



# MEMORANDUM

Date: April 18, 2000

To: The Honorable Chair and Members  
Pima County Board of Supervisors

From: C.H. Huckelberry  
County Administrator *[Signature]*

Re: Pima County's Watersheds and Watercourses

### Overview

The attached report, prepared by Barbara Tellman of the Water Resources Research Center at the University of Arizona and her co-authors, makes a significant contribution to the scientific evaluation for the Sonoran Desert Conservation Plan by building upon the *Biological Stress Assessment* drafted by Recon through the identification of threats and stressors to watercourses within Pima County. Entitled *An Overview of Pima County's Watersheds and Watercourses*, this document provides background on technical and water policy matters, describes potential and existing impacts to watercourses within Pima County, suggests options for reducing stressors, and outlines a number of issues for discussion within each watershed planning unit. A complete glossary of terms, and an appendix of relevant laws and regulations is included. In this memorandum, some of the highlights of the report will be summarized and discussed in light of the two reports by Recon issued on April 17, 2000: *Review of Vulnerable Species* and the *Biological Stress Assessment*.

### Watercourse Types in the Subareas

<u>SUBAREA</u>	<u>SHEET FLOW</u>	<u>DISTRIBUTARY FLOW</u>	<u>NATURAL TRIBUTARY</u>	<u>ENTRENCHED TRIBUTARY</u>	<u>CHANNELIZED WASHES</u>	<u>PERENNIAL/ INTERMITTENT</u>
M.SAN PEDRO			yes			yes
CIENEGA-RINCON		yes	yes	at times	yes	yes
U. SANTA CRUZ		yes	yes	yes	yes	in mountains
M. SANTA CRUZ		at times	yes	yes	yes	effluent
TORTOLITA		yes	yes		yes	effluent
ALTAR VALLEY		yes	yes	yes		yes
AVRA VALLY	yes	yes	yes		yes	effluent
W. PIMA CO.		yes	yes		at times	at times

The report describes the variety of characteristics that define Pima County's watercourses, ranging from perennially flowing streams, to channelized washes, to effluent dominated reaches. The chart above summarizes the types of watercourses within the planning units of the Sonoran Desert Conservation Plan.

**Generalized Effects of Human Activities on Stream Discharge**

The *Biological Stress Assessment* described the effects of land and water use activities on biological resources with a particular focus on the effect of activities on species. The *Watercourse* study applies similar analysis to the effect of activities on watercourse function, noting in the opening chapters that:

- "Some 80% of all wildlife in Arizona depends on watercourses ... for some portion of the life cycle."
- "Because we have already damaged so many of the natural watercourses in Pima County, many native wildlife populations have been reduced or lost."
- "There are still a few locations in eastern Pima County where the water table is high enough to support riparian vegetation, but for the most part the water table is 200 feet or more below the surface – too deep for roots to reach."

The chart below, found on page 40 of the *Watercourse* study, summarizes the generalized impact of eight major activities on stream discharge.

<u>ACTIVITY</u>	<u>EFFECT ON FLOOD PEAK</u>	<u>EFFECT ON PERENNIAL FLOW</u>	<u>EFFECT ON SEDIMENT LOAD</u>	<u>OTHER EFFECTS</u>
LAND CLEARING / CONSTRUCTION	increase	decrease	increase	Decreased vegetation
IMPERVIOUS SURFACES	increase	increase	either, depends	More water in channels with greater velocity; more sediment discharge downstream
STORM DRAINS	increase	decrease	either, depends	Decreased recharge to local groundwater; increased rate to conveyance system
MINING SAND OR GRAVEL	minimal	minimal	short or long term decrease	Lowering of stream bed; decreased extent of flooding; increased bank erosion; decreased local recharge.
VEGETATION PLANTED ON THE FLOODPLAIN	decrease	no change	decrease	Increased habitat and aesthetic values; can increase local depth of flooding
GROUNDWATER PUMPING	decrease	decrease	increase	Loss of riparian habitat; increase erosion and sediment load
INSTREAM RECHARGE	minimal increase	increase	minimal increase	May move local recharge downstream at low flow periods.
GRAZING	increase	decrease	increase	These effects do not occur with good grazing management.

**Particular Effects of Activities on Riparian Function in Each Watershed Planning Unit**

Pages 73 through 158 of the *Watercourse* study contain an analysis of each of the watershed subarea planning units within Pima County, covering the topics of watershed and watercourse characteristics, human impacts on the watercourses such as flood management and transportation, water and wastewater-related uses, waters supply, existing public land uses, existing private land uses, projected land uses, and issues for discussion. Each watershed analysis is summarized below in four parts:

- A table describing potential and existing impacts on the watercourses within the subarea;
- A table describing potential options for reducing stress on watercourses within the subarea;
- A list of issues suggested for discussion as part of the Sonoran Desert Conservation Plan; and
- A summary of the species of concern by watershed, as identified in the Recon reports.

**Middle San Pedro Subarea (Subarea 1):**

The Middle San Pedro subarea is discussed in pages 73 through 81 of the text. The summaries of the (1) potential and existing impacts on the watercourses within the subarea, and (2) potential options for reducing stress on watercourses within the subarea, are reproduced below.

**Potential and existing impacts on the watercourses in the Middle San Pedro**

REGION WITHIN THE SUBAREA	GRAZING	WILDCAT SUBDIVISION	PLANNED SUBDIVISION	COPPER MINE	SAND & GRAVEL MINE	PUMPING	AGRI CULT URE	REC
RIVER AREA	yes	potential	potential			yes	yes	yes
MOUNTAINS AND FOOTHILLS	yes			potential				yes

**Potential options for reducing stress on watercourses within the Middle San Pedro subarea**

REGION WITHIN THE SUBAREA	LESS PUMPING (ALT WATER)	NON STRUC FLOODPLAIN MANAGE	LAND USE MANAGE MENT	FEDERAL LAND, PROTECTION	STATE TRUST LAND PROTECTED	OTHER PRESERVE INCREASE	BETTER GRAZING
RIVER AREA			potential				potential
MOUNTAINS/ FOOTHILLS				potential			potential

Issues suggested for discussion as part of the Sonoran Desert Conservation Plan

- Are additional preserved areas needed? County owned? State land?
- Should ranches be purchased or conserved instead of sold for development?
- If developed, what provisions should be made to protect groundwater?
- Should the major north-south road in the area be improved?
- What should be done to protect watercourses from potential mining?
- Should efforts be made to revegetate the river or improve the habitat?

Summary of the species of concern within the watershed, as identified in the Recon reports

Suggested for potential coverage under the multi-species conservation plan:

- Gila topminnow
- Pygmy-owl
- Yellow billed cuckoo
- Gila chub
- Western red bat
- Lowland leopard frog
- Needle-spined pineapple cactus

Species of concern:

- Mexican spotted owl
- Weeping muhly
- Desert sucker
- Sonora sucker
- Speckled dace
- Apache northern goshawk
- Southwestern willow flycatcher

Cienega-Rincon Subarea (Subarea 2):

The Cienega-Rincon subarea is discussed in pages 81 through 90 of the text. The summaries of the (1) potential and existing impacts on the watercourses within the subarea, and (2) potential options for reducing stress on watercourses within the subarea, are reproduced below.

Potential and existing impacts on the watercourses in the Cienega-Rincon subarea

REGION WITHIN THE SUBAREA	GRAZING	WILDCAT SUBDIVISION	PLANNED SUBDIVISION	COPPER MINE	SAND & GRAVEL MINE	PUMPING	AGRI CULT URE	REC
CIENEGA CREEK	yes	yes	yes	potential	yes	yes		yes
RINCON VALLEY	yes	yes	yes		yes	yes		yes

Potential options for reducing stress on watercourses within the Cienega-Rincon subarea

REGION WITHIN THE SUBAREA	LESS PUMPING (ALT WATER)	NON STRUC FLOODPLAIN MANAGE	LAND USE MANAGE MENT	FEDERAL LAND, PROTECTION	STATE TRUST LAND PROTECTED	OTHER PRESERVE INCREASE	BETTER GRAZING
CIENEGA CREEK	potential	potential	potential	potential		potential	potential
RINCON VALLEY	potential	potential	potential	potential	potential	potential	

Issues suggested for discussion as part of the Sonoran Desert Conservation Plan

- Should efforts be taken to preserve surface water supplies?
- Should alternate sources of water, such as CAP, be provided to landowners?
- Are additional measures needed to prevent damage from downstream flooding?
- What should be done, if anything, to protect watercourses from mining?
- What measures, if any, should be taken to protect limestone caves and springs?
- Should the majority of the watershed become and NCA or have protection?

Summary of the species of concern within the watershed, as identified in the Recon reports

Suggested for potential coverage under the multi-species conservation plan:

- Gila topminnow
- Pygmy-owl
- Yellow billed cuckoo
- Gila chub
- Western red bat
- Lowland leopard frog
- Needle-spined pineapple cactus
- Huachuca water umbel
- Pima pineapple cactus
- Lesser long nosed bat
- Pale Townsend's big-eared bat
- Chiricahua Leopard Frog
- Mexican Garter Snake

Species of concern:

- Saiya
- Apache northern goshawk
- Box Canyon Muhly
- Weeping Muhly
- Mexican spotted owl
- Arizona Shrew

**Upper Santa Cruz Subarea (Subarea 3):**

The Upper Santa Cruz subarea is discussed in pages 91 through 102 of the text. The summaries of the (1) potential and existing impacts on the watercourses within the subarea, and (2) potential options for reducing stress on watercourses within the subarea, are reproduced below.

**Potential and existing impacts on the watercourses in the Upper Santa Cruz subarea**

REGION WITHIN THE SUBAREA	GRAZING	WILDCAT SUBDIVISION	PLANNED SUBDIVISION	COPPER MINE	SAND & GRAVEL MINE	PUMPING	AGRI CULTURE	REC
SANTA CRUZ RIVER VICINITY		yes	yes		yes	yes	yes	yes
PIEDMONTS	yes	yes	yes			yes		yes
MOUNTAINS	yes			yes				yes

**Potential options for reducing stress on watercourses within the Upper Santa Cruz subarea**

REGION WITHIN THE SUBAREA	LESS PUMPING (ALT WATER)	NON STRUC FLOODPLAIN MANAGE	LAND USE MANAGE MENT	FEDERAL LAND, PROTECTION	STATE TRUST LAND PROTECTED	OTHER PRESERVE INCREASE	BETTER GRAZING
SANTA CRUZ RIVER VICINITY	potential	potential	potential			potential	
PIEDMONTS	potential	potential	potential		potential		potential
MOUNTAINS							potential

**Issues suggested for discussion as part of the Sonoran Desert Conservation Plan**

- Should efforts be taken to preserve water supplies?
- Should alternate sources of water, such as CAP, be provided to landowners?
- How should the distributary flow issues be handled as the east terrace is developed?
- Should the trend toward wildcat development be discouraged for planned development?
- Should effluent be used in this area for riparian restoration? Turf? Groves?
- What should be done in response to pressure to improve Sahuarita Road? The road to Madera Canyon?

Summary of the species of concern within the watershed, as identified in the Recon reports

Suggested for potential coverage under the multi-species conservation plan:

- Gila topminnow
- Yellow billed cuckoo
- Western red bat
- Lowland leopard frog
- Needle-spined pineapple cactus
- Pima pineapple cactus
- Lesser long nosed bat
- Pale Townsend's big-eared bat
- Chiricahua Leopard Frog
- Tumamoc globeberry
- San Xavier Talussnail
- Mexican Garter Snake

Species of concern:

- Apache northern goshawk
- Saiya
- Box Canyon Muhly
- Weeping Muhly
- Arizona Shrew
- Mexican spotted owl

Middle Santa Cruz Subarea (Subarea 4):

The Middle Santa Cruz subarea is discussed in pages 103 through 116 of the text. The summaries of the (1) potential and existing impacts on the watercourses within the subarea, and (2) potential options for reducing stress on watercourses within the subarea, are reproduced below.

Potential and existing impacts on the watercourses in the Middle Santa Cruz subarea

REGION WITHIN THE SUBAREA	GRAZING	WILDCAT SUBDIVISION	PLANNED SUBDIVISION	COPPER MINE	SAND & GRAVEL MINE	PUMPING	AGRI CULTURE	REC
MOUNTAINS	yes			potential				yes
FOOTHILLS		yes	yes			yes		yes
RIVERS AND TRIBUTARIES		yes	yes		yes	yes		yes
CENTRAL CORE			yes			yes		

**Pima County's Watersheds and Watercourses**

April 18, 2000

Page 8

Potential options for reducing stress on watercourses within the Middle Santa Cruz subarea

REGION WITHIN THE SUBAREA	LESS PUMPING (ALT WATER)	NON STRUC FLOODPLAIN MANAGE	LAND USE MANAGE MENT	FEDERAL LAND, PROTECTION	STATE TRUST LAND PROTECTED	OTHER PRESERVE INCREASE	BETTER GRAZING
MOUNTAINS				potential			potential
FOOTHILLS	potential	potential	potential	potential	potential	potential	
RIVERS AND TRIBUTARIES	potential	potential	potential			potential	
CENTRAL CORE	potential	potential	potential				

Issues suggested for discussion as part of the Sonoran Desert Conservation Plan

- How should higher priority washes be protected or rehabilitated?
- Are stronger city and county riparian ordinances needed?
- What kind of floodplain management should be utilized without soil cement?
- Are there important floodplain properties that should be acquired?
- Should road accessibility policies be coordinated with watercourse preservation?

Summary of the species of concern within the watershed, as identified in the Recon reports

Suggested for potential coverage under the multi-species conservation plan:

- Gila topminnow
- Pygmy-owl
- Lesser long nosed bat
- Yellow billed cuckoo
- Pima Pineapple cactus
- Gila chub
- Needle-spined pineapple cactus
- Pale Townsend's big-eared bat
- Lowland Leopard Frog
- Mexican Garter Snake
- Tumamoc globeberry

Other species of concern:

- Mexican spotted owl
- Trelease agave
- Sabino canyon damselfly
- Desert pupfish
- Box Canyon Muhly
- Weeping Muhly
- Apache northern goshawk
- Goodding onion



Issues suggested for discussion as part of the Sonoran Desert Conservation Plan

- If the Tortolita Fan is developed, what flood precautions should be taken in light of its distributary flow?
- To what extent should roads with dip crossings be converted to all weather roads with culverts or bridges?
- What roads are needed in the area? Which roads should be expanded?
- Using effluent, what efforts if any should be made to improve the habitat value of the river? Turf use?
- How should the loss of overbank storage are along the CDO be addressed?

Summary of the species of concern within the watershed, as identified in the Recon reports

Suggested for potential coverage under the multi-species conservation plan:

- Gila topminnow
- Pygmy-owl
- Lesser long nosed bat
- Swainson's hawk
- Lowland Leopard Frog
- Tumamoc globeberry

Other species of concern:

- Apache northern goshawk
- Trelease agave
- Goodding onion
- Mexican spotted owl
- Weeping Muhly

Altar Valley Subarea (Subarea 6A):

The Altar Valley subarea is discussed in pages 129 through 140 of the text. The summaries of the (1) potential and existing impacts on the watercourses within the subarea, and (2) potential options for reducing stress on watercourses within the subarea, are reproduced below.

Potential and existing impacts on the watercourses in the Altar Valley subarea

REGION WITHIN THE SUBAREA	GRAZING	WILDCAT SUBDIVISION	PLANNED SUBDIVISION	COPPER MINE	SAND & GRAVEL MINE	PUMPING	AGRI CULT URE	REC
Arivaca, Buenos Aires	yes	yes	yes	yes		yes		yes
Brawley Wash	yes		potential			yes		
Remainder of the Valley	yes	yes	yes			yes	yes	yes

**Pima County's Watersheds and Watercourses**

April 18, 2000

Page 11

Potential options for reducing stress on watercourses within the Altar Valley subarea

REGION WITHIN THE SUBAREA	LESS PUMPING (ALT WATER)	NON STRUC FLOODPLAIN MANAGE	LAND USE MANAGE MENT	FEDERAL LAND, PROTECTION	STATE TRUST LAND PROTECTED	OTHER PRESERVE INCREASE	BETTER GRAZING
Arivaca, Buenos Aires	potential		potential	potential			potential
Brawley Wash	potential			potential	potential		potential
Remainder of the Valley	potential	potential	potential			potential	

Issues suggested for discussion as part of the Sonoran Desert Conservation Plan

- Should measures be taken to limit groundwater pumping affecting Arivaca Creek?
- What is the best use of ranches that are sold by the owners?
- If Ryan Airfield is expanded, how should drainage issues be handled?
- Is recharge a good use for land in Altar Valley?
- Should efforts take place to restore the Brawley Wash?

Summary of the species of concern within the watershed, as identified in the Recon reports

Suggested for potential coverage under the multi-species conservation plan:

- Gila topminnow
- Pygmy-owl
- Pima Pineapple cactus
- Yellow billed cuckoo
- Chiricahua leopard frog
- Western red bat
- Pale Townsend's big-eared bat
- Lowland Leopard Frog
- Mexican garter snake
- Tumamoc globeberry

Other species of concern:

- Masked bobwhite
- Jaguar
- Kearney's Blue Star
- Desert pupfish
- Weeping Muhly

**Pima County's Watersheds and Watercourses**

April 18, 2000

Page 12

**Avra Valley Subarea (Subarea 6B):**

The Avra Valley subarea is discussed in pages 141 through 150 of the text. The summaries of the (1) potential and existing impacts on the watercourses within the subarea, and (2) potential options for reducing stress on watercourses within the subarea, are reproduced below.

**Potential and existing impacts on the watercourses in the Avra Valley subarea**

REGION WITHIN THE SUBAREA	GRAZING	WILDCAT SUBDIVISION	PLANNED SUBDIVISION	COPPER MINE	SAND & GRAVEL MINE	PUMPING	AGRI CULTURE	REC
Tucson Mountain Foothills		yes	yes			yes		yes
Marana West of the River		yes	yes			yes		
Valley Floor		yes	yes		potential	yes	yes	
Silverbell, Aguirre, Waterman Area	yes			yes		yes	yes	

**Potential options for reducing stress on watercourses within the Avra Valley subarea**

REGION WITHIN THE SUBAREA	LESS PUMPING (ALT WATER)	NON STRUC FLOODPLAIN MANAGE	LAND USE MANAGEMENT	FEDERAL LAND, PROTECTION	STATE TRUST LAND PROTECTED	OTHER PRESERVE INCREASE	BETTER GRAZING
Tucson Mountain Foothills	potential	potential	potential	potential	potential		
Marana West of the River	potential	potential	potential			potential	
Valley Floor	potential	potential	potential		potential		
Silverbell, Aguirre, Waterman Area				potential	potential	potential	potential



Issues suggested for discussion as part of the Sonoran Desert Conservation Plan

- Are grazing management changes needed to protect watercourses?
- What measures are needed to minimize impacts of recreation?
- Should the current road between Lukeville and I-10 be widened?
- What should be done, if anything, to protect watercourses from mining?

Summary of the species of concern within the watershed, as identified in the Recon reports

Suggested for potential coverage under the multi-species conservation plan:

- Pygmy-owl
- Lesser long nosed bat
- Organ Pipe shovelnosed snake
- Red-backed whiptail lizard
- Acuna cactus
- Tumamoc globeberry

Other species of concern:

- Sonoran pronghorn
- Desert pupfish
- Trelease Agave
- Sonoyta mud turtle
- Ajo rock daisy
- Quitobaquito tryonia (snail)

Summary of Major Issues for Discussion to Determine Impact to Watercourses

Pages 159 through 168 contain a number of general issues for discussion based on the watercourse analysis. These issues are common to the region or several subareas:

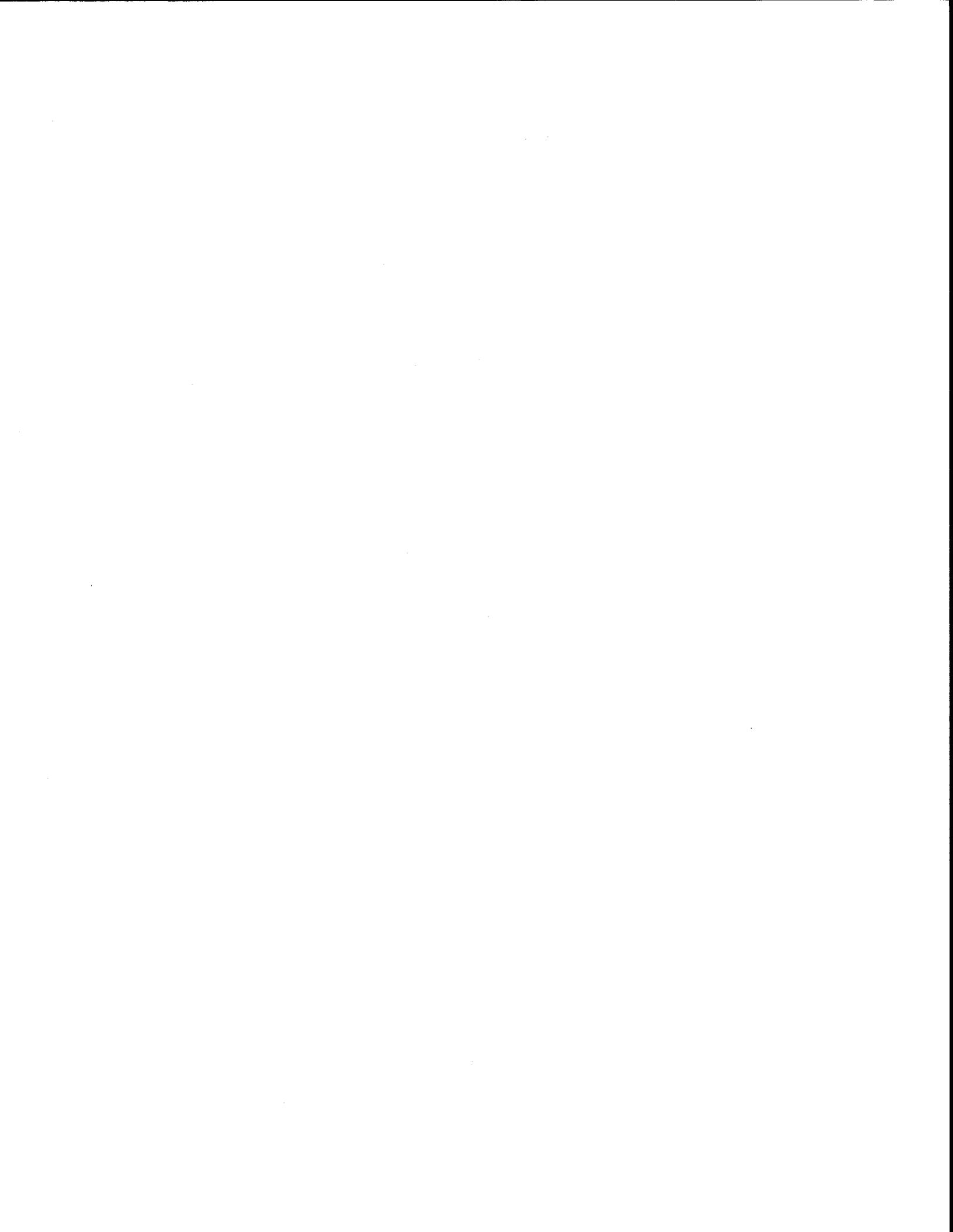
- Bank erosion in flood events
- Flooding in sheet flow areas
- Flooding in distributary flow areas
- Flooding in tributary flow areas
- Street drainage and all weather access
- Planned development versus wildcat development
- Natural recharge or overbank storage
- Role of state trust land
- Loss of riparian vegetation
- Protection of xeroriparian washes with native vegetation
- Dewatering of streams
- Structural versus non-structural flood control
- Groundwater pumping affecting streamflow
- Preservation of natural watercourses
- Rehabilitation of watercourses
- Coordination between jurisdictions
- Use of CAP and effluent

**Summary of Potential and Existing Impacts on the Watercourses in All Watershed Subareas**

SUBAREA	GRAZING	WILDCAT SUBDIVISION	PLANNED SUBDIVISION	COPPER MINE	SAND & GRAVEL MINE	PUMPING	AGRI CULTURE	REC
U San Pedro	yes	potential	potential	potential	potential	yes	yes	yes
Cien- Rincon	yes	yes	yes	potential	yes	yes		yes
U Santa Cruz	yes	yes	yes	yes	yes	yes	yes	yes
M Santa Cruz		yes	yes		yes	yes		yes
Tortolita Fan	yes	yes	yes		yes	yes	yes	yes
Altar Valley	yes	yes	yes			yes	yes	yes
Avra Valley	yes	yes	yes	yes	potential	yes	yes	yes
W Pima Co	yes	yes	potential	yes		yes		yes

**Summary of Potential Options for Reducing Stress on Watercourses in All Watershed Subareas**

SUBAREA	LESS PUMPING (ALT WATER)	NON STRUC FLOODPLAIN MANAGE	LAND USE MANAGE MENT	FEDERAL LAND, PROTECTION	STATE TRUST LAND PROTECTED	OTHER PRESERVE INCREASE	BETTER GRAZING
U San Pedro			potential	potential		potential	potential
Cien- Rincon	potential	potential	potential	potential	potential	potential	potential
U Santa Cruz	potential	potential	potential			potential	potential
M Santa Cruz	potential	potential	potential	potential		potential	potential
Tortolita Fan	potential	potential	potential		potential	potential	potential
Altar Valley	potential	potential	potential	potential		potential	potential
Avra Valley	potential	potential	potential	potential		potential	potential
W Pima Co			potential				potential



# **An Overview of Pima County's Watersheds and Watercourses**

**Pima County  
Sonoran Desert Conservation Plan Report**

**April 2000**

**Barbara Tellman, Water Resources Research Center, University of Arizona  
Clint Glass, CMG Drainage Engineering  
John Wallace, J.E. Fuller, Consultants**

## **Acknowledgements**

The subarea watershed maps were prepared by  
Clint Glass, CMG Drainage Engineering and John Wallace, JE Fuller Co.

The graphics on pages 34, 39, 51, 53-55 are from the  
Water Resources Research Center, University of Arizona's publication  
*Water in the Tucson Area: Seeking Sustainability*

The graphics on pages 3, 5-15, 25, 37, 43-50, 52, 56-62, and the subarea land use maps were prepared by  
the Graphics Design Department of Pima County Flood Control District, in some cases using materials  
from the Pima Association of Governments as noted on the map.

