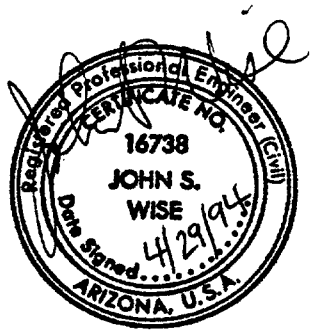
SOUTHWEST BASIN MANAGEMENT STUDY
PHASE II, PART A

(INCLUDING SECTION 34, T14S, R12E AND TUCSON ESTATES SUBDIVISION)

VOLUME 1 OF 2



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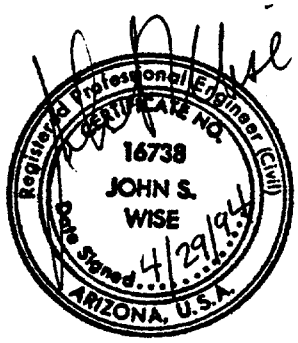

INTRODUCTION

The Southwest Basin Management Study: Phase II, Part A (SWBMS/IIA) has been initiated due to flooding and drainage complaints from the local citizenry and internal Pima County Staff request to develop and compare alternative methods of mitigating existing flooding hazards within Section 34, Township 14 South, Range 12 East. Existing problems in the area include sheet flooding and roadway access. Phase II represents the concept alternative/plan stage, while Part "A" represents a specific portion of the overall SWBMS area, that being Section 34 and its contributing watershed (see Figure 1, Location Map).

The study area for purposes of this report is in Section 34 of Township 14 South, Range 12 East, and the areas tributary thereto (see Figure 1, Location Map). This study addresses two of five problem areas recommended for additional analysis in the original Southwest Basin Management Study Phase I (SWBMS-I) report. The two problem areas are the Tierra Bonita/Golden Gate/ Camino Verde area within Section 34 and the Tucson Estates Subdivision upstream of Section 34. The study area, as described in the SWBMS-I report, consists of poorly defined flow patterns and inadequate channel capacity where channels do exist. Floodplain definition and associated damage potential is indeterminate; however, documentation of extensive and recurrent flooding problems has accumulated over the years.

Phase IIA focuses on identifying alternatives for mitigating the hazards and problems, evaluating the alternatives for flood mitigation potential and cost effectiveness, and recommending a preferred alternative and flood control policy. The study considers implementation of alternatives which involve improvements anywhere in the study area, including locations within Tucson Mountain Park. In particular, the study includes an evaluation of potential benefits and impacts on the Tucson Estates Subdivision resulting from any improvements considered within the areas upstream of the subdivision. A detailed Scope of Work is contained in Appendix A of this report.

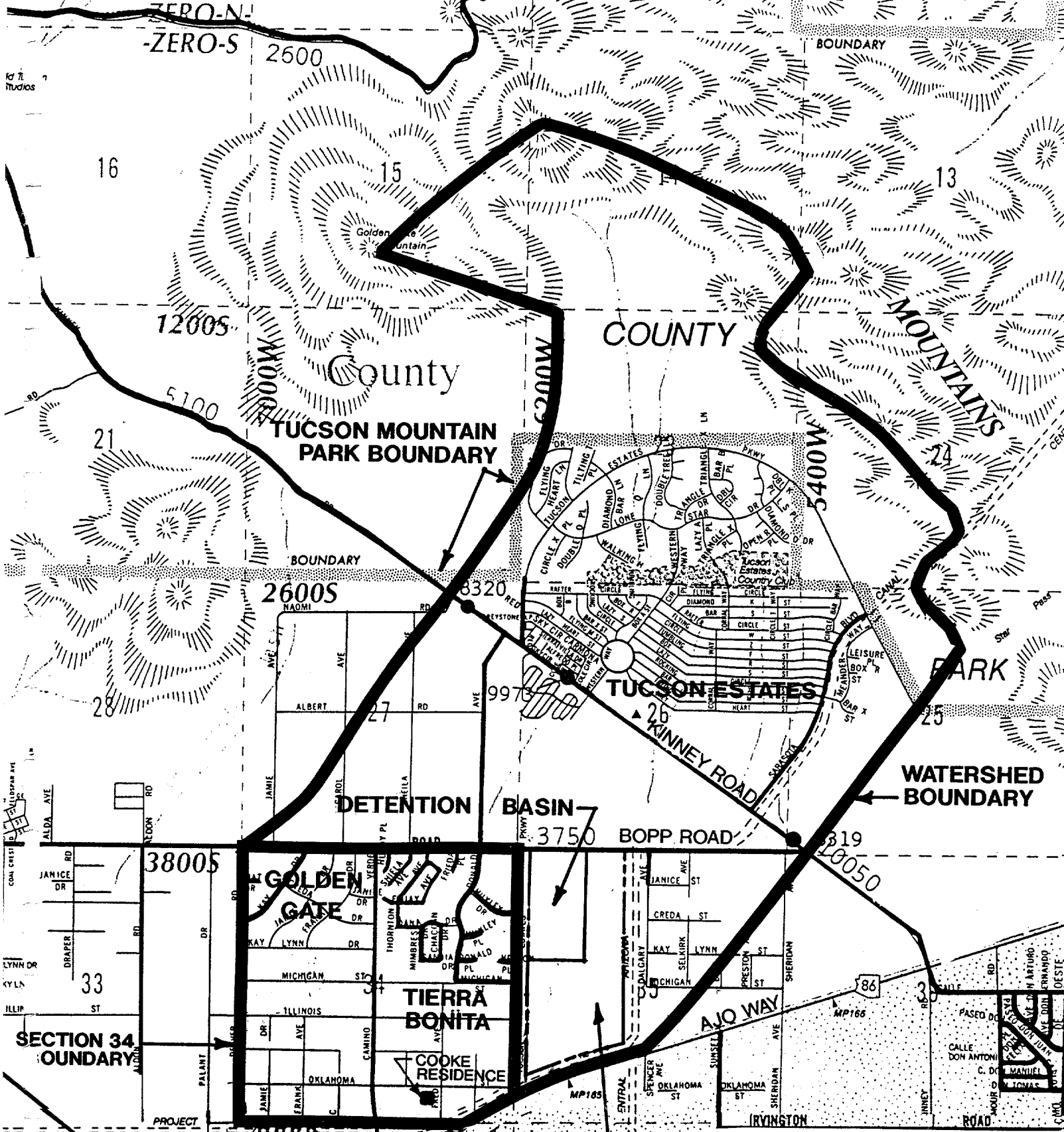

Figure 1
Location Map

Southwest Basin Management Study Phase IIA

CBA File No. 106579-01-280

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SECTION 1 - REVIEW OF EXISTING INFORMATION

Existing available data and reports pertaining to the Study area were collected and subsequently reviewed and evaluated to the specific objectives of the SWBMS. The data/report search is summarized below.

1. The "Hydrologic and Hydraulic Analysis for Cook Residence Drainage Complaint," prepared by Finn Associates, Ltd., revised October 1991.

   The Cooke residence, located in Section 34 west of Fred Avenue and north of Irvington Road was flooded during a rain event on July 24, 1990, with up to 4.67 inches of rainfall measured in a two-hour duration within the study area. This report investigated the runoff sources and the impact of the CAP treatment, located upstream of the residence, east of Tucson Estates Parkway. The report concluded that "the devastating effects of the flow events of July 24, 1990 were not the result of any improperly designed flood protection facilities for CAP. Treatment Facility, nor lack thereof." Watershed boundaries, 100-year peak discharges, and detention basin data developed for the report will be utilized in Task 2 of this report.

2. The "Conceptual Plan for Flood Protection for Tucson Water Treatment Facility," prepared by Johnson Brittain & Associates, Inc., revised August 21, 1986.

   The Tucson Water Treatment Facility (CAP Water Treatment Plant) lies immediately east of Section 34 in the northwest corner of Section 35. This report presents the basis for the currently constructed flood control improvements including a detention basin located at the north end of the facility and improved drainageways. Based on the above-mentioned report for the Cook Residence, some of the watershed boundaries developed in this report are erroneous and therefore, hydrologic data from this report will not be utilized. However, the detention basin has not been fully built out at this point in time and

data generated in this report regarding ultimate basin configuration will be discussed in Task 5 -Identification of Possible Structural and Non-structural Flood Control Alternatives.

3. The "Southwest Basin Management Study Basin Inventory/Drainage Report," prepared by Anderson, Passarelli & Associates, July 1990.

   In this report, Phase I of the SWBMS addresses basin conditions, feasible flood control alternatives/projects and identified floodplain management policies. Watershed boundaries and 100-year peak discharges at select concentration points were developed throughout the study area. These analyses will be utilized in Task 2.

4. Pima County Department of Transportation Drainage Complaints

   Phase I of the SWBMS included a listing of drainage complaint files. In conjunction with this study, Pima County files were reviewed for post-1990 complaints. Surprisingly, there are only three complaints immediately after the July 24, 1990 storm event referred to in the Cooke residence report. There is a cluster of complaints in September and October of 1990; however, the majority of these complaints concern debris and blockage of flow. There is no indication that the July storm event caused drainage pattern changes. Also, a surprise is the lack of drainage complaints following the January, 1993 heavy rainfall and subsequent flooding which impacted most of the Tucson area.

   The complaints are summarized in Table 1. Completion of this report necessitates a limit to collection of Pima County drainage complaints, with December 31, 1993 chosen as a cut-off date. A Location Map of drainage complaints is included as Figure 2. Post-1990 complaints in Section 34 are also shown on the Floodplain Maps, Appendix B. Post July, 1990 drainage complaints for the eastern portion of Section 33 are due to possible downstream effects from the study area of this report, and are included in Table 1a.

Some drainage complaints at the southern boundaries of Sections 33 and 34 are due to the Central Arizona Project (CAP) underground pipeline fill that is approximately two feet above the surrounding topography. Neighborhood residents have noted the CAP pipeline fill as an obstruction which has concentrated and diverted flows. There are existing drainage ditches across the CAP pipeline graded fill area at natural washes; however, the obstruction appears to aggravate the upstream sheet flooding.

Table 1
Pima County Drainage Complaints

Township 14 South, Range 12 East

1	Section 34	CAP floods road (3 feet) and property Tucson Estates Parkway, north of Ajo	7-16-90
2.	Section 34/33	4750 South Deaver Road. Flow to the west along Oklahoma Street crossed property and flooded home approximately 1 foot across property.	7-25-90 7-30-90
3.	Section 34	Tierra Bonita II, Lot 42 (6461 West Emjay) soil piled in wash, flooding. County investigation indicated breakout area upstream	7-26-90
4.	Section 34	4545 South Camino Verde. Drainageway from Tierra Bonita I and II discharges larger than normal sheet flow. Due to July 24, 1990 storm (rain gauges in area recorded 4 inches or more in one hour)	7-26-90

Note:#25 is also in Section 34, dated 7-26-90.

5.	Section 34	Tierra Bonita II, Lot 36 (6571 West Emjay Avenue) Headcut on property from waters spilling into Camino Verde drainage ditch	7-31-90
6.	Section 27	Milstone Manor #3 (3636 South Donald Avenue) Donald Avenue floods	8-20-90
7.	Section 34	Tucson Estates Parkway and Ajo - drainage problems on State highway	9-17-90
8.	Section 34	Tierra Bonita III, Lot 9 (6580 West Dana Drive) County graded road and filled in wash next to house with sediment	9-19-90
9.	Section 26	Tucson Estates, debris in wash 9-19-90	10-3-90
10.	Section 34	Tierra Bonita, Lot 18 (4162 South Donald Avenue) Neighbor piling boulder and dirt up against fence	10-5-90

Table 1 (Cont.)
Pima County Drainage Complaints

11.	Section 34	Tierra Bonita II, Lot 24 (4201 South Chacoan Drive) culverts plug with sediment and cause property to flood	10-9-90
12.	Section 34	6571 West Emjay Avenue. Water runs down Shiela Avenue and into property	10-16-90
13.	Section 34	Tierra Bonita III, Lot 5 (6500 West Dana Drive) building block wall across wash	10-29-90
14.	Section 23	Tucson Estates complainant concerned about concrete golf cart crossings in washes	4-5-91
15.	Section 34	4201 South Palant Drive - Kay Lynn Drive diverts water onto property	4-16-91
16.	Section 33	Palant Drive flooded 12"-18" and flooded property at Paradise Est. Lot 10 (complainant says CAP diverted flow)	7-8-91
17.	Section 34	Tierra Bonita III (5461 West Sandia Drive) arroyo in front of property overtopped and eroded lot	7-11-91
18.	Section 26	3046 South Cole Circle (Tucson Estates Unit 4, Sierra Villas Townhouses, Lot 17). Drainage from adjacent property and alley flooding business. Street was suppose to be inverted crown, existing grades don't match design	8-15-91
19.	Section 23	Common Area C of Tucson Estates No. 2 (Unit 5, Lot 118). Fill material in Common Area C diverts flows	1-20-92
20.	Section 23	Lot 33 Tucson Estates No. 2. Fears flood from drainage in road	5-18-92
21.	Section 34	6315 West Michigan Street. Wash between Fred and Donald Streets diverting down Michigan Street and breaks south	6-8-92
22.	Section 26	Tucson Estates, debris in wash	6-15-92

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Table 1 (Cont.)
Pima County Drainage Complaints

