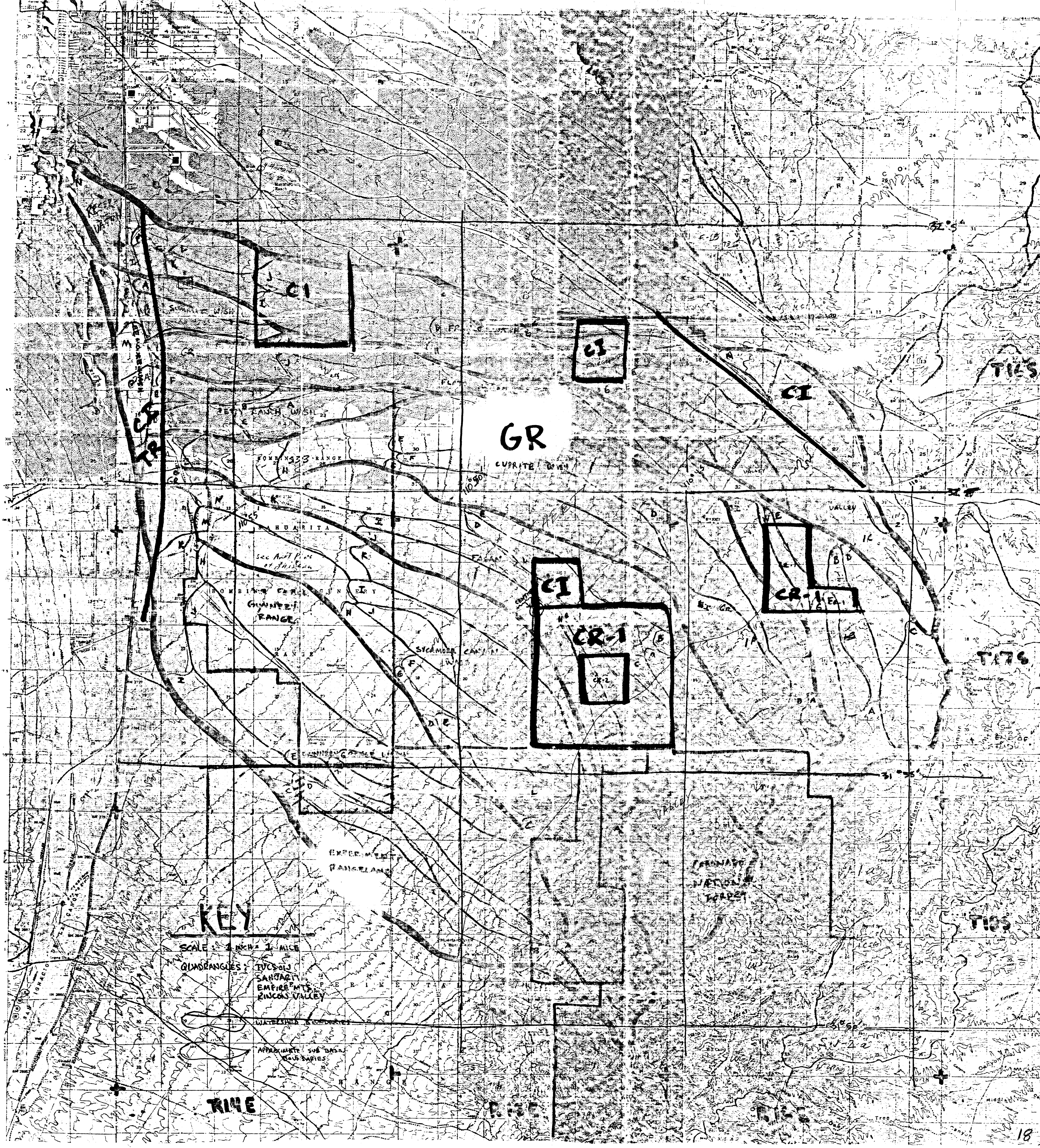
References

Hydrology Investigation of the Santa Cruz Basin, AZ, Miguel Ponce, 1984.

Hydrology Report for Summit Hills, C012-81-76, Blanton and Cole, June 1981.

Hydrology Report for Desert Wind Mobile Home Park, C012-88-48, Ryan Engineers, Inc., July 1988.

National Engineering Handbook of the Soil Conservation Service, Section 4: Hydrology, 1960.


GR
CI
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CR-1
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TR
CUPRITE WASH
SAHUARITA
EXPERIMENTAL RANGELAND
CORONADO NATIONAL FOREST
T15S
T17S
T19S
R14E
KEY
SCALE: 1 INCH = 1 MILE
QUADRANGLES: TUCSON
SAHUARITA
EMPIRE MTS
RINCON VALLEY
WATERSHED BOUNDARIES
APPROXIMATE SUB BASIN BOUNDARIES