# CONTENTS

List of Figures .....	ii
Chapter 1 Introduction .....	1
Chapter 2 Overview of Watersheds and Watercourses .....	5
Chapter 3 Land Use and Watercourses .....	21
Chapter 4 Subarea 1 - Middle San Pedro .....	73
Chapter 5 Subarea 2 - Cienega-Rincon .....	81
Chapter 6 Subarea 3 - Upper Santa Cruz .....	91
Chapter 7 SubArea 4 - Middle Santa Cruz .....	103
Chapter 8 Subarea 5 - Tortolita Fan .....	117
Chapter 9 Subarea 6a - Altar Valley .....	129
Chapter 10 Subarea 6B - Avra Valley .....	141
Chapter 11 Subarea 8 - Western Pima County .....	151
Chapter 12 Summary and General Issues for Discussion .....	165
Appendices	
A. Glossary .....	167
B. Laws and Regulations .....	171
C. Pima County Floodplain Management Programs and Riparian Delineations .....	196
D. City of Tucson Floodplain Management Programs .....	203
E. Pima County Projects Funded by the Arizona Heritage Fund and Arizona Water Protection Fund .....	209
F. Land Classification in Pima County .....	210
G. For More Information .....	211

# LIST OF FIGURES

## Chapter 1

1-1	Watercourse types in the subareas .....	2
1-2	The subareas in Pima County .....	3

## Chapter 2

2-1	Schematic diagram of watersheds .....	5
2-2	Schematic diagram of the effects of impervious surfaces on watersheds .....	6
2-3	Schematic diagram of retention and detention systems .....	6
2-4	Example of a topographic map .....	7
2-5	Major watercourses in Eastern Pima County .....	8
2-6	Schematic diagram of types of watercourses .....	9
2-7	Schematic diagram of planforms .....	10
2-8	Perennial & intermittent streams in Pima County .....	11
2-9	Schematic diagram of how erosion changes watercourses .....	14
2-10	Schematic diagram showing the water needs of riparian species .....	15
2-11	Slopes of geographic zones .....	18
2-12	Average precipitation in the Tucson area. ....	19

## Chapter 3

3-1	Generalized ownership of public lands in Pima County .....	21
3-2	Table of public lands in Pima County .....	22
3-3	Land ownership in Eastern Pima County .....	25
3-4	Tucson Active Management Area. ....	30
3-5	Schematic diagram of channel cutting in Brawley Wash. ....	32
3-6	Agricultural land in Pima County .....	34
3-7	Agricultural acreage in Pima County .....	34
3-8	Sand and gravel mines in Eastern Pima County .....	37
3-9	Population growth in Eastern Pima County .....	39
3-10	Population distribution in Eastern Pima County .....	39
3-11	Generalized Effects of Human Activities on Stream Discharge .....	40
3-12	Golf courses in Eastern Pima County .....	43
3-13	Major properties acquired by Pima County Flood Control District .....	45
3-14	Shallow groundwater areas in Eastern Pima County .....	47
3-15	Schematic diagram of erosion of channels .....	49
3-16	Schematic diagram of the effects of channelization .....	50
3-17	Groundwater pumping in the Upper Santa Cruz River basin .....	51
3-18	Schematic diagram of how pumping affects streams .....	52
3-19	Schematic diagram of a cone of depression .....	53
3-20	Map of the Central Arizona Project in Pima County .....	53
3-21	Major water providers in Eastern Pima County .....	54
3-22	Schematic diagram of recharge .....	55
3-23	Existing and proposed recharge projects in Eastern Pima County .....	56
3-24	Public wastewater facilities in Eastern Pima County .....	59
3-25	Historic and active landfills in Eastern Pima County .....	62
3-26	Tucson Electric Power's generating capacity .....	64
	Color photo section of watercourses and flood control measures .....	65

<b>Chapter 4</b>	
4-1	The Middle San Pedro Subarea . . . . . 73
4-2	The Middle San Pedro Subarea watershed . . . . . 77
4-3	Generalized matrix of existing and potential impacts . . . . . 79 on watercourses in the Middle San Pedro Subarea
4-4	Generalized matrix of potential options for reducing stress . . . . . 80 on watercourses in the Middle San Pedro Subarea
<b>Chapter 5</b>	
5-1	The Cienega-Rincon Subarea . . . . . 81
5-2	The Cienega-Rincon Subarea watershed . . . . . 87
5-3	Generalized matrix of existing and potential impacts on watercourses . . . . . 89 in the Cienega-Rincon Subarea
5-4	Generalized matrix of potential options for reducing stress on watercourses . . . . . 90 in the Cienega-Rincon Subarea
<b>Chapter 6</b>	
6-1	The Upper Santa Cruz Subarea . . . . . 91
6-2	The Upper Santa Cruz Subarea watershed . . . . . 99
6-3	Generalized matrix of existing and potential impacts on watercourses . . . . . 101 in the Upper Santa Cruz Subarea
6-4	Generalized matrix of potential options for reducing stress on watercourses . . . . . 102 in the Upper Santa Cruz Subarea
<b>Chapter 7</b>	
7-1	The Middle Santa Cruz Subarea . . . . . 103
7-2	City of Tucson Hydrologic Units . . . . . 108
7-3	The Middle Santa Cruz Subarea watershed . . . . . 113
7-4	Generalized matrix of existing and potential impacts on watercourses . . . . . 115 in the Middle Santa Cruz Subarea
7-5	Generalized matrix of potential options for reducing stress on watercourses . . . . . 116 in the Middle Santa Cruz Subarea
<b>Chapter 8</b>	
8-1	The Tortolita Fan Subarea . . . . . 117
8-2	The Tortolita Fan Subarea watershed . . . . . 125
8-3	Generalized matrix of existing and potential impacts on watercourses . . . . . 127 in the Tortolita Fan Subarea
8-4	Generalized matrix of potential options for reducing stress on watercourses . . . . . 128 in the Tortolita Fan Subarea
<b>Chapter 9</b>	
9-1	The Altar Valley Subarea . . . . . 129
9-2	The Altar Valley Subarea watershed . . . . . 137
9-3	Generalized matrix of existing and potential impacts on watercourses . . . . . 139 in the Altar Valley Subarea
9-4	Generalized matrix of potential options for reducing stress on watercourses . . . . . 140 in the Altar Valley Subarea
<b>Chapter 10</b>	
10-1	The Avra Valley Subarea . . . . . 141
10-2	The Avra Valley Subarea watershed . . . . . 147
10-3	Generalized matrix of existing and potential impacts on watercourses . . . . . 149 in the Avra Valley Subarea
10-4	Generalized matrix of potential options for reducing stress on watercourses . . . . . 150 in the Avra Valley Subarea

<b>Chapter 11</b>	
11-1	The Western Pima County Subarea ..... 151
11-2	The Western Pima County Subarea watershed ..... 155
11-3	Generalized matrix of existing and potential impacts on watercourses in the Western Pima County Subarea ..... 157
11-4	Generalized matrix of potential options for reducing stress on watercourses in the Western Pima County Subarea ..... 158
<b>Chapter 12</b>	
12-1	Generalized matrix of existing and potential impacts ..... 165
	on watercourses in the subareas ..... 166

# CHAPTER 1

## INTRODUCTION

Water is crucial to life - to humans, other animals and plants. Humans can bring water up from underground and import it from distant areas, but most other forms of life must depend on water at or near the surface. Watercourses play a vital role in providing water to plant and animal life. In fact, some 80% of all wildlife in Arizona depends on watercourses, lakes, or marshy areas for some portion of its life cycle. Even watercourses that are dry most of the time are important areas where a little more water is collected than in the surrounding desert, allowing more vegetation to grow which becomes a source of food or shelter for some wildlife. Preserving these watercourses, then is an important step in preserving other lifeforms. Because we have already damaged so many of the natural watercourses in Pima County, many native wildlife populations have been reduced or lost. Pima County now faces the challenge of saving some of the remaining natural watercourses and of rehabilitating some others.

Watercourses also play an important role for humans. They may provide places for recreation such as hiking, bicycling, or wildlife viewing. They may help improve the quality of stormwater and help recharge the aquifer. Some have been used as places to dump trash, mine sand and gravel or discharge treated wastewater. Occasionally, some of them present hazards to humans when flood waters rush down the watercourses, overtop the banks, or erode nearby lands. People trying to cross flooded watercourses may be swept away, homes too close to the edge may be lost, and utilities such as power poles or sewer lines may be damaged. Repairing flood damage can be very costly. Costs for repairing damages to public structures from the 1993 flood in Pima County, for example, were estimated at more than \$39 million. Coordinating human uses and wildlife uses and minimizing flood potential are major challenges facing local citizens and are significant elements of the Sonoran Desert Conservation Plan.

Over the years attitudes towards watercourses have changed. People for centuries viewed some of them as crucial sources of water until the demand exceeded the supply. In some years the watercourses flooded, causing major damage. For many years approaches towards prevented flood damage featured measures to remove water from floodprone areas as quickly as possible, with little concern for how this might impact residents downstream or how that impacted wildlife and vegetation. The emphasis was on making the floodprone areas livable for people. More recently, preserving recharge potential of streams and maintaining wildlife values have become more important. Economic factors have led to approaches which preserve the floodplains and keep dwellings away from floodprone areas. Today's watercourses run the full gamut of this piecemeal approach, from fully cemented washes removing water quickly to washes preserved for their recharge, recreation and wildlife value.

This report is one of a larger series of reports done under the aegis of the Sonoran Desert Conservation Plan (SDCP). Some reports discuss wildlife and vegetation issues in great detail. Others describe land uses. The purpose of this report is to look at the variety of watercourses in Pima County, with emphasis on how they function physically, how human activity can affect those functions. The report provides background information and identifies the major questions and issues. It does not look specifically at every watercourse in the County, but rather takes a general approach in order to inform the public about trends and some options for reducing or minimizing or even reversing some of the impacts of human activities.

### MAJOR TYPES OF WATERCOURSES IN PIMA COUNTY

Pima County has watercourses with a great variety of characteristics. These range from perennial streams with high value for recreation and wildlife habitat to normally dry, fully channelized and cemented washes in the urban area whose value is limited to removing flood flows quickly.

The following descriptions demonstrate this variety.

1. Sabino Creek and a few others with perennially flowing waters and rich riparian habitat. Many of these are at higher elevations.
2. Arivaca Creek and a few others which have perennial surface flow for a distance and a rich riparian habitat and also have occasional flow in other areas with less riparian habitat.
3. The Santa Cruz River and other watercourses that are normally dry, but which once had surface flow when the water table was near the surface,
4. Pima Canyon and many medium to small washes that are normally dry (and were dry also before 1850) but which usually support more (and sometimes different) vegetation and wildlife than surrounding areas.
5. Alamo Wash and other watercourses that have been radically altered by urban development and flood control

structures ranging from full cementing of the channel to vegetation clearing on the banks and/or in the channel.

6. The Santa Cruz River which flows continually downstream of Roger Road because treated wastewater is discharged to the river.

**Subareas**

Pima County has been divided into subareas, as shown on Fig. 1-1. These are large areas based on watersheds, but appear to be rather artificial divisions if viewed from the land use point of view. The boundaries in most cases are the ridge lines of the mountains or high points between drainages.

Subarea 1 includes the Pima County section of the middle San Pedro River, east of the Catalina and Rincon Mountains and will be discussed only briefly in this report in connection with the private lands along the river. Subareas 2 through 6 are all parts of the Santa Cruz River watershed and are interrelated. Subarea 2 is the Cienega Creek watershed (which feeds into the Rillito River). The Pima County portion of the Upper Santa Cruz River through the San Xavier District comprises Subarea 2. The major part of the metropolitan area is in Subarea 4 which includes a section of the Santa Cruz River and many tributaries including Sabino Creek, Tanque Verde Creek, Rillito Creek and flows from the east side of the Tucson Mountains. Subarea 5 includes the Oro Valley-Tortolita-Marana area which receives flows from the west side of the Catalina Mountains and the Tortolita Mountains and includes a portion of the Santa Cruz River. Subareas 6A and 6B comprise most of the Altar and Avra Valley drainage and tributary flows from the west side of the Tucson Mountains. Subarea 7 includes most of the Tohono O'odham Nation and will not be discussed in this report because Pima County lacks planning jurisdiction for that area. Finally, Subarea 8 includes Ajo, Organ Pipe National Monument, and other federal lands and will be discussed only briefly in this report with emphasis on private lands around Ajo.

Detailed subarea watercourse maps were produced in conjunction with this report. They are too large to include within the pages of the report, but may be viewed at the Pima County Flood Control District Web site [www.dot.co.pima.az.us/flood/](http://www.dot.co.pima.az.us/flood/). Simplified versions of the maps are included in the subarea chapters.

**Fig. 1-2. Watercourse types in the subareas**

Subarea	Sheet flow	Distributary Flow	Natural Tributary	Entrenched Tributary	Channelized Washes	Perennial & Intermittent
Upper San Pedro			S			S
Cienega-Rincon		S	S	O	S	S
Upper Santa Cruz		S	S	S	S	M
Middle Santa Cruz		O	S	S	S	M E
Tortolita		S	S		S	S E
Altar Valley		S	S	S		S
Avra Valley	S	S	S		S	E
Western Pima County		S	S		O	O
<b>Key:</b> S = Significant feature in the subarea    O = Occasional or Significant unique occurrence E = Effluent flow    M = Mountainous areas only						

# CHAPTER 2

## OVERVIEW OF WATERSHEDS AND WATERCOURSES

### WATERSHEDS

A watershed is an area from which a watercourse or series of watercourses gets its water. Watersheds play important roles in stabilizing soils, promoting recharge, improving water quality, and slowing down floodwaters, as well as in providing habitat for wildlife. Tucsonans live in many watersheds. On the large scale we live in the Colorado River watershed. That is the area in parts of seven states on which water falls that theoretically may eventually flow into the Colorado River. The entire Santa Cruz watershed is a small part of the Colorado River Watershed and includes the mountainous areas from which water flows downhill eventually to reach the Santa Cruz River. That water may flow first into one of the tributaries such as the Rillito River or Sabino Creek, each of which is part of the Santa Cruz watershed, but has its own watershed too. Watersheds can be subdivided into smaller and smaller units until one reaches the watershed level of the small dry wash so common in this area.

Watershed size is the size of the total land area (in acres or square miles), which contributes runoff to a given location on a watercourse. Watershed size is a key factor in the determination of the characteristics of a watercourse. More than any other single factor, watershed size determines the magnitude and frequency of flood discharges that a watercourse will experience. Flood discharges, in turn, determine the general size and shape of a watercourse through adjustment of the watercourse to the erosive forces of these flows. In fact, the general size and shape of many watercourses is directly related to what is known as the "dominant discharge" of the wash. The and depth of a watercourse . The magnitude of the dominant discharge is in turn directly affected by the size of the watershed feeding the stream. It may also be affected by the amount of elevation difference. Since more precipitation falls at the higher elevations, more water will be available to flow down to the valley where precipitation is less.

The condition of the each watershed is important to the condition of the overall area. A "natural" vegetated watershed absorbs much of the rain that falls on it. Some of the water will flow downwards to another area and some will recharge the aquifer, be taken up by plants or evaporate. When vegetation is removed from a watershed,

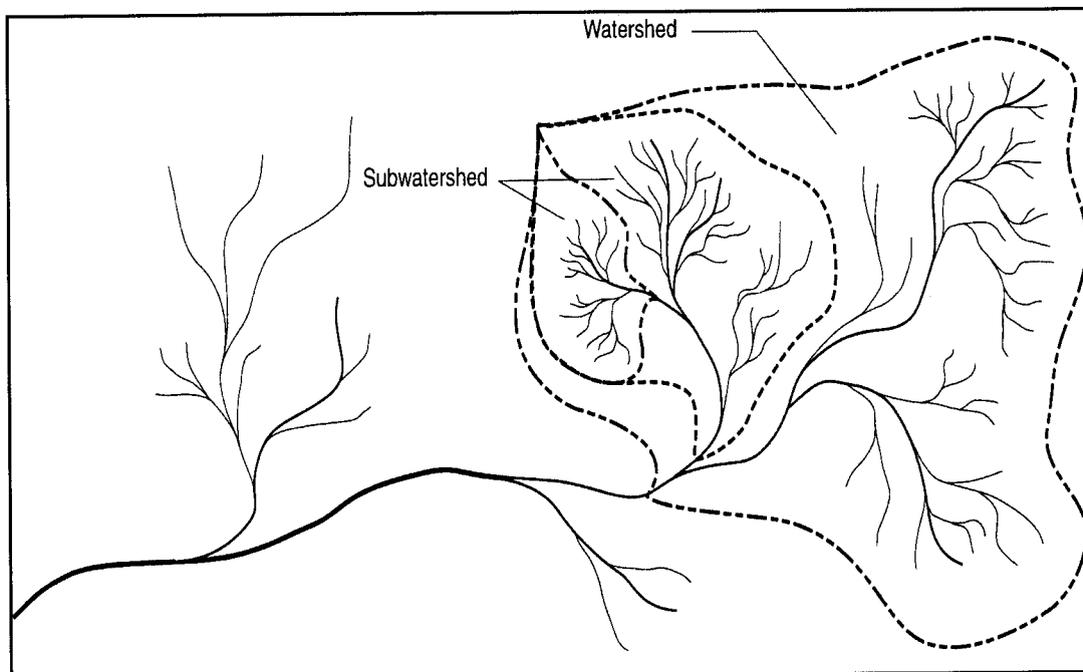


Fig. 2-1. Schematic diagram of a watershed.

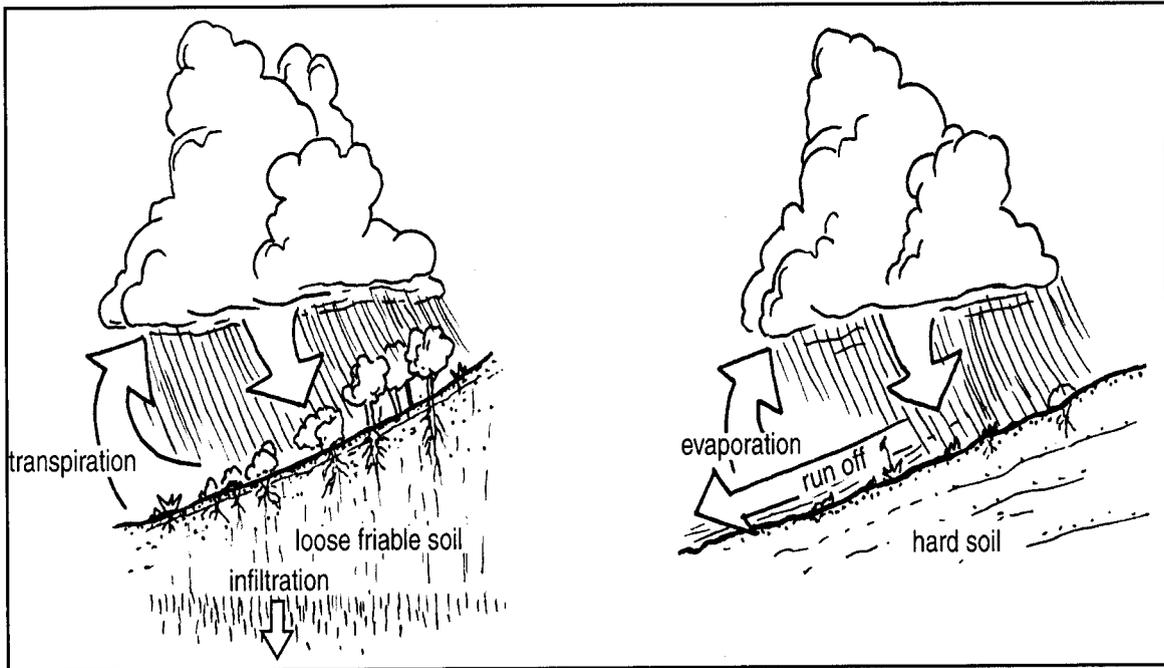


Fig. 2-2. Schematic diagram of the effects of impervious surfaces on watersheds

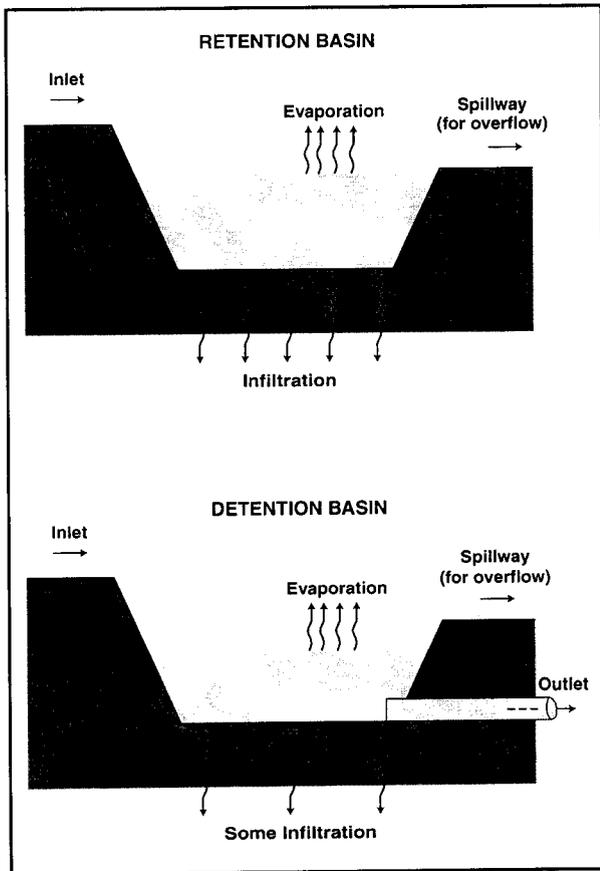


Fig. 2-3. Schematic diagram of retention and detention systems.

the patterns of flow are altered because soil without vegetation is easily eroded and new rivulets and channels may form. When parts of a watershed are paved, water tends to run off faster than it would in a vegetated area and less water is absorbed by soils or used by plants. More water is liable to end up in the larger watercourses, often in the form of floods. Similarly buildings change the character of the watershed. Any time an impervious surface replaces permeable soils, some change is liable to take place that will affect downstream areas.

Measures can be taken, however, to lessen the effects. Retention or detention basins, for example, can be built to retain rainwater flowing on a particular area and releasing the water gradually (detention) or letting it sink into the ground or evaporate (retention). Urban landscapes can be designed to at least partially mimic natural flow patterns. Roads can follow the natural topographic forms to some degree. These factors will be discussed further in Chapter 3.

### Elevation Changes

A topographic map shows the elevation levels of an area, and specifically in the example below shows elevation change along and within a given watercourse. These elevation changes determine the slope of the bed of a watercourse, the amount of fall between the watercourse and the adjacent overbank floodplain areas and the general elevation of the contributing watershed. This change in elevation is heavily influenced by the geographic zone (i.e., valley floor, foothills, mountain)

and the geology of the area within which the watercourse is located.

The slope of the bed of the watercourse generally determines how fast water will run. Because of this, the slope of the bed is a major factor in determining how much sediment (rocks, sand, and silt) the watercourse will carry during flood flows. If the watercourse is so steep that it carries more sediment than is being brought in from upstream, then the bottom or sides of the watercourse will be eroded too, thus widening or deepening the channel. If the watercourse slope is low the opposite may happen, causing the channel to fill up or narrow.

The amount of relief (elevation difference) between the bed of the watercourse and the adjacent floodplain is a major factor in determining how much water the stream can carry. In some cases the amount of relief is great, banks are steep, and floods are confined to the watercourse.

In other cases the amount of relief is small, the watercourse is shallow and flows spill into the adjacent floodplain more frequently. The overall elevation of the watershed feeding the watercourse is a factor in the amount of runoff reaching the stream because of the variation in vegetation and geology that occurs at different elevations. As elevations increase, the amount and density of vegetation tends to increase in response to climatic conditions (more rainfall, less intense heat) more favorable for certain plants. The increased vegetation generally acts to intercept rainfall through plant transpiration and surface water storage by the plants. This in turn generally decreases runoff and reduces the severity of flood flows that often determine channel shape.

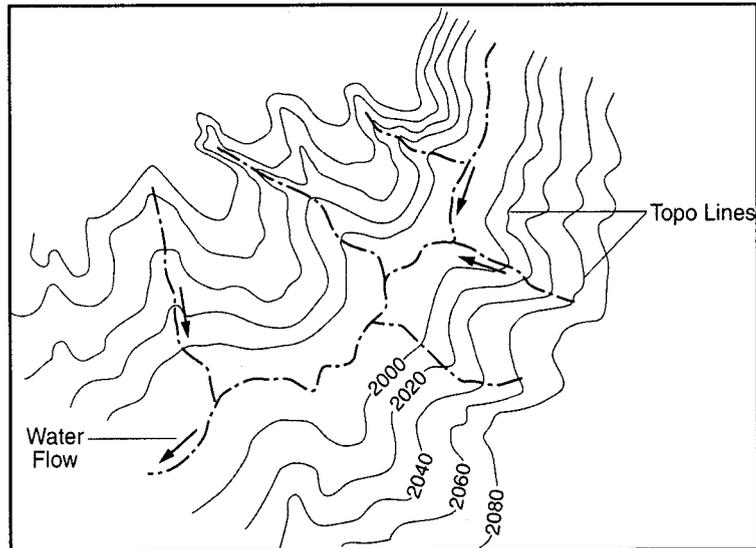


Fig. 2-4. Example of a topographic map.

## WATERCOURSES

Watercourses are the conduits through which most of the water flows in a watershed. There are many types of watercourses, as described below ranging from washes that seldom receive water to rivers with steady flow. Even the small natural ones, however, usually share one characteristic with the larger ones. They may support more (and often different) vegetation than the surrounding desert and provide useful habitat for some types of wildlife.

The general direction of flow of surface water in eastern Pima County is from the higher to lower elevations and then roughly northwest towards the Gila River which is a tributary of the Colorado River. The Santa Cruz River originates on the east side of the Santa Rita Mountains, flows into Mexico, and then loops back into the U.S. east of Nogales. From there it flows approximately north. The Rillito also originates on the east side of the Santa Rita Mountains where it is called Cienega Creek. Cienega Creek flows north-northwest towards Tucson, with a name change to Pantano Wash. Tanque Verde Creek originates in the south side of the Santa Catalina Mountains, with Sabino Creek as a major tributary. Tanque Verde Creek and Pantano Wash join to form the Rillito, which in turn flows into the Santa Cruz River near Orange Grove Road. The Cañada del Oro which also originates in the Catalina Mountains joins the river just downstream of that same area. Most of the other watercourses in eastern Pima County are tributary to this river system, including those that originate in the Tucson or Rincon Mountains.

In western Pima County, the Santa Rosa Wash and Vekol Wash are part of the Santa Cruz River system and flow north to meet the Santa Cruz River in Pinal County. Many other ephemeral washes in the Tohono O'odham Nation flow from the higher elevations, with some extending to the Gila River and others not joining a river system. A small part of the extreme southwest of the county is part of the Sonoyta River system which flows in Mexico.

## TYPES OF WATERCOURSES

### Some terminology

Natural watercourses are scientifically classified by size and amount of water and by form, as described below.

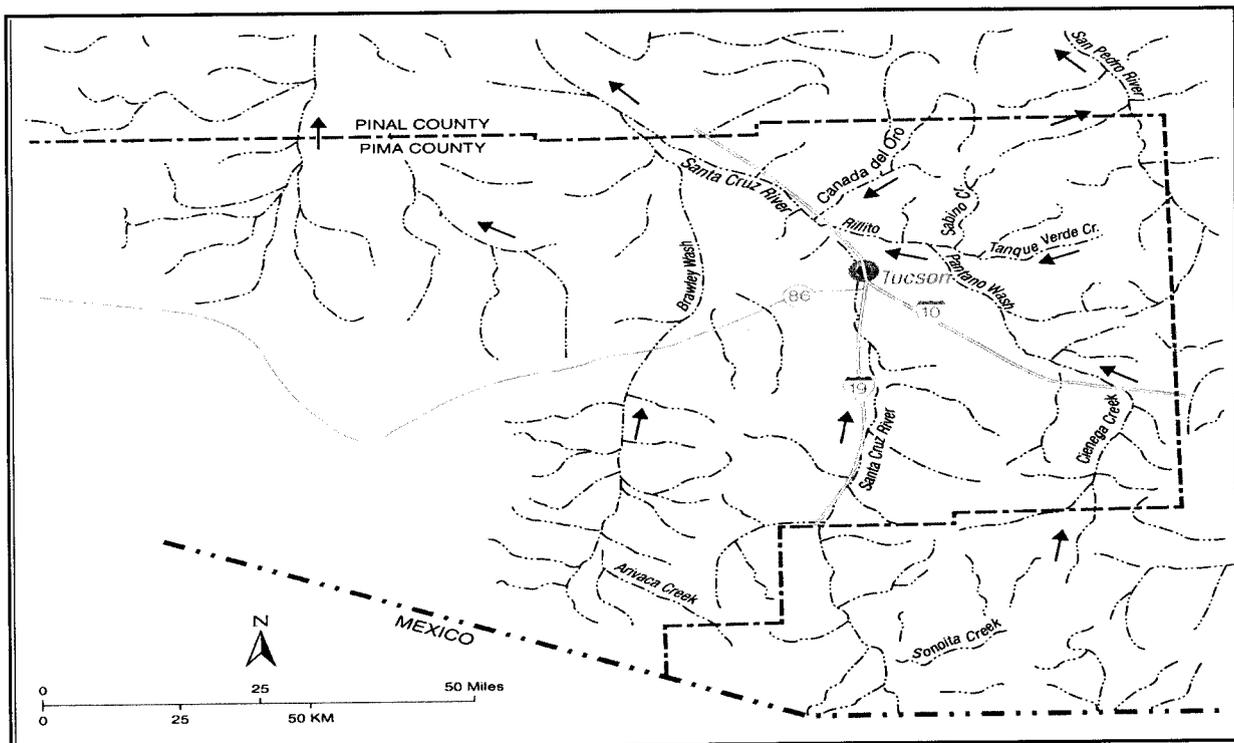
The common terminology, however, for kinds of watercourses is often confusing and not consistently used. We generally use the term “*arroyo*” to describe a dry watercourse that is deeply incised (the banks are eroded to form steep sides), although “*arroyo*” is also commonly used to describe any dry watercourse. “*Wash*” refers to any dry watercourse, usually the smaller ones. “*Creek*” usually refers to a small watercourse which has water most of the time, although Tucsonans also speak of “*Rillito Creek*” which is one of our larger watercourses and is usually dry. That same watercourse is also called “*Rillito River*” by many. The very name “*Rillito*” means “*little river*” in Spanish so the addition of “*creek*” or “*river*” is actually superfluous. According to the dictionary “*stream*” refers to a flowing body of water, but in Arizona the term is also used for normally dry watercourses. “*River*” usually refers to a larger watercourse which may or may not have permanent water. There are no hard and fast size limits between “*wash*,” “*creek*,” and “*river*.” In this report we will use the common names for the watercourses (e.g., “*Santa Cruz River*” or “*Arroyo Chico*”). “*Watercourse*” is a general term which avoids the problems of naming and will be used most frequently, although “*wash*” will be often be used to denote the small, normally dry watercourses.