23.	Section 34	6631 West Kay Lynn Drive, 3 inches of water in backyard	6-22-92
24.	Section 34	Kinney and Bopp Roads area. Debris in drainageway between Kay Drive and Jamie Avenue at Kay Lynn Drive, Golden Gate II	7-15-92
25.	Section 34	6331 West Oklahoma Street (Oklahoma Street and Deaver Road) 1-1.5 feet of water	7-26-90
26.	Section 26	Tucson Estates complaint about wash which traverses Lazy Heart and Kinney Road. Cable trenching requires restoring wash and embankments.	9-15-92
27.	Section 34	6371 West Oklahoma Street. Chainlink fence was installed without a permit.	3-31-93
28.	Section 34	6581 West Dana Drive. Drainage ditches on either side of property clogged with debris and vegetation	4-28-93
		6581 West Dana Drive. Drainage easement to south clogged with debris.	6-2-93
29.	Section 34	4255 South Deaver. Driveway flooding between Deaver and Kay Lynn periodically for past 5 years.	7-12-93
30.	Section 34	7022 West Irvington. CAP pipeline grading prevents water from draining south at Deaver Road, Jamie Drive, Frank Avenue and other roadways to the north.	7-29-93
31.	Section 26	Tucson Estates R.V. storage area blocks drainage ditches. Flow causes damage to golf course grass.	8-26-93
32.	Section 34	6737 West Kay Lynn Drive. Water drains to driveway, past residence to a wash. Grading of street created windrow at everyone's driveway except this resident's driveway.	8-26-93

Table 1 (Cont.)
Pima County Drainage Complaints

33.	Section 26	Western Way and Rafter Circle. Tucson Estates homeowners dumping debris in wash, results in diverting flow.	11-17-93
34.	Section 26	3131 South Kinney Road. Water from Western Way crosses intersection and sheet floods their building.	11-30-93
35.	Section 26	Rafter Circle and Tucson Estates Parkway. Wash has spillway side erosion.	12-1-93

Table 1a
Post-July 1990 Drainage Complaints Within Section 33

Township 14 South, Range 12 East
Eastern Portion of Section 33, Outside Study Area

36.	Section 33	4522 South Palant Drive, cement blocks in culvert, 2-foot berms on Palant Drive diverts runoff to north	7-16-90
37.	Section 33	4750 South Deaver Road, flow to the west along Oklahoma Street crossed property and flooded home approximately 1 foot across property	7-25-90
38.	Section 33	4750 South Deaver Road, water ran down Oklahoma Street, crossed property and flooded home approximately 1 foot across property	12-17-90
39.	Section 33	4410 South Palant Drive, yard eroded away, unusually heavy rainfall may have caused the problem. Flow was 6 inches deep across property	8-20-90
40.	Section 33	4201 South Aldon Road, neighbor had blocked the wash at the property boundary	10-20-01
41.	Section 33	4750 South Deaver Road, flow from cap is directed toward Oklahoma Street, road acts as channel, need improvements	7-16-93
42.	Section 33	7022 West Irvington Road, large amount of sediment has accumulated, piling up in driveway of residence	8-30-93

5. Pima County Files

Subdivision files and plats, drainage reports and rezoning cases were researched and assessed for flooding, erosion, floodplain use permits, violations and litigations to gain historical perspective of the project area. Historically, problems include sheet flooding, poorly defined channels with limited capacity and limited access in times of flooding. Increased residential densities have been identified as one of the primary causes of the high concentration of drainage complaints. Several Subdivisions in the study area (Tucson Estates, Golden Gate and Tierra Bonita) were platted 1958-1983 and therefore, do not adhere to current floodplain regulations. Hence, improved channels are generally inadequate for 100-year peak flows. A list of the data reviewed is summarized in Table 2 below. This data will be utilized in future tasks.

Table 2
Summary of Pima County Data Review

Subdivision Files

Golden Gate #3 (CO12-73-122)
Section 34, Township 14S, Range 12E

Old Tucson Estates, Lots 136-499 (CO12-64-24)
Section 26, Township 14S, Range 12E

Sierra (Pueblo) Villas North (CO12-84-29)
Section 26, Township 14S, Range 12E

Tucson Estates, Lots 403-758 (CO12-60-49)
Section 26, Township 14S, Range 12E

Tierra Bonita III (CO12-80-63)
Section 34, Township 14S, Range 12E

Westernway R.V. Resort, Old Tucson Estates, Block No. 1, (CO12-83-74)
Section 26, Township 14S, Range 12E

Drainage Reports

Hydrology and Hydraulic Report for Kinney Rd. Business Park, McGovern, MacVitte, Lodge and Associates, Inc., April 22, 1988.
Section 26, Township 14S, Range 12E

Hydrology and Hydraulic Report for Pueblo Villas North, Buck Lewis, Inc., March, 1984.
Section 26, Township 14S, Range 12E

Hydrology Report for Westernway R.V. Park, Anderson, Passarelli & MacVittie, Inc., July 21, 1983.
Section 26, Township 14S, Range 12E

Rezonings

Amos Properties, September 1992
Southside of Illinois Ave., approximately 700 ft. east of Camino Verde, one-half mile north of Ajo Highway.

Stark-Deaver Dr., June 1989
Northwest corner of Deaver Rd. and Oklahoma St., 800 ft. North of Irvington Rd., and three quarters of a mile west of Ajo Highway.

Table 2 (Cont.)
Summary of Pima County Data Review

Plats

Golden Gate Subdivision III, Lots 1-23, BK 26 PG 29
Section 34, Township 14S, Range 12E

Golden Gate Subdivision, Blocks 3 & 4, BK 13, PG 30
Section 34, Township 14S, Range 12E

Golden Gate Subdivision, Blocks 1, 2, & 5, BK 13, PG 13
Section 34, Township 14S, Range 12E

Golden Gate Subdivision, Blocks 6 & 7, BK 13, PG 31
Section 34, Township 14S, Range 12E

Millstone Manor No. 2, BK 10, PG 55
Section 27, Township 14S, Range 12E

Tierra Bonita, Lots 1-76, BK 23 PG 89
Section 34, Township 14S, Range 12E

Tierra Bonita II, Lots 1-66, BK 36, Pg 60
Section 34, Township 14S, Range 12E

Assessors Maps

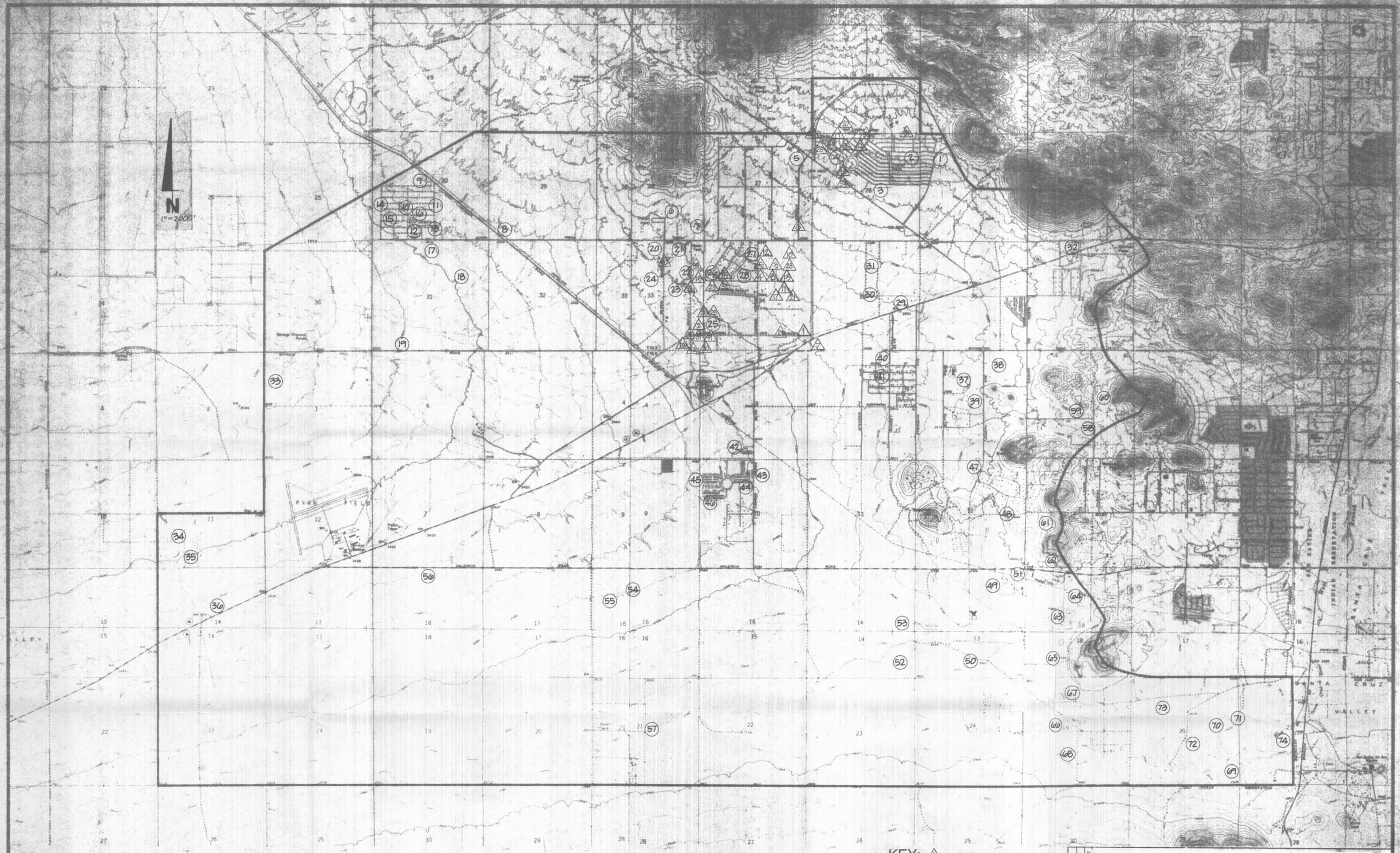
Tierra Bonita III, Lots 1-38, BK 36 PG 29
Section 34, Township 14S, Range 12E

Section 34, Township 14S, Range 12E
Lots 5-12, 13-28, 29-36, 37-44, 45-60, 61-68

6. Aerial Photographs/Topography

Available aerial photographs/topography have been collected and are reviewed and evaluated in future tasks. Availability includes, May, 1983 aerial topography (1"=100' and 1"=200' scale); 1990 aerials (1'=400' scale); 1941, 1973, 1979, 1985 and 1988 contact prints.

Figure 2 Drainage Complaint Map



KEY: ⚠ Drainage complaints on file with Pima Co.(July 1990–December 1993

(2) Previous Drainage Complaints taken from Southwest Basin Management Study Phase I, July 1990

REVISION	BY	DATE

Figure 2
Drainage Complaint Location Map

Southwest Basin Management Study Phase II, Part A (use in conjunction with Table 1)

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SECTION 2 - PERFORM HYDROLOGIC AND TOPOGRAPHIC ANALYSES

A. Map existing flood and erosion hazards and drainage-related problems.

SWBMS-I watershed boundaries were evaluated and modified within the study area. Land conditions, elevations and relief were field and air verified, and 1990, 400-foot scale topographic aerial maps were utilized in the evaluation. Existing available 100-year peak discharges were collected from previous reports pertaining to the study area. These reports include: the "Southwest Basin Management Study Basin Inventory/Drainage Report," prepared by Anderson, Passarelli & Associates, July 1990; the "Hydrologic and Hydraulic Analysis for Cooke Residence Drainage Complaint," which includes a HEC-2 analysis, prepared by Finn Associates, Ltd., revised October 1991; and the "Conceptual Plan for Flood Protection for Tucson Water Treatment Facility," prepared by Johnson Brittain & Associates, Inc., revised August, 1986. The specific 100-year peak discharges for the representative watersheds impacting Section 34 of the study area are summarized in Table 3. Certain existing 100-year peak discharges were not available at specific concentration points pertinent to the study area, and were therefore developed to complete the analysis of the project area. These additional peak discharges, calculated using the Pima County Method, are also included in Table 3 and Appendix E.

Table 3
100-Year Peak Discharge Summary Table*

Taken from Previous Reports

Concentration Point	Area (acres)	Existing Q_{100} (cfs)
Cross-Section 12-3	491	2,293
a	27.3	167
b	107	336
c	14.9	93
d, Cross-Section 12-2	470	1,758
I33	491	2,293
I36	269	1,386
I18	266	663
P.O.C. A	1,660	3,913

Generated by Cella Barr Associates

Concentration Point	Area (acres)	Existing Q_{100} (cfs)
CBA 1	11	62
CBA 2	566	2,539
CBA 3	581	2,606
CBA 4	688	3,086
CBA 5	715	3,207
CBA 6	91	341
CBA 7	868	3,542
CBA 8	964	3,980
CBA 9	134	475
CBA 10	20	92
CBA 11	64	279
CBA 12	864	3,567

* Hydrologic data sheets are included in Appendix E.