### Characterization of Watercourses by Flow Conditions

In Pima County there are three main categories of everyday flow conditions: perennial, intermittent, and ephemeral.

*Perennial streams* are those which flow year round. As most observers of the natural environment will quickly discover, there are relatively few perennial streams in Pima County. Perhaps the most well known of these is the running stream through Sabino Canyon in the Catalina Mountains. Generally speaking these streams either receive sufficient runoff from rainfall year round or are geologically connected to ground water flows in the subsurface such that flows come to the surface and run along the stream. Because of the availability of water, perennial streams are home to a wide variety of flora and fauna, many of which are found nowhere else in the county. Typical plant species that occur along these streams include cottonwood and willow. This type of stream is more commonly found at the higher elevations in the county. Pima County’s perennial streams are shown on the map below.

*Intermittent watercourses* are those which flow for part of the year when they receive water from springs or snowmelt. Such streams typically flow in response to the winter rainy season which offers sufficient rainfall over an extended time period to allow flow to occur for a few weeks or months. These streams also exhibit an unusual range



**Fig. 2-5. Major watercourses in Eastern Pima County.  
Most of them flow generally north/northwest.**

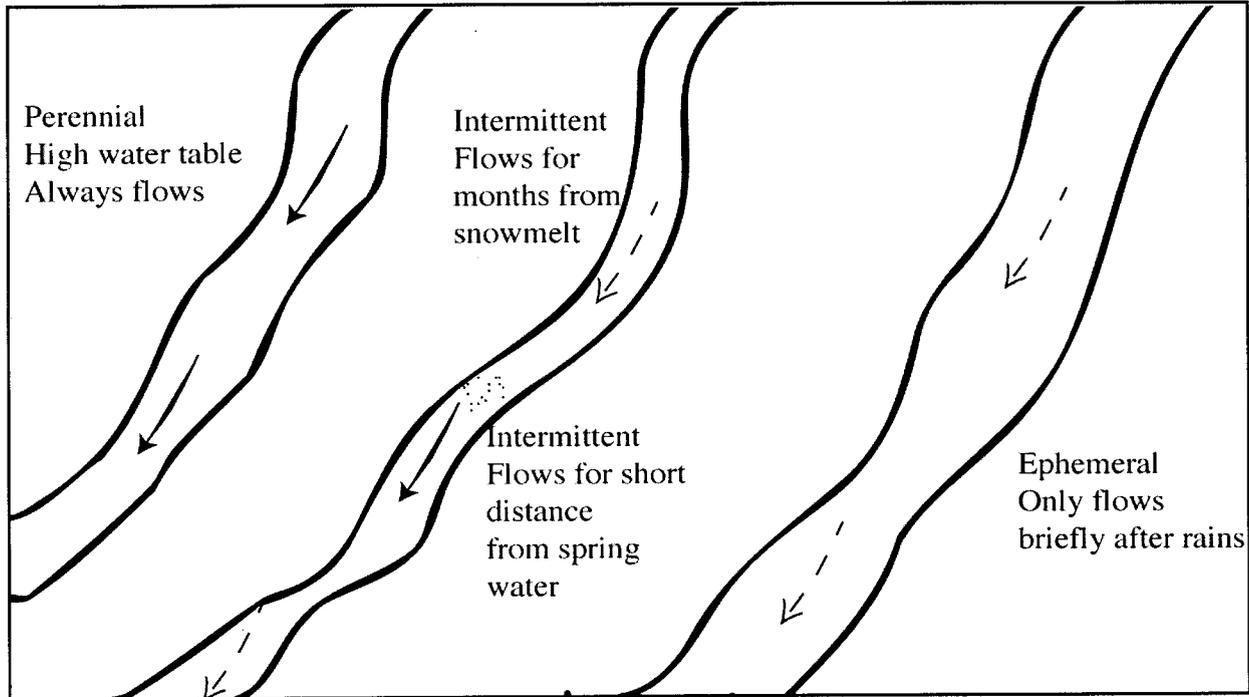


Fig. 2-6. Schematic diagram of types of watercourses

of flora and fauna, although typically not nearly as striking as the perennial streams. Typical plant species that occur along these streams include mesquite, ash, netleaf hackberry and sycamore-ash association. For a complete survey of the perennial and intermittent streams see Pima County's GIS Coverages of Perennial and Intermittent Streams.

*Ephemeral watercourses* are those that experience little or no flow most of the time and flow only in response to precipitation such as a summer monsoon storm. Most of the streams in Pima County are ephemeral. Nonetheless, vegetation tends to be concentrated along these watercourses because of the moisture associated with these storm flows. These are too numerous to show on a small map.

Finally, the term *effluent dominated* watercourse refers to a watercourse that flows all the time primarily because of discharge of treated wastewater - effluent - from a wastewater treatment plant. The Santa Cruz River downstream of Roger Road through Marana, for example, is effluent dominated.

#### Characterization of Watercourses by Plan Form

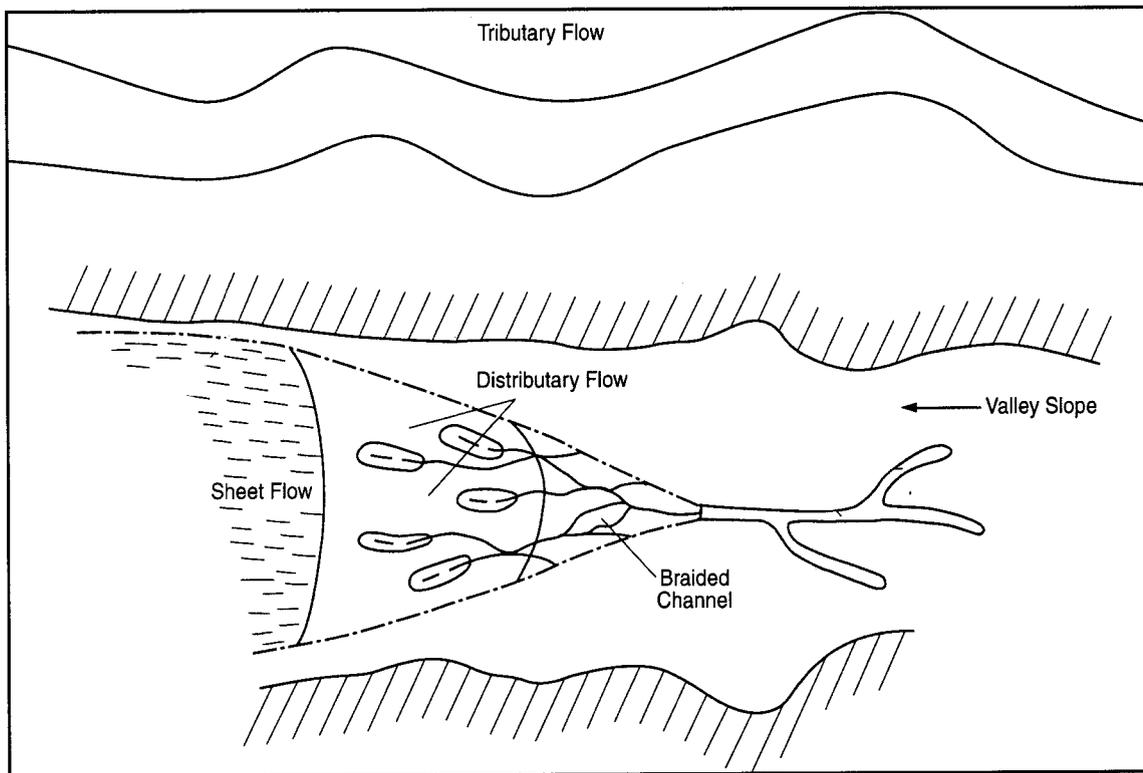
Plan form refers to the general appearance, shape and areal occurrence of the watercourse. Watercourse plan forms in Pima County generally fall into one of three categories including; Tributary, Distributary and Sheet Flow.

##### *Tributary Flow Areas*

Tributary plan forms are the most common types of flow areas in Pima County. These watercourses usually have a well-defined channel bed and banks with adjoining overbank floodplain areas. These watercourses combine with other branches and increase in size as they work their way in the downstream direction. These streams can range in size from a few feet to several hundred feet in width depending on the size of the watershed concentrating at any given location along the watercourse. Typical examples of these types of watercourses include streams draining the Catalina Mountains and Foothills, the Rillito River, the Santa Cruz River. All of these watercourses are fairly well defined and combine with tributaries in the downstream direction.

##### *Distributary Flow Areas*

Distributary plan forms are the opposite of tributary plan forms and are less common, though still easy to find, in Pima County. These streams are characterized by poorly defined drainage patterns that tend to split into branches



**Fig. 2-7. Schematic diagram illustrating various plan forms.**

as the channel works its way downstream. These areas may also include recombinations of branches but overall the net result is a dividing of the watercourse into more branches in the downstream direction. Such watercourses are often referred to as “braided.” Watercourses in these systems often behave in unpredictable patterns and may shift location and flow direction during severe flow events. The individual channels in a distributary flow system generally have poorly defined beds and banks that are easily overtopped during flow events causing the creation of new channels as overflow works its way downstream. Examples of distributary flow areas include portions of the Tortolita, Tucson and Sierrita Mountain foothills.

Alluvial fans are a subset of distributary flow areas. Alluvial fans are areas with distributary flow patterns that are unpredictable and subject to sudden and complete changes during extreme flow events. Alluvial fans have recently been defined as areas where flow path uncertainty is so great that the uncertainty cannot be set aside in realistic assessment of flood risk or in the reliable mitigation of the hazard (National Research Council, 1996). The above reference identified portions of the Tortolita Mountain Piedmont northwest of Interstate-10 near Marana as meeting the definition of an alluvial fan area.

#### *Sheet Flow Areas*

Sheet flow areas are those areas where channel definition is absent altogether. Sheet flow areas experience flooding over comparatively wide flat areas that lack any real defined pattern of drainage. Sheet flow areas usually develop because topographic conditions do not promote the collection and concentration of flow in any one particular location and because the flatness of the terrain does not allow flow of sufficient erosive velocity to achieve channel formation. True sheet flow areas are generally neither tributary nor distributary in nature, although very minor channel formation may occur at isolated locations within sheet flow areas. Occasionally, sheet flow areas may be created as a result of extensive agricultural activity or urbanization that can obliterate natural drainage patterns beyond recovery. Examples of natural sheet flow areas can be found at isolated locations in Avra Valley west of the Tucson Mountains and along the low lying divide between the Pantano Wash and Santa Cruz River.

Some streams exhibit two or more of the characteristics described above. They may, for example, have a

definite channel alternating with a distributary flow area and a sheet flow area. These are fairly common in the southeast part of the county south of I-10.

### **Characterization of watercourses by amount of vegetation**

Pima County watercourses are home to a wide variety of vegetation communities. These communities vary depending largely on the amount and frequency of flow that occurs within the watercourse. Perennial and intermittent streams (see discussion under “Flow Conditions” above) are home to the most dense and varied assortment of vegetation while ephemeral watercourses tend to have less vegetation but are still readily identifiable from the surrounding terrain by the amount of vegetation along their banks. In the early 1990’s, the Pima County Flood Control District performed an extensive evaluation and inventory of the amount and distribution of different types of vegetation along Pima County’s watercourses. The inventory was performed as a part of the development of revisions to the county’s floodplain management ordinance to provide protection of riparian areas. The result of the vegetation inventory process was the development of a series of maps showing riparian vegetation in Pima County. Five major classes of riparian vegetation are shown on the county’s maps including, Hydroriparian/Mesoriparian, and Xeroriparian Class A through D. Although separate classes of riparian habitat are defined, these areas are best thought of as a continuum of plant communities with considerable overlap between each class. Since they are considered to be of equal importance for preservation, Hydroriparian and Mesoriparian classes were combined in one class on the maps. (See Appendix C and web site [www.dot.co.pima.az.us/flood/](http://www.dot.co.pima.az.us/flood/)).

#### *Hydroriparian and Mesoriparian*

Hydroriparian areas are ecosystems associated with perennial watercourses characterized by dense coverage of wetland plant species. Cottonwood and Goodding willow are commonly found in Hydroriparian areas. Mesoriparian habitat areas are supported by perennial or intermittent streams, or areas of shallow groundwater. They are similar to Hydroriparian habitats but with less dense plant communities. Typical species in this class include mesquite, ash, netleaf hackberry and sycamore-ash association.

#### *Xeroriparian*

Xeroriparian areas are habitats associated with intermittent or ephemeral water supplies and may include species from adjoining upland areas. Typical species include palo verde and mesquite, along with occasional Mesoriparian species. The maps developed by the county show four sub-classes of Xeroriparian habitat (A-D) based on total vegetative volume per square meter, with A representing higher densities and D representing lower densities. These classifications do not distinguish between types of vegetation (exotic grasses vs. trees, for example), so that a golf course with turf to the edge of the wash might be in the same class as a natural riparian area. Extensive areas of Xeroriparian subclass D habitat occur in the county that are not shown on these maps. Xeroriparian subclass D is only shown when it is adjacent to, or associated with, other classes of riparian habitat.

### **Characterization of watercourses by the degree of human impact**

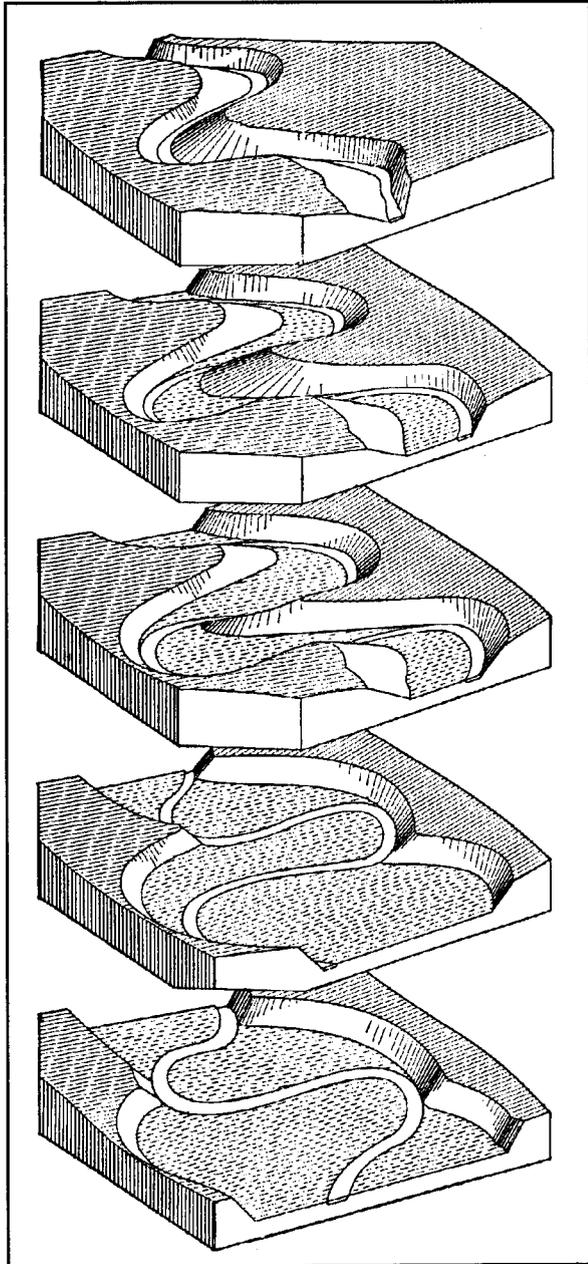
Almost all watercourses in Pima County have been impacted to some degree by humans. The following are descriptions of various degrees and types of human impact. In general, the greater the human impact, the more the functions of the watercourse are affected and the behavior of the watercourses changes. Human impacts are discussed more fully in Chapter 3.

#### *Natural watercourses*

These are watercourses where human impact has been minimal. These include some ephemeral watercourses in remote areas in the desert as well as those high in the mountains. Human impacts have been limited to occasional visits or very small amounts of ranching.

#### *Watercourses where the watershed has been modified*

In some areas there have been few or no direct changes to the watercourse itself, but there have been modifications to some part(s) of the watershed that have in turn affected the watercourse. These include areas where there land has been cleared and there is increased flood flow to the watercourse and additional erosion or sedimentation as well as areas where grazing has affected the watershed.



**Fig. 2-9. Schematic diagram of how erosion can change a watercourse.**

channel is constrained so that erosion cannot occur or so that the waters cannot spread out into the floodplain, the waters are liable to increase their energy and spread out or cause erosion when they reach an unconstrained area. If the ability of the overbank to store water is limited by pavement, structures, or a constrained channel, more water moves rapidly downstream and is lost to the immediate area. Watercourses and their floodplains are also important places for storage of sediment and storage and recharge of water. See Fig. 3-14 for an illustration of overbank storage.

Natural watercourses tend to meander, rather than flow in straight lines. They also tend to cut new channels where the soil of the banks is soft. Old maps and aerial photos of the Rillito, for example, indicate that in the

#### *Watercourses with limited direct modification*

These include watercourses with road crossings that bring about changes in the function of the watercourse, and watercourses where land has been cleared in places up to the floodplain but there is no direct encroachment on the floodplain itself except for road crossings.

#### *Watercourses with major use of the floodplain or channel*

These include watercourses where agricultural uses occur on the floodplain, where homes or businesses have been built on the floodplain, and where mining activities have thoroughly altered the watercourses. They also include watercourses where severe overgrazing has been a problem.

#### *Watercourses heavily modified by flood control structures*

These include small urban watercourses that have been straightened and vegetated with grassy swales, watercourses that have been lined with rock or some type of cement on the sides but not the bottom, and watercourses that have been lined side and bottom with cement. They also include watercourses that have flood control structures such as enforcement of bridge supports at discrete locations but not along the rest of the channel. Flood control structures are discussed in Chapter 3.

## **THE ROLES OF WATERCOURSES**

### **The functional roles**

Watercourses serve as passageways for water to travel downhill. The channel carries most of the water, but when precipitation is too high, the channel is insufficient and the water spreads out over the floodplain. This is most likely to occur when storms last for several days or weeks, as sometimes happens when a Pacific hurricane arrives in the autumn. Heavy summer monsoon rains, or long-lasting winter storms can also over-fill the channels.

As water flows downhill it picks up energy which must be dissipated, often in the form of scouring a channel. The water also picks up sediment as it wears away the rock, sand, and dirt. Many Arizona watercourses are especially vulnerable to erosion after they have been dry for months and the soil easily erodes when it gets wet. Where the water slows down, sediment may be dropped to add to the channel or floodplain. If the

historic past its channel has changed location many times, and formerly flowed in some areas where today there are neighborhoods or businesses between Craycroft Road and First Avenue.

One reason that the floodplains in areas such as Marana are so fertile is that floods have in the past left sediment that nourished the soils. The velocity of the water tends to increase on the outside curves because of centrifugal force. This is where channel changes are most liable to occur unless some natural or manmade barrier prohibits it.

Watercourses are also the areas where the most natural recharge of groundwater occurs. The beds of the watercourses tend to be sandy in the valley and the underlying soils are usually capable of allowing water to permeate down to the aquifer. In general, when the flows are relatively slow, recharge occurs effectively. When the water arrives as rapid storm flow, they move quickly downstream and the recharge also occurs farther downstream, sometimes outside of the area from which water can be pumped to metropolitan users.

### **The biological roles**

Watercourses are very important to vegetation and wildlife. It is only along watercourses with plenty of water that trees such as cottonwood, willow or bulrush can grow. The community of the watercourse, its vegetation and its wildlife are collectively referred to as a riparian area. Some of the vegetation, such as cattails and bulrushes, must be in water or moist soil all the time, while other vegetation such as willow can reach downward to get water through its roots. Cottonwood trees have very particular needs in order to germinate. Established trees can reach downwards for water, but establishment of new trees requires floods that spread out onto the floodplain at a time when the seeds are viable in the spring, and then the water retreats leaving dry soil on the surface and water close to the surface. This happens only in years when the conditions are right. If the channel has become deeply incised and there is no floodplain to inundate, cottonwood seedlings have difficulty becoming established, although some may get started in the channel only to be eliminated in the next flood. Mesquite can grow in upland areas, but grows much larger along watercourses where its roots can reach down for water. Saltcedar (tamarisk), a non-native tree, is not nearly as particular and can easily become established if there is flowing water at some time during the year, so is liable to compete with the cottonwoods for water and take over a watercourse that does not have a natural flow regime.

During flow events, nutrients are washed into the watercourses from the surrounding uplands. In the long period between flows, the riparian zone slowly gives back nutrients to the less productive surrounding desert in the form of algae, insects, and plant growth.

Riparian areas are very important to wildlife. In Arizona, at least three fourths of all the wildlife species need to use a riparian area, wetland, or wetland for some part of its life cycle. This includes migrating and nesting birds, frogs, fish, many insects that provide food for other creatures, and mammals such as raccoons. Even xeroriparian areas may provide amenities such as extra vegetation for insects and nesting areas for birds.

They may also provide relatively safe corridors for wildlife and since so many of the riparian areas and wetlands in eastern Pima County have been lost or degraded, the remaining ones have even greater importance. Even unvegetated watercourses provide better travel corridors than do city streets for some species.

### **Water quality roles**

Another role that vegetated washes serve is in improving water quality. Stormwater runoff from urban areas often contains a mixture of petroleum products from vehicles and other kinds of pollution from materials dumped on the streets. As the water runs off, much of that pollution will reach the main watercourses and some will reach the groundwater through recharge. If the runoff occurs relatively slowly along vegetated washes, the vegetation helps to absorb some of the pollution, minimizing the risk to groundwater quality. Grassy swales and other vegetation are relatively effective pollution absorbers. The Santa Cruz River in the Tubac area, for example, has a lush riparian area which effectively improves the quality of the treated wastewater flowing from the Nogales Wastewater Treatment Plant.

Flood waters also flush accumulated salts downward below the root zone, thus preventing a long-term accumulation of salts which could inhibit plant growth.

### **Recreational and social roles**

Watercourses can play important values for humans. The linear trails along the Santa Cruz and Rillito River are popular biking and jogging routes for people, away from the city streets. Some of these trails have been landscaped

to increase their appeal. The watercourses with riparian areas provide another kind of recreational value, especially popular with bird watchers and hikers. Pima County's Cienega Creek Preserve, for example, offers a very pleasant environment for humans as well as for many kinds of wildlife. Sabino Canyon is one of Tucson's most popular retreats because of its beauty, serenity, coolness, and wildlife viewing. The dry washes offer another kind of recreational opportunity which many people enjoy, especially when such a wash is preserved within a neighborhood. Sometimes watercourses can serve to unite a community which appreciates and enjoys them. The value of these opportunities cannot be given in economic terms, but they may benefit the community enormously.

## FACTORS THAT INFLUENCE THE WATERCOURSES

### GEOGRAPHIC AND CLIMATIC FACTORS

#### Geography/Topography

Pima County is located within the Arizona Upland Region of the Sonoran Desert. Geologically, the region is located within the Basin and Range Physiographic Province which is characterized by southeast to northwest trending mountain ranges separated by basins of alluvial fill carried down from the mountains over millions of years. These mountain ranges extend to elevations in excess of 9,000 feet in the Santa Catalina Mountains of Eastern Pima County while the valley basin elevations generally range from 1,000 to 3,000 foot elevation. Between the mountains and the valley basins lie the foothills zones. Generally speaking land slopes are flattest in the valley floor and steepest in the mountain ranges. The table below provides general ranges of slope steepness in the three geographic regions described above.

The valley floors are home to the larger watercourses within Pima County including the Santa Cruz River, Rillito River, Pantano Wash, Tanque Verde Creek and (in extreme northeastern Pima County) the San Pedro River, to name a few. These watercourses typically drain hundreds to thousands of square miles of upland desert and mountain range areas. The terrain in the valley floor is generally characterized by soils brought down over time from the mountain ranges and transported to the valley by the action of wind, water and, in some cases, by geologic activity such as earthquakes. These alluvial soils are highly effective in storing water. The flora of the valley floor generally includes brush such as creosote and salt bush, mixed with a variety of cactus and other succulents including saguaro, prickly pear, cholla and ocotillo to name a few.

The piedmont zones, or foothills, typically consist of higher ground, ranging in elevation from 3,000 to 5,000 feet, which is host to more dense vegetation of greater variety than the valley floor. Additional flora in this region includes Palo Verde, juniper, manzanita, and some smaller species of oak, to name a few. The terrain in the piedmont zone is generally drained by well-defined drainages between steeply sloped ridges. However, these zones can also be relatively flat in some cases where the elevation difference (relief) between the mountains and valley floor is less pronounced and does not provide sufficient grade for drainages to erode more deeply into the piedmont surface. The relatively flat region of the Tortolita Mountains piedmont north of Tucson is a good example of this condition.

The mountain regions within Pima County can generally be described as those above 4,000 feet or where slopes exceed 10% in the lower valley areas. These regions include the Santa Catalina, Rincon, Santa Rita, Baboquivari, Tucson, and Sierrita ranges in Eastern Pima County and the Ajo and Growler ranges in Western Pima County, to name the most prominent. These ranges can extend up to 9,000 feet in elevation and can include forest vegetation

**Fig. 2-11. Slopes of Different Geographic Zones within the Basin and Range Terrain of Pima County**

Geographic Zone	General Steepness Range in % slope(i.e., vertical feet per 100 horizontal feet)
Valley Floor (e.g., Santa Cruz River)	Less than 1 %
Foothills (e.g., Tortolita Area)	1% to 10%
Mountain Ranges (e.g., Santa Catalina range)	Greater than 10%

<b>Fig. 2-12. Average Precipitation in Metropolitan Tucson</b>				
<b>Month</b>	<b>Temperature Normals (deg F)</b>			<b>Precipitation Normals (inches)</b>
	<b>High</b>	<b>Low</b>	<b>Average</b>	
<b>January</b>	63.0	38.6	51.3	0.87
<b>February</b>	67.8	41.0	54.4	0.70
<b>March</b>	72.8	44.6	58.7	0.72
<b>April</b>	81.2	50.4	65.8	0.30
<b>May</b>	89.9	58.0	74.0	0.18
<b>June</b>	99.6	67.9	83.8	0.20
<b>July</b>	99.4	73.6	86.6	2.37
<b>August</b>	96.8	72.1	84.5	2.19
<b>September</b>	95.3	67.5	80.4	1.67
<b>October</b>	84.3	56.6	70.4	1.06
<b>November</b>	72.7	45.6	59.2	0.67
<b>December</b>	64.3	39.8	52.0	1.07
<b>ANNUAL</b>	<b>82.2</b>	<b>54.6</b>	<b>68.4</b>	<b>12.00</b>

National Weather Service, Tucson Website, <http://nimbo.wrh.noaa.gov/Tucson/climate/tus.html>

such as spruce and fir. Typically the terrain in these ranges consists of very steep slopes, which make construction or development difficult or economically impractical. These areas are typically remote and are often under public ownership of one form or another.

### **Climate**

The climate of Pima County is that of the Arizona Upland Division of the Sonoran Desert, but varies highly with elevation. Summers in the valley are hot, with daytime highs often exceeding 100 degrees Fahrenheit in late July and August. Winters are mild, with few days below freezing and little or no snow except in the higher mountain areas. The table below provides a summary of climatic data for metropolitan Tucson

Rainfall in the region occurs primarily during two distinct rainy seasons in the summer and winter. The summer (and early fall) rainy season is caused by two distinct atmospheric patterns (U.S. Geological Survey, 1992). The summer monsoon generally happens in July and August when high intensity thunderstorms occur. These storms draw on moisture that enters the region from the eastern Pacific Ocean in late June and early July and builds up as the heat increases. Approximately 4.6 inches of Tucson's annual 12 inches falls during July and August. Major storms sometimes occur in September and October when Pacific hurricanes drop moisture in the desert areas. Approximately 2.7 inches of Tucson's annual 12 inches falls during September and October.

The winter rainy season is caused by large-scale low-pressure frontal systems within the westerly winds of the Pacific Ocean. These frontal systems typically move along a track from the northwest Pacific, across the Cascade and Sierra Nevada Mountains and into the interior western basins where they provide the moisture for large scale low-intensity storms from about November through March. This rainy season accounts for approximately 4.0 inches of Tucson's annual 12 inch rainfall.

At the higher elevations this picture changes dramatically. At the top of Mount Lemmon snow falls (often providing enough for at least a short winter ski season) and temperatures usually drop below freezing from November through March. Annual precipitation at the higher elevations is more than twice as great as it is in the valleys. Some of this precipitation ends up in the valleys as streamflow.

At the other extreme, rainfall at the extreme western edge of Pima County may be as low as 3" and freezing temperatures are almost never recorded. The summer storms reach this area less frequently.

### **Geology/Soils**

As mentioned earlier, Pima County is located in the Basin and Range physiographic province of Arizona, which is characterized by southeast to northwest trending mountain ranges separated by basins of alluvial fill carried down from the mountains over millions of years. All three of the major rock classes of igneous, metamorphic and sedimentary occur with Pima County. The condition of the piedmont slopes between the valleys and mountain fronts varies depending on the specific geology and relief of the area. Some piedmont slopes have well defined ("foothills") topography with ridges and washes and others have little or no relief. Many of the flatter piedmont slopes with little relief have poorly defined drainage patterns which can either diverge or converge as they work their way down the piedmont surface.

Soil conditions in Pima County vary considerably but tend to follow certain patterns depending on geographic zone (i.e., valley floor, foothills or mountains). Valley floor soils are usually associated with floodplain deposition and tend to be composed of loose alluvium of a fine texture and containing relatively high levels of organic material. These soils usually allow water to infiltrate easily, but they are easily erodible. Foothills (piedmont slope) soils, having been deposited on steeper slopes than floodplain areas, tend to be coarse. The amount of soil development on piedmont surfaces depends on the age of the piedmont slope with older surfaces having better developed soil profiles (i.e., more definite layering of deposits and accumulation of clay layers and organic material). Older piedmont soils tend to have more clay and caliche, and may as a result allow less water to infiltrate. Sandy piedmont soils can be very erodible where disturbances are frequent and slopes are steep. Mountain soils tend to be shallow and more rocky than foothills and valley soils. They tend to shed runoff quickly, but usually contribute little sediment unless the watershed has been highly disturbed by activities such as land clearing or overgrazing.

### **Channel Stability**

Another important characteristic of watercourses in Pima County is the stability of the bed and banks of the channel. Pima County has, on occasion, been the site of dramatic changes in channel location and configuration as a result of channel instability. The October 1983 and January 1993 floods saw extensive erosion along many of Pima County's major waterways through the metropolitan area. Channel stability can vary from watercourse to watercourse within a particular area and even within adjacent reaches of a single watercourse. Channel stability is largely a function of geology and soils of the watercourse, the geographic zone (valley floor, foothills, mountain) where the channel is located, the alignment of the channel, and, to a certain extent, the topography of the areas adjacent to the channel. Clearly, some channels are very stable. Mountain streams located within bedrock are very stable as are many foothills channels located in well-developed soil between well-defined ridges. Valley-floor streams in fine, unconsolidated alluvium, such as the Santa Cruz and San Pedro Rivers, have been called inherently unstable. They can alternate between periods of deposition and erosion, both over the short term of human life spans, and also over periods of thousands of years. Urbanization can also contribute to either stability or instability.

Stability can be created through comprehensive structural stabilization of channel bed and banks while instability can be created through poorly planned placement of isolated improvements that stabilize a channel at one location only to transfer instability upstream or downstream to unprotected areas. Disturbance of the amount of sediment supplied to a watercourse during times of flood, through paving and other construction, can also lead to channel instability. This is because the power of flood flows to carry sediment remains constant even when the supply of material is decreased, resulting in erosion of channel bed and banks to make up the difference.

### **Human Factors**

Humans affect watercourses in many ways that will be discussed in Chapter 3 in general and in more specific instances in the chapters that follow for each subarea.

# CHAPTER 3

## LAND USE AND WATERCOURSES

### INTRODUCTION

The way land is used can dramatically affect watercourses since virtually all land use occurs on the watershed of some watercourse. This chapter looks first at land ownership patterns in Pima County and describes the differences between what is allowable on various types of public land and on private land. It then discusses various categories of land use and the impacts of each on watersheds and watercourses. These land uses include the range of uses from heavy commercial and residential to preserves. This chapter presents an overview, while the chapters dealing with individual subareas take a more detailed look at uses and impacts in those regions.

### PIMA COUNTY'S PUBLIC LANDS

Pima County has a very high percentage of lands in federal, state, or Indian ownership. In many cases this has effectively led to protection of watercourses, especially on National Park, National Forest, State Parks, and some County Park land. However, since so much of the public land is at the higher elevations, it is the watercourses in the valley, often on private lands, that have been especially vulnerable to alteration.

Each government agency which owns or manages lands has a different mission and thus manages land differently. Some agencies must protect the lands and the watercourses within them, while others have more complex missions. Most public lands are not available for commercial development, but some can easily be transferred into private ownership. The following is a general description of the major agencies managing land in Pima County in order to set the larger framework for discussion of the protection options. For more information see the SDCP Report: History of Land Use in Pima County.

#### Land Preservation and Recreation Agencies

##### *U.S. National Park Service*

The Park Service operates the Saguaro National Park in the Tucson area and Organ Pipe National Monument near Ajo. National Parks and Monuments are established to protect some historic or environmental value for the future and for use by the public. New National Parks must be established by Congress, but new National Monuments may be established by the President. National Parks can only be expanded or decreased by an Act of Congress - land within them cannot easily be sold or traded. In most cases outside uses such as grazing and mining are prohibited.

##### **Lands Managed Primarily for Protection or Recreation**

##### *U.S. Fish and Wildlife Service*

There are two large National Wildlife Refuges in Pima County: Buenos Aires in the Altar Valley and Cabeza Prieta Refuge west of Ajo (mostly in Yuma County).

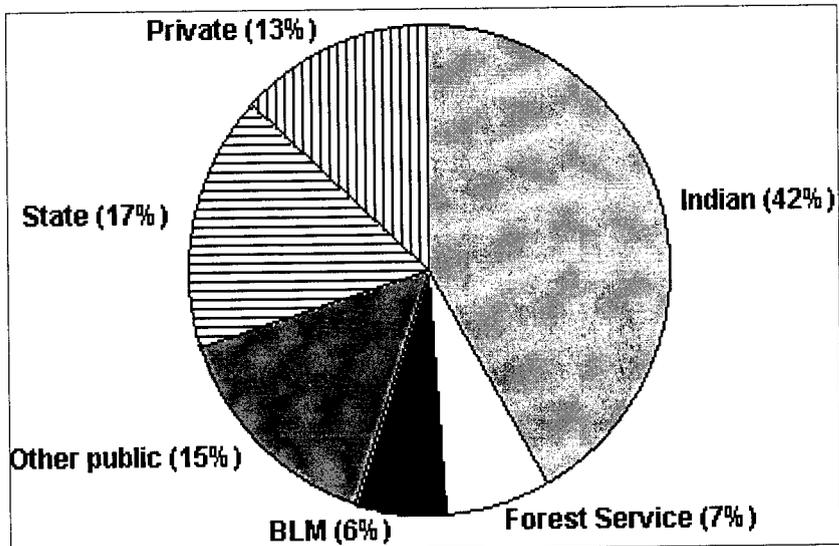


Fig. 3-1. Generalized land ownership in Pima County. The lands indicated by hatch marks are either private or easily subject to becoming private lands. The Other Public category includes land owned by local government, military lands and other miscellaneous.

**Fig. 3-2. Acreage, Elevations, and Major Watercourses of Public Lands in Pima County**

	<b>Pima County Acreage</b>	<b>Adjacent County Acreage</b>	<b>Major watercourses</b>	<b>Elevation Range (in feet)</b>
<b>National Parks</b>				
Saguaro East NP	67,385	0	Rincon Creek	2,697 - 8,599
Saguaro West NP	24,000	0	Many ephemeral washes	2,184 - 4,391
Organ Pipe NM	320,800	0	Many ephemeral washes	985 - 5,534
Coronado National Forest	337,383	419,000		2,729 - 8,999
<b>BLM</b>				
Empire-Cienega CA	(31,906)	13,094		
Silverbell RCA	(100,369)	0	Cienega Creek	3,737 - 5,000
Waterman ACEC	(3,245)	0	Ephemeral washes	1,742 - 4,051
Wilderness areas	(7,182)	0	Ephemeral washes	3,008- 7,484
Wildlife corridor	(2,514)	0	Brawley Wash	2,319-2,544
Department of Defense Goldwater G.R.	44,279	2,655,721	Ephemeral washes	641 - 2,392
<b>Wildlife Refuges</b>				
Cabeza Prieta	529,750	330,260	Ephemeral Washes	689 - 3,013
Buenos Aires	121,308	0	Arivaca Creek	3,020 - 5,923
<b>Indian Lands</b>				
Tohono O'odham	2,490,105	0	Santa Cruz River, Santa Rosa Wash, Vekol Wash	
Yaqui	895	0		
<b>State Parks</b>				
Catalina State Park	5,493	0	Cañada del Oro, Sutherland Wash	2,714 - 2,725
State Trust Land Santa Rita Exp. Range	975,000 (50,811)	0	Madera Creek	4,426 - 4,800
<b>Pima County</b>				
<b>Natural Parks</b>				
Tucson Mt. Park	18,422	0	Many washes	2,392 - 4,184
Tortolita Park	3,446	0	Many washes	3,453 - 4,397
Colossal Cave	2,238	0		3,399 - 4,191
<b>Flood Control District</b>				
Cienega Creek	3,979	0	Cienega Creek, Davidson Canyon	2,799 - 2,904
Bingham Cienega	284	0	San Pedro River	3,198 - 3,711
<b>City of Tucson</b>				
Avra Valley farmland	20,000	0	Brawley Wash	2300-2500
Bellota Ranch	6,800	0		

**Note:** Figures in parentheses are also included in the total Pima County acreage of the agency above.

Buenos Aires Wildlife Refuge includes some very significant riparian areas and wetlands, especially in the Arivaca Area and Brown Canyon at the foot of Baboquivari. The Cabeza Prieta Wildlife Refuge has high wildlife value and some ephemeral waterways and some permanent waterholes. Part of the refuge is a wilderness area, administered by BLM. The refuge is adjacent to the Goldwater Gunnery Range.

The refuge mission of the Fish and Wildlife Service is to operate the refuge for the benefit of the species or habitat for which it was established. Other uses, such as hunting, are allowed only if they are compatible with fulfilling the main mission. Wildlife Refuges are established by Congress and Congress must approve expansion or decrease of acreage. Refuge land cannot be sold for private use, although in some cases land exchanges may be possible if they fulfill the mission of the refuge.

#### *Arizona State Parks Department*

State Parks are managed for preservation of historic or environmental values and for recreational purposes. Few outside uses such as grazing are permitted in State Parks. Catalina State Park abuts the Coronado National Forest and includes a number of streams that originate in the Catalina Mountains, including a significant portion of the Cañada del Oro and Sutherland Wash before they approach the town of Oro Valley. State Parks can only be established, expanded, or decreased by an Act of the Arizona Legislature.

#### *Pima County Parks Department and Flood Control District*

Pima County's natural parks are operated primarily for recreation purposes and also for preservation of significant lands. Tucson Mountain Park was one of the first natural county parks established in Arizona, and was set aside specifically to protect this saguaro-rich area from homesteading and mining. It is next to the Saguaro National Park West and the two areas protect a large portion of the Tucson Mountains and the many washes within them. Pima County also operates the Tortolita Mountain Park and Colossal Cave Park as natural preserves.

County Parks are established, enlarged or decreased by the Board of Supervisors. In some cases, Tucson Mountain Park lands are subject to reversion to BLM if used for other than park purposes.

Pima County Flood Control District acquires floodplain land for flood control purposes. When these lands also have recreational value they may be managed by the Parks Department. This is discussed more below.

### **Multiple Use Agencies**

#### *U.S. National Forest*

The Forest Service has lands in the Catalina Mountains, the Santa Rita Mountains (largely in Santa Cruz County), in the Rincon Mountains as part of the Coronado National Forest. National Forests were originally set aside in the early 1900s primarily to protect important watersheds from activities such as logging that would degrade the value of the watershed for downstream purposes. National Forests are operated as multiple use lands on which grazing, mining, lumbering, recreation, and some commercial operations such as ski lifts and hotels are allowed. One issue of concern to many is the impact of the 1872 Mining Laws which grant individuals and businesses the rights to mining in National Forest lands, with few restrictions or fees. The federal government may restrict access to the site (not allow roads, for example) and regulates mining activities to minimize potential water pollution from an operation.

The National Forest lands in the Catalina, Rincon, and Santa Rita Mountains include the headwaters of Pima County's major watercourses. Within the National Forest are designated Wilderness Areas, as indicated on the map. These areas are more strictly managed than other National Forest Lands and generally exclude roads and other manmade structures, although hiking is allowed. Grazing may in some cases also be allowed if it was grandfathered in from prior uses. National Forests can only be established, expanded or decreased by Congress, although land trades are possible, especially if they consolidate holdings or protect valuable areas such as perennial streams. A public hearing is required for land trades.

#### *U.S. Bureau of Land Management (BLM)*

BLM lands were established early in the state's history as lands reserved by the federal government at the time of statehood. BLM lands are operated for multiple uses for the most part, except that BLM Conservation Areas are operated to protect a particular resource. Grazing is the most common use of BLM lands. Conservation areas are established, enlarged, or decreased by Congress. The 1872 Mining Law described above also applies to BLM lands. BLM lands or mineral patents may be traded to consolidate holdings or enhance an area after public hearings.

BLM lands are scattered around the County and difficult to show completely on a small map. The largest holdings are shown on the map, including the two conservation areas. The Empire-Cienega Resource Conservation area in Subarea 2 was established in large part to protect a portion of Cienega Creek and the adjacent grasslands. BLM also manages the Silverbell Resource Conservation Area and the Waterman Area of Critical Concern in the Avra Valley subarea. In addition there is a BLM Wilderness Area adjacent to the Buenos Aires Wildlife Refuge in the Baboquivari Mountains which the Tohono O'odham are claiming .

#### *Department of Defense*

The Department of Defense manages land in Pima County, chiefly the Goldwater Gunnery Range at the extreme western side of the County, adjacent to the Cabeza Prieta National Wildlife Refuge. (Only a small portion of the Range is in Pima County, the rest in Yuma and Maricopa Counties). DOD lands are managed chiefly for their value to the military for training or other purposes, but incidentally sometimes have excellent habitat values as they do in this case. Use of this DOD land is reviewed periodically through a public participation process. DOD also owns the Davis-Monthan Air Base in the Tucson metropolitan area which is used for military training, old aircraft storage, and military housing. It has a golf course and its own wells.

#### *Indian Nations*

Indian lands are under the jurisdiction of the tribes, with some management authority by the U.S. Bureau of Indian Affairs. The Tohono O'odham Nation is one of the largest in the U.S. and is almost entirely within Pima County. A disjunct part of that nation is the San Xavier District. The Santa Cruz River runs through this area and the District has an ongoing project to enhance the river and its tributaries. Some of this District land is owned individually, but most is tribal. The Shuk Toak District protrudes into the Avra Valley and is currently being actively transformed into agricultural land to be irrigated with CAP water. Indian lands are used for a great variety of purposes such as grazing, agriculture, residential, mining, recreational and commercial uses. The boundaries are established by law, but tribal land may be leased for commercial purposes such as mining or agriculture. Parts of the San Xavier District owned by individual allottees may be sold if all the allottees agree. In the 1980s a developer proposed a project on allottee land, but the allottees did not approve that action.

The Pasqua Yaqui Tribe also has a small amount of land which is north of the San Xavier District.

#### *Arizona State Land Department*

The Arizona State Land Department owns State Trust Land in Pima County, spread out throughout the area. These lands cannot easily be represented on a small map because they are "checkerboarded" throughout the area. These lands were deeded to the state at the time of statehood (1912) by the federal government and their use is governed by provisions in the Arizona Constitution and the federal law establishing the state. They are to be operated in such a way as to bring revenue for funding education and certain other purposes. They may be leased and sold but generally not traded. Most of Arizona's State Trust Land is currently leased for grazing. State land is open for recreational purposes only with a permit or a valid hunting or fishing license.

Legislation passed in 1996 offers some provisions for helping communities to preserve environmentally valuable State Trust Land, under the Arizona Preserve Initiative (API). State Trust lands within incorporated cities and towns, within ten miles of them (in Pima and Maricopa counties) are eligible for conservation consideration. This includes the entire Tortolita Mountains. Among other provisions, a public-private matching grant program was created under the auspices of the State Parks Board for acquisition or lease of state Trust lands for conservation. Entities applying for these lands must find their own funding, but State Land Department will reserve the land for some unspecified period of time to allow communities to locate adequate funding. Some funds are available to assist with purchase. (See Funding Sources below.)

State Trust Lands are the most vulnerable of all public lands and sometimes in very environmentally sensitive areas. New measures being proposed under the Growing Smarter Initiative, which voters approved 1998, may provide additional protection to environmentally sensitive State Land. Approximately 70,119 acres have been identified statewide for inclusion in an initial package of State Trust lands to be placed in an Arizona Conservation Reserve. Reclassification of this property for conservation makes it eligible for consideration for Growing Smarter grants.

In 2000 the Legislature set aside approximately three percent of State Trust Land to be preserved as open space. This, however, is subject to approval by Arizona voters as it involves a change in the constitution. Areas within Pima County that could be affected are Las Cienegas, Big Wash in the Tortolita area, part of the Tortolita

Mountains, a portion of the Cañada del Oro, Tumamoc Hill, I-19 and Valencia, and Pistol Hill in the Rincon Mountains.

### **PIMA COUNTY'S PRIVATE LANDS**

All private land is regulated at some level of government. Municipalities have major regulatory power within their jurisdiction, although each higher level of government also has applicable laws and regulations. Pima County has regulatory authority over private lands outside of municipalities and has cooperative agreements with some small municipalities. It, too, is subject to regulation by the higher levels of government. Counties basically have only the authority granted to them by the state, while cities with charter governments have much more latitude.

The applicable laws that impact use of watercourses are summarized in Appendix C and only briefly described below.

#### *General Laws and Regulations*

Two federal environmental laws have impacts on management of watercourses: the National Environmental Policy Act (NEPA) and the Endangered Species Act (ESA). NEPA requires that any major land use activity involving federal funds be studied for any possible environmental impacts that activity may have. This applies to federally owned and managed land as well as to non-federal projects using federal funding. An Environmental Assessment (EA) may be done first to make a general assessment of the scope of the impacts. If the EA indicates possible concern, or if citizens question the action, an Environmental Impact Statement (EIS) would probably also be conducted, utilizing a public process. Finding negative impacts does not necessarily mean that the project will be altered or stopped, but mitigation measures are often implemented. As a result of the EIS for the CAP canal, for example, the Bureau of Reclamation established a wildlife corridor in the Avra Valley to mitigate impacts on endangered species.

The primary purpose of the ESA is to determine which species are in need of special protection, threatened or endangered (T&E species) and to conserve and attempt to recover severely diminished species. Actions by federal agencies must be reviewed to assess their potential for harming such species. The Act prohibits individuals and businesses from conducting activities that would do things such as harm, harass, or kill listed species. The definition of the term "harm" is unclear as to how much it is directed toward harming the species directly and how much toward reduction of habitat. Agencies must also identify critical habitat for certain species. It is this provision that is a primary incentive to develop the Sonoran Desert Conservation Plan which involves a multi-species critical habitat plan. In this region 25 plant and animal species are listed as endangered.

The Arizona Native Plant Law is designed to prevent theft of protected species and to encourage salvage of native plants for landscape use. The law does not prohibit destruction of native plants by the property owner, but does require notification and a waiting period during which someone with a valid permit may salvage plants with the owner's permission. After this period plants may be destroyed to make way for construction. (See Appendix for more details).

Plant laws at the City of Tucson, Oro Valley, and Pima County levels place some additional restrictions on clearing of land with protected species and in some cases require preservation or salvage of a percentage of those plants. (See Appendix for more details).

#### **Land Use Laws and Regulations**

Land use laws and regulations are designed to protect people and their property, to provide for growth in a somewhat systematic manner, and to benefit the public. They include comprehensive planning policies, zoning regulations, and also deal with more specific matters such as development on hillsides.

The Federal Government has no direct role in private land use regulation except as the federal laws described above affect local land use.

State Law sets basic requirements and guidelines for planning at the local level, but has no direct involvement in local planning and zoning decisions. State Law, for example requires counties to have comprehensive plans and specifies the kinds of things that must be included, but does not enforce those plans. The state allows counties to charge impact fees for new development, but does not require them.

At the local level, there is an important distinction between planning and zoning. At the county level, both functions are handled by the same commission, while the City of Tucson handles zoning at the staff level and the commission has only planning responsibility. A Comprehensive Plan contains a set of policies and guidelines which

are supposed to be followed when land use decisions are made. The zoning maps and ordinances are legal documents and can only be changed through a public process and approved by the elected officials.

Pima County has a Buffer Overlay Zoning Ordinance (BOZO) which applies to developments of 80 acres or more within a mile of a public preserve, as well as "Resource Transition" areas in the County Comprehensive Plan. The most important feature is that fifty percent of the area must be preserved as open space, although golf courses, parking lots and tennis courts count as open space. The County, City of Tucson and Oro Valley have a Hillside Development Zone Ordinance that prohibits development on certain designated peaks and ridges, with allowable development dependent on slope. Maps show which areas are included. The same entities have grading ordinances the purpose of which is to regulate the development on potentially hazardous terrain and preserve the natural scenic beauty and vegetation. Grading must minimize scars and adverse impacts of cut-and-fill.

In addition both county and municipalities have building codes, subdivision requirements and other requirements beyond the scope of this report. See the SDCP Report, History of Land Use in Eastern Pima County for a history of the development of local planning and zoning codes and a more detailed description of them.

#### *Floodplain Management Laws and Regulations*

Floodplain management laws and regulations are designed primarily to protect people and property from potential flood damage. They are also designed in some cases to provide relief from flood damage.

At the federal level, the Federal Emergency Management Agency (FEMA) which is responsible for dealing with flood disasters (among other things) has established requirements which must be complied with in order for people in a particular area to qualify for federally subsidized flood insurance. These are accompanied by FEMA floodplain maps which delineate floodplains and possible hazard areas. Floodplain maps for areas within Pima County may be viewed at Pima County Flood Control District office or at the appropriate office of the municipalities. Federal flood insurance covers flood damage, but not erosion damage, which is a problem in this area.

The State sets minimum requirements that counties and municipalities are to meet and requires each county to have a flood control district with certain characteristics.

The Pima County Board of Supervisors performs the duties of the county flood control district board and the Department of Transportation and Flood Control performs the staff functions. The county floodplain ordinances includes requirements for such things as how far a structure must be set back from an erosion control area, what may be placed in the floodplain and under what conditions, and what kinds of flood control structures are permitted or required under different conditions. Permits are required for new construction on any land within a floodplain, except that for some structures such as transmission poles, public bridges and water crossings, plans for the structure must be provided but no permit is needed. The permit application must include detailed plans for the proposed structure along with a description of how that structure will be protected against flood damage, and will not cause flood damage to others. Within the floodway the only uses allowed are agricultural, some commercial-industrial uses such as parking areas, recreational uses and landscaping. Sand and gravel operations are allowed under certain conditions in the floodplain, but not the channel. (The City of Tucson does allow sand and gravel mining in the channel itself). Rules also govern what can be done in the floodway fringe area and include provisions such as requiring them to offer minimum obstruction to the flow of water. (See PCFCD web site for more detail).

Certain areas with high potential for flood damage because of existing conditions are designated as "Critical Basins." Others where the potential for flood damage is high because of anticipated conditions are designated "Balanced Basins." Pima County has special rules in these areas requiring such mitigating measures as detention basins to minimize the impacts of development. Where such designations occur in the subareas, they are discussed in those chapters.

Tucson, Marana, and Oro Valley have flood control offices, but Pima County handles flood control duties for the smaller municipalities. The municipal flood management laws are relatively similar to Pima County, with some exceptions. (See Appendix C). The City of Tucson's Stormwater Master Plan states that protection and preservation of natural drainage systems should be the primary emphasis of City stormwater management efforts. Nonstructural solutions to flooding hazards are be the preferred strategy over structural solutions.

#### *Riparian Protection Laws and Regulations*

Riparian protection laws and regulations are designed primarily to protect riparian areas, vegetation, and habitat.

**Federal Law** - The most relevant federal laws are the ESA (see above) and the Clean Water Act (CWA). The CWA, implemented by the Environmental Protection Agency (EPA), deals with water quality as well as with

activities that may affect watercourses in other ways. If someone wishes to make alterations to watercourses as defined in the law, that person must apply for a Section 404 permit. Permits are not only reviewed by EPA but also by agencies such as the U.S. Fish and Wildlife Service and are finally granted or denied by the U.S. Army Corps of Engineers.

Pima County's Watercourse and Riparian Habitat Protection Ordinance is intended to preserve riparian vegetation along watercourses in unincorporated areas. Since June 1999 the law applies to individual home construction which was previously exempted. It applies to certain areas delineated as containing riparian habitat on official maps. The ordinance is incentive based, not prohibitive, and includes incentives such as allowing smaller setbacks and smaller lot sizes in exchange for preserving vegetation. Allowable mitigation measures include replacement of habitat and payments into a county fund to pay for acquisition and preservation of riparian habitat elsewhere.

Tucson has two ordinances designed to protect riparian areas. The Environmental Resource Zone Ordinance (ERZ) is intended to preserve fourteen major washes around the urban fringe in their natural state, including Agua Caliente, Anklam and Enchanted Hills Washes. It encourages developers to leave washes in their natural state and, if alterations are proposed, the developer must submit a plan that provides for 100 percent restoration of the riparian habitat. The Watercourse, Amenities, Safety, and Habitat (WASH) Ordinance is an urban complement to the ERZ. It applies to all development within the city extending fifty feet from the banks of 34 identified washes, including Sabino Creek, Pima Wash and Arroyo Chico. It does not apply to single house construction.