The resultant peak discharge data was utilized to evaluate existing conditions, including the determination of main flow paths and sheet flow areas. The Watershed Map is included as Figure 3. Cross-sections were developed within Section 34, using Manning's Rating, and the existing 100-year floodplains were delineated. Figure 4 is the graphical interpretation of a representative cross-section rated with Manning's Rating. Appendix F contains the remaining cross-section ratings. The specific 100-year peak flow was employed fully at each cross-section to permit a conservative yet realistic

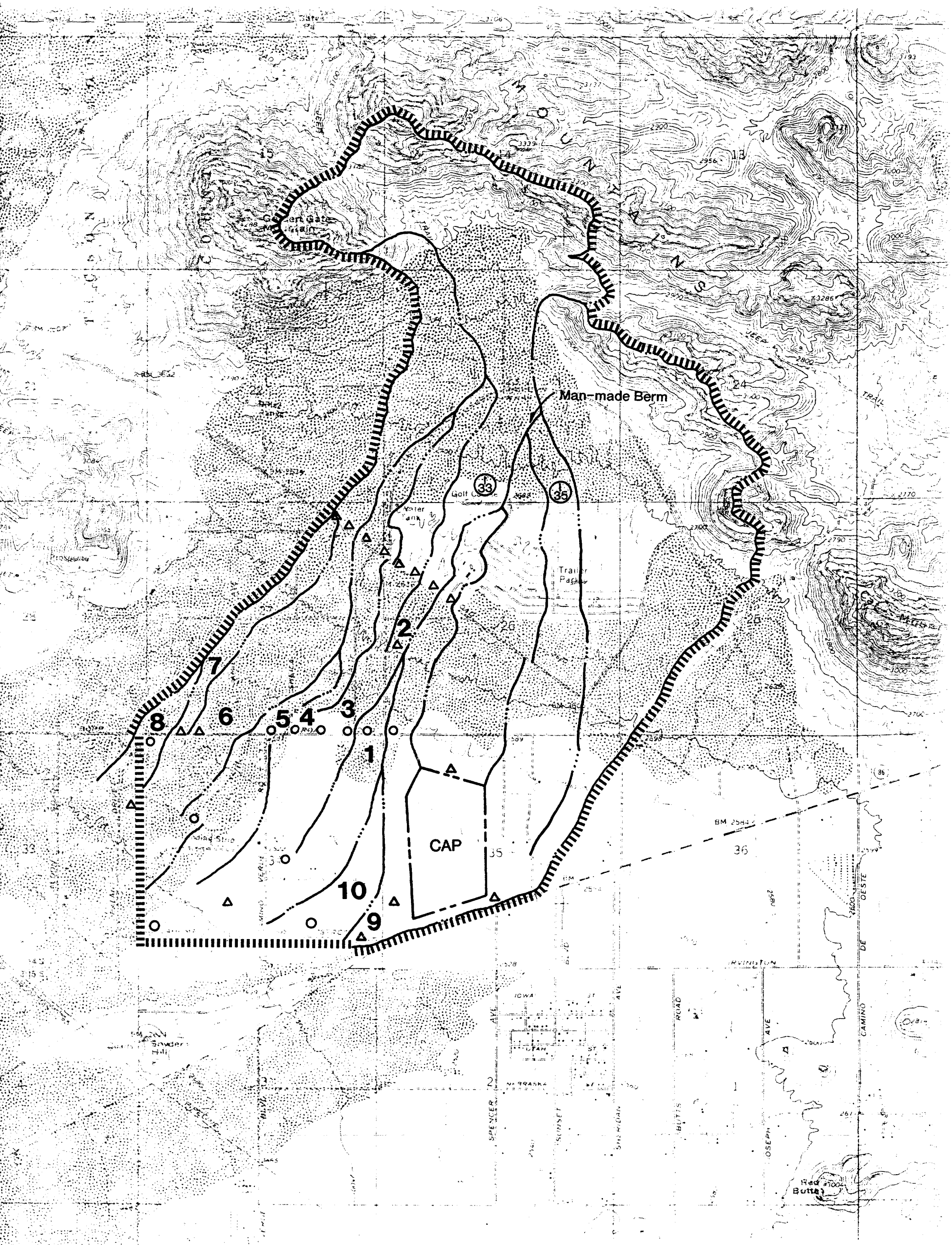


Figure 3 Watershed Map

Southwest Basin Management Study Phase IIA

4 drainage basin area

△ = Q100 from other sources

O = Q100 generated by CBA

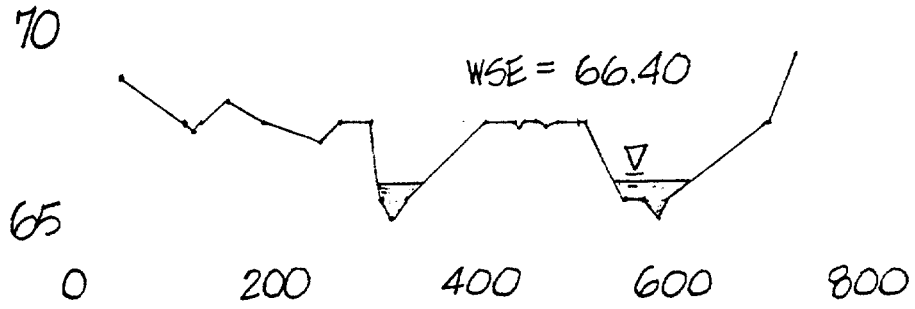
Study Area

C.B.A. JOB # 106579-01

CELLA BARR ASSOCIATES

SUBJECT: SOUTHWEST BASIN - AREA 1 JOB NO.:

CROSS-SECTION 1A



CROSS-SECTION TYPE	STATION	WATER SURFACE ELEVATION	CHANNEL SLOPE
EXIST	2 +00	66.40 ft	.90%

SUBSECTIONS FROM LEFT TO RIGHT

LEFT OFFSET (ft)	RIGHT OFFSET (ft)	TOP WIDTH (ft)	n VALUE	AREA (sqft)	WETTED PERIMETER (ft)	DISCHARGE (cfs)	VELOCITY (ft/sec)	FROUDE NUMBER
315.00	357.00	42.00	.040	18.8	42.06	39	2.06	.542
520.60	536.20	15.61	.040	3.1	15.63	4	1.20	.475
589.00	628.41	39.42	.040	13.1	39.46	22	1.69	.516
						64		

PREPARED BY: HL DATE: 4/30 CHECKED BY: SHEET NO.: 1 OF 1

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FIGURE 4

mapping of the 100-year floodplain limits. An earthworks computer model (COGO Software), developed by Cella Barr Associates, can be utilized to determine cut and fill quantities for grading projects. An additional routine has been added to the model which allows the user to conduct a Manning's Rating analysis for any specific cross-section. The model generates a conservative water surface elevation for a Q_{100} that is close, but not less than the established 100-year peak discharge. This model allows extreme flexibility in conducting Manning's Rating: cross-sections may be very wide (one mile plus if desired), 300 station/elevation points, Manning's "n" values between each point if desired, imaginary "walls" to contain flow between specific stations (thereby not allowing breakout to occur).

The analysis of Section 34 was initiated upstream of Bopp Road in Section 27, in order to begin with concentrated flow locations, where breakout does not occur. Cross-sections in Drainage Areas 2 and 3, (see Figure 3), downstream of Kinney Road, north of Bopp Road, were rated using an existing 100-year peak discharge of 2,293 cfs, obtained from the SWBMS-I. Three watersheds (Areas 2, 3 and 4 on Watershed Map, Figure 3) with a combined 100-year peak discharge of 3,086 cfs, merge north of Bopp Road before crossing the roadway, between Donald and Sheila Avenues. In addition, Areas 6 and 7 join at Bopp Road west of Jamie Avenue with an estimated 100-year peak discharge of 663 cfs. Additional cross-sections were rated beginning at the northeastern portion of Section 34, and whenever breakout occurred the cross-section was extended into the adjacent Area in the direction of the breakout (west). The resulting Floodplain Maps and cross-section locations are included in Appendix B.

There is limited channel definition along most reaches and sheet flow is prevalent throughout Section 34. Area 1, with an estimated 100-year peak discharge of 62 cfs at Bopp Road, east of Donald Avenue, begins north of Bopp Road and east of Tucson Estates Parkway. The flow crosses Section 34 at a southwesterly direction, and then converges with the consolidated flow in Area 4 south of Michigan Street, generating a combined 100-year peak discharge of 3,542 cfs at Illinois Street, between Fred Avenue and Camino Verde. Within the north portion of Section 34, Areas 4 and 5 are separated by Camino Verde

until south of Kay Lynn Drive. The 100-year peak discharges in Areas 4 and 5 flow in a southwesterly direction and ultimately join at Illinois Street. This combined 100-year peak discharge of 3,567 cfs sheet flows to the south and west exiting Section 34 at Deaver Drive and Oklahoma Street. A portion of Area 5, at Kay Lynn Drive, breaks out to the west and merges with Areas 6 and 7 creating a 100-year peak discharge of 3,980 cfs immediately south of Jamie Drive. Area 10 lies south of Area 1, along Tucson Estates Parkway, and the 100-year peak flow of 279 cfs at Illinois Street, drains to the south across Oklahoma Street. Area 9, with an estimated onsite 100-year peak discharge of 70 cfs, traverses Section 34 at the southeast corner and joins the outflow of the CAP Treatment Plant, eventually crossing Irvington Road (Q_{100} = 3,913 cfs). Area 8 is a minor watershed that cuts across the northwestern corner of Section 34, exiting along Deaver Road with an estimated 100-year peak discharge of approximately 92 cfs at Bopp Road.

Average flow depth zones of AO1 (average depth = one foot) and AO2 (average depth = two feet) were mapped according to the distribution of flow along the main flow paths. The natural washes and improved channels typically were designated Zone AO2, with a depth of flow at 1.5 feet to 2.5 feet. In general, Section 34, which is primarily a sheet flow area, was rated Zone AO1, with an average depth of flow at approximately one foot. The majority of the southern half of Section 34 lies within a 100-year floodplain, and the natural washes are inadequate during the 100-year event. The entire southwest quarter section of Section 34 lies in the 100-year floodplain. The depth of sheet flooding can be as shallow as less than one foot to close to three feet. A zone designation of AO2 is recommended for a portion of the extreme southeast half of Section 34, based on the HEC-2 water surface model in the Cooke residence hydrology analysis.

Geomorphic Analysis

A field observation survey of the study area was conducted to verify the determination of hydrologic/hydraulic data, and to investigate existing land conditions and changes within the project reach. Technical information taken

from the Phase I Southwest Basin Management Study was utilized to facilitate hydrologic/hydraulic criteria. Quantitative and qualitative assessments were performed to assist in identifying flow paths, and erosion problem areas and reaches. Available aerial photographs were collected, reviewed and evaluated to measure historical channel behavior in the study area. The available aerials included 1990 aerial maps (1"=400'), 1988, 1985, 1979, 1973 and 1941 contact prints. The comparison of the photography indicated, in general, that waterways have not been significantly altered by suburban development. An earthen berm with grouted rock riprap has been constructed north of Tucson Estates which effectively truncates the watershed delineation for Basin I35 and diverts runoff to Basin I33 (see Figure 3). There is visual evidence that site specific channel widening or narrowing has occurred within and downstream of developed areas as increased flow has been diverted to either existing natural washes or improved waterways. However, the historical meandering flow is similar to the current existing conditions within the study reach.

The erosion hazard setback (EHS) zone delineations according to the "Floodplain and Erosion Hazard Management Ordinance for Pima County," are: the minimum erosion hazard setback for minor washes with a 100-year peak discharge of 2,000 cfs or less is 50 feet; all major waterways with a 100-year peak discharge of 10,000 cfs or less, but more than 2,000 cfs will have an erosion hazard setback of 100 feet. Due to the sheet flow nature of the project area, channel bank capacities were utilized to determine the recommended EHS limits in Section 34. The EHS limits determined by Pima County criteria are depicted on the Floodplain Maps, Appendix B. The EHS limits along main flow paths were based upon actual channel capacity (range of capacity rated at approximately 100 cfs to 700 cfs), and the minimum setback limits should be set at 50 feet, with future setbacks to be evaluated on an individual, case by case basis.

The degradation and aggradation potential was ascertained through application of engineering analysis via the "City of Tucson Standards Manual for Drainage Design and Floodplain Management" and the "Pima County Hydrology Manual for Engineering Design and Floodplain Management." The prediction of general

scour on the regional watercourses within Section 34 was estimated by utilizing the following equation (Zeller, 1981):

$$Zgs = Ymax\left(\frac{0.0685\ Vm^{0.8}}{Yh^{0.4}\ Se^{0.3}} - 1 \right)$$

The general scour calculations were performed on several watersheds in Section 34 and the results were evaluated and considered to be representative of the sand-bed channels within the study area. The general scour depth of the study area is basically negligible. The sample scour calculations are included in Appendix C.

Most natural, undisturbed channels in the Tucson area are assumed to be at or close to a state of dynamic equilibrium. The channel bed slope is therefore stable (reference the City of Tucson "Standards Manual for Drainage Design and Floodplain Management"). Urbanization generally increases peak discharges, flow velocities and depth, and frequency of runoff. The study area, specifically Section 34, is moderately urbanized, and the channel bed will experience degradation until the channel slope is flat enough to ensure a natural stable equilibrium slope. General existing slopes within the study area, on average, are 0.5 to 1.0 percent. The equilibrium slope for natural washes within Section 34 was computed using a generalization of the theoretically derived sediment-transport relationships for sand-bed channels by Zeller and Fullerton, 1983:

$$Seq = \left[\left(\frac{Nu}{Nn} \right)^2 \left(\frac{Qu,10}{Qn,10} \right)^{-1.1} \left(\frac{bu}{bn} \right)^{0.4} (1 - Rs)^{0.7} \right] Sn$$

The equilibrium slope calculations indicate aggrading situation, where peak flows are laden with sediment deposits, and the channel bed slopes are flattened and the channel is widened beyond existing or natural conditions. Appendix D contains equilibrium slope calculations for Section 34.

SECTION 3 - IDENTIFY PRIMARY PROBLEM AREAS

The identification of existing flooding problems within the study area included the review of drainage complaints on file at Pima County Flood Control District during 1991 through December 1993, the preliminary assessment of drainage problems performed within Phase I of the Southwest Basin Management Study, field reconnaissance, and the utilization of the data resulting from Section 2. The drainage system within the study area consists of a distributary flow pattern. Limited relief and natural channel definition has created sheet flow which appears to be inadequately controlled under present conditions. Existing structures are located within areas of 100-year flooding and sheet flow up to approximately one foot in depth. Human encroachments, such as homes and driveways, have diverted natural flow within the study area. Specific drainage complaints and their locale, severity, cause and damage within Section 34 are listed in Table 1. Generally, the complaints are located in several key areas. Approximately one dozen complaints were voiced from the northeast quarter section of Section 34, north of Michigan Street, east of Camino Verde, and are located in the 100-year floodplain. The 100-year peak discharge that sheet flows across this area is approximately 3,542 cfs. However, only one complaint on file was associated with actual flooding of homes, with exception to the Cooke residence. This does not necessarily denote that such flooding has not occurred, or that the possibility for future flooding is not likely. Typically, complaints focused on the diversion and redirection of flow by individuals, such as the construction of berms, fences, driveways and rock riprap. In some incidents, the causes were natural, such as debris blocking flow and the erosion of existing waterways, which ultimately are maintenance related problems. Although the majority of the southern half of Section 34 lies within a 100-year floodplain, the lack of numerous drainage complaints immediately following the July, 1990 and January 1993 storm events is puzzling.