#### *Water Laws*

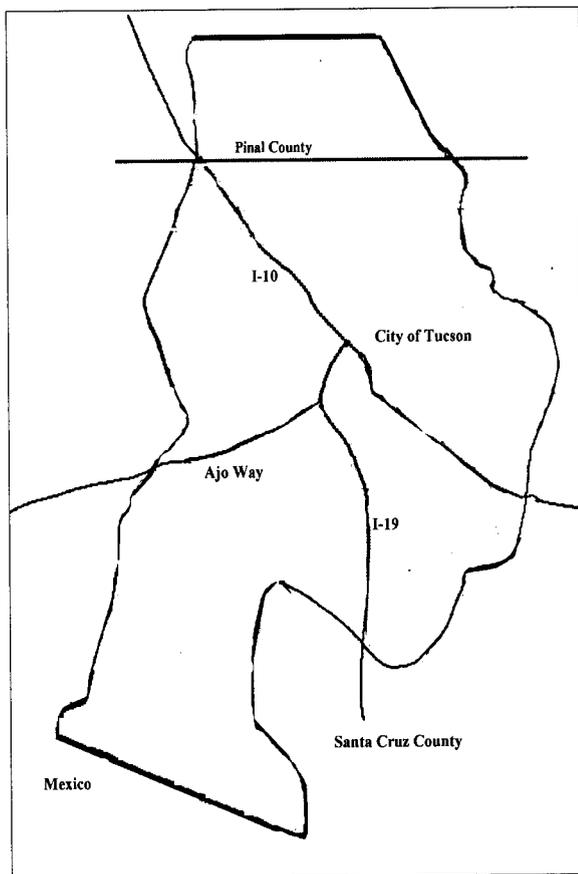
**Water Quantity** State government has primary responsibility for management of water quantity. The Arizona Department of Water Resources (ADWR) is responsible for allocation of surface water and for certain types of management of groundwater use. Surface water is allocated through a permit system where senior permit holders have precedence over those who get their permits later. ("First come first served.") Most of the surface water in the County was allocated early in the twentieth century and there is no more surface water to allocate. Virtually all surface water rights are being adjudicated through a lengthy process which involves settlement of Indian water rights claims.

ADWR also issues instream flow permits for appropriation of water to be used in the stream for habitat or recreational purposes. Applicants need to show that there is a value to be preserved, that there is adequate water for that purpose, and must include thorough documentation with the application. The process can be lengthy, but if successful the permit protects the stream from later diverters of surface water. Existing rights holders at the time of the application have priority over the instream flow permit holder, so existing surface water rights are not reduced. A instream flow permit is not protected from damage by groundwater pumping. Within Pima County, Cienega Creek has full instream flow certification. Instream flow applications have been filed for Buehman Creek, Sabino Creek, and Arivaca Creek. Applications have also been filed for portions of the San Pedro River in Cochise County.

Groundwater is regulated under a different set of laws, also administered by ADWR. Most of eastern Pima County is included in the Tucson Active Management Area (TAMA). Prior to passage of the Groundwater Management Act (GMA) in 1980, the only legal restrictions on groundwater use were on expansion of agriculture in some areas. The GMA established goals for the AMAs. The main goal of TAMA is to reach "safe yield" by 2020, although projections in the Third Management Plan are that this will not be achieved. Safe yield means that water use must be balanced by renewable water supplies,

Another tool is "assured water supply" a provision that new developments have an assured supply of water for at least 100 years, as defined by the law. This can be shown by a number of methods which do not necessarily guarantee that water will actually be available for the particular development. For example, a developer or water provider can demonstrate assured water supply by signing a subcontract with an entity that has a CAP contract, or by paying into a fund (administered by The Central Arizona Groundwater Conservation District) to recharge water somewhere in the AMA even if it is not physically available for that development.

Arizona law does not recognize that there is a connection between groundwater and surface water for the most part. Even though groundwater withdrawals may affect surface water flow, they are treated as separate entities unless the pumping is right in or adjacent to the stream. Although hydrologists have long shown that groundwater pumping can have a major impact on surface flow, Arizona law has never been amended to accommodate this scientific reality, as is the case in many other western states. The GMA deals with groundwater and has no authority to restrict pumping for the purpose of protecting streamflow. The Arizona Supreme Court has under advisement an



**Figure 3-4. Tucson Active Management Area.**

appeal which could extend that authority somewhat. The Santa Cruz AMA (in Santa Cruz County), on the other hand, already has some authority to relate groundwater and surface water under state law.

In certain limited situations the Federal Government has "reserved water rights" on federal lands that can limit other water uses. This applies to Indian lands where courts have established that in general water can be claimed for those lands to the amount necessary to fulfill the purpose for which the reservation was made. Most of the Indian water rights claims in Arizona are being adjudicated, although a settlement was reached with the Tohono O'odham that guarantees them the right to 37,800 acre feet of CAP water and 28,200 acre feet of water from other sources such as treated wastewater. (Southern Arizona Water Rights Settlement Act - SAWRSA). The Tohono are just beginning to use their share of the water for agriculture and riparian restoration projects. Federal reserved rights may also be claimed for properties such as National Parks, but those rights date to the time the park was established and are junior to earlier rights. In some cases the Federal government has succeeded in restricting groundwater pumping to protect a species on federal land.

#### Water Quality

Both federal and state governments have responsibility for protecting water quality. Entities that wish to discharge water to a "water of the U.S." must apply for a permit from EPA and meet those permit requirements, under the CWA. These permits are called NPDES permits (National Pollution Discharge Elimination System). Permit

requirements are reviewed on a scheduled basis and sometimes made more stringent. They are tailored to the particular circumstances of the discharger and the watercourse. ADEQ, under the Environmental Quality Act (EQA) and CWA must classify the watercourses of the state in terms of their uses (e.g., fish and wildlife, human full body contact, or agriculture) and review those classifications every three years. Some uses carry with them much stricter standards than other uses. Discharge permit conditions are based on those classifications. ADEQ has designated a few streams as "unique waters" which warrant stricter water quality protection than other streams. A portion of Cienega Creek has this designation.

The CWA also regulates non-point sources of pollution - those pollutants that come from a number of sources and do not reach the watercourse through a discrete source such as a pipeline. Urban stormwater is a form of non-point source pollution as the pollutants flow off a great variety of sources. Large communities are required to have programs for reducing the water quality impacts of stormwater runoff. Both Tucson and Pima County have such programs under their stormwater permits. Pima County's plan includes such measures as street sweeping, land development controls, a household hazardous waste program, and a stormwater sampling program. The county also advises businesses about ways to reduce the problems. The City's Stormwater Master Plan mentioned above emphasizes the preservation of vegetated watercourses and urges water harvesting. There are also incentives for retaining storm flows on site.

The EQA also regulates discharges to groundwater. Anyone with activities that might result in polluting the groundwater must apply for an Aquifer Protection Permit (APP), although some activities such as golf courses are exempt. These permits may be reviewed and the permit issued in connection with the NPDES permit application or if they are not near a watercourse will be reviewed separately. Release of water to a stream (in a recharge project, for example) may include different (often more strict) permit conditions under APP than under NPDES. Finally ADEQ regulates how wastewater may be reused, and regulates usages with direct human contact much more strictly

than uses where human contact is restricted by measures such as fencing. Use on food crops, for example, has different requirements than use on crops such as alfalfa. For more information on all these laws, see Appendix C.

## **Funding**

### *Floodplain Management*

Floodplain management is funded primarily through a tax levy on Pima County landowners, by local municipalities, and through bond funds. Some examples of flood-mitigation and prevention expenditures follow. Voters authorized \$63.8 million in bond funds in Pima County's 1984 election to be used for a variety of flood control projects throughout the area, including incorporated areas. These funds were augmented by another \$20 million in funds from various sources including federal aid, state aid, tax levies and other sources. (See appendix D for a summary of projects funded by bonds and other sources). The estimated cost of Pima county's 5-year Capital Improvement Program for flood mitigation is approximately \$42 million dollars, including funds for floodprone land acquisition. Some of these expenditures also benefit wildlife or recreation, so are not strictly all flood mitigation costs.

Programs are also financed through Improvement Districts, which are special districts established by the county at the request of property owners in the district. A tax levy on landowners in the district may be augmented by Pima County Flood Control District funds. See Appendix D for a list of such district funding.

Federal funds are also available for flood control structures, including rehabilitation. The U.S. Army Corps of Engineers can fund studies, flood control project design, and construction of projects that meet federal cost-benefit guidelines. Similarly, the U.S. Bureau of Reclamation funds a variety of flood-related projects with emphasis on projects involving rehabilitation of riparian areas. It also can fund some kinds of constructed wetland projects.

### *State Riparian Protection and Rehabilitation Opportunities*

While the state does not have any special laws to require protection of riparian habitat, it does have three provisions for obtaining funding for protection. The Arizona Heritage Fund was established by initiative and sets aside \$20 million annually to fund projects of several types. It funds research efforts, land preservation and restoration projects, and environmental educational activities. The fund is administered half by the Arizona Game and Fish Department and half by Arizona State Parks. Some of the funds are used directly by the agencies, often for land acquisition and some are awarded competitively to groups, individuals and other agencies. Several riparian-related projects have been funded in Pima County.

The Water Protection Fund was established by the Arizona Legislature specifically to fund projects to preserve and restore riparian habitat. This fund is administered by an office housed at the Arizona Department of Water Resources and partially administered by the State Land Department. Projects are awarded competitively and a many projects have been funded in Pima County. See Appendix E for a list of projects funded by these two programs in Pima County.

Money is available for State Trust Land acquisition through the Growing Smarter Initiative, using monies from the State Land Conservation Fund which is administered by the Arizona State Parks Board. Twenty million dollars per year are available for eleven years, beginning in state fiscal year 2001, to award grants for the acquisition of State Trust Lands. The goal of these grants is "to conserve open spaces in or near urban areas and other areas experiencing high growth pressures." Conservation may occur through permanent or temporary acquisitions, such as leases of up to 50 years in length, purchases of a parcel's development rights, or "fee simple" purchase of a parcel. Grants may be made for up to 50% of the appraised value of a land parcel. This is a new program, so there is no history of funded projects in Pima County.

## **HUMAN FACTORS THAT AFFECT WATERCOURSES**

### **Tucson's Watersheds and Watercourses in the Past**

Many of our watersheds and watercourses are very different from what they were in past times, while others have changed little. Before 1850, for example, the Santa Cruz River was a shallow creek with springs and marshy areas in some places. The water flowed under the surface in spots and on the surface in others, but there was usually enough vegetation in the parts of the river through Tucson to support cottonwood trees and other riparian vegetation. Archaeological remains indicate that people caught edible fish in the river in the past. The Rillito River, too, had shallow surface flow and riparian vegetation for much of its length. One report even mentions beaver dams on the

river near Ft. Lowell. Both of these rivers are usually dry today and have steep banks in many places. There are few areas along those rivers with healthy riparian habitat. Other watercourses such as Sabino Creek are not too different from what they were in past times. The Creek still flows perennially through Sabino Canyon.

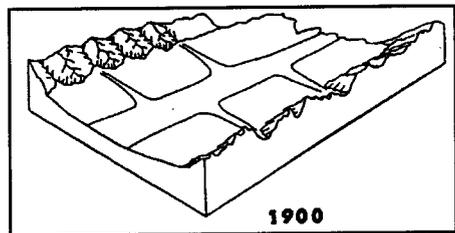
Most of the washes in the area that are normally dry today were also normally dry in past times. Most of our urban washes have, however, changed as a result of urbanization or because of flood control structures. Some are completely human-engineered, some are vastly altered and some are relatively natural. Arroyo Chico embodies all of these characteristics. It looks like a natural dry wash from Reid Park to Country Club Road, but was actually constructed as part of a desert-environment for the nearby housing development. Although there was a drainage in earlier times, it was not the wash we see today. The wash is hardly visible in the upstream areas where in some places it goes under the streets and in others the water flows down alleys. Downstream of Country Club it has been channelized and where it goes under Kino Boulevard it has been cemented. It goes once again into a natural-looking channel between Kino Avenue and Park Avenue, but with steep sides and finally reaches the Santa Cruz River through man-made channels and tunnels. The City of Tucson has been looking at alternate flood control projects for the section east of Kino Boulevard which must now carry greater volumes of water due to upstream urbanization.

Building flood control structures is very costly, but so is the cost of repairing damages from floods. Repairing damage to public infrastructure from the 1983 flood in Pima County cost more \$64 million, and costs from the 1993 storm were at least \$13.9 both for emergency repairs and long-term improvements. These do not include any costs incurred by individual landowners.

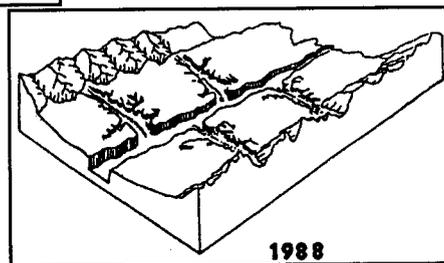
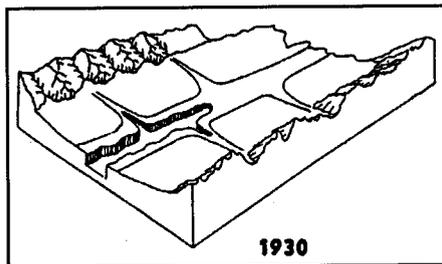
**The Human Role in Arroyo Formation**

Deeply cut arroyos are common features of the Southwest, but many of today's arroyos were shallow watercourses with ill-defined banks in past times. Some arroyo formation is natural and arroyos have formed and filled up in the past depending on factors such as climate change. The pace of arroyo cutting quickened at the end of the 19<sup>th</sup> century and beginning of the 20<sup>th</sup> century as human activity increased. Overgrazing is one major cause of arroyo cutting in much of Arizona.

Typically, in years of high precipitation people grazed large numbers of cattle. Then when the much less for the animals to eat of edible plants. In subsequent eroded away, leaving arroyos in arroyo cutting were roads, where ruts which subsequently eroded



drought years came, there was and the watersheds were stripped high-water years the bare soil their wake. Other major causes of wagon ruts or cattle trails left long and became arroyos. Fig. 3-5 illustrates conceptually arroyo formation in the Altar Valley. (Source: Soil Conservation Service 1992).



**Fig. 3-5. Schematic diagram of channel cutting in Brawley Wash.**

**The Human Role in Flooding**

Floods are referred to legally as "acts of God." The news media also tends to use similar terminology and sometimes refers to the natural impacts of "mother nature." Most flood damage, however, is exacerbated by human activity, whether it is clearing of vegetation from the watershed which leads to soil erosion and less water-retaining capacity or whether it is putting vulnerable structures in the floodplain itself. The impacts range from changes to individual properties to region-wide problems. As one Catalina Foothills resident complained recently "The wash has begun to erode towards my house since that damned church put in a huge parking lot and the runoff goes down my wash." On a larger scale, a lawsuit that Marana filed over flood damages led Pima County to agree to build the multimillion dollar levee described in Chapter 8. This lesson was learned at great expense in Costa Rica and China in the past few years, both of which suffered enormous flood damage caused by the

combination of heavy precipitation and unwise human modification of the watersheds by lumbering and land clearing and location of residences in floodprone areas.

Wise use of the floodplain, then, can reduce costs of repairing damaged areas and can reduce the cost of building flood control structures, as well as providing benefits for wildlife, recreation and aesthetic enjoyment.

### LAND USE TYPES AND IMPACTS

Various kinds of land uses can impact watersheds and watercourses by changing how they function, altering their potential to damage human structures, and by changing their value as riparian areas and wildlife habitats.

Each of these land uses can be implemented in ways that either increase or minimize those changes. Land uses that are expected to maintain the status quo or decrease are agriculture (except on Tohono O'odham land), and ranching. Most of the copper mines in the area have a limited amount of ore and limited lifetime for active extraction and will eventually have an inactive status, although their impacts on the land will continue. There is always a possibility of new copper mining activity in the Santa Rita Mountains and elsewhere. Land uses that are expected to continue to increase are residential, industrial, and commercial uses, with transportation, utilities, flood protection, sand and gravel mining, and recharge, projects keeping pace with growth. Present tendencies also indicate that preservation and rehabilitation efforts will also increase.

#### Primary Uses

##### *Ranching/Grazing*

Ranching has been a significant land use in this region since the Spanish introduced cattle and horses starting in the late seventeenth century. Cattle need to be near water and Father Kino noted in the early eighteenth century that the Indians were complaining that their springs were drying up because the padres were pasturing so many cattle. The need for water is highly significant for riparian areas because cattle tend to stay in areas with water if they can, causing damage to those areas. Ranchers can supplement these water supplies with stock ponds (often made by damming small drainages) and watering holes utilizing groundwater to keep the cattle from staying in one place.

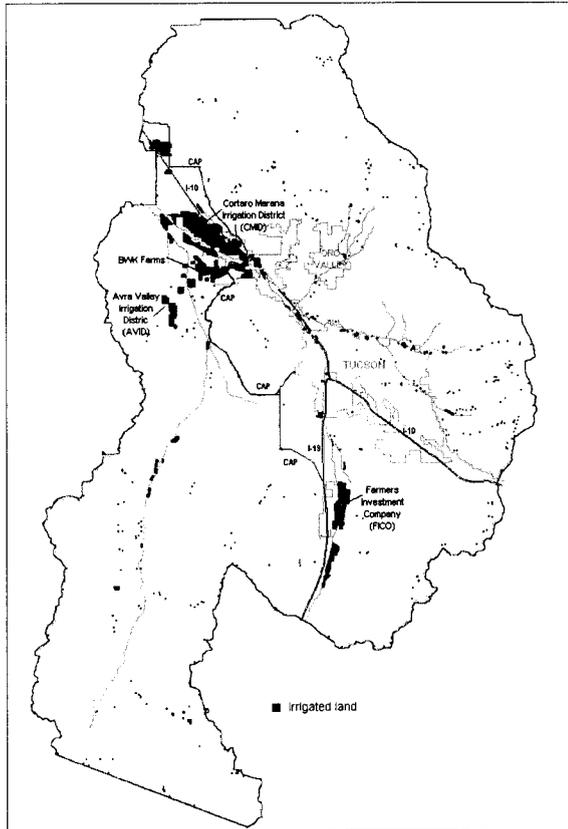
Cattle are grazed on most of the National Forest, BLM, and State Lands in the region, and on some private lands, including riparian areas on many of these lands. Arizona law taxes private land used for grazing purposes at a lower rate than most other uses, so some landowners graze cattle on property they intend to develop, in order to minimize their tax bill.

In 1997 there were 166 ranches in Pima County that grazed about 39,000 cattle and calves (including dairy cattle), down from more than 50,000 in 1992. 2,066 of those cattle were on allotments in the Santa Catalina Ranger District of the National Forest. Cattle grazing is also extensive on the Tohono O'odham Nation. Carefully managed, grazing can have minimal or even beneficial impacts. The Arizona Nature Conservancy, for example, has used managed cattle grazing along Sonoita Creek in Santa Cruz County to help control non-native grass species. If poorly managed, however, grazing can have severe impacts on watersheds and riparian areas. The most extreme case of this in Pima County occurred in the 1880s when an usually rainy period, which produced lush forage, led ranchers to believe that the range could handle many thousands of cattle. When a drought period followed, many of the cattle died, but not before they had eaten all edible vegetation. This in turn led to severe erosion when a flood period followed and changed the character of some watercourses and to the introduction of non-native forage species to replenish the depleted vegetation.

Grazing may impact watercourses by:

- Trampling of vegetation, especially along pathways to water. The impacts of trampling are most severe when young seedlings are getting established.
- Consumption of vegetation, with impacts severest in the early growing season and in drought years. If too much vegetation is eaten, the bare ground is subject to erosion. They also prefer some plants to others sometimes leading to depletion of the palatable plants such as cottonwood seedlings or grass which then are supplanted by less palatable plants such as saltcedar or cholla.
- Degradation of water quality occurs both from soil erosion and from bacteria build-up from defecation.
- Competition with wildlife for food and pressures to remove predators.

All of these activities can impact habitat for a wide range of species including insects, fish and birds. Loss of



**Fig. 3-6. Agricultural lands in Eastern Pima County**

sheltered areas and consequent increase of water temperatures may affect fish breeding, for example, and loss of food and nesting areas for birds can impact their reproduction. The Forest Service has begun to place more restrictions on grazing in parts of Arizona partly in order to protect an endangered species, the Southwest Willow Flycatcher. The Arizona Department of Environmental Quality has issued Best Management Practices guidelines for grazing, designed to minimize the water quality impacts.

Grazing management involves providing a variety of water sources, and moving cattle frequently and on a schedule that avoids use of riparian areas entirely, or at least during the spring growing season. It also involves carefully matching the number of cattle to the available resources. Fencing off riparian areas has produced dramatic regrowth of riparian vegetation in some areas such as the San Pedro Riparian Natural Conservation Area in Cochise County.

In July 1999, the U.S. Fish and Wildlife Service issued a biological opinion regarding the Forest Service's proposals on grazing in the Coronado National Forest to assess the impacts that various grazing levels could have on certain threatened and endangered species. (ASDO/SE 2-21-98-F-399. See the Catalina Ranger District web site for the full opinion. <http://www.fs.fed.us/r3/coronado/scrd/>) This process was intended to reduce negative impacts of grazing on habitat and includes proposals to reduce grazing significantly in drought years. Both agencies determined that limits on the amount of vegetation grazed and other controls were needed to protect the habitat of some species. Some critics feel that more action needs to be taken to control the impacts of grazing in these

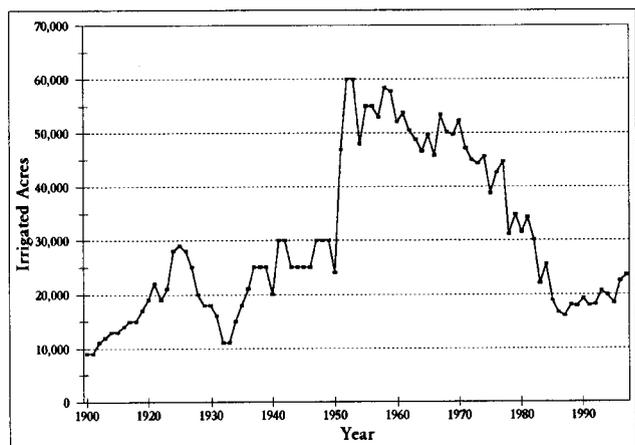
areas.

Ranching is one of the open space uses proposed for protection under the SDCP. Modern grazing management strategies can contribute to preservation of open space, watersheds, and riparian areas, minimizing impacts and usually leading to higher long-term viability of the ranchland.

### Agriculture

People have been farming in Pima County for at least 2,500 years. For most of that time crops produced were almost always used locally. Some farming was done by taking advantage of the summer rains. Nutrient-rich water was captured as it flowed in small washes and was diverted to fields.

Archaeologists have found Hohokam irrigation systems near the Santa Cruz River dating to about 500 BC. These canals were never as extensive as they were along Salt River and Gila River because the dependable water supply is so much less in this area. The canals were dug by hand with short-handled hoes and needed constant maintenance. Little is known about what impact that farming had on the watercourses, but it was minimal in comparison with what came later. The Spaniards, too, used irrigated farming at San Xavier and in the Tucson area. They had water distribution



**Fig. 3-7. Agricultural acreage in Eastern Pima County.**

systems which divided the available water among the Spanish farmers according to the water supply, but this system did not apply to their Indian neighbors and disputes arose from time to time when the Indians felt that they did not have enough water for their needs.

After Arizona became a territory a new legal system developed that divided surface water according to priority of claims as described in the legal section above. Chinese vegetable gardeners and farmers producing hay or other crops had disputes with municipal supplies over water allocation. After the railroad arrived, farming gradually changed from production primarily of what was needed locally to production primarily of cash crops for sale elsewhere. At the beginning of the twentieth century the U.S. Geological Survey reported that there was no regular flow past the Congress Street Bridge, as all the water at low flow times was diverted, mostly for agricultural purposes.

As pumping technology improved groundwater became the primary source of water for agriculture and by the 1930s groundwater pumping had increased greatly. Cotton and alfalfa have been the major crops, along with corn, pecans and vegetable crops. Agriculture does best with a dependable supply of water, relatively flat land, and fertile soil, all of which are most readily available near parts of the Santa Cruz River, the Rillito and the Avra Valley. There is no large-scale commercial farming along the Rillito today, but it still persists near portions of the Santa Cruz River (Marana and Green Valley) and in the Avra Valley.

Since broad floodplains and the lands adjacent to them are so well suited to agriculture, the areas near watercourses with the characteristics mentioned above are most impacted by agriculture. Early in Arizona's territorial history most of the irrigable land near watercourses was claimed by someone. The watercourses are impacted by land clearing and reduction or elimination of riparian vegetation and by water diversions and groundwater pumping. Periodic inundation by floodwater enriches agricultural lands, leaches out salts, and helps restore groundwater supplies, but in some cases the farmers have attempted to prevent or reduce incursion of flood water onto farm land. (See Flood control below)

Since the 1970s agricultural acreage has declined in Pima County. Part of this is due to urbanization of farm land in the Green Valley and Marana areas. Part of this is due to the City of Tucson's purchase of agricultural land in the Avra Valley in order to claim its water rights for urban use. This trend is expected to continue with one major exception. As part of the water rights settlement, the Tohono O'odham have begun to develop more agricultural land in the Shuk Toak area (west Avra Valley) and will do the same near San Xavier when a CAP pipeline reaches the district in 2001.

Conversion of farm land to urban uses has mixed consequences. Depending on the crop and on the type of urban use, water use can either increase or decrease. Conversion of land use from growing alfalfa, for example, to apartments with desert landscaping may result in lower water use per acre, while conversion from vegetable crops to golf course-resort use may result in higher water use. In some cases conversion will may require flood control structures, as it has in the Marana area where a berm will protect new and existing residential areas on the east side of the river.

The fate of abandoned farmland is another significant issue. When the City of Tucson bought thousands of acres of farmland in the Avra Valley, the City did not generally use the land for another purpose or make plans to rehabilitate it. Since the City bought the land for its water rights any land use that would use water needed by city customers was undesirable. Tumbleweed and other non-native plants took over the land, as has happened on farm land in Pinal County and elsewhere. One Tucson Audubon Society rehabilitation project on some abandoned farmland in the Marana area near the Santa Cruz River is discussed in Chapters 8 and 10. This may prove to be a model for other rehabilitation efforts.

### *Mining*

Mining for minerals began in Spanish times in Pima County and grew after Arizona became a territory. The area has many abandoned prospecting holes and abandoned mines, sometimes accompanied by ghost towns. Many mountain ranges in Pima County show evidence of prospecting. While silver was mined in the early years, copper has been the mainstay of the mining industry in this area for about one hundred years, along with various other minerals extracted with the copper such as molybdenum and zinc. A series of copper ore locations (the copper belt) extends for many miles through Central Arizona and includes the area around Green

Valley, the Santa Rita Mountains, in the Silverbell Mountains and on the north side of the Catalina Mountains near San Manuel.

Mining has two major requirements: availability of ore and availability of water for processing. The mines near Green Valley could draw on a water table related to the Santa Cruz River and the mines at San Manuel have the San Pedro Valley for a water source. Another need is a way to transport the processed ore to a smelter and to markets. The arrival of the railroad in the 1880s was a great help in this regard and branch lines were built to connect to the main railroad lines.

#### Large open pit copper mines

While there is underground mining near San Manuel, most of the mining in this area is done in open pit mines where the top layers of soil and rock are removed to reach the copper ore-bearing rock. The ore is processed by a flotation process which uses water and the rejected material must then be reused and eventually discarded in tailings ponds. This water is contaminated with various chemicals and minerals so measures have to be taken to assure that groundwater is not polluted. The tailings are exposed in large basins where the water evaporates leaving a growing pile of mineralized materials. Twenty years ago it appeared that copper mining was coming to an end in this area, but new techniques for economically extracting copper from low-quality ore have extended the lifetime of the copper mines. It is now possible to leach rejected low quality ore-bearing rock to obtain concentrated copper. The viability of the copper industry is closely related to the price of copper which fluctuates on the world market. New, more productive mines in other countries with lower production costs have partially supplanted the American mines.

Cyprus Climax operates three open-pit copper-molybdenum mines, and two molybdenum roasting plants, at its Sierrita facility north of Green Valley. The ore is the lowest grade ore (0.27%) of any U.S. mining operation. ASARCO operates the Mission near Green Valley and the Silverbell west of Marana. The mines and tailings ponds extend from Green Valley into the San Xavier District which leases land for mining. Phelps Dodge is reopening its mine and smelter at Ajo which had been closed since 1985. BHP recently closed its mine at San Manuel just over the County line on the San Pedro River for economic reasons.

There has been a proposal for opening up another copper mine at the northern end of the Santa Rita Mountains, but this proposal has been put on hold at least for the time being.

Copper mining impacts watercourses in a number of ways. The amount of water used lowers the water table and in some cases interferes with surface water flow. The transformation of the land through the open pit mines, tailings ponds, and other accouterments of a mine completely changes the landscape and alters drainage patterns. The possibility of contamination of groundwater or surface water is always present, although the state now closely regulates the water quality and the Cyprus mines have continual groundwater quality monitoring in the vicinity of the tailings ponds.

The long-term prospect for copper mining is for it to decrease as the ore bodies are emptied of their ore and the financial returns decline in the face of foreign competition. New ore bodies may, of course, be found in areas where mining is feasible, which may change the picture for a while. Mining for construction and landscape materials

The mining of materials for construction depends on population growth in the area, and that growth in turns depends on availability of construction materials. Rock is broken down by erosion at the higher elevations and carried downstream. When the water reaches the valley it spreads out in the channel. The change in gradient causes deposition of sediment. The coarser material is deposited near the mountains and the materials become increasingly finer in the alluvial valleys.

Since it is costly to transport these materials, the pits are located as near as feasible to where the materials will be used. As growth expands to outlying areas, new pits may be located in those areas where possible if the cost is to be kept low. Most sand and gravel is taken from in and near the streambeds where it is readily available. Water is used to wash the materials which are sorted by size for sale. The next big flow deposits more gravel which can then be mined. Some of the sand and gravel operations are very extensive and move many tons of material daily. An easily accessible very large gravel pit can be seen near the Orange Grove exit of the I-10.

The presence of gravel pits in the streambeds can have a variety of impacts related to how they affect the flow of water. They may slow down the water, allowing it to accumulate in ponds or may cause erosion as water swirls into new channels. When flood waters inundate the pit, sand and rocks settle to the bottom rather than go downstream, and are thus available for mining. Sand and gravel mining ultimately lowers the level of the channel if the amount removed exceeds the amount being deposited.

Landscape materials such as decomposed granite and boulders are also mined in the area. In some cases the

decomposed granite is collected and in others chunks of granite are broken up to create the landscape materials. While this is not a water-intensive operation and does not have to occur in streambeds, it may affect the watershed and the watercourses depending on the location and methods of extraction.

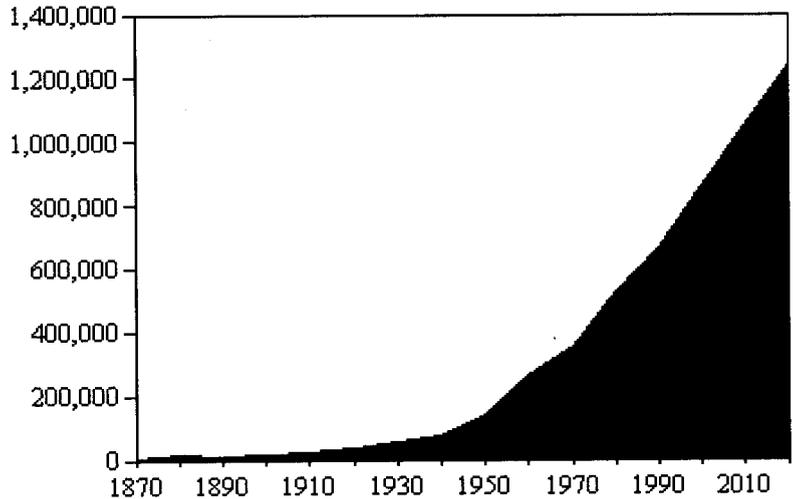
**The Impacts of Urbanization on Watersheds**

Urbanization can have major impacts on watercourses. As more people and their buildings and roads occupy the watershed, the way water flows to the watercourse or seeps underground changes. Usually this means that large amounts of water flow off buildings and pavement, collect in the streets and flow rapidly downhill to the nearest watercourse and then are conveyed further downstream. Some streets are especially well-known for being nearly impassable during a storm. These floodprone streets are often the remnants of former watercourses.

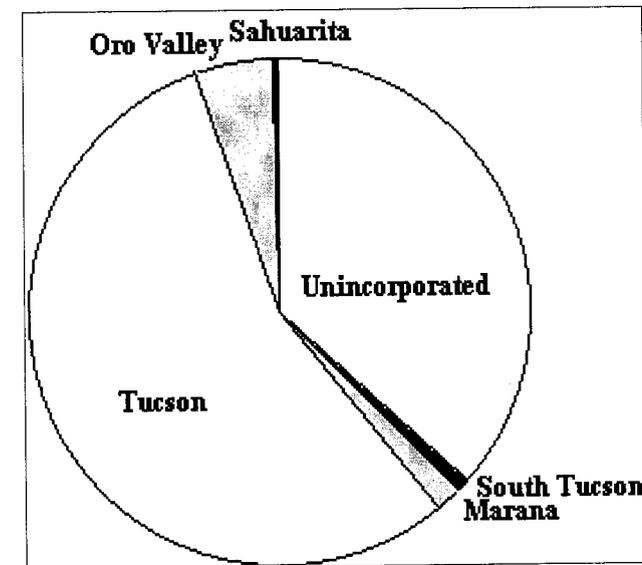
The closer that development occurs to the watercourse, the more direct the effect on it. Where riparian vegetation is cleared to the edge of the banks, most of the normal watershed functions are lost in that area and the stream is affected. If riparian vegetation is replaced by turf, as it has been, for example, in some golf courses, some of the functions of the floodplain are retained even though the wildlife value is not.

*Residential and commercial development*

The population of the Tucson area has increased steadily over the past century, with major acceleration occurring after World War II. The city limits have also grown from walled presidio and the one square mile city limits to the spread out metropolitan area we see today. In 2000 the population of the city is almost 475,000 and this is expected to grow to 565,700 by 2015. The population of the county, on the other hand, is 854,000 in 2,000 and is expected to grow to 1,119,342 by 2015. Approximately 63 percent of the population lives in the five incorporated areas of Marana, Oro Valley, Sahuarita, South Tucson, and Tucson.



**Fig. 3-9. Population growth in Pima County.**



**Fig. 3-10. Population Distribution in Eastern Pima County**

**Residential development**

In past times people had to live near surface water supplies because they had no other alternative. The areas along the Santa Cruz River and the Rillito where there were springs or flowing water were the first settled. As water diversion and groundwater pumping technology improved, people were able to live farther from their water supply. Our newest water supply, the CAP comes from hundreds of miles distant.

Locations for homes and apartments are chosen for a variety of reasons.

- Availability of land
- Cost of land and construction
- Scenic beauty, including views of watercourses
- Proximity to convenient transportation routes
- Proximity to services and quality schools
- Minimal legal constraints

The cheapest available residential land is often on the outskirts of town or in parts of town with other

drawbacks, such as land near the airport with its noise problems. Construction costs are generally lower for land that is relatively flat, where land clearing costs are low, where utilities can be provided cost-effectively, and lower-cost houses can be produced in quantity. The most scenic lands tend to be on the outskirts of town, especially near the public lands and in the foothills. In many of these areas the cost of construction is higher because of the terrain so homes tend to be expensive and on larger lots. In addition, it is more costly to provide services in remote areas or areas with hilly terrain, but many people are willing and able to pay more for the scenic amenities, even though homebuilding diminishes some of the scenic views for others.

**Fig. 3-11. Generalized Effects of Human Activities on Stream Discharge**

Activity	Water		Sediment Load	Other Effects
	Flood Peak	Perennial Flow		
<b>Land clearing, construction</b>	increase	decrease	increase	Decreased vegetation
<b>Impervious surfaces</b>	increase	increase	either, depends	more water in channels with greater velocity, more sediment discharge downstream
<b>Storm drains</b>	increase	decrease	either, depends	decreased recharge to local groundwater, increased rate of conveyance to stream
<b>Mining sand/gravel</b>	minimal	minimal	short or long term decrease	lowering of stream bed; decreased extent of flooding, increased bank erosion, decreased local recharge. Flow may add sediment to the pit which can then be further excavated.
<b>Vegetation planted on floodplain</b>	decrease	no change	decrease	increased habitat and aesthetic values; can increase local depth of flooding
<b>Groundwater pumping</b>	decrease	decrease	increase	Loss of riparian habitat. These effects only felt in areas where surface and groundwater connected. Lack of vegetation to stabilize banks may increase erosion and sediment load.
<b>Instream recharge</b>	minimal increase	increase	minimal increase at low flow	May move local natural recharge downstream at low flow periods, clogging of channel with vegetation may increase downstream flood effects.
<b>Grazing</b>	increase	decrease	increase	These effects do not occur with good grazing management.

Transportation routes may influence where homes are built. A new major road, such as Tangerine Road or Sahuarita Road, may provide easy access to a rather remote area and lead to more rapid development, while an overloaded freeway system may lead people to seek homes elsewhere.

Dense urban development generally has very different impacts from large-acreage rural development. A concentrated population in a small area requires a high percentage of impervious surface area in roads and buildings. This increases the runoff from the land, although detention basins or water harvesting techniques can mitigate this, but themselves bring about change from the former condition. These impacts can be minimized by

clustering the homes and leaving appropriate open space areas.

Drainages within the area developed are liable to be altered in order to optimize use of the land. The laws limiting this are briefly described above, but in general it is possible to change drainage patterns significantly in order to build a dense development. Where roads must cross drainages or watercourses, they may bring about change whether bridges, culverts, or grade crossing are used. (See Transportation, below) As a general rule, the denser the development, the greater the alteration to the watershed and watercourses. Water may rush more rapidly down to the next watercourse or it may be retained on the land and not reach the watercourse at all.

Low density rural development, on the other hand, has fewer impacts of the type described above, but may have impacts of its own. When homes are far apart, the access roads themselves may change drainage patterns. Homes in more remote areas may have their own wells and septic systems. If they are fenced they may hamper movement of wildlife, or if not, conflicts between humans, pets, and wildlife may ensue. If homes are designed to accommodate natural washes, the impacts on those washes can be minimal. One growing impact of this kind of development is the increase in the spread of non-native plants such as Fountain grass that may escape into a watercourse, displacing native vegetation.

Resort developments have different impacts, especially if they involve a golf course. Resorts developments are usually built where there are superb scenic views, especially near public lands, Starr Pass or La Paloma, for example. Grass replaces native habitat. If the washes are left natural with a buffer between the turf and the wash, impacts on the washes themselves may be minimal. If, however, they become part of the golf course playing area, with turf to the edge of the wash, greater impacts will occur. One concern regarding golf courses relates to the use of pesticides on the turf. In some cases these pesticides may run off into washes, although no serious cases have been documented in the Tucson area.

#### Commercial and industrial development

Commercial development (shopping and services) needs to be conveniently located near where people live and work. New commercial development generally accompanies new residential development, whether it is a new convenience store or a large shopping center. Impacts on watercourses vary widely. A small store away from a drainage area may have minimal impact, while a large shopping center may result in rerouting of watercourses underground or around the area. Large shopping centers require large parking areas which may completely alter the natural drainage patterns of the watershed. Runoff from the parking area may be directed to a detention basin or to the nearest drainage, or may leave the area in more than one location. Water quality problems may occur. (See below).

Industrial development is often located near a dependable transportation route, such as a freeway, airport or railroad for ease in bringing supplies in and getting finished products to market. In most cases neither needs to be near a watercourse in Pima County (although a watercourse might be a good transportation route in other parts of the country). Industrial development is minimal in Pima County, compared to many other cities.

Tucson's largest and oldest industrial area is near the Tucson International Airport where aircraft companies were established during World War II. Major long-term water quality problems developed here when solvents were dumped into washes or shallow ponds and eventually reached the aquifer. One of those solvents, TCE (trichloroethylene) was detected in groundwater near the airport in the 1970s, health problems ensued, and remediation efforts are now underway. Groundwater contamination has also occurred in other parts of town because of electroplating businesses, leakage of petroleum products, and other sources. In some cases, watercourses have been affected. Industrial pollution in the urban area is far more strictly controlled these days than it was in the past.

Other impacts from industry are similar to those of urbanization, change in drainage patterns, increased runoff, and need for flood control measures.

#### Recreation

Recreational activities occur along many of the watercourses. Many people enjoy activities such as bicycling along the Santa Cruz and Rillito linear parks, horseback riding using the dry watercourses, bird watching, off-road vehicle driving, hunting, dog walking, picnicking, camping, and riding the Sabino Canyon tram. As the population grows, so does the demand for these types of recreation. Recreational activities impact watercourses in ways that range from very low to very high, depending on the type of activity, the number and behavior of people and their pets, and the facilities built to accommodate them.

Golf courses are spread throughout the area and often include washes, especially those located at resorts in the

foothills. (See Fig. 3-12). How much the golf course affects the wash depends on the design of the course. In some places the washes have been left relatively natural including native riparian vegetation. In other places the turf is laid right up to and even in the wash. While turf performs the functions of native vegetation in slowing down the water and allowing recharge, it does not serve the wildlife habitat functions of native shrubs and trees. In a few places the wash is channelized, even cemented (See photo in the color photo section following this chapter).

Sabino Canyon, Pima County's most popular riparian recreation spot, illustrates the major issues in recreational use of watercourses. It was once a long journey for the early settlers and sparsely used, but now receives more than one million visitors annually. In the 1930s, the Civilian Conservation Corps built bridges, restrooms and picnic areas to accommodate the increasing number of visitors, and a small dam to increase fishing and swimming opportunities. When the number of visitors reached a critical point in the 1970s, a shuttle bus was introduced and private vehicle traffic was later prohibited because of the stress placed on the area by too easy access and too many cars.

Restroom facilities were expanded, a visitor center added, and educational programs introduced partly to help people understand the fragile nature of the area and help protect it. Some of the problems that had to be addressed were litter, conflicts with bicyclists, introduction of exotic fish species that threatened the native species, threats to wildlife using the area, conflicts between people and wildlife, expansion and maintenance of restrooms to avoid water quality problems, and maintenance of roads and picnic areas after occasional floods.

The Cienega Creek Preserve avoids most of those problems by using a permit system and limited parking facilities to keep the number of visitors below the level at which serious problems could occur. People enjoy the area for birdwatching, wildlife viewing, hiking and train watching. There are no restrooms or trash collection facilities but so far this has not been a big problem with the relatively small number of visitors.

The Nature Conservancy operates a number of preserves in Arizona along riparian corridors such as Sonoita Creek in Santa Cruz County. In order to allow the visitor the opportunity to enjoy the watercourse but not cause damage to vegetation or disturb wildlife, trails are designed to cross the river at selected spots, but otherwise to guide the hiker away from sensitive areas.

Other areas are popular with off-road vehicle drivers. Some areas along the Santa Cruz River, for example, are heavily marked with tracks of those vehicles and in places the banks of the river have been eroded by their trails. ORV drivers cause major damage when they drive their vehicles without regard for vegetation, especially plants in their early stages. Where the vegetation has been destroyed, soil erosion is likely. Even where ORVs are prohibited, enforcement is difficult.

Horseback riding can also impact trails and riparian areas if usage is high and precautions are not taken. Horse trails can start or increase erosion near and in riparian areas and horse manure from some highly used trails can cause water quality problems. Most horseback riding in the area does not cause damages to watercourses in Pima County at the present time.

Recreational areas in the mountains are also highly used, especially in the summer. Fishing is popular at places such as Rose Canyon Lake and similar problems occur in these areas - litter, water quality problems, ORV use, introduction of exotic species, domestic pets interfering with wildlife, conflicts between wildlife (especially bears) and people, and the demand for access roads which may themselves damage areas and in turn increase visitation.

In summary, the impacts from recreation come from direct human activity and from having to build structures and roads to accommodate growing numbers of people. Impacts can be minimized by a variety of methods such as limiting the numbers of people, building trails with preservation in mind, or providing alternate modes of transportation.

### ***Supporting Activities and Services***

#### **Flood and Erosion Control Structures and Floodplain Management**

Any time human occupation of an area occurs, modification of the natural drainage system almost always follows, particularly as urbanization increases. As urban areas expand, land values increase making even floodprone areas more valuable. Human occupation of an area can result in a variety of different impacts on the natural drainage system. Some of the most frequent ways in which humans modify the natural drainage system are discussed below.

There are two related, but very different flood-related problems in Pima County, flooding and erosion, and each type of problem requires different solutions, although the solutions are often combined. There are two basic approaches to flood and erosion management in general: keeping structures away from hazardous areas and building some type of flood control structure to allow construction within the floodplain. Some kinds of structures are

unavoidable in the floodplain, such as bridges and other road crossings, water and sewer lines, and power lines. All of these require protection to avoid being damaged by erosion or the force of the flood waters.

Traditionally, federal and local governments have tended to prefer building flood control structures and federal money has sometimes been available for this purpose, but in the past thirty years the tendency has been more towards ordinances to keep people from building in the floodplain and towards acquisition of floodprone land, often for open space purposes.

Again, the more than urban development spreads into remote areas, the greater the need for flood protection will be. The type of flood management will determine the extent of impact on the watercourses.

Appendices C and D list major flood control projects in Tucson and Pima County and each subarea chapter discusses significant flood control projects in that area.

### Structural Approaches

The primary purposes of structural approaches are to move water quickly away from a developed area, to prevent erosion, to keep watercourses from changing their location, and to increase the amount of land available for residential or business structures. Some structural approaches specifically protect a public structure in the floodplain such as a utility pole or bridge. See the Color Section for some examples of flood control structures

### Channelization and Bank Stabilization

Channelization and bank stabilization are the most common and readily identifiable ways that humans modify the drainage system and are often used together. Channelization is straightening or excavating the channel to direct flows or increase flow capacity and bank stabilization consists of lining the banks with hard surface such as concrete, soil cement, or rock in order to prevent the force of flood flows from eroding the sides or bottom. The combination approach typically consists of some combination of straightening, narrowing, widening or deepening the natural channel to convey more flow. Bank stabilization is also sometimes done without increasing the size of the channel simply to prevent unwanted erosion.

Channelization and bank stabilization became quite common in Pima County, particularly after the devastating flood of October 1983. The October 1983 flood resulted in large-scale erosion and movement of some of the largest flow conveying watercourses in the county, such as the Santa Cruz and Rillito Rivers. In some cases this erosion damaged or destroyed roads, bridges, utility lines and in some cases buildings and other private improvements. By channelizing and stabilizing the watercourses, structures adjacent to them are less threatened by flooding and erosion. However, as suggested in the Channel Stability discussion above, such improvements can also exacerbate problems elsewhere if they are not done in a thoughtfully planned and comprehensive manner.

### Stormwater Storage

One of the effects of urbanization is to increase the total amount of paved and other impervious areas in the community. The effect of this on the drainage system is to cause an overall increase in runoff since subsurface infiltration in the impervious areas is no longer possible. Over time this effect can be dramatic as significant

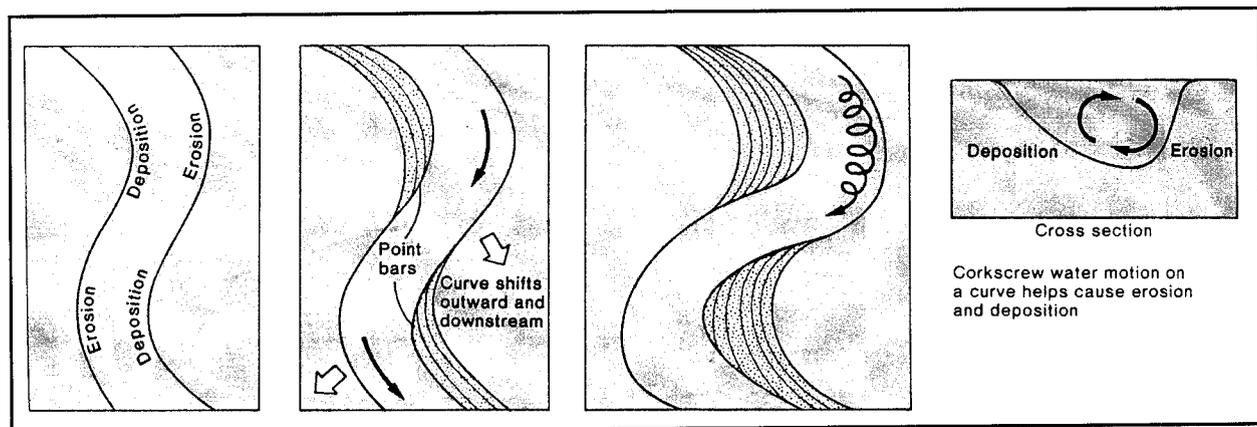


Fig. 3-15. Schematic diagram showing how streams banks tend to erode on the outside curves of the channels and to build up sediments on the inside curves of the channels.

percentages of the urban area become impermeable. Loss of storage capacity is especially felt when flood waters are kept from flowing onto the floodplain because the area is paved or because flood control structures have constrained the water to the channel. Overbank storage is thus reduced and the waters flow rapidly downstream.

Over the last thirty years or so, this problem has increasingly been addressed through the construction of stormwater storage basins. Typically, these basins are designed to intercept runoff and store it for a period of time such that when it leaves the stormwater storage basin, the magnitude of the flow is decreased from the rate created by the effects of urbanization. These stormwater facilities vary in size, shape and location. Sometimes a large facility will be constructed at a strategic location to provide reduction of flood flow rates for a larger area that includes many developments. In other cases, stormwater basins are provided for each development as it is built and only to address the impacts of that development. Stormwater basins are also often provided for reasons other than reducing urban runoff rates. Sometimes they are built to promote infiltration of storm water into the underground aquifer and replenish groundwater supplies. Other times they are constructed to trap and treat runoff from industrial areas and other areas that might be prone to generating polluted runoff.

Although their use is widespread and in most cases has been quite beneficial, stormwater basins have their drawbacks too. In some cases stormwater basins can deprive

downstream watercourses of sufficient water to allow vegetation to survive and flourish. In other cases, stormwater basins have been known to trap too much of the supply of sediment in a drainage system. As a result the watercourse downstream of the basin can experience excess erosion as the power of the flow eats into the banks and bed of the channel to make up for the lack of sediment in the flow.

#### Storm drains and culverts

Sometimes the intensity of urbanization is so great as to leave no portion of the ground surface available to properly accommodate runoff and through passage of drainage. In such cases storm drain systems or culverts are often built underground with inlets to the system at the surface. This approach is quite common on urban roadways where conveyance of runoff within the roadway is not desirable from a transportation standpoint. This approach is also sometimes used on large commercial and industrial projects where space is at a premium. In such cases the high value of the land can make construction of the relatively expensive storm drains economically feasible and free up the land surface for additional construction. In still other cases, storm drains offer the only alternative to pass beneath an existing large-scale utility, such as a highway or railroad, where

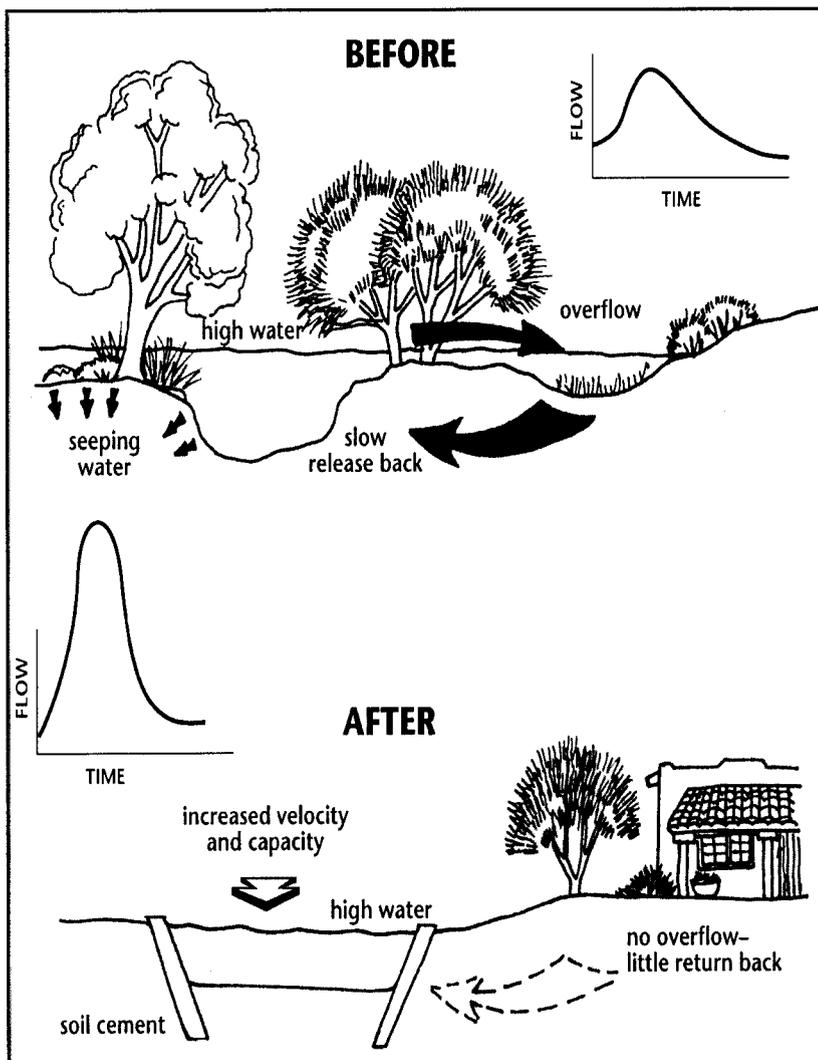


Fig. 3-16. Schematic diagram of the effects of channelization on a watercourse and overbank storage capacity.

although the minerals will be periodically diluted or flushed out by floodwaters.

### Wastewater

Dealing adequately with wastewater (sewage) is a vital to maintaining the health of any community and its long-term water supply. Wastewater may contain a variety of potential pollutants including viruses, nitrates, and toxic materials, but properly treated wastewater can also be a valuable resource in this water-short region.

In late nineteenth century Tucson most people used outhouses and often reused their washing water on their plants. Later the City started to gather wastewater in pipes and to treat it by spreading it on farmland at the city's sewage farms. As the population grew and knowledge about pollution increased wastewater treatment became more sophisticated and regulation increasingly stricter.

Wastewater can be treated by any of three basic approaches.

- Treatment at the large-scale community level in large wastewater treatment plants.
- Treatment at a small to medium scale level (in a subdivision or small community)
- Treatment for individual homes in septic systems or occasionally composting devices

Each of these methods has very different requirements and will be discussed more below, with most emphasis on the large scale systems which most directly impact watercourses.

Most of the wastewater in the Tucson area is treated in two large treatment plants owned and operated by Pima County. These facilities need to be downhill from the population centers so the sewage can flow by gravity to the treatment plant. These downhill locations in Pima County are along the Santa Cruz River near Roger Road and Ina Road. Location near the river also provides a convenient place for discharging the treated water. This downhill location, however, means that if treated wastewater is to be reused, it often must be pumped back uphill to its destination in the community. As the population expands to areas downstream of Ina Road, the need arises for another facility farther downstream.

Medium size systems (sometimes called "package plants") are located within the area served by the system and the water is sometimes used within the same area to water golf course turf. Sometimes a pond or constructed wetland is part of the system.

Individual systems are located on individual property or sometimes a small group of homes. The use of individual systems allows homes to be built in locations where they cannot easily be connected to the larger treatment systems.

Treated wastewater from each size system can be reused or recharged. In addition, about ten percent of Tucsonans reuse graywater (water from washing machines, showers, and sinks) around their own homes. While this reducing pumping needs, it also reduces the amount of effluent available for reuse and recharge, so has little effect on the basin's water balance.

### Large wastewater treatment plants

Two major factors are important when looking at the relationship between large treatment plants and watercourses:

- The water supply and water quality impacts of discharges of water to the river
- The impacts of flood control structures to protect the treatment facilities and on flood flows.

### Water quality

These facilities are primarily designed to remove solid matter and infectious agents. Filters remove large solid material and particles, microbes break down and reduce many microscopic entities and disinfectants are applied to kill any remaining germs. The treatment facilities are not designed to deal with toxic materials. Not only does the process not remove toxics, but an influx of toxics may kill the microbes which the system uses to treat the water, thus disrupting the treatment process. An industrial pretreatment program requires businesses that use toxics to have on-site methods of dealing with them so that they do not enter the wastewater system. Toxics from individual homes, however, sometimes enter the system, although no major problems have developed from this.