Although the CAP underground pipeline fill lies outside the study area, the fill obstruction causes backwater consequences which aggravate the upstream sheet flooding in Sections 33 and 34. The CAP underground pipeline is located

at the southern boundary of the study area; however, the backwater effects to the sheet flows should be corrected by the responsible agency by removing and regrading the CAP pipeline fill to match the surrounding topography. Existing drainage ditches could then function as designed and allow runoff to exit from roadways.

At the southern boundary of the southwest quarter of Section 34 are roadway/ drainage easements between 5-acre Veteran's parcels. Appendix H provides flow capacities for various cross-sections to grade roadways as drainage easements that are still safe for traffic. The best cross-section is an inverted crown road across the entire 66-foot easements that will convey approximately 311 cfs.

The Tucson Estates Subdivision, a tributary to Section 34 is located within the northern portion of Section 26. The improved channel (identified as I-33 in SWBMS-I), which conveys flow from the Tucson Mountains through the west end of the subdivision, has been determined in SWBMS-I to have limited capacity, and only the 10-year peak flow of 1,136 cfs is contained within the channel banks. The 100-year floodplain encompasses a number of mobile homes which exist along the channel. There is potential for flood damage to residences adjacent to the channel and other adjoining improvements. The capacity of the two culvert crossings at Kinney Road and Lonestar Drive were also determined to be far below the 100-year peak capacity, with the estimated capacity at the 25-year for Kinney Road and the 5-year peak event for Lonestar Drive. These two crossings, as well as dip sections of local streets within the subdivision do not provide required all-weather access. Due to conditions of the watercourse, specifically limited ground relief and channel definition, culvert structures at Kinney Road appear to be inadequate as available head water is lacking for proper containment of flow. Sedimentation problems were not evident during field investigation; however, any future detention in Tucson Mountain Park will require periodic maintenance. Sediment deposits exist at culvert and roadway dip sections north of Bopp Road.

The original hydrology report for the Tierra Bonita Subdivisions (see Figure 1) did not acknowledge the potential for sheet flow through the study area. Consequently the dip section crossing at Bopp Road for the main wash flowing through the subdivision has inadequate capacity to contain the 100-year flow. A roadside channel adjacent to Camino Verde Road conveys the discharge exiting the Tierra Bonita Subdivision. Future development proposes the use of Camino Verde as a major arterial; therefore, its use as a flow conveyor may prove to be inappropriate. Sedimentation is a significant problem along roadway shoulders and consistent maintenance is required to alleviate the situation. The occurrence of significant runoff flow along the subdivision streets within the Golden Gate Subdivision (located west of Camino Verde) were visually apparent, with sedimentation and erosion.

SECTION 4 - QUALITATIVE ASSESSMENT OF NON-COMPLIANCE WITH PIMA COUNTY FLOODPLAIN MANAGEMENT AND EROSION HAZARD ORDINANCE (1988-FC2)

Current Pima County ordinance and policies were evaluated relative to the identified flooding potential and existing flooding problems within the study area. Specific areas were inspected within Section 34 and the Tucson Estates Subdivision. The subdivisions within Section 34, Tierra Bonita and Golden Gate Subdivisions (see Figure 1) are subject to sheet flow, with an average depth of one foot. A majority of the homes within Section 34, approximately 70%, are located in the developed 100-year floodplain. The subdivision developments lack operative drainage schemes for the 100-year storm. Individual residents in the Tierra Bonita Subdivisions have resorted to correcting their own flooding problems which resulted from low flow events. The adjustments vary from building floodwalls and fences, placing riprap along roads and along minor washes that traverse individual lots, and building small foot bridges over minor washes. The Golden Gate Subdivision drainage layout appears to convey the low flow discharges adequately through the property via earthen drainage channels. The channels were built to correspond to natural flow direction and field visits indicated that maintenance has been thorough.

The existing roadway designs do not comply with current Pima County all-weather access criteria. The existing 100-year peak discharges, in general, exceed 50 cfs and are not contained in the dirt roads built within the 100-year floodplain limits. The flooding conditions which occur along the roads would not be permitted under current standards. Existing dip sections on Bopp Road are inadequate and contribute to access limitations and flooding to surrounding areas.

There are several well defined channels within Section 34, conveying 100-year peak discharges of a minimum of 100 cfs. Current regulations would require erosion hazard building setbacks, measured from the channel banks. Applicable erosion hazard setbacks per Pima County are 50 feet (<2,000 cfs) to 100 feet (>2,000 cfs and 10,000 cfs). There are approximately five existing structures in Section 34 which have been constructed within a portion of the erosion

hazard setback limits, and these structures are potentially at risk to damage and flooding, if bank protection has not been provided.

The current regulation for residential development within a delineated floodplain dictates that the dwelling be constructed so as to place the minimum finished floor elevation at a minimum of one-foot above the 100-year water surface elevation. Recent field observations revealed that the majority of homes appear to be elevated at least one foot above adjacent grade. Since the average flow depth within Section 34 is approximately one foot (Zone AO1), the majority of homes are not properly elevated given current regulations. However, field observation indicates that the majority of homes appear to be elevated to approximately the average 100-year floodplain depth of one foot.

SECTION 5 - IDENTIFICATION OF POSSIBLE STRUCTURAL AND NON-STRUCTURAL FLOOD CONTROL ALTERNATIVES

A. *Non-Structural Components*

Non-structural measures are described in the following text, along with unit cost estimates based on 1993 construction costs.

Description	Unit cost
Floodplain/Erosion Hazard Property Acquisition (convert to parks, open space, trail systems)	
Preservation of land through purchase, fee ownership, easement or other mechanisms is the most effective way of preventing impacts in sensitive areas and preserving options for system improvements. The locations and types of land acquisitions necessary for stormwater system development and maintenance are identified through the basin planning process, where coordinated approaches including land management and other project concerns can be efficiently developed. Besides fee ownership, various types of easements are available, including:	$2,000-$50,000/acre

- Conservation easements to preserve natural vegetation from disturbance;
- Open space easements to preserve natural areas including floodplains and erosion-susceptible slopes;

Description	Unit Cost
• General public easements to allow public facilities (including storm sewers) to cross private property, including drainage easements and flowage easements.	
Easements are most easily obtained during the plan review process as a condition of approval. Where responsible stormwater stewardship has been demonstrated, easements can sometimes be obtained at little or no cost.	
Floodproofing/Erosion Proofing	
Floodproofing consists of structure-specific improvements to reduce or eliminate flood damage in known floodprone areas.	
- Structures	
Sealants	$0.45-$1.00/SF
Closures (special treatments for openings such as doors, windows, driveways, etc.)	
Elevation (raise structure above flood hazard, via fill, piers)	$4-$15/SF
Floodwalls and Levees	$300-$350/CY - Concrete and $4-$10/CY - Fill
Cutoff walls	$300-$350/CY - Concrete
Pier replacement/deepening	$30K-$60K/house
Slope stabilization	$1-$3/SY

Description	Unit Cost
Peripheral landscaping for erosion mitigation	$0.50/FT^2
- Lots	
Elevation via fill, piers	$4-$10/CY - Fill
Floodwalls and Levees	$300-$350/CY - Concrete

New Development Design Criteria

Establishing and applying design criteria to new development proposals is one of the most effective non-structural means by which the County can control the drainage impacts of growth. However, design criteria must be carefully developed and applied utilizing a full understanding of the drainage systems throughout the County and the specific needs of individual basins and sub-basins. This understanding is usually gained through basin planning efforts and long-term system observation.

Drainage Plan Review/Approval

The plan review and approval process is another key element in effective management of stormwater systems for new developments. The demands on the plan reviewer include the following: a thorough familiarity with County requirements; sound understanding of basic hydrologic and hydraulic principles; working knowledge of the basins; understanding of constraints on

Description	Unit Cost

developers; and a willingness to be creative in attaining goals within the framework of County requirements. In addition, the nature of the development review process requires an ongoing vigilance and attention to detail. Once the plans are approved, the opportunities to effect desirable storm drainage management measures are lost.

Building/Floodplain Permitting

Requirement for permits for individual, site specific properties, identified to be located in designated floodplain zones, allows the County to ensure the proposed use of the property is compatible with current floodplain ordinance and design criteria. Appropriate criteria and drainage solutions will need to be presented in order for a permit to be issued. The process would involve much the same elements as identified above for drainage plan review/approval.

Maintenance/Operation

Drainage maintenance, including maintenance of detention facilities, is currently the responsibility of the Operations Division of the Pima County Department of Transportation and Flood Control District. The majority of

drainage maintenance generally occurs as a result of a citizen complaint or a flooding event.

There are many benefits of a well operated and maintained stormwater system. First, the useful life of capital facilities will be extended with proper maintenance. Second, well maintained systems should have fewer emergencies associated with system operation under extreme conditions (major storms), thereby reducing the County's liabilities for flood damage. Third, the maintenance staff will understand the system better by virtue of systematic maintenance and may be better able to fend off emergency situations.

Enforcement

Many flooding and water quality problems can be linked to lack of knowledge or are the by-products of current lifestyles. Public education is the appropriate response to lack of knowledge. However, there are people who, knowing the harmful results of their actions, choose to dispose of material in washes or channels, place obstructions in drainage facilities or pour hazardous substances into the stormwater system. For these situations, enforcement mechanisms need to be in place

Description	Unit Cost

which fully convey the seriousness of the offense. Examples of typical enforcement options include citations, fines and penalties.

Public Education/Involvement

One of the more critical components of a comprehensive approach to storm drainage management is public education and involvement. Basin residents who understand their role in the watershed will not only reduce the potential for hazardous substance spills in the system, but will also be more likely to report spills or other changes they observe. The dual role of awareness and active involvement can go a long way in preserving and protecting watersheds, thus lowering the degree of dependence on "structural solutions". There are a variety of opportunities for public involvement which could greatly enhance stormwater management by raising resident awareness as to the importance of individual actions. It is the responsibility of Pima County to coordinate and sponsor public involvement in the stormwater program. Public education opportunities include public involvement programs connected to individual wash improvements, neighborhood

Description	Unit Cost

associations near existing natural washes, and the construction industry through trade organizations.

Educational displays can provide ongoing reminders of the values of natural drainage systems. The displays can be shown in schools, libraries, shopping centers, community centers and other public gathering places to reach as many residents as possible.

A Best Management Practices (BMP) manual can be developed for distribution to watershed residents. Such a manual would describe actions which residents could take to maintain and improve conditions in the watershed.

There are many project-oriented programs which solicit public involvement and develop a sense of public identification and ownership of washes and other drainage system components. Following are examples of public involvement projects which the community can sponsor both to aid in preserving the systems and to encourage public support for drainage related issues.

Description	Unit Cost

- Wash Clean-up Days: Periodically, volunteer groups could be organized to remove debris and provide general clean-up of a specific wash. The effort could be coordinated with regional and local political figures to broaden awareness among different sectors of the watershed residents.

- Signing: Designing and installing signs identifying the washes would regularly remind residents of the washes' presence and trigger greater understanding of their condition during subsequent County preservation or enhancement efforts. Local service organizations (i.e., Kiwanis, Boy Scouts) are often eager to assist in manufacturing, placing and maintaining such signs.

Ordinances/Policies

- Zoning restriction regulations
- Maintain existing floodplain limits via regulations
- Basin Management Plans

Through the proper use of ordinances and land-use planning, several stormwater goals can be achieved. By controlling the location, extent and density of land-use

Description	Unit Cost

and related activities, the quantity and quality of storm runoff can be influenced and capacities of the existing drainage system preserved. Brief discussions of the types of ordinances in general use are presented below.

- Stormwater Management Ordinances are typically used to limit runoff from a developing site to pre-development characteristics. Approval of drainage plans which include runoff-control facilities (onsite retention/detention) is typically required as a centerpiece of such ordinances. Implementation of the ordinance is predicated upon the development of design standards by Pima County.

- Clearing/Filling/Grading Ordinances recognize the need to manage efforts associated with removal of vegetation and movement of soils. They may include restrictions on clearing, filling or stockpiling of soils on a site, or movement of soils or fill to other than naturally occurring elevations (grading).

Description	Unit Cost

- Erosion/Sediment Control Ordinances have been used by some jurisdictions instead of, or as a supplement to, a clearing/filling/grading ordinance to ensure that, from the start of vegetation removal through completion of construction, the loss of sediment from a site is limited.

- Floodplain Management Ordinances are typically developed in compliance with Federal flood insurance requirements and include restrictions on development within the 100-year floodplain associated with major bodies of water. The availability of and ability to purchase flood insurance is one of the most effective inducements for encouraging community adoption of a floodplain management ordinance.

- Sensitive Areas Ordinances include a variety of measures to prevent degradation of washes, steep slopes, riparian habitats and other vicinity-specific features. Most typically such ordinances limit the uses of sensitive areas and reserve an undisturbed "buffer zone" adjacent to the areas.

Description	Unit Cost

- Zoning Ordinances can be used to protect critical areas such as floodplains and steep slopes from impacts due to unplanned development. These ordinances can also be used to regulate the density of population and intensity of land use.

- Subdivision regulations may complement, but not supersede the zoning ordinance. Whereas zoning regulations describe where different types of land use shall occur, subdivision regulations describe how the development shall occur to ensure proper functioning of the development.

Organization/Management

An organizational structure which provides the staffing and authority to implement stormwater policies and regulatory requirements for a proactive stormwater management program.

Development Inspection

The critical link between establishment of sound design criteria, plan review and stormwater protection is field inspection. Inspectors must understand stormwater

Description	Unit Cost

issues and communicate with others involved in stormwater management. Inspectors are key to identification of problem areas, erosion control and compliance with design plans.

Data-Base Management

Data-base management includes the collection, recording and cataloging of data pertaining to the stormwater system such as as-built drawings, complaints, reports, easements and fee title properties and construction documents. A good data-base aids in system design and analysis and increases the efficiency of maintenance efforts.

Complaint/Emergency Response

Awareness of a stormwater program comes when residents observe a problem with the storm drainage system. The community's response to a complaint often forms the basis for that resident's subsequent opinion of the community's effectiveness. Thus, a well managed complaint and emergency response program can be a foundational element of a community-supported stormwater management program.

Description	Unit Cost

Flood Warning/Monitoring

Collection of water quantity and quality data is integral to system analysis. In the absence of data, conservative assumptions are made to assess the range of outcomes from a given action or event. An increase in understanding of the hydrologic and water quality characteristics of an area increases the ability to design facilities and implement measures which both address the problems and make the best use of available resources.

Monitoring of physical system characteristics, such as water quantity, water quality, groundwater, and slope stability, may include the following:

- Baseline monitoring to determine the "background" characteristics.

- Storm event monitoring to determine the impacts of storms on the physical system such as rainfall measurements, locations of flooding, peak flows and volumes, and levels of pollutants.

Description	Unit Cost

- Enforcement monitoring to identify the source of a hazardous substance spill into the stormwater system.

- Emergency response system which will notify local jurisdiction/agency of impending storm/high water level potential, and means to notify residents to implement flood control measures or evacuation procedures.

Financing

Available financial resources largely determine the community's ability to attain its stated goals. The level of funding is critical in determining whether structural or non-structural solutions should be applied to a particular problem.

Do Nothing

Based on existing land use, future land use, drainage conditions, existing and proposed infrastructure; a "do-nothing" component will be evaluated as to feasibility and impacts to the specific watershed area(s).

B. *Structural Components*

Typical structural measures are described in the following text with associated Unit Cost:

Description	Unit Cost
Structure Relocation	
Structure relocation consists of physical relocation of existing structures within a flood- or erosion-hazard area as a means of reducing or eliminating personal flood risks and potential damages to existing properties and structures.	$30K-$60K/structure
Improved Drainage Channels/Corridors	
Bank Protection	
Riprap	$40-$75/CY
Rock and Rail	$170/LF
Soil Cement	$90-$200/LF
Concrete	$25/SY
Geotextiles	$15-$20/SY
Modular Lining	$45/SY
Concrete (fully lined)	$180/CY
Channelization	
Encroachment	
Channel Parkways	$0.50/SF (Landscaping)
Vegetated/Unlined Channels	$4/CY (Excavation)

In addition to the option of preserving channels in their current state, several choices of channel stabilization designs are available to the community. These include vegetation, rock, synthetic fabrics, soil cement, gunite, and

concrete. The choice of channel lining is generally a function of aesthetics, the desired capacity of the channel, availability of land for right-of-way needs, hydraulic parameters such as existing land slopes, and desired level of operation and maintenance for the life of the channel. The choice of channel lining should also be a function of wildlife benefits, local neighborhood and adjacent property owner needs, existing condition of the resource, and community visibility of the project.

Establishing vegetation in a channel increases the channel's resistance to erosion, thereby contributing to water quality preservation and the structural stability of the channel. Vegetated channels are also aesthetically pleasing in comparison to some other structural improvements. Establishment of vegetation must be accounted for in the hydraulic design of the channel, and sufficient right-of-way must exist to accommodate the channel and maintenance accesses. The vegetation must also be maintained regularly to avoid obstruction of flows, to minimize weed infestations and to ensure desired plant establishment. Revegetation and management approaches must be continually tested and updated to improve success rates.

Description	Unit Cost
"Hard" channel stabilization methods protect channel banks and floors from the erosive forces of runoff. These measures include rock lining, gabions, revet mattresses, and gunite or concrete lining. Some of these measures also serve to increase both the flow capacity of the channel and downstream flood peaks by creating more uniform and efficient hydraulic sections. An additional benefit is a relatively narrow cross section, which may allow for the preservation of existing vegetation and space for trails, if sensitively designed. Drawbacks to these measures are high cost, hazards associated with high flow velocities, little or no water quality benefits, and lower aesthetic value. Maintenance requirements are typically lower, however, than for comparable vegetated channels.	
Dip Crossings	
Roadway dip crossings are at-grade crossings of washes primarily used in rural or suburban areas where all-weather access is neither necessary nor economically feasible.	$30/LF - Concrete cutoff wall

Description	Unit Cost
Culverts/Storm Drains Storm drains and culverts are the most commonly used method of stormwater conveyance in urbanizing areas. They are particularly well suited to developed areas where available land area is restricted. In less intensely developed areas, culverts are widely used to pass storm flows under roadways. Storm drains are used to convey flows to major natural drainages and to divert excess runoff from erodible or floodprone locations. Proper sizing of storm drains and culverts to meet flow demands throughout their expected service life is achieved through careful basin planning and specific site analysis during design. Storm drains serve to accelerate the flow rate of stormwater and may in turn contribute to faster concentration of runoff within a basin and greater downstream flooding. Routine maintenance of storm drains, culverts (especially those with flatter slopes) and associated catch basins is necessary to preserve design capacity and ensure proper functioning during flow events.	$300-$350/CY - Cast in Place Concrete $1-$1.5-/inch of diameter - CMP $2-$3/inch of diameter - RCP

Description	Unit Cost
Detention/Retention Facilities Regional Local Constructed storage facilities, used to supplement natural storage created by channels and topographic depressions, can consist of: short-term detention of runoff, on-line or off-line of conveyance facilities, and longer-term retention of runoff. The primary purpose of these facilities is to lower peak flow rates so as to reduce downstream flooding. However, they may also be designed to meet multiple objectives including: reduce onsite flooding; capture sediments; reduce water pollution; enhance the appearance of the community by promoting vegetation and use of the facility by wildlife; replenish groundwater; and provide recreational benefits. Stormwater detention facilities may take a variety of forms with regard to the existing drainage system. If feasible, natural areas such as channels and topographic depressions can be modified to meet stormwater management objectives. Constructed facilities may be designed as a continuation of a natural or constructed channel ("on-line") or as separate from the channel ("off-line"). Six locations	$4/CY (Excavation only)

are typically considered for detention: 1) subsurface storage; 2) rooftop storage; 3) parking lot storage; 4) recreational area storage; 5) storage in ponds or lakes; and 6) underground storage in seepage pits and groundwater recharge facilities. Storage facilities may occur as small, onsite basins designed to serve individual developments or as larger-scale, regional facilities designed to serve a large watershed area. Because of the volume of stormwater required, "regional" facilities are often integrated with other uses requiring large land areas or having other common attributes. Recreational facilities such as parks, ballfields, golf courses, trails, and open space uses are often incorporated into the design of regional detention facilities. Detention facilities can also be designed to provide enhanced sediment removal. Because many pollutants within stormwater attach themselves to and are transported by sediment particles, sediment removal often provides a large benefit in terms of water quality.

Retention systems preclude the passage of runoff downstream by collecting and storing the entire volume of a runoff event. The runoff is released through

Description	Unit Cost
evaporation and percolation into the underlying soils. Groundwater recharge may be incorporated into retention facilities; however, the potential for groundwater pollution must be considered in this option. Groundwater recharge systems include drywells and engineered infiltration beds. Perforated pipes and permeable paving materials may also be utilized for infiltration purposes within urban settings where small retention systems are desired.	
Sediment Basins These are structures which may be utilized to collect incoming sediment loads to prevent clogging, siltation, agradation, and are usually implemented in conjunction with detention/retention facilities, culverts, and channels; as required.	$4/CY (Excavation Only)
Erosion Protection/Energy Dissipation Structures/Grade-Control Structures (Check Dams) Measures to protect channel bottom, channel sides, fill slopes, inlets/outlets to drainage structures, natural surfaces exposed to runoff are employed to prevent erosion of native/placed material. Grade-control structures, dams and energy dissipators are used to decrease the	$75-$350/CY - Concrete/Soil Cement

Description	Unit Cost
velocity of concentrated flows, thereby reducing erosion in a channel, and can also be employed to stabilize stream beds. Grade control structures and energy dissipators are constructed of both natural and man-made materials and often have a low capital cost. They must be inspected and maintained regularly to ensure stability.	
Levees/Dikes/Dams/Floodwalls/Diversion Structures (Potentially effective at apices and avulsion zones)	
These are structures designed to contain and control stormwater within specific areas or limits.	$300-$350/CY - Concrete and $4-$10/CY - Fill
Roadway Improvements	
Detention/Retention Facilities	$4/CY (Excavation Only)
Collector Systems/Channels	$90-$200/LF (Soil Cement) $25/CY (Concrete)
Culverts	$300-$350/CY Cast in Place Concrete
Bridges	$65/SF
Storm Drains	$1-$1.50/dia. in. - CMP $2-$3/dia. in. - RCP
Roadway Levees	$4-$10/CY Fill
As roads are improved/constructed in the Southwest Area, they provide a unique opportunity to concentrate, collect,	

Description	Unit Cost
divert and convey runoff which may improve/mitigate adjacent drainage conditions.	
Street (Parking Lot) Conveyance Street design consists of street planning on two levels: design of streets to convey stormwater runoff and layout of streets within developing areas according to natural terrain. Pima County has utilized streets to convey storm runoff in the past. In general, the design criteria for street conveyance has generally been the 10-year event or less, particularly in conjunction with use of storm drains. In some instances, however, streets have been designed to convey runoff resulting from events as large as the 100-year as long as depths and velocities of flow did not exceed certain limits. Layout of streets in developing areas according to natural terrain allows the existing, natural drainage system to be protected. It also minimizes the need for roadway crossings of the existing washes.	$15-$25/SY

SECTION 6 - PERFORM AN EVALUATION OF THE ALTERNATIVES

All structural and non-structural alternatives were evaluated utilizing collected data, existing hydrologic information and calculated results gathered in Tasks 1-5. The evaluation consisted of ranking the flood control components based on specific criteria within the areas of completeness, effectiveness, efficiency and acceptableness. Rankings on an advantage/disadvantage basis are tabulated in Tables 4 and 5. Each alternative was rated relative to hydrologic, hydraulic, geomorphic, social, cultural, legal, political and economic impacts or benefits. The overall desired benefit for the study area is to mitigate/control runoff and erosion, and the components were conceptually analyzed with the intention of achieving this goal. Identifying levels of flooding/erosion protection provided by each component involved realistic effectiveness without creating adverse impacts to adjacent areas. These matrix tables were then averaged to determine the components which ultimately would beget the "concept" alternatives.

Evaluation Criteria

The following definitions for the evaluation criteria were established and utilized in the selection matrix to rate structural and non-structural components.

Engineering Feasibility - Structural solutions are limited due to the challenge of adequately collecting, conveying and discharging sheet flow, and the lack of concentrated downstream outlet points. Non-structural solutions can be restricting due to intangible elements such as safety, aesthetics, environmental issues, etc.

Acceptability to Public - All components were ranked assuming the public would either approve or disapprove if they were involved. Evaluation motives focused on perceived public considerations regarding safety, traffic, costs, land use, aesthetics, etc.

Implementation/Construction Costs - Relative costs for construction/design of structural component and implementation cost of non-structural components.

Effectiveness - Relates the cause and affect of a component in its ability to regulate/control/mitigate drainage and flooding problems.

Transportation - Evaluates compatibility of component with existing or proposed roadways, and rates access possibilities.

Short Term versus Long Term - Compares the effectiveness over time of the specific component's performance within the basin.

Phased Construction Potential (Structural Components Only) - Construction of proposed improvement could be completed in phases without significant consequences to the hydraulic performance of the basin. Phased Construction could be limited by existing sheet flow, wide floodplains, and low density development.

Benefit Area versus Impact Area - Compares the true outcome of implementing a component into the area, and reviews the result as a benefit or negative impact.

ROW Restrictions/Requirements - Evaluate in terms of land acquisition requirements to initiate particular drainage improvements.

Utility Conflicts (Structural Components Only) - Assuming that components within or adjacent to roadways would require utility relocation.

Maintenance Requirements - Rate in terms of maintenance regarding performance over time, and upgrade/update as new information is gathered.

Multiple Use Potential - Evaluate the relationship between a component and multiple-use potential to flood control, transportation, recreation, aesthetics, etc.

Impact on Infiltration - Evaluate component regarding positive or negative impact on infiltration, direct or indirect.

Loss of Flow Attenuation - The direct and indirect impact potential of components effect on flow attenuation.

Environmental Considerations - Evaluate the influence on riparian habitats and the environmental repercussions of component to the study area.

Water Quality - Evaluate the component in relation to plausible impact on water quality, directly and indirectly.

Aesthetics - Rate component regarding general compatibility with residents' lifestyle, rural atmosphere, architectural issues, etc.

Pima County, State, Federal Regulations (General) - Refers to the adaptability of component regarding regulations.

Compatibility with Existing Land Use - Evaluate component's harmony with existing development.

Financing - Availability of funds for design/construction of proposed improvements based on greatest needs within study area.

Riparian Habitat Protection - Evaluate compliance with Pima County's Riparian Habitat and Green Belt Protection Ordinance.