Wastewater is rich in nitrates that are not removed by the treatment process. Nitrates, however, are plant nutrients and actually enrich treated water for use on plants. They, however, can be a health hazard to humans and animals in excessive amounts, whether in surface water or if they reach the groundwater. Nitrates have reached the groundwater in the Marana area, probably both from wastewater and from agricultural operations. A disinfectant, usually chlorine is added at the end of the process to assure disinfection. Since chlorine may be toxic to gill-breathing

life, EPA has established conditions for its use.

Both the Ina Road and Roger Road plants had sludge drying beds at one time, where evaporation removed the water from the solids that were then disposed of in landfills. Sludge from both facilities is now treated in drying facilities and trucked for use on farms, reducing the potential for pollution seeping through them down to the aquifer. At one time there were ponds in connection with the Roger Road Treatment Plant, but these were abandoned when concern was raised that they were leaking contaminants to the aquifer partially through an old landfill. One pond remains between the treatment plant and the river, away from old landfills.

The Environmental Protection Agency (EPA) regulates the quality of water discharged into watercourses under the Clean Water Act and reviews permit conditions every few years. Sampling and reporting is done by Pima County which reports to EPA.

#### Water supply and reuse

Approximately 70,000 acre feet of water are produced annually by the two big wastewater treatment plants, about 81 percent of which is discharged to the river. The amount produced is projected to more than double by 2025. The wastewater, however, although treated by Pima County, is mostly owned by the City of Tucson under an Intergovernmental Agreement made in the 1970s, an arrangement which Pima County has for years disputed. In February 2000, the City and County reached an agreement rather to go to court. The major provisions of this agreement include the City making reclaimed water available to the County at a cost less than what private users pay, reservation of some wastewater for riparian preservation purposes and county ownership of effluent from treatment facilities away from the urban core.

Part of the wastewater produced at Roger Road does not enter the river but goes to recharge basins near the river and to turf irrigation through the City's Reclaimed Water System which includes a tertiary treatment plant to further improve the quality. A small amount of effluent from the Ina Road Plant is also reused but without further treatment.

Wastewater is a continually increasing water supply as the population grows. Questions about the overall community water supply, however, have also led to pressures to reuse more of that resource rather than release it to the river. Increasingly stringent water quality permit conditions also tend to create incentives to eliminate that discharge rather than spend more on additional treatment. Questions about obligations under the water rights settlement with the Tohono O'odham, on the other hand, have led the City to be cautious about committing effluent to other uses when the tribe has valid claims to some of it in the future. Building and operating a reclaimed water system is an expensive operation as may involve additional water treatment as well as facilities to store and distribute the water to where it can be used. More of the wastewater may in the future be sent to recharge or artificial wetland facilities (See below). There will probably continue to be a flow in the river for the foreseeable future.

#### Habitat value

The river is a perennial effluent-dominated stream from the Roger Road Treatment Plant discharge (east of Columbus Park) through most of the Marana area. This stream provides a constant water supply for vegetation and animal life. Parts of that stream provide good bird habitat, for example, especially where the channel is broad and unconfined. Herons and hawks, for example, are frequently seen near the treatment plant and its pond. The presence of soil cemented banks in some areas, however, makes it difficult for an extensive riparian forest to develop.

The Upper Santa Cruz River near Tubac also has perennial flow, in this case from the Nogales International Wastewater Treatment Plant. In that area the wastewater has brought about an extensive cottonwood-willow forest which provides excellent habitat for fish, birds and other creatures. Regular water quality monitoring indicates that the quality is generally high and improves as the water moves downstream and vegetation help mitigate the minor water quality problems. In recent years, however, a trend has developed towards higher nitrate levels for reasons as yet undetermined. The Pima County effluent dominated area is much less valuable habitat for a number of reasons including use of the floodplain in some areas, presence of trash along parts of the river, presence of non-native plants, the presence of soil cement structures, and a different river configuration (including an incised channel) and underlying geology. Much potential exists, however, for improvement of the habitat and recreation value of the river in the Tucson area.

Tucson opened the Sweetwater Wetland adjacent to the Santa Cruz River in 1998. It was built partly to reuse some backwash water (water resulting from cleaning out filters at the reclaimed water facility) and partly to provide a new wildlife habitat. Water flows from the wetland into recharge basins connected to the reuse system. This small constructed wetland has proven attractive to thousands of birds of many species. A major mosquito problem,

landfills near the Santa Cruz River from south of the airport to Marana and 12 along the Pantano-Rillito. The largest landfills of concern are along the Pantano between Speedway and 22<sup>nd</sup> Street and along the Santa Cruz from Ajo Way to Grant and again at Camino del Cerro.

Since the 1980s landfills have been highly regulated and can no longer be constructed in or adjacent to the floodplain by state law. The main problems today stem from old landfills as well as continued illegal "wildcat" dumping. Wildcat dumping sites are spread throughout the area and are often small and in washes. Construction debris is sometimes illegally dumped in or along watercourses rather than trucked to a landfill. Where trash is not regularly collected or where people want to avoid the cost of trash collection, illegal dumping is a problem because enforcement is difficult. As the community grows, landfills reach capacity and new sites must be found, usually farther away from the metropolitan where land is available. The increased use of recycling prolongs the needs to find new sites.

Landfills and dumps affect watercourses if they are located in a place where contaminants may reach the watercourse, especially during high flow periods. Some old landfills contain toxic substances while others are potential threats primarily because they release methane as the organic materials decompose. Old landfills can also affect where and how new structures can be built and even where water can be pumped or where it can be recharged. In some cases, the most economical use of an old landfill area may be recreational if the recreational use does not involve use of water that could leach pollutants to the water table or to the watercourse. These issues will be discussed further in the Subarea Chapters as they impact specific areas.

A prime example of how the presence of an old landfill may affect decisions about a watercourse occurs along the Santa Cruz River near A Mountain. Several old landfills are located in area proposed for parts of the Rio Nuevo Project, a City of Tucson sponsored project that may include museums, historic preservation, river parks and commercial and residential development. Some proposals include water features, including a steady flow of water in the river itself. While this is certainly feasible, the impacts of pollution from the old landfill need to be carefully studied. New methods of treating landfills include introducing air and water into the landfill to accelerate decomposition. This method is to be tried for the first time in Pima County at the Rio Nuevo Project. This project will be discussed further in Chapter 7.

Problems caused by landfills are less likely away from the metropolitan area, although illegal dumping continues to be a problem. Trash that accumulates in a watercourse can interfere with flood flows as it moves downstream, especially if it piles up under bridge structures restricting flow under the bridge. One problem that has grown in recent years is the amount of trash discarded along trails used by people crossing the international border. This is a problem, for example, on the O'odham Nation.

### Electric Power and Natural Gas

Most of Tucson's electric power is provided by Tucson Electric Power Company (TEP) which is part of a large network of power providers. Power production can have major impacts on watercourses and aquifers as most types of production require water for some part of the process. Hydropower requires construction of dams and generation of power from fossil or nuclear fuels requires water for cooling.

Most of Tucson's generating capacity is in the Four Corners region, with only about 29 percent produced locally. The energy produced locally is generated from oil and gas imported from elsewhere. In addition, TEP can also draw on power from many other sources including hydropower along the Colorado River. It has interchange agreements with more than 180 electric systems and suppliers. Thus, the impacts (air pollution, water supply, and water quality) of generating power are very significant along watercourses, but those impacts are felt hundreds of miles distant from the local area. The hydroelectric dams along the Colorado River, for example, produce power for the networks from which TEP gets some of its power. The Four Corners coal mines that provide fuel for the generating plants have an impact in that area, as does the water used in the generating plants.

In order to take advantage of those distant power sources, and get power to where it is wanted, large transmission lines are needed and these sometimes follow watercourse lines. Transmission lines are, for example, found in the channel of the Santa Cruz River. These must be protected against flood damage. Power lines have proven to be hazardous to some kinds of birds, such as hawks, and Tucson Audubon and TEP are cooperating in implementing fairly inexpensive measures to reduce this problem.

The use of alternate energy sources, such as solar energy and wind power, has increased somewhat in recent years and is expected to increase even more in the future, mitigating the total impacts of power production on water supplies and watercourses.

**Fig. 3-26. TEP's Generating Capacity 1998**

<b>Location</b>	<b>Fuel</b>	<b>TEP megawatts</b>	<b>Percent</b>
Springerville Station	Coal	760	40%
San Juan Station	Coal	316	16.6%
Navajo Station	Coal	168	08.5%
Four Corners Station	Coal	110	06.4%
Irvington (Tucson)	Gas/Oil	544	28.5%
<b>Total</b>		<b>1,898</b>	<b>100%</b>

Natural gas reaches this area through underground pipelines. The same problems may occur as occur with water and wastewater lines as they traverse watercourses. Pipeline construction and road maintenance to the area may also in some cases affect watercourses, but this is not a significant problem in Pima County, especially if the area is revegetated after construction.

Transportation

Transportation routes must often cross watercourses. Crossings may range in magnitude from just having the road cross the wash (dip crossing) to freeway and railway bridges that require protective structures. Past floods have affected the accessibility of transportation systems. When the railway was first constructed along Cienega, the tracks washed out numerous times until the track were moved to the upland with high crossings. Sometimes, however, the best topographic routes for highways and railroads lie along the routes of watercourses, Rillito Road, for example.

Where roads cross the washes, they are liable to be impassable when there is more than a little water in the wash. People who have entered washes in these conditions have at times either found themselves stuck or have experienced their vehicles floating downstream. If people are willing to wait a while, the waters recede and the road is passable again, although it may be covered with sand or debris, or the pavement may have crumbled. Under some circumstances dip crossings may alter the channel, with sediment building up or erosion occurring on the downstream side. While most dip crossings are imperceptible except at flood time, others require protective cement, asphalt, or rocks to protect the road.

Heavily used roads can be made passable during storms by directing the water through culverts under the road. Culverts may become clogged with sediment and debris unless they are maintained. Culverts change the flow of the watercourse, sometimes lowering the level of the channel where the water discharges with considerable force, depending on how they are constructed and sized. Undersized culverts will generally discharge water with greater force and have greater risk of clogging. Undersized culverts can cause water to pond and flood upstream areas.

The next level of crossing is the bridge. The construction of roads and bridges can have a significant impact on watercourses. Roads inevitably need to cross watercourses and their floodplains. To do this, a bridge is often built over the main channel of the watercourse and possibly a portion of the floodplain as well. Such structures generally provide an adequate crossing to allow small flows to pass under the roadway. However, larger floods can inundate the floodplain adjoining the main channel. Such floods may extend beyond the limits of the bridge and can cause damage to the roadway or bridge. In some such cases, inadequate bridges can cause flood flows to back up behind them as well, especially if debris has collected against the bridge supports. Also, on occasion, bridges have been known to control erosion of a watercourse at the crossing location to the extent that the erosion potential is moved upstream or downstream to a more vulnerable spot. The above phenomena are often encountered with railroads and sometimes with large linear utilities such as pipelines which must cross watercourses. Bridges can be designed so that the bridge approaches break away during heavy flow events, releasing pressure on the bridge itself and reducing repair costs. The need to provide structural protection for the bridge supports is liable to have effects downstream if the protection leads to stronger flows downstream. This may lead to protecting the next downstream location.

In general, the farther that urban development spreads, the more watercourses will be affected by the demand for all-weather transportation corridors. How great the impacts are depends on how much care is taken in road construction to minimize them while optimizing ease and safety of travel.

# Chapter 4

## Subarea 1 - Middle San Pedro

### WATERSHED/WATERCOURSE CHARACTERISTICS

#### THE WATERSHED

The San Pedro River watershed begins in Mexico with the headwaters originating approximately 25 miles south of the international border south of the Sierra Vista region. The river grows gradually from a number of small streams until it flows perennially before it crosses the border in ranching and farming country. It flows north in Cochise County perennially through the San Pedro Riparian National Conservation Area to the town of Benson where it becomes a dry stream due to groundwater pumping and changes in the underlying geology. See Fig. 4-1 for a map of the subarea. See Fig. 4-2 for a map of the watershed.

The Middle San Pedro Subarea consists of the small portion of the San Pedro River Watershed which extends across the extreme northeast corner of Pima County. The subarea is located on the east side of the Santa Catalina and Rincon Mountains. The San Pedro watershed is bounded on the east by the Galiuro, Dragoon and Mule Mountains and on the west by the Catalina, Rincon, Whetstone and Huachuca Mountains. An approximately 12 mile segment of the river passes through the northeast corner of Pima County.

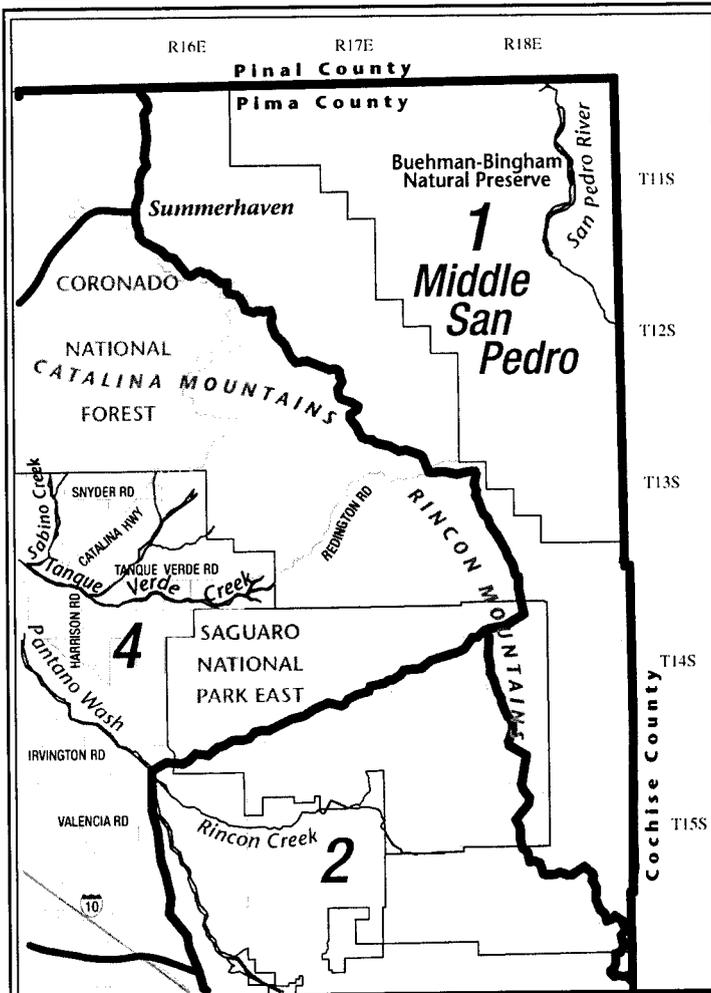


Fig. 4-1. The Middle San Pedro Subarea

The San Pedro River valley through northeast Pima County consists of a sand bed river varying in width from one to several hundred feet located within a wider geologic floodplain. The San Pedro River channel bed has degraded several feet since the turn of the century (1900) as a result of overgrazing within the upstream watershed. This degradation has narrowed the floodplain and increased downstream flood peaks. Higher flow velocities associated with the channel entrenchment have increased bank erosion. This degradation has narrowed the floodplain and increased downstream flood peaks. Higher flow velocities associated with the channel entrenchment have increased bank erosion. Tributary drainage within the valley consists of fairly well defined washes draining the foothills of the Santa Catalina and Rincon Mountains to the west and the Galiuro Mountains (in Graham and Cochise Counties) to the east. The uppermost portions of the watershed within Pima County extend into the highest reaches of the Santa Catalina and Rincon Mountains with elevations exceeding 9,000 feet near the summit of the Santa Catalina Mountains. Elevations along the San Pedro River range from nearly 3,000 feet where it enters the county to about 2,700 feet where it exits into Pinal County.

Several perennial and intermittent streams flow from the higher elevations of the subarea. Buehmann Canyon is the most biologically significant of these.

## HUMAN IMPACTS ON THE WATERCOURSES

### TRANSPORTATION

There are no major highways within the area. In fact the only paved, county-maintained road is a short segment of roadway associated with the Redington bridge over the San Pedro River. Access to the area is limited to the graded road which runs along the San Pedro River entering from either Cochise or Pinal County or the rough graded dirt road which runs from the Tanque Verde valley area over Redington Pass between the Santa Catalina and Rincon Mountains. Neither route is heavily traveled or maintained by Pima County. It is a 30-45 minute drive to Benson or San Manuel from Redington in dry weather, with another half hour to Tucson and county services. The roads can be impassable during the rainy season and are not maintained by the County. There are numerous private ranch roads.

### WATER AND WASTEWATER- RELATED USES

#### Water Supply

In the 1960s the City of Tucson purchased land along the middle San Pedro with a view towards exporting water to the city. This project did not prove feasible and the land was eventually sold. There are no plans for exporting water from the area and such exports are no longer possible under Arizona law.

All water users in the area have their own wells which are quite productive, as the area has very shallow groundwater. There is no wastewater treatment system, homes are generally on septic systems.

### EXISTING PUBLIC LAND USES

A substantial portion of the subarea is under public ownership within the Coronado National Forest. The vast majority of the remaining part is under state ownership with isolated pockets and sections of privately owned land, particularly along the river itself. Grazing is a common use of both of these areas. There is some recreational use in the National Forest.

The San Pedro River is widely regarded as one of the last remaining relatively natural southwest riparian areas. Considerable efforts have been taken to protect the river and its base flow in the upper reaches within Cochise County. The Pima County segment of the river does not flow on a regular basis.

The 180 acre Bingham Cienega Natural Preserve is located on the San Pedro River near the settlement of Redington and is managed under contract by the Arizona Nature Conservancy. The cienega was formerly part of the Bingham Cienega Ranch and contains lush riparian vegetation associated with a perennial spring at the ranch. This area is not open for recreational use, but can be accessed by tour groups with appointments. The Flood Control District and the Conservancy are actively involved in restoration efforts with a Water Protection Fund grant administered by a knowledgeable local resident.

Buehmann Canyon has Unique Waters status and an instream flow permit has been applied for on this stream. It is managed by the Arizona Nature Conservancy which owns and holds conservation easements on 2,793 acres of the stream and its environs. The Conservancy bought the area at a time when mining activities were imminent and now operate the property to maintain its natural state, but mining activities are still possible in the future on parts of the land. This area is only open to the public on a very limited tour basis.

Most recently, the Bellota Ranch was put up for sale for development. In an effort to stem development of the area, the City of Tucson bought 6,800 acres of private land and 34,200 acres of state-land grazing leases that were part of ranch. The intent is to preserve the area as open space. This is not currently open to the public for recreational use.

### EXISTING PRIVATE LAND USES

The only developed area is the small community of Redington located about midway along the Pima County segment of the river. Some residents produce pottery, wood products, and crafts. Some of the residents have joined in efforts to protect the river and its tributaries from damage and repair past damage. The Redington Natural Resource Conservation District has been actively involved in streambed restoration through a Water Protection Fund grant which involved installing small check dams on tributaries to collect sediment and correct problems caused by past erosion.

Ranching has been the predominant human activity within the non-federally owned portion of the subarea and on some leased public land. Some descendants of the original pioneers still own property and live in the area. Some of the areas are farmed, although less so than in earlier times.

## **PROJECTED LAND USES**

Although this area is isolated geographically and accessed by roadways of limited capacity, this area is also likely to see development pressure as area residents continue to seek out locations to live which lie beyond the metropolitan urban area. The purchase of the Bellota Ranch by the City of Tucson is one step toward controlling development in the area. Potential impacts of development in the area include continued degradation of stream flows in the San Pedro River and potential lowering of the stream and its tributaries as the sediment supply to the natural system is altered through urbanization.

In the Mountain Parks and the Sonoran Desert Conservation Plan, Pima County proposes the establishment of the Buehmann-Bingham Natural Preserve, joining the two existing preserves described above. The County's Open Space Acquisition Master Plan proposes adding along 400 acres to Bingham Preserve. Almost 700 acres of the area are designated Critical Habitat for the pygmy owl.

## **ISSUES FOR DISCUSSION**

### **PRESERVES**

Should Pima County's open space proposals be implemented? Are additional preserved areas needed? Should some State Trust Land in this area be preserved as open space?

### **CONVERSION OF RANCHES**

If ranches in the area are to be available for sale, should any measures be taken to preserve the area as open space? Should they be rezoned to allow for subdivision or ranchette development? If they are developed, what provisions should be made to ensure that the groundwater table is not lowered? Should land be purchased to ensure that new pumping does not adversely affect the water supply for Bingham Cienega?

### **ROAD PAVING/WIDENING**

The major north-south road in the area is currently unpaved, not maintained by the county, and is not accessible in all weather. Should it be improved? If so, how should the crossings be treated?

### **MINING**

If new proposals for mining in the National Forest were forthcoming, should local governments play a role in the approval decisions? What limits should be placed on new mining to protect the watercourses?

### **REHABILITATION OF THE RIVER**

Should efforts be made to revegetate the river or otherwise improve the habitat of the area?



Region Within the Subarea	Grazing	Wildcat Subdivision	Planned Subdivision	Copper Mine	Sand & Gravel Mine	Pumping	Agriculture	Recreation
River area	X	P	P			X	X-	X
Mountains and foothills	X			P				X

**Key:** X = Existing    X+ = Existing with potential to increase    X- = Existing with potential to decrease  
X++ = Existing with potential to increase or decrease    P = Potential

**Fig. 4-3. Generalized Matrix of Potential and Existing Impacts on Watercourses in the Middle San Pedro Subarea**

Region Within the Subarea	Alternate Water Less Pumping	More Non-structural Floodplain Management	Stricter Land Use Management	Federal Public Lands Expansion	State Trust Land Preserved	Other Preserves Increase	Better Grazing Management
River area			X				X
Mountains and foothills				X			X
Key: X = Is possible and could have significant impact if it occurred.							

Fig. 4-4. Generalized Matrix of Potential Options for Reducing Stress on Watercourses in the Middle San Pedro Subarea

# Chapter 5

## Subarea 2 - Cienega-Rincon

### WATERSHED/WATERCOURSE CHARACTERISTICS

#### THE WATERSHED

The Cienega-Rincon Subarea includes the watersheds of the Pantano Wash and Rincon Creek upstream of their point of confluence near the Drexel Road alignment. The subarea is formed by the Santa Rita Mountain Range to the west and the Rincon and Whetstone Mountain ranges to the east. The subarea starts at the Santa Cruz County line to the south and continues to the confluence of Pantano Wash and Rincon Creek. See Fig. 5-1 for a map of the subarea.

The subarea consists of two fairly distinct regions which will be referred to as the Cienega Region and the Pantano Region for purposes of this discussion. Pantano Wash begins as Cienega Creek and the name changes to Pantano Wash downstream of the Cienega Creek Preserve. The Cienega Creek watershed is the only large basin in southern Arizona surrounded by mountain ranges containing extensive amounts of the kind of limestone that promotes the development of caves, of which Colossal Cave is the best known example locally, but there are numerous others, one of which is a National Natural Landmark. Karchner Caverns on the other side of the Whetstone Mountains is part of this general geologic formation. The caves support some unusual flora and fauna some of which depend on springs associated with the caves. These, in turn, are dependent on a high water table.

#### Cienega region

The Cienega region is that portion of the subarea between Colossal Cave Road and the Santa Cruz County line. This region can generally be described as a broad grassland valley rising gently to the steeper foothills and mountains of the Santa Rita and Whetstone Mountains ranges. The Cienega Creek through this region is also generally a sand-bed channel but with markedly increased vegetation along its margins. At some locations groundwater levels are close enough to the surface to result in intermittent flow. Such a condition exists within the Cienega Creek Natural Preserve owned by the Pima County Flood Control District and administered by the Pima County Parks and Recreation Department.

#### Pantano region

The Pantano region is that portion of the subarea between Colossal Cave Road and the Rincon Creek confluence. This area is fairly similar in landform and vegetation community to the Middle Santa Cruz Subarea which includes the lower part of the Pantano Wash. It is characterized by well defined desert arroyos with typical desert brush vegetation including creosote, mesquite, and numerous species of cacti. The Pantano Wash exists through this region as a wide, fairly incised sand-bed channel with sparse vegetation along its margins. Within the Pantano region, the Rincon Creek is a major tributary which drains the Rincon Valley. See Fig. 5-2 for a map of the watershed.

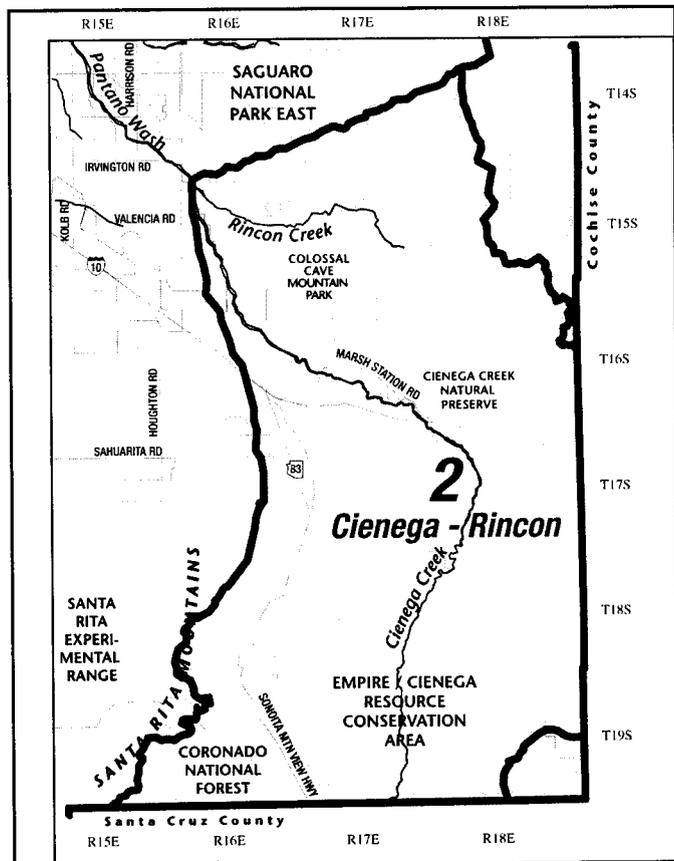


Fig. 5-1. The Cienega-Rincon Subarea.

## **MAJOR WASH CHARACTERISTICS**

The major washes within this subarea are Pantano Wash and its two largest tributaries Cienega Creek and Rincon Creek. The lower reaches of Pantano Wash between the Rincon Creek confluence and Houghton Road have degraded several feet during past decades. This degradation has been related to urbanization along the reaches further downstream and due to in-stream sand and gravel mining. Very little in-stream mining continues today but future degradation should be anticipated as a result of past changes to the channel hydraulics which support higher flow velocities and sediment transport capacity. This degradation could propagate to the upstream reaches if grade controls are not installed.

The cross-section of Cienega Creek has not been severely changed by man-made modifications. Cienega Creek is, however, vulnerable to change such as streambed degradation if proper measures are not taken to prevent the intrusion of significant development within the watershed or the propagation of downstream channel bed degradation. Presently, the broad floodplain areas along the upper reaches of Cienega Creek function to provide overbank flood storage. This decreases soil/sediment loss within the watershed and decreases in downstream peak flow rates.

Rincon Creek has been modified by man-made changes only through the Rocking K Ranch reach east of Old Spanish Trail (a distance of about two miles). In the 1940's this reach was cleared for farming and the wash was channelized around the fields. Several floods that have occurred during the last sixty years have filled in the channel with sediment leaving a broad sheetflow area across the valley floor. The riparian vegetation which was removed to facilitate farming has not recovered to any significant degree. The Rocking K Ranch master plan (approved by the Pima County Board of Supervisors in 1996) proposes modifying the floodplain geometry to include residential development, a golf course, and restoration of 118.5 acres of riparian habitat.

The reach of Rincon Creek west of Old Spanish Trail has degraded a few feet as a result of degradation along Pantano Wash. Up till now, the degradation has not propagated east of Old Spanish Trail because Pima County has installed remedial grade control measures to maintain the existing roadway dip crossing of Rincon Creek. East of the Camino Loma Alta crossing, Rincon Creek largely remains in a natural condition. The floodplain area provides some overbank storage which acts to reduce downstream flood peaks.