TABLE 4

Flood Control Components Selection Criteria Matrix

SOUTHWEST BASIN MANAGEMENT PLAN
PHASE IIA
NON-STRUCTURAL

FLDPLN ACQ	FLOOD PROOFING	DESIGN CRITERIA	PLAN REVIEW	FLDPLN PERMITTNG	MAINT. OPERATION	ENFORCE-MENT	EDUCATION	ORDS. POLICIES	ORG/ MGMT	DEV. INSPEC.	FLOOD MONITOR-ING	DATA BASE MGMT.	COMPLAINT EMERG. RESPONSE	POLLUTION MONITOR-ING	DO NOTHING
XX	XXX	XX	XXX	X	XX	X	XXX	XXX	XXX	XX	XX	XX	X	XX	XXX
XX	XX	XX	XX	X	XXX	XXX	XXX	XX	XXX	XX	XXX	XXX	XXX	XXX	X
	X	XX	XX	X	XX	X	XXX	XX	X	X	X	X	X	X	XXX
XX	XX	XXX	XXX	XX	XXX	XX	XXX	XXX	XX	XXX	XX	XX	XX	XX	X
X	XX	XX	XX	X	XX	X	XX	XXX	XXX	XX	XX	XX	XX	X	X
XX	XXX	XX	XXX	XXX	XX	X	XXX	XXX	XXX	XXX	XXX	XXX	XX	XXX	X
XX	XXX	XXX	XXX	XX	XXX	XX	XXX	XXX	XXX	XXX	XXX	XX	XXX	XXX	X
XX	XXX	XX	XX	XX	XXX	XXX	XXX	XX	XXX	XXX	XXX	XX	XX	XX	XX
	X	XX	XX	XXX	XXX	XX	XXX	X	XX	X	X	X	X	X	XXX
XX	XX	X	XX	X	X	XX	XXX	XX	XXX	XX	XX	XX	XX	XX	X
XX	XX	XX	XX	XX	XXX	XXX	XX	XXX	XXX	XXX	XXX	XXX	XX	XX	X
XX	XX	XX	XX	XX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XX	XX	X
XX	XX	XXX	XXX	XXX	XXX	XX	XXX	XXX	XXX	XXX	XX	X	X	XXX	XX
X	XX	XX	XX	XX	XX	XX	XXX	XXX	XXX	XXX	XXX	XX	XX	XXX	XX
X	X	XX	XX	XX	XXX	XXX	XXX	XX	XXX	XXX	XX	X	XX	XX	X
X	XX	XX	XX	XX	XX	XXX	XXX	XXX	XX	XXX	XXX	XX	XX	XX	X
XX	X	XXX	XXX	X	XX	X	XXX	XX	XX	XXX	XXX	XX	XX	XXX	X
X	XX	XXX	XXX	XX	XX	XX	XX	XXX	XXX	XXX	XX	X	X	XXX	XXX
X	XX	XX 1/2	XX 1./2	XX	XX 1/2	XX	XXX	XXX	XXX	XX 1/2	XX 1/2	XX	XX	XX 1/2	X 1/2

TABLE 4

Flood Control Components Selection Criteria Matrix

SOUTHWEST BASIN MANAGEMENT PLAN
PHASE IIA
NON-STRUCTURAL

EVALUATION CRITERIA	FLDPLN ACQ	FLOOD PROOFING	DESIGN CRITERIA	PLAN REVIEW	FLDPLN PERMITTNG	MAINT. OPERATION	ENFORCE-MENT	EDUCATION	ORDS. POLICIES	ORG/ MGMT	DEV. INSPEC.	FLOOD MONITOR-ING	DATA BASE MGMT.	COMPLAINT/ EMERG. RESPONSE	POLLUTION MONITOR-ING	DO NOTHING
Engineering Feasibility	XXX	XXX	XX	XXX	X	XX	X	XXX	XXX	XXX	XX	XX	XX	X	XX	XXX
Acceptability to Public	XXX	XX	XX	XX	X	XXX	XXX	XXX	XX	XXX	XX	XXX	XXX	XXX	XXX	X
Implementation Cost	X	X	XX	XX	X	XX	X	XXX	XX	X	X	X	X	X	X	XXX
Effectiveness	XXX	XX	XXX	XXX	XX	XXX	XX	XXX	XXX	XX	XXX	XX	XX	XX	XX	X
Transportation	XX	XX	XX	XX	X	XX	X	XX	XXX	XXX	XX	XX	XX	XX	X	X
Short Term vs. Long Term Effects	XXX	XXX	XX	XXX	XXX	XX	X	XXX	XXX	XXX	XXX	XXX	XXX	XX	XXX	X
Benefit Area vs. Impact Area	XXX	XXX	XXX	XXX	XX	XXX	XX	XXX	XXX	XXX	XXX	XXX	XX	XXX	XXX	X
ROW Restrictions/Requirements	XXX	XXX	XX	XX	XX	XXX	XXX	XXX	XX	XXX	XXX	XXX	XX	XX	XX	XX
Maintenance Requirements	X	X	XX	XX	XXX	XXX	XX	XXX	X	XX	X	X	X	X	X	XXX
Multiple Use Potential	XXX	XX	X	XX	X	XX	X	XXX	XX	XXX	XX	XX	XX	XX	XX	X
Impact on Infiltration	XXX	XX	XX	XX	XX	XXX	XXX	XX	XXX	XXX	XXX	XXX	XXX	XX	XX	X
Loss of Flow Attenuation	XXX	XX	XX	XX	XX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XX	XX	X
Env. Considerations	XXX	XX	XXX	XXX	XXX	XXX	XX	XXX	XXX	XXX	XXX	XX	X	X	XXX	XX
Water Quality	XX	XX	XX	XX	XX	XX	XX	XXX	XXX	XXX	XXX	XXX	XX	XX	XXX	XX
Aesthetics	XX	X	XX	XX	XX	XXX	XXX	XXX	XX	XXX	XXX	XX	X	XX	XX	X
Pima Co., State, Fed. Regs. (General)	XX	XX	XX	XX	XX	XX	XXX	XXX	XXX	XX	XXX	XXX	XX	XX	XX	X
Compat. with Existing Land Uses	XXX	X	XXX	XXX	X	XX	X	XXX	XX	XX	XX	XXX	XX	XX	XXX	X
Riparian Habitat Protection	XX	XX	XXX	XXX	XX	XX	XX	XX	XXX	XXX	XXX	XX	X	X	XXX	XXX
OVERALL EVALUATION	XX 1/2	XX	XX 1/2	XX 1./2	XX	XX 1/2	XX	XXX	XXX	XXX	XX 1/2	XX 1/2	XX	XX	XX 1/2	X 1/2

RNG: XXX - Very Advantageous
XX - Somewhat Advantageous
X - Disadvantageous

TABLE 5

Flood Control Components Selection Criteria Matrix

SOUTHWEST BASIN MANAGEMENT PLAN
PHASE IIA
STRUCTURAL

	EVALUATION CRITERIA	STRUC RELOC	IMPR CHANNELS	DIP CROSSINGS	CULVERTS/ STORM DRAINS	DET/RET FACILITY REGIONAL	SEDMNT BASINS	ENRGY DSP GRADE CONTROL	EROSION PROTCT	LEVEES DIKES FLDWLLS	RDWAY IMPR	STREET CONVEY
1	Engineering Feasibility	XX	XX	XXX	XXX	XX	XX	XXX	XXX	XXX	XXX	X
2	Acceptability to Public	XX	XXX	XX	XXX	XX	XX	XXX	XX	XX	XXX	XX
3	Construction Cost (Design)	X	X	XXX	XXX	XX	XX	XXX	X	XX	X	XX
4	Effectiveness	X	XXX	XX	XXX	XXX	XXX	XXX	XXX	XXX	XX	XX
5	Transportation	XXX	XXX	XX	XXX	XX	XXX	XXX	XXX	XXX	XXX	X
6	Short Term vs. Long Term Effects	X	XXX	XXX	XX	XXX	XXX	XXX	XXX	XXX	XXX	XXX
7	Phased Construction Potential	XXX	XX	XXX	XXX	X	X	XXX	XX	XXX	XX	XX
8	Benefit Area vs. Impact Area	X	XXX	XXX	XX	XXX	XXX	XXX	XX	XX	XXX	XX
9	ROW Restrictions/Requirements	X	X	XXX	XX	X	X	XX	X	X	X	XXX
10	Utility Conflicts	XX	X	XX	X	XXX	XXX	XX	XX	XX	X	XX
11	Maintenance Requirements	XX	X	XXX	X	XX	X	X	XX	XX	XXX	XXX
12	Multiple Use Potential	X	XXX	XX	XXX	XXX	XX	X	X	X	XXX	X
13	Impact on Infiltration	XX	XX	XX	XX	XXX	XXX	XX	X	XX	XX	X
14	Loss of Flow Attenuation	XX	X	XX	XXX	XXX	XXX	XX	X	XX	XX	X
15	Env. Considerations	XX	XX	XXX	XX	XXX	XX	XX	XX	X	XX	X
16	Water Quality	XX	X	XX	XX	XX	XX	XX	XX	XX	XX	X
17	Aesthetics	XX	XX	XX	XX	XXX	X	X	X	X	XXX	XX
18	Pima Co., State, Fed. Regs. (General)	X	XXX	XXX	XXX	XX	XX	XX	XX	XX	XXX	XX
19	Compat. with Existing Land Uses	X	XX	XXX	XX	XXX	XXX	XXX	XXX	X	XXX	XX
20	Financing	X	XX	XXX	XX	X	X	XX	XX	X	XXX	XXX
21	Riparian Habitat Protection	X	X	XX	XX	XXX	XXX	XX	XX	XX	X	XXX
	OVERALL EVALUATION	X 1/2	XX	XX 1/2	XX 1/2	XX 1/2	XX	XX 1/2	XX	XX	XX 1/2	XX

RATING: XXX - Very Advantageous
XX - Somewhat Advantageous
X - Disadvantageous

Non-structural Components

Implementation of non-structural measures can reduce or offset the need for some structural improvements. The components that received very advantageous rankings were Education, Ordinances/Policies, and Organization/Management. Components that received a ranking of more than somewhat advantageous were Floodplain Acquisition, Design Criteria, Plan Review, Maintenance Operation, Development Inspection, Flood Monitoring and Pollution Monitoring. These ten components ranked high because: 1) they are directly or indirectly supportive to each other, i.e. highly compatible, and 2) they ensure that existing policies and regulations established by Pima County to mitigate flooding/ drainage concerns are recognized, initiated, and maintained.

Flood Proofing, Floodplain Permitting, Enforcement, Data Base Management and Complaint/Emergency response ranked somewhat advantageous. These components also are effective in ensuring that established regulations are enlisted and maintained, yet their impact on the study area may involve rigorous manhours. In particular, Flood Proofing and Floodplain Permitting are components that primarily reduce or eliminate flood damage at specific locales; however, the implementation costs are estimated to be higher than previously discussed components. Floodproofing existing structures within the 100-year floodplain is usually the owners decision and responsibility. The majority of homes in the floodplain within Section 34 is approximately 70%, and the cost then is multiplied accordingly. Other higher ranked components have less direct cost associated with them, while continuing to benefit the study area as a whole.

The only non-structural alternative ranked disadvantageous is the Do Nothing component, which provides no benefit to the study area, and may possibly be detrimental to the overall watershed.

Structural Components

Structural components offer a variety of physical approaches at the level of effectiveness in flooding/erosion protection. No structural components ranked

very advantageous due to the inherent characteristics (rural) of the study area. Components were ranked with careful consideration to their probability in providing improved flow conveyance with no ill effect to existing neighborhood homes and downstream structures. Generally, structural components are a more aggressive means to mitigate drainage problems.

Components receiving more than somewhat advantageous scores were Dip Crossings, Culverts/Storm Drains, Detention/Retention Facilities, Energy Dissipator and Grade Control, and Roadway Improvements. These components are compatible with existing land use and environmental concerns and create little conflict when complemented with other components. Due to the existing and proposed development of low to moderate residential density (1.2 to 3.0 RAC), Dip Crossings and Culverts/Storm Drains are considered positive, acceptable alternatives to any proposed drainage design.

Components receiving a somewhat advantageous ranking were Improved Channels, Sediment Basins, Erosion Protection, Levees, Dikes and Floodwalls, and Street Conveyance. These components are effective in a limited fashion within Section 34, as they are not conducive to low density residential areas. The existing roadways within the study area are not designed to efficiently carry runoff. Roadway Improvements, including regrading and inverted crown road sections, are necessary in order to utilize particular roadways as flow conveyors. It is our interpretation that curbed streets are not desirable for the rural setting of the existing subdivisions in Section 34. Improved Channels, Erosion Protection, and Levees/Dikes/Floodwalls have the potential to increase velocity, and if floodplain encroachment is necessary, a high construction cost is associated with bank protection. Improved Channel Construction is not feasible for the majority of the waterways in Section 34 and Tucson Estates because of space limitations. Also, concentrating sheet flow into Improved Channels has the potential to cause downstream drainage problems if not properly discharged. Levees/Dikes/Floodwalls would primarily be associated with identified breakout areas, along Bopp Road for example, and adjacent to potential culvert/dip crossings to contain and control runoff.

Summary

A summary of the recommended components which will constitute the proposed alternatives, is provided below:

Non-Structural Components

Very Advantageous

1. Education
2. Organization/Management
3. Ordinance/Policies

More Than Somewhat Advantageous

1. Maintenance Operation
2. Development Inspection
3. Floodplain Acquisition
4. Plan Review
5. Flood Monitoring
6. Design Criteria
7. Pollution Monitoring

Somewhat Advantageous

1. Enforcement
2. Floodproofing
3. Data Base Management
4. Floodplain Permitting
5. Complaint/Emergency Response

Structural Components

More Than Somewhat Advantageous

1. Dip Crossings
2. Detention/Retention Facilities
3. Culverts/Storm Drains
4. Roadway Improvements
5. Energy Dissipator/Grade Control

Somewhat Advantageous

1. Sediment Basins
2. Improved Channels
3. Levees/Dikes/Floodwalls
4. Erosion Protection
5. Street Conveyance

SECTION 7 - SELECT A PREFERRED ALTERNATIVE

Sections 5 and 6 were consolidated to create a master list of the alternatives based on completeness of purpose, effectiveness in achieving desired goals, economic efficiency and acceptability with social, economic, environmental, legal and political considerations. A systematic, logical approach provided the justification for the final listing of five alternatives, which include non-structural, structural, and multiple combinations of the two. A matrix table was used to evaluate the five "concept" alternatives.

The application of a non-structural or regulatory approach is two-fold: 1) for existing and future development - Education, Ordinance and Policies, and Organization/Management (ranked very advantageous), and 2) leave existing conditions/problems as is, and set the focus on the future. The structural approach includes one or more components from the following groups to solve existing and future flooding problems: Dip Crossings, Culverts/Storm Drains, Detention/Retention Facilities, Energy Dissipators and Grade Control Structures, and Roadway Improvements (ranked more than somewhat advantageous), and Improved Channels, Sediment Basins. Erosion Protection, Levees/Dikes/ Floodwalls, and Street Conveyance (ranked somewhat advantageous). The combination of non-structural and structural approaches consist of two strategies: 1) build around existing flooding problems and concentrate on preventing/minimizing future problems, and 2) mitigate existing flooding problems and plan/design for the future.

Non-Structural or Regulatory Alternatives

Specific floodplain management methods which are designed to control the approach to drainage design in future development comprise Alternative 1:

Alternative 1

A. Education is the responsibility of the community, and can be provided easily to the local residents within the study area.

Workshops, public meetings, mailings, public demonstrations and displays are just a few actions that will invite the residents to participate in minimizing/preventing flooding problems in their neighborhoods.

B. Organization/Management and Ordinance/Policies gives the opportunity for accountability and leadership from the governing agency, and direct interaction with the concerned residents.

C. Development Inspection, Maintenance Operation and Flood and Pollution Monitoring are a public safety priority, and will ensure proper operation of future flood prevention procedures, as well as monitoring the existing and design flood management structures.

D. Plan Review and Design Criteria are related to Ordinance/Policies and will provide consistency in the methods and design of drainage systems for future development.

E. Ordinance/Policies gives the opportunity for accountability and leadership from the governing agency, and direct interaction with the concerned residents.

F. Maintenance Operation is a public safety priority, and will ensure proper operation of future flood prevention procedures, as well as monitoring the existing and design flood management structures.

Structural Alternatives

Proposed individual improvement projects designed to mitigate existing and future flood hazards in specific locations within the study area comprise Alternative 2a:

Alternative 2a

A. Dip Crossings are beneficial in low density residential communities and distributary flow areas.

B. Culverts/Storm Drains are less applicable for the existing low density rural development. However, these structures are useful at highly traveled roadway crossings of washes, along Bopp Road, Camino Verde Road and Tucson Estates Parkway. In areas of future development, Culverts/Storm Drains offer the opportunity to avoid flooding problems associated with transportation. Additional right-of-way may be required.

C. Roadway Improvements within the study area are feasible in conveying runoff to specific improved drainage crossings. All private and public roadway improvements should be designed so as to be either parallel or perpendicular to the natural flow pattern. This will allow for flow retention and to concentrate flow, i.e., road alignment will function as a diversion levee or dike.

D. Energy Dissipator/Grade Control Structures are site specific and are associated with roadway improvements and Culverts/Storm Drains.

E. Levees/Dikes and Floodwalls will be used in conjunction with drainage improvements discussed in this section. The primary advantage to Dikes and Floodwalls is flow diversion and management at particular sites.

Alternative 2b

This alternative consists of the five components listed previously in Alternative 2a, with the addition of the following component:

A. Regional Detention/Retention Facilities will be designed as a continuation of a natural channel and will be constructed on-line. Two specific drainage areas north of Tucson Estates, upstream of Lone Star Drive, have been selected as possible basin locations. One detention basin, approximately 65 acre-feet within the I33 watershed, will mitigate flooding potential within Section 34 of the study area. The second detention basin, approximately 44 acre-feet within I36 watershed, will reduce flooding potential for a portion of Section 26, specifically the east side of Tucson Estates. Refer to watershed map, Figure 3. Creating these additional detention basins will decrease discharges at roadway crossings downstream, reduce the delineated 100-year floodplain widths, and remove existing structures from the floodplain.

Non-Structural and Structural Alternatives

The combinations of non-structural and structural components are designed to ensure flood mitigation as a result of focusing on future development and/or solving existing flood problems and plan for the future.

Alternative 3a

A. Education is the responsibility of the community, and can be provided easily to the local residents within the study area. Workshops, public meetings, mailings, public demonstrations and displays are just a few actions that will invite the residents to participate in minimizing/preventing flooding problems in their neighborhoods.

B. Organization/Management and Ordinance/Policies gives the opportunity for accountability and leadership from the governing agency, and direct interaction with the concerned residents.

C. Development Inspection, Maintenance Operation and Flood and Pollution Monitoring are a public safety priority, and will ensure proper operation of future flood prevention procedures, as well as monitoring the existing and design flood management structures.

D. Plan Review and Design Criteria are related to Ordinance/Policies and will provide consistency in the methods and design of drainage systems for future development.

E. Ordinance/Policies gives the opportunity for accountability and leadership from the governing agency, and direct interaction with the concerned residents.

F. Maintenance Operation is a public safety priority, and will ensure proper operation of future flood prevention procedures, as well as monitoring the existing and design flood management structures.

G. Dip Crossings are beneficial in low density residential communities and distributary flow areas.

H. Culverts/Storm Drains are less applicable for the existing low density rural development. However, these structures are useful at highly traveled roadway crossings of washes, along Bopp Road, Camino Verde Road and Tucson Estates Parkway. In areas of future development, Culverts/Storm Drains offer the opportunity to avoid flooding problems associated with transportation. Additional right-of-way may be required.

I. Roadway Improvements within the study area are feasible in conveying runoff to specific improved drainage crossings. All private and public roadway improvements should be designed so as to be either parallel or perpendicular to natural flow pattern. This will allow for flow retention and to concentrate flow, i.e., road alignment will function as a diversion levee or dike.

J. Energy Dissipator/Grade Control Structures are site specific and are associated with roadway improvements and Culverts/Storm Drains.

K. Levees/Dikes and Floodwalls will be used in conjunction with drainage improvements discussed in this section. The primary advantage to Dikes and Floodwalls is flow diversion and management at particular sites.

Alternative 3b

This alternative consists of the nine components listed previously in Alternative 3a, with the addition of the following component.

A. Regional Detention/Retention Facilities will be designed as a continuation of a natural channel and will be constructed on-line. Two specific drainage areas north of Tucson Estates, upstream of Lone Star Drive, have been selected as possible basin locations. One detention basin, approximately 65 acre-feet within the I33 watershed, will mitigate flooding potential within Section 34 of the study area. The second detention basin, approximately 44 acre-feet within I36 watershed, will reduce flooding potential for a portion of Section 26, specifically the east side of Tucson Estates. Refer to watershed map, Figure 3. Creating these additional detention basins will decrease discharges at roadway crossings downstream, reduce the delineated 100-year floodplain widths, and remove existing structures from the floodplain.

Results

The matrix rating, Figure 5, indicates that Concept Alternative 3b provides for a satisfactory, viable approach to flood mitigation in Section 34. This preferred alternative contains non-structural and structural components intended to work together in offering positive, timely solutions to flooding

problems. Table 6 provides estimated costs of the preferred Alternative 3B improvements. The structural components are practical, compatible and cost effective, as well as conducive to the rural setting of the existing neighborhoods. The non-structural components support the existing subdivisions and favor future subdivision developments that will coexist with the country-style living environment.

Figure 5

THE SOUTHWEST BASIN MANAGEMENT STUDY

PART IIA

Matrix Rating of Alternatives

	Alternative #1	Alternative #2a	Alternative #2b	Alternative #3a	Alternative #3b
Provide for Flood Control Effectiveness	1	3	3	2	2
Protect Public Safety	2	3	3	3	3
Minimize Construction Cost	3	1	2	1	2
Preserve/Enhance Natural Channels	3	1	3	2	3
Provide for Public Acceptability	2	1	3	1	3
Minimize Environmental Impacts	2	1	2	2	3
Minimize Hydrologic/Sediment Impacts	3	1	2	2	3
Compatibility with Drainage	2	2	3	2	3
Compatibility with Development	3	2	3	3	3
Opportunity for Multiple Use	1	3	2	3	2
Provide for Phased Construction Potential	1	2	3	2	3
Provide for Flood Insurance Mitigation	1	3	2	2	2
Minimize Future Maintenance	1	2	2	3	3
Compatibiltiy with Roads	3	2	2	2	2
Enhance Visual Quality	2	1	2	1	2
Availability of Funding Options	3	1	2	2	3
Minimize Disruption to Public	3	1	2	2	3
Minimize Displacement of Structures	3	3	3	3	3
Protect Areas of Cultural/Historic Significance	2	2	2	2	2

Ranking Range: 1 - Low ⟶ 3 - High

Explanation - Alternative #1: Non-structural or regulatory approach to flood mitigation. RANKING = 2.2

Alternative #2a: Structural approach to flood mitigation. RANKING = 1.8

Alternative #2b: Structural approach to flood mitigation with regional detention/retention facilities. RANKING = 2.4

Alternative #3a: Combination of non-structural and structural approach to flood mitigation. RANKING = 2.1

Alternative #3b: Combination of non-structural and structural approach to flood mitigation with regional detention/retention facilities. RANKING = 2.6

0893/JLL00131.0225/106579-01-0280

Aggressive flood control measures were initially investigated and scrutinized, and then rejected due to construction cost, general project irrelevance, and severe consequence to downstream properties. These measures were seen as inappropriate additions to the current lifestyle and rural setting of the residents. Specifically, the following components were evaluated and discarded:

1. CAP Detention Basin Expansion - The proposed future expansion of the existing detention basin at the CAP Water Treatment Plant would not necessarily benefit the study area. The existing watershed draining into the CAP plant ultimately drains to the southern portion of Section 34 and joins with the runoff traversing the majority of Section 34. Therefore, the region most affected by the future basin expansion would be to the east of Tucson Estates Parkway (not a part of this study as this region does not contribute to the drainage which impacts Section 34), and a small portion of Section 34, at the southeast corner, near the detention basin outlet, along Oklahoma Street (reference "Conceptual Plan for Flood Protection for Tucson Water Treatment Facility," Johnson Brittain & Associates, Inc.). Diversion of flow from the watersheds impacting the majority of Section 34 into the CAP basin via a collector channel (discussed below) was also examined. However, the CAP basin expansion would not be adequate to attenuate this additional flow. The possibility of additional storage provided by retention was not considered.

2. Improved Channels within Section 34 - Specific channels in the study area have potential to convey larger peak flows, with future physical improvements. However, the resulting increase in capacity is not suitable to downstream outlet sites. The increased discharges have no acceptable definite destination and could pose as major flood hazards within and beyond the basin under investigation.

3. Major Collector Channels - Four earthen collector channels were suggested at particular locales within the study area. These channels were conceptually designed to collect sheet flow and carry peak discharges; a) in Section 27, north of Albert Road, flowing to the east and then, b) south, along Tucson Estates Parkway to the existing CAP detention basin, c) in Section 34 at Illinois Street and Camino Verde, flowing southwest, exiting Section 34 at Deaver Road, ultimately merging with d) the outflow of the CAP detention basin, south of Oklahoma Street, along the Old Ajo Highway. A general estimated cost for one excavated earthen channel at a length of 5,000 feet, with a top width of 200 feet, is approximately $990,000.00. Given the high cost, lack of downstream outlets and ineffectiveness of the CAP expansion, collector channels were discarded as viable alternatives to alleviate flooding in Section 34.

4. Detention Basins North of Bopp Road - Preliminary calculations were performed to determine feasibility of creating detention basins north of Bopp Road. As a whole, detention in Section 27 would require a minimum of 31 acre-feet. From an engineering standpoint, the resulting decrease of flow is minimal, and the acquisition of land is not economically feasible. Therefore, design/construction of detention basins immediately upstream of Bopp Road would not be cost effective nor substantially helpful to the flooding situation in Section 34.

In addition, a stormwater detention basin was considered within Section 34, west of Donald Avenue and approximately 950 feet south of Bopp Road. This location is consistent with a recommended site included in the "Transportation and Flood Control Facility Implementation Plan for the Southwest Area Plan," prepared by Pima County Department of Transportation and Flood Control District, April, 1980. The 1.95-acre parcel proved to be inadequate in significantly reducing peak discharges for the 100-year and 10-year storm events. However, the site would be

advantageous in providing sediment deposition and partial flow attenuation for low flow events.

SECTION 8 - PREPARE CONCEPT PLANS FOR THE PREFERRED ALTERNATIVE

A Preliminary concept plan, consisting of identification and locations for recommended structural improvements is included as Figure 6. The specific type, size and estimated construction cost of the proposed improvements are in Table 6. Concept plans and construction cost estimates do not include utility relocations. In addition, typical concept cross-sections of improved roadways, proposed culverts, detention basins and berms, and drainage schematics are included in Appendix G.

The preferred alternative will consist of the following components:

1. One 36-inch RCP located at Huxley Drive to convey estimated 10-year peak discharge of 54 cfs, with optional dip section for 100-year peak discharge of 107 cfs. These improvements will provide all-weather access on Huxley Drive.

2. Earthen berms with riprap (channel side only) along both sides of natural drainageway, beginning at Huxley Drive, extending to Donald Avenue. The berms will ensure that the flow during a 100-year event (107 cfs) is contained within the channel.

3. One 36-inch RCP located at Donald Avenue to continue conveyance of estimated 10-year peak discharge of 54 cfs, with optional dip section for 100-year peak discharge of 107 cfs. These improvements will provide all-weather access at the juncture of Donald Avenue and Huxley Place. The capacity of the existing downstream channel is estimated to be approximately 200 cfs.

4. One 42-inch RCP located at Michigan Street, east of Donald Avenue, to convey estimated 10-year peak flow of 62 cfs, which will provide low flow access on Michigan Street between Fred Avenue and Tucson Estates Parkway. Due to the width of the 100-year floodplain at Michigan Street

(approximately 780 feet), a dip section is not practical or beneficial and therefore not proposed.

5. One 42-inch RCP located at Michigan Street, west of Tucson Estates Parkway (east of the above-mentioned 42-inch RCP), also conveying an estimated 10-year flow of 62 cfs. These improvements will provide access along Michigan Street during a low flow event. Due to the width of the 100-year floodplain at Michigan Street (approximately 780 feet), a dip section is not practical or beneficial and therefore not proposed.

6. Inverted crown roadway 600 feet along Mimbres Drive and 400 feet along Dana Drive, west of Mimbres Drive. Construction of the improved roadways will provide street conveyance during a low flow event.

7. Regrade cul-de-sac at west end of Dana Drive to achieve positive grade for drainage.

8. 500 feet of road improvement along Camino Verde, north of Michigan Street to facilitate drainage conveyance and direct flow across Camino Verde.

9. Provide all-weather access at Illinois Street approximately 300 feet east of Camino Verde with dip section and three 60-inch RCPs.

10. Provide all-weather access at Donald Road approximately 600 feet north of Bopp Road. Due to the width of the 100-year floodplain at Bopp Road (approximately 1,400 feet) and the downstream constraints explained in No. 6 above, a road crossing is not practical or beneficial and therefore not proposed.

11. Provide all-weather access (3-cell 6' x 10' CBC and dip section) at Tucson Estates Parkway at outlet to CAP treatment plant drainage channel. In the interim, as an immediate yet short-term solution, the existing earthen berm grade break in Oklahoma Street should be paved to

(approximately 780 feet), a dip section is not practical or beneficial and therefore not proposed.

5. One 42-inch RCP located at Michigan Street, west of Tucson Estates Parkway (east of the above-mentioned 42-inch RCP), also conveying an estimated 10-year flow of 62 cfs. These improvements will provide access along Michigan Street during a low flow event. Due to the width of the 100-year floodplain at Michigan Street (approximately 780 feet), a dip section is not practical or beneficial and therefore not proposed.

6. Inverted crown roadway 600 feet along Mimbres Drive and 400 feet along Dana Drive, west of Mimbres Drive. Construction of the improved roadways will provide street conveyance during a low flow event.

7. Regrade cul-de-sac at west end of Dana Drive to achieve positive grade for drainage.

8. 500 feet of road improvement along Camino Verde, north of Michigan Street to facilitate drainage conveyance and direct flow across Camino Verde.

9. Provide all-weather access at Illinois Street approximately 300 feet east of Camino Verde with dip section and three 60-inch RCPs.

10. Provide all-weather access at Donald Road approximately 600 feet north of Bopp Road. Due to the width of the 100-year floodplain at Bopp Road (approximately 1,400 feet) and the downstream constraints explained in No. 6 above, a road crossing is not practical or beneficial and therefore not proposed.

11. Provide all-weather access (3-cell 6' x 10' CBC and dip section) at Tucson Estates Parkway at outlet to CAP treatment plant drainage channel. In the interim, as an immediate yet short-term solution, the existing earthen berm grade break in Oklahoma Street should be paved to

prevent frequent erosion and to eliminate breakout flows down Oklahoma Street.

12. Excavate existing open space northwest of Donald Avenue and Dana Drive to provide sediment deposition and partial flow attenuation for low flow events. This 1.95-acre parcel is privately owned, and would need to be acquired by Pima County. Cost estimate in Table 6 does not include annual maintenance cost for sediment removal.

13. Bank protection on a portion of west side of improved channel between Donald Avenue and Emjay Avenue, approximately 400 feet south of Bopp Road, and improved channel west of Kay Drive, north of Mat Drive. Bank protection to protect existing structures within EHS.

14. Earthen drainage channels to be constructed by others as development progresses south of Kay Lynn Drive.

15. Two detention basins (approximately 65 acre-feet and 44 acre-feet each) to be constructed in Tucson Mountain Park. Basins at conceptual design uses outlets to match capacities of existing channels in Tucson Estates and subsequently reduces flows in Section 34. Each basin will mitigate the flooding potential for their respective downstream channels within Tucson Estates Subdivision.

TABLE 6

PROPOSED STRUCTURAL IMPROVEMENTS, AS SHOWN ON FIGURE 6, CONCEPT PLAN
SPECIFIC SIZE AND ESTIMATED COST

10- and 100-year peak discharges are estimated based on proposed construction of two detention basins north of Tucson Estates Mobile Home Park, in Tucson Mountain Park.

	DESCRIPTION	PEAK DISCHARGE	ESTIMATED COST
1.	1-36" RCP with dip section	Q10 = 54 cfs Q100 = 107 cfs	$ 2,880.00 1,500.00
2.	Earthern berms 700 feet each side of natural channel, with riprap protection	Q100 = 107 cfs	42,000.00
3.	1-36" RCP with dip section	Q10 = 54 cfs Q100 = 107 cfs	2,880.00 1,500.00
4.	1-42" RCP	Q10 = 62 cfs	3,360.00
5.	1-42" RCP	Q10 = 62 cfs	3,360.00
6.	Inverted crown roadways South 600 feet West 400 feet		 18,000.00 12,000.00
7.	Re-grade cul-de-sac		4,500.00
8.	Road Improvement 500 feet		15,000.00
9.	3-60" RCP with dip section	Q10 = 512 cfs **Q100 = 1024 cfs	14,400.00 14,490.00
10.	Road improvement 600 feet		18,000.00
11.	3 cell 6'X10' box culvert with dip section	Q10 = 1513 cfs Q100 = 3913 cfs	45,800.00 24,000.00
12.	Sediment basin (Purchase parcel for sediment basin)	**Q100 = 570 cfs Q10 = 285 cfs	41,000.00 29,000.00
13.	Riprap Bank Erosion Protection ≈ 1850 feet 2-3 Feet Deep with Toedown		38,250.00
14.	Earthen Drainage Channels ≈ 7350 feet 2-Feet Deep or 3-Feet Deep		 5,500.00 7,300.00*

Figure 6 Preliminary Concept Plan

Cooper Aerial Survey Co.
TUCSON, ARIZONA

1″ = 400′

90 TUCSON

MARCH 19

4-13

KEY:
- BANK PROTECTION
- BERM
- R.C.P.
- BOX CULVERT
- ROAD IMPROVEMENTS
- SEDIMENT BASIN
- DETENTION BASIN
- DRAINAGE CHANNEL

FIGURE 6

CONCEPT PLAN

PROPOSED STRUCTURAL IMPROVEMENTS SOUTHWEST BASIN MANAGEMENT STUDY, PHASE II , PART A , IN CONJUNCTION WITH TABLE 6

CBA JOB NO.

Kinney Road

Naomi Road

Tucson Estates Drive

Cooper Aerial Survey Co.
TUCSON, ARIZONA

1″ = 400′

90 TUCSON

MARCH 19

4-14

KEY:

- BERM
- R.C.P.
- BOX CULVERT
- ROAD IMPROVEMENTS
- SEDIMENT BASIN
- DETENTION BASIN
- DRAINAGE CHANNEL

CONCEPT PLAN

PROPOSED STRUCTURAL IMPROVEMENTS SOUTHWEST BASIN MANAGEMENT STUDY, PHASE II , PART A

CBA CELLA BARR ASSOCIATES
4911 EAST BROADWAY
TUCSON, ARIZONA 85711
(602) 750-7474

CBA JOB NO.
106670.01.0000

Kinney Road

Bopp Road

C.A.P.
Treatment Plant

Cooper Aerial Survey Co.
TUCSON, ARIZONA

1″ = 400′

90 TUCSON

MARCH 19

5-13

KEY:

- BERM
- R.C.P.
- BOX CULVERT
- ROAD IMPROVEMENTS
- SEDIMENT BASIN
- DETENTION BASIN
- DRAINAGE CHANNEL

CONCEPT PLAN

PROPOSED STRUCTURAL IMPROVEMENTS SOUTHWEST BASIN MANAGEMENT STUDY, PHASE II , PART A

CBA CELLA BARR ASSOCIATES
4911 EAST BROADWAY
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(602) 750-7474
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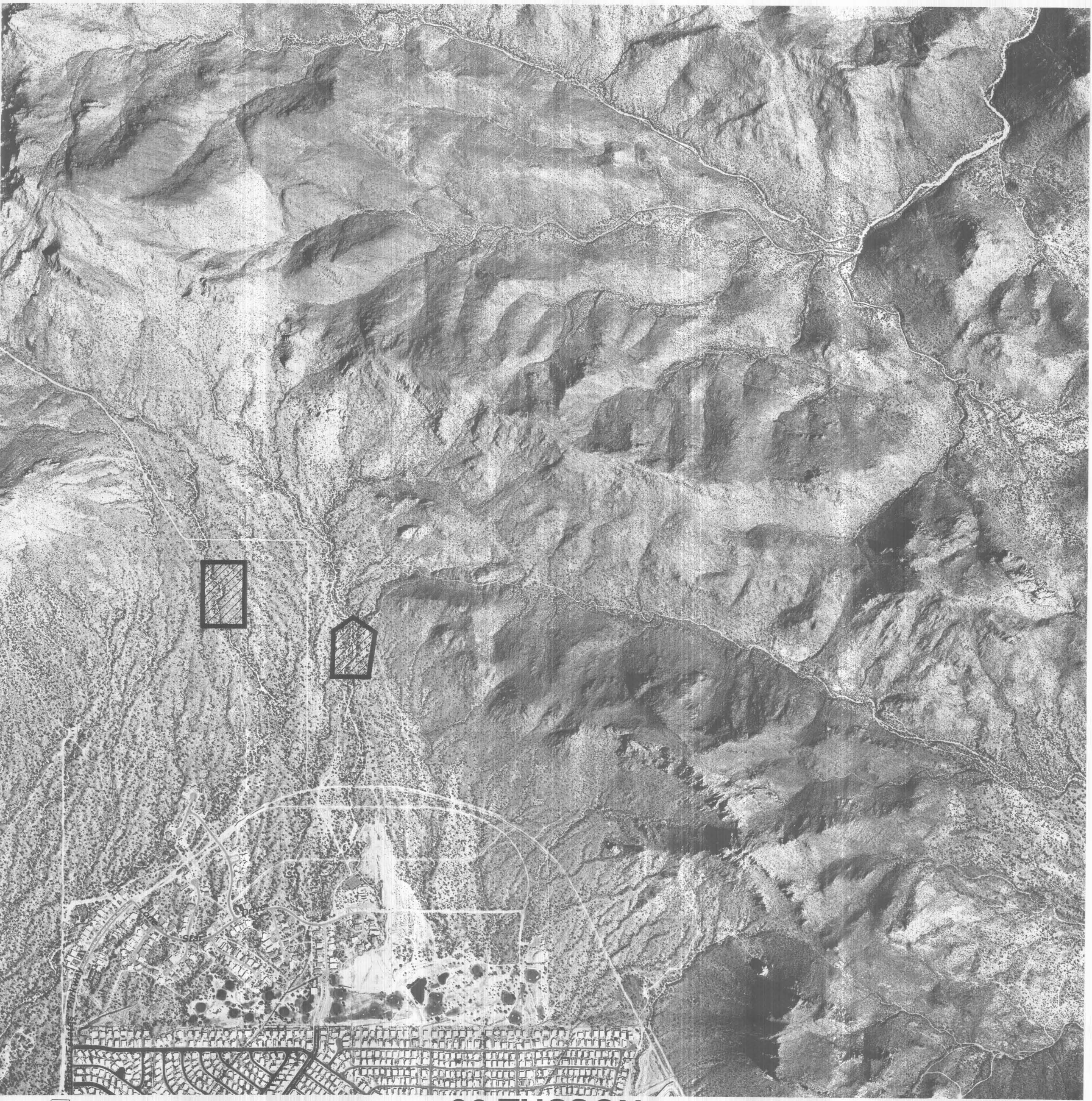
CBA JOB NO.
106579-01-0280



Copper Aerial Survey Co.
TUCSON, ARIZONA

1″ = 400′

90 TUCSON

MARCH 19

5-14

KEY:
- BANK PROTECTION
- BERM
- R.C.P.
- BOX CULVERT
- ROAD IMPROVEMENTS
- SEDIMENT BASIN
- DETENTION BASIN
- DRAINAGE CHANNEL

FIGURE 6

CONCEPT PLAN

PROPOSED STRUCTURAL IMPROVEMENTS SOUTHWEST BASIN MANAGEMENT STUDY, PHASE II , PART A , IN CONJUNCTION WITH TABLE 6

CBA JOB NO. 106570-01-0280

improvements, which act to confine the 100-year sheet flow and further aggravate the existing flooding problems.

4. All future roadways designed along alignments which act to divert, retard or obstruct floodwaters should be constructed parallel or perpendicular to the direction of natural drainage.

5. Pima County should implement a continuous maintenance program for existing roadways; with roadway grades and cross-slopes meeting current Pima County design criteria. Proper maintenance is necessary to ensure that private property is not impacted by road alterations following storm events.

6. Erosion hazard setbacks are to be determined for any well defined natural channels within the study basin, per Pima County standards. The erosion hazard setbacks for washes in Section 34 have been shown on the Floodplain Maps in Appendix B.

7. In the southwest portion of Section 34, low flow channels have been proposed as extensions of existing drainageways in the northwest area (refer to Figure 6 for conceptual locations). Erosion hazard setback requirements will pertain to these future drainage channels, and the building setbacks will be determined utilizing the true capacities of each channel.

8. The study area lies in a critical basin, and has been identified as already having severe flooding problems as a result of existing watershed conditions. All future development must adhere to existing Pima County regulations regarding detention/retention facilities, with emphasis on reducing existing peak discharges.

9. Public involvement can be planned in a variety of forms. The neighborhood open house format is appropriate for the study area. The local residents living in the Southwest Basin Area can be notified via

the mail, and can also be educated by mailings as well. Sharing in a friendly, open environment is a positive way to focus on the preferred alternative and the individual recommended solutions, explaining the construction/implementation procedures, and promoting the welfare of the community as a whole.