## **TRIBUTARY WASHES**

The tributary washes within this watershed are well defined. Distributary sheet flooding is limited to a small area (approximately 1 square mile) within portions of Township 15 South, Range 16 East, Section 34.

## **HUMAN IMPACTS ON THE WATERCOURSES**

### **FLOOD MANAGEMENT PLANS AND ACTIVITIES**

Pima County Flood Control District has acquired floodprone land at the confluence of Pantano Wash and Rincon Creek and at the confluence of Pantano Wash and Tanque Verde Wash in order to prevent downstream flood problems.

Pima County studied the possible impacts of sand and gravel mining in the Pantano Wash in the general vicinity of Vail. Increased needs for construction materials were anticipated with the growth of population in the area, especially Rocking K. The study recommended that if such mining were to occur, the company would have to install grade control structures to minimize problems from erosion. The demand for materials in this area has not yet developed to the point that extensive gravel mining is needed, but may occur at some time in the future. If the City of Tucson annexed the area, the city rules would apply and a new analysis would probably be needed.

Pima County operates a network of precipitation and flow sensors in this area to report storms coming from the east. Rincon Creek and Cienega Creek have numerous sensors as part of this network.

### **TRANSPORTATION**

I-10 runs east-west through the Cienega region. Old Spanish Trail is the major road through the Pantano region, connecting the City of Tucson with I-10 and Saguaro National Park and I-10. Highway 83 runs through the Cienega region, connecting I-10 with Sonoita. There are many urban roads throughout the area.

## **WATER AND WASTEWATER- RELATED LAND USES**

### **Water supply**

Depth to water ranges from surface flows at Cienega Creek to more than 550 feet in the mountain foothills. Most of the area is served by Tucson Water, but significant sections are served by eight private water companies, such as the Spanish Trail Water Company, the Forty Niners Water Company, and the Vail Water Company. There are also many private wells in the area.

### **Wastewater**

There is no large wastewater treatment plant in this area, most of the wastewater from this area goes to the Ina Road and Roger Road Treatment Plants. A very small amount of it returns to the western edge of the area through the city's reclaimed water system which provides water to the Rolling Hills Golf Course and is capable of providing water even farther into this area. Most of the homes in less densely populated areas are on septic systems. The University of Arizona Science Center, The Arizona State Prison and the Pima County Fairgrounds have their own systems.

## **EXISTING PUBLIC LAND USES**

The upper watershed is within the Coronado National Forest in the Santa Rita and Rincon Mountains. This area is managed for multiple use and grazing occurs in the watershed. Mining is allowed in National Forests under the 1872 Mining Law. A proposal was made in the early 1990s to open a mine in the Rosemont area where small-scale mining had occurred historically. As a result of public opposition and economic factors, this proposal is no longer active, but this or another one could be renewed if world copper market conditions change. The Forest here has moderate recreational use, with rather heavy use during hunting season.

At the southern end of the subarea is the 45,000 acre Empire-Cienega Resource Conservation Area (of which 31,906 acres are in Pima County). Since June 1988, the Empire and Cienega ranches (365 acres), along with portions of the adjacent Rose Tree Ranch, have been under the administration of the Bureau of Land Management (BLM). Prior to BLM's acquisition, these rolling grasslands and woodlands faced an uncertain future that almost assuredly included housing and commercial development. Such development would have eliminated the sweeping vistas and substantially harmed the watershed and habitat needed for rare native fish and a rich diversity of other wildlife. Pima and Santa Cruz county supervisors officially requested that BLM become involved in protecting this land. Through BLM's efforts, this area is now under public ownership and is being managed under the principles of multiple use. Grazing is allowed, but very carefully managed to protect the watercourses. Recreation is encouraged, including camping.

Headwaters of the creek bubble to the surface three miles east of the historic adobe ranch house. From that point the stream meanders for 10 miles before again disappearing underground. Its narrow water- course is six to eight inches deep. Occasionally pools of greater depth occur. Three native fish species are found in the stream (both here and in the Pima County section): the Gila topminnow, which is endangered; the Gila Chub, an endangered candidate; and the Longfin Dace. Additional information on the Empire-Cienega Resource Conservation area can be found at <http://tucson.az.blm.gov/e-cinfo.html>.

Pima County's 1,243 acre Cienega Creek Natural preserve was created in 1987 to maintain the running creek water and to preserve the native plants and animals that thrive on it. It is administered by the Pima County Parks Department. Pima County has an instream flow permit for the preserve and ADEQ has designated the creek "unique water." Recreational use of the preserve is limited by parking permits and vehicles are now allowed within the preserve. A management plan directs how the preserve is used and what facilities may be made available in the future. Pima County is attempting to restore native vegetation to some of the lands along the preserve that were farmed or otherwise altered. The area was grazed for many years, but Pima County has now eliminated grazing along the creek. A railroad crosses the creek at the preserve and is one of the attractions for visitors. At the lower end of the preserve is an old submerged dam which has been used for water diversions downstream. This dam has helped retain water within the preserve. Additional information on the Cienega Creek Natural Preserve can be found at <http://www.webofgibraltar.com/cienega/>. Parts of the watershed for the Pantano subsection are in the 67,385 acre Saguaro National Park East. (See Chapter 7 for more information).

The Rincon Mountain Wilderness Area, part of the Saguaro National Park, (36,962 acres) has no public roads but is accessible via hiking trails. The U.S. Forest Service owns some of the upper portions of the watershed. The popular Colossal Cave County Park occupies 1,895 acres in the Rincon Mountains foothills, and includes picnic areas as well as the concession at the cave itself.

## **EXISTING PRIVATE LAND USES**

In the 1920s Vail was a bustling trailhead and railway station, with approximately 400 residents. Little remains of the old town and its small school, but because of rapid growth in the area, the Vail School District has been continually expanding. In the early 1980s IBM built a large facility along I-10 and population growth mushroomed in the area. In 1989 IBM closed the manufacturing part of its operation and growth slowed. In 1995 the University of Arizona took over the mostly vacant IBM facility and the tax base of the school district dropped, but population growth increased, making it difficult to fund new schools. At the present time the district has three elementary schools, a middle school and a charter high school, and has plans to build new elementary, middle and high schools with state financial assistance. At one time residents attempted to incorporate, but this attempt failed. The town itself has some small commercial facilities, but most school children come from low and medium density developments scattered around the area.

The Tucson city limits extend into this subarea in a jagged line, including parts of Pantano Wash. In places city limits reaches to the Saguaro National Park boundary.

During the second half of the 20<sup>th</sup> century, land use in the Rincon Valley has shifted from ranching to private residential development. Beginning in the 1960s, some of the traditional 40-acre-plus ranches were subdivided into 10 to 20-acre "ranchettes." By the 1980s, several ranches in the valley had been transformed into 1-acre private residential neighborhoods. Development of an extensive mixed-use, resort-oriented planned community on the Rocking K Ranch began in the 1990s. The legacy of cattle ranching can still be seen in the Rincon Valley, even in areas that are no longer grazed. In desert scrub areas, the grasses and wildflowers preferred by cattle are now dominated by unpalatable weedy shrubs such as burro weed. Where grazing still occurs along the more natural upper Rincon Creek, understory species are nearly absent and cattle trails across the creek have caused some bank erosion and undermining of the trees that line the channel. Unchecked development in this area could result in upstream continuation of the channel erosion which has occurred on the Pantano Wash and the attendant threat to public and private improvements. Additional information on the Rincon Valley is available at <http://srr.arizona.edu/~gimblett/rinproj.html>.

The Pantano Wash through this reach has been the subject of considerable mining for sand and gravel over the years. An approximately 14 foot drop in the bed profile of the stream over the latter half of the 20<sup>th</sup> century has been attributed in large part to such sand and gravel mining. Channel bed lowering can have dangerous repercussions as underground utilities, roadways, bridge support structures and natural channel bank stability are threatened by the lowering stream.

There are many acres of State Trust Land south of I-10 in this area and some private acreage, mostly ranches, wildcat development, and some subdivisions.

## **PROJECTED LAND USES**

### **The Pantano subsection**

The Comprehensive Plan for this area is highly complex. It calls for Resource Transition Zones along the boundary of the National Park, along with some Resource Conservation Zones along the boundary and along some watercourses. Industrial and commercial zones prevail along I-10 and south from Harrison Road to Nogales Highway in the Middle Santa Cruz Subarea. Zoning densities range from dense in the city portions to rural densities on the outskirts.

Despite the substantial public preserves in the upper part of the subarea, there are still significant areas which will face development pressure in the future, particularly within the Rincon Valley, the upland areas along the upper Pantano Wash. Major rezonings still in effect, although not yet built out are in the Rocking K Ranch Area and the Posta Quemada area. The Rocking K Area which is within city limits in the Rincon Valley, extending to the National Park boundary, was approved in the early 1990s (amidst great public opposition) and provides for enough homes for at least 25,000 people as well as commercial, resort and golf courses uses. Loss of the IBM manufacturing facility in 1989 somewhat lessened the growth pressures in this area, but population growth is again proceeding. Planners speculate that with designation of much of the Tortolita Fan area as Critical Habitat and difficult to develop, population growth will accelerate in the Rincon Valley.

The Posta Quemada rezoning was approved in the 1950s and is still in effect although the area has not yet been developed. This area abuts the Saguaro National Park on the southwest and includes residential and resort development.

Important management steps to be taken include insuring that the upper Pantano Wash and Rincon Creek are properly managed to control erosion of the streambed and upland areas. The Rincon Institute has taken the initiative

to rehabilitate and preserve sections of Rincon Creek and to work with landowners in the area on protection measures.

### **The Cienega Subsection**

Most of this part of the subarea is in public ownership, as described above, and protected from development. There is, however, a significant amount of State Trust Land south of I-10 which could be released for private ownership. This is also true in parts of the Davidson Canyon area where wildcat development is the greatest concern. Private interests also own pumping rights on some of this land and pumping could endanger the flow of the stream.

Downstream of the preserve, the possibility of groundwater pumping could also threaten water supplies for the riparian area. Surface water is currently diverted from the creek downstream of the preserve, but this will be inadequate to supply water to new developments.

Another possible problem for this area would come from new mining operations in the watershed of Davidson Canyon within the National Forest. While this is not currently being actively pursued, this could be a problem in the future.

Opportunities, however, also exist for this area. The Sonoran Institute has done detailed studies of Rincon Creek and restoration efforts are underway, assisted by funding from the Arizona Water Protection Fund. A 600 foot wide riparian woodland corridor along the creek will restore a channel that was destabilized by farming and grazing. The developer's plan will control flood water and erosion without invasive structures. Vegetation will be planted and a multi-use trail system developed.

The County is conducting restoration programs along Cienega Creek to restore an historic mesquite bosque and Sacaton grass habitats. Grazing has been curtailed in the preserve. In addition, Pima County could restore one to five miles of perennial flow within the preserve by acquiring a one-acre inholding with the dam and diversion structure and its water rights. For this to succeed, the Vail Water Company would have to obtain an alternate source of water, preferably effluent or CAP rather than groundwater in the area.

Pistol Hill and Davidson Canyon are both proposed as State Trust Lands which should be set aside for preservation under the Growing Smarter Initiative. (See Chapter 3).

A group of residents in the Sonoita-Cienega Creek area have proposed creation of the Las Cienegas National Conservation Area (NCA) including the BLM Empire-Cienega Resource Conservation Area and other lands within the watershed. The Sonoran Institute held workshops for about 200 people to explore the options and preferences of attendees and also produced a report on various aspects, utilizing both public and expert technical opinions. The element of greatest concern was the water supply for the area, followed by wildlife, landscape integrity and other features. People felt that if the water supply was compromised, the other values would also be compromised and that acquisition of water rights was crucial. The most contentious issues were the extent and type of recreation that should be allowed (e.g., off-road vehicle access) and overgrazing issues. The proposal is moving through Congress with support from the Arizona delegation. A proposal to instead create a National Monument by Executive Order has been dropped in favor of the NCA approach.

## **ISSUES FOR DISCUSSION**

### **WATER SUPPLIES**

What measures, if any, should be taken to preserve surface water supplies in the Cienega Creek and Rincon Creek watersheds? Should alternate sources of water, such as CAP water, be provided to landowners in these areas? Should efforts be made to use wastewater in these areas either through the city's reclaimed system or through a local treatment facility? Should acquisition of the Cienega Creek Preserve inholding have priority?

### **POPULATION GROWTH IN THE RINCON VALLEY AND POSTA QUEMADA RANCH**

Zoning is already in place for thousands of homes and other facilities in these areas. Are additional measures needed to prevent damage to the watershed and to prevent new downstream flooding? What restrictions should be placed on new zonings?

### **DEVELOPMENT IN DAVIDSON CANYON**

Should measures be taken to restrict wildcat development in the Davidson Canyon area in order to prevent flooding problems in Cienega Creek or to restrict groundwater pumping which might affect the flow of the creek?

### **MINING**

What actions, if any, should local governments take action in the future to protect parts of this area from new copper mining? How should new sand and gravel mining in the Vail region of Pantano Wash be handled?

### **PROTECTION OF THE CAVES AND SPRINGS**

What measures, if any, should be adopted to protect the limestone caves and springs in the foothills area from development?

### **NATIONAL CONSERVATION AREA**

Should the majority of the Cienega Creek watershed become a National Conservation Area, or have other additional protected designation?

Region Within the Subarea	Grazing	Wildcat Subdivision	Planned Subdivision	Copper Mine	Sand & Gravel Mine	Pumping	Agriculture	Recreation
Cienega Creek	X-	X+	X+	P	X+	X+		X+
Rincon Valley	X-	X+	X+		X+	X+		X+

**Key:** X = Existing    X+ = Existing with potential to increase    X- = Existing with potential to decrease  
X+- = Existing with potential to increase or decrease    P = Potential

**Fig. 5-3. Generalized Matrix of Potential and Existing Impacts on Watercourses in the Cienega-Rincon Subarea**

Region Within the Subarea	Alternate Water Less Pumping	More Non-structural Floodplain Management	Stricter Land Use Management	Federal Public Lands Expansion	State Trust Land Preserved	Other Preserves Increase	Better Grazing Management
Cienega Creek	X	X	X	X		X	X
Rincon Valley	X	X	X	X	X	X	

**Key:** X = Is possible and could have significant impact if it occurred.

**Fig. 5-4. Generalized Matrix of Potential Options for Reducing Stress on Watercourses in the Cienega-Rincon Subarea**

# Chapter 6

## Subarea 3 - Upper Santa Cruz

### WATERSHED/WATERCOURSE CHARACTERISTICS

#### THE WATERSHED

The subarea extends roughly from the northern San Xavier Indian Reservation boundary at Los Reales Road on the north to the Pima-Santa Cruz County line on the south and from the crest of the Sierrita Mountains on the west to the crest of the Santa Rita Mountains on the east. Elevations along the Santa Cruz River in the subarea range from approximately 2500 feet where the river passes Martinez Hill, to approximately 3000 feet where the river crosses out of Santa Cruz County. Elevations within the watershed range up to almost 6000 feet at Samaniego Peak in the Sierrita Range and 9400 feet at the peak of Mt. Wrightson in the Santa Rita Mountains. The subarea is shown on Fig. 6-1. The watershed is depicted on Fig. 6-2.

#### The Santa Cruz River Section

The Santa Cruz River originates on the east side of the Santa Rita Mountains, goes south into Mexico and then loops back to the United States east of Nogales. It gains additional flows from Sonoita Creek and several smaller watercourses. Mountain snows provide a significant amount of water to the watershed. The river is an effluent-dominated stream downstream of the Nogales International Wastewater Treatment Plant, but that flow dries up before it enters Pima County.

The Pima County portion of the watershed consists of two broad terraces between the river and the bordering mountain ranges to the east and west. Both terraces are drained by watercourses which vary in definition from well-defined foothills type watercourses to poorly defined sand bed channels which sometimes transition to a distributary flow pattern.

The Santa Cruz River is a wide sandy channel through most of this reach. The river once flowed perennially in some spots, most notably through the San Xavier Indian Reservation. The river and floodplain have seen dramatic

changes over time. During the 19<sup>th</sup> and 20<sup>th</sup> centuries the river experienced widening and deepening as a result of numerous factors including human activity in the floodplain. During the period 1936-1986, the reach of the river through the San Xavier Reservation experienced 20 to 30 feet of vertical entrenchment and the mean width of the channel more than doubled. (Parker, 1995). Between the San Xavier reservation and Green Valley the river experienced about 20 feet of incision which cut off several other flow paths of the river. Channelization along this reach also shortened the overall river length by about one mile (Parker, 1995). Between Green Valley and the Santa Cruz County line the river was fairly stable until the floods of 1977 and 1983 when this segment underwent major channel widening as a result of the floods. Between 1976 and 1986 alone this segment experienced about 1,200 feet of widening (Parker, 1995). Opinions vary as to the cause of the channel cutting and entrenchment along the Upper Santa Cruz river during the 19<sup>th</sup> and

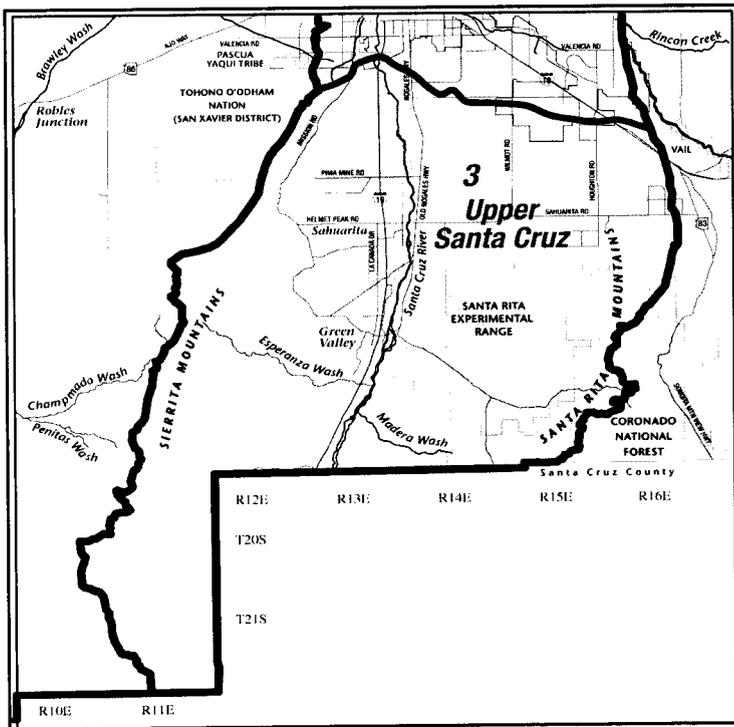


Fig. 6-1. The Upper Santa Cruz Subarea.

20<sup>th</sup> century with some attributing it to a dry climatic period, over-grazing of cattle, improperly designed diversion canals, geologic events or a combination of these three.

The west terrace, between the Santa Cruz River and the Sierrita Mountains, is also characterized by steeply sloping alluvial surfaces extending down from the mountains to the river. Numerous small drainages carry runoff from the mountains to the Santa Cruz River. This terrace is the site of numerous copper mining operations and the community of Green Valley. The large mines in this area effectively preclude runoff from a considerable portion of the mountain front from draining down into the river. The community of Green Valley is traversed by numerous improved drainageways that convey runoff from the remaining mountain front and terrace areas down to the river. These drainageways vary in size and shape but are generally lined with rock or cement on either the sides and sometimes the bottoms. They are generally well defined and trapezoidal in cross-section. As with the east terrace, drainages here are relatively steep (1 percent slope or greater).

### **The East Piedmont**

The east piedmont, between the Santa Cruz River and the Santa Rita Mountains, is characterized by broad expanses of grasslands intermixed with desert brush and rangeland. This terrace generally drains the north and west faces of the Santa Rita range. A substantial portion of this piedmont is state land, including the Santa Rita Experimental Range (SRER) which is owned by the state and administered by the University of Arizona College of Agriculture. The SRER consists of 83 square miles characterized by small areas of steep, stony foothills and a few isolated buttes but the greater part consists of long, gently sloping alluvial fans (Medina, 1996). Upper fans slope rather steeply and are cut by canyons and arroyos. At lower elevations, the slope diminishes to about 100 feet/mile and drainages become relatively shallow. Some parts of the lower range are characterized by terraces, breaks, or low escarpments and numerous gullies. Elevations range from 2,900 feet in the northwestern corner to about 5,200 feet in the southeastern part. Average annual rainfall within the SRER increases with elevation, from 10 inches at 2,900 feet to almost 20 inches at 4,300 feet (Medina, 1996). Research indicates that the grasslands on this terrace have experienced a decline since the middle of the 20<sup>th</sup> century (Medina, 1996). Recently, some major development has occurred along the southern portions of this terrace where it meets the geologic floodplain of the Santa Cruz River.

### **MAJOR WASHES**

The only major wash within this subarea is the Santa Cruz River which flows south into Arizona from Mexico. The drainage area for the Santa Cruz River at Continental Road is 1682 square miles. The 100-year discharge for the Santa Cruz River along this reach is 45,000 cfs.

The Santa Cruz River channel is entrenched several feet below the adjoining geologic floodplain grades. The depth of incisement varies from about 15 feet in the vicinity of Pima Mine Road to about 6 feet near the south boundary of Pima County. The degradation (incisement) has decreased the amount of overbank storage provided by the upper Santa Cruz River. However, the floodplain continues to extend across the valley floor during high-magnitude floods. This overbank flooding which occurs at widths generally ranging between 0.5 and 1.7 miles continues to provide some peak flow reduction benefits to downstream channel reaches.

Bank erosion is evident along most reaches of the upper Santa Cruz River. This bank erosion is associated with the higher velocities of flow which occur as a result of historical channel bed degradation. The banks along most reaches are comprised of fine grain silts and clays which erode easily during floods. Bank protection has been installed along the west bank adjoining the Santa Rita Springs development and along the east bank extending approximately 1.0 miles downstream of the Continental Road bridge. A short segment of bank protection has been installed by Pima County along the reach adjoining the Wastewater Treatment Plant.

### **TRIBUTARY WASHES**

The character of tributary washes varies from one location to another. There is a broad area of distributary flooding which covers many of the washes emanating from the Santa Rita Mountains east of the Santa Cruz River. This tributary flooding also occurs intermittently where tributary washes approach the Santa Cruz River along the west floodplain fringe.

Sopori Wash is the largest tributary wash within this subarea. This wash enters the Santa Cruz River along the west side of the basin at the Pima County/Santa Cruz County line. Upper reaches of Sopori Wash are located within Pima County at a point approximately seven to ten miles west of the confluence with the Santa Cruz River. The

upper reaches of Sopori Wash provide a significant amount of overbank storage capacity through the broad valley passing through Township 20 South, Range 11 East.

## HUMAN IMPACTS ON THE WATERCOURSES

### FLOOD MANAGEMENT PLANS AND ACTIVITIES

Because of the potential for flooding of the Santa Cruz River, Pima County maintains a warning system of precipitation and flow sensors at Nogales, Arivaca Junction and Green Valley.

The east terrace has been the subject of a technical investigation for floodplain management purposes. The "Hydrologic Investigation for the Lee Moore Wash Watershed" quantified hydrologic conditions and recommended floodplain management policies for the roughly 213 square mile watershed of the Lee Moore Wash which lies to the north of the Santa Rita Experimental Range. This area consists primarily of a tributary network of poorly defined watercourses within an inactive alluvial fan. The findings of the 1988 investigation indicate that lack of proper management of development in the area could result in an up to 300% increase in flood peak discharges on the Lee Moore Wash if channelization of the poorly defined washes were allowed to occur. The increase in flood peak discharges would largely be the result of loss of flood storage in the floodplains adjacent to the under capacity washes and the associated acceleration of collective downstream flow concentration. Somewhat prophetically, the report recommends adoption of policies prior to an increase in development of the area which has been occurring in recent years along Sahuarita and Houghton Roads. This concern was expressed in 1988 as plans for extension of Sahuarita Road through the area were underway. Only two years later, in 1990, the recently completed Sahuarita Road was badly damaged by flooding during a July 1990 storm, highlighting the flooding potential of the area.

During the early and mid 1990's some grading and berming of material was done along the river between Pima Mine Road and Continental Road to protect pecan groves along the river. In addition, some channelization was done upstream of the San Xavier Indian Reservation which caused entrenchment of the channel and cut off of other flow paths.

Development in Green Valley has led to construction of flood control structures on most of the washes which drain the Sierrita Mountains and foothills. These washes exist now as excavated and in many cases, rock or cement lined canals. In some cases however, the washes have been left relatively undisturbed with houses set back from the wash instead.

Pima County has \$1,000,000 in bond funds authorized in the 1997 election to do drainage improvements at Camino Portillo in Green Valley. The culverts will be expanded and a 160' long earthen dike protected by concrete installed on the north bank of the wash. In the downstream section the channel will be excavated and new bank stabilization constructed along the entire 2,300' reach.

Another bond project at Continental Ranch in the Green Valley area involve bank stabilization and berm construction with rip-rap and gabions to protect homes in the subdivision from flooding and erosion damage.

Pima County also has plans to improve drainage crossings in Sahuarita with construction of culverts and other drainageway structural measures. The conveyance capacity will be increased, reducing flooding.

The Bureau of Reclamation and the Tohono O'odham Nation constructed an erosion control project near the west bank of the river north of the Mission Road bridge. The purpose is to protect the bank from further erosion and provide an area for riparian habitat regeneration using a flow of CAP water.

The northern and south central parts of Green Valley have been declared critical basins because the existing culverts are inadequate and because several neighborhoods experience flooding or severe erosion. The southern and north central parts have been declared balanced basins because they have adequate capacity to convey runoff but the culverts under I-19 are inadequate and limit the capacity of the system. The northern part of the east terrace is designated as a balanced basin and discussed further in the Middle Santa Cruz chapter. (See Chapter 3 for information on critical and balanced basins).

### TRANSPORTATION

Interstate 19 traverses the area, roughly following the Santa Cruz River and connecting Nogales with Tucson. The Arivaca Road (paved 2-lane) connects I-19 with Arivaca and the Altar Valley. Sahuarita Road (paved 2-lane) connects I-19 with the southeast side of Tucson and I-10 at Houghton Road. Some truckers use the road to bypass the metropolitan area. A railroad track roughly parallels I-19 from Nogales to Tucson. The Tucson International Airport is at the northern end of the subarea.

## **WATER AND WASTEWATER-RELATED LAND USES**

### **Water Supply**

Depth to water ranges from about 70 feet just north of the Santa Cruz County line to more than 500 feet at the northern flank of the Santa Rita Mountains, with some near-surface flow at the higher elevations. The area has experienced a major drop in the water table because of groundwater pumping for the mines, for agriculture, and for urban uses. Springs that once flowed near San Xavier no longer flow because of this drop in the water table.

The Green Valley-Sahuarita-Continental area is served by seven private water companies. In addition, the mines and the pecan growers have their own wells, as do individuals in the area. There are CAP allocations in the area, but not yet the delivery system to use it. ASARCO may participate in the Groundwater Savings Facility Program (in lieu-recharge) by using CAP water in lieu of pumping groundwater if technical and economic issues can be resolved. (See Chapter 3 for information on this program).

The City of Tucson has one of its most productive wellfields in the metropolitan region on the northern boundary of the subarea, adjacent to the Tohono O'odham Nation. In this area the water table declined more than 100' between 1940 and 1995 and there is a cone of depression at the northern boundary of the subarea. The Water Development Corporation documented the connection between the decline of the water table and the demise of a giant mesquite bosque and cottonwood forest south of San Xavier, which died in the 1940s and 1950s when the water receded beyond the root zone of the trees. The Tohono O'odham are considering using part of their CAP allocation to add flows to tributary washes to rehabilitate the habitat. (See below)

### **Wastewater**

Pima County operates a wastewater treatment facility in Green Valley, using aerated lagoons. Sahuarita is in the process of becoming designated as the management agency for most of the town. Many individuals in the rural parts of the area are on septic systems. There is little reuse of wastewater in the region, but the recent agreement between the City and County (See Chapter 3), should open up new opportunities for use of wastewater.

### **Recharge**

Parts of this subarea are used and more are proposed for use for CAP recharge projects. At Pima Mine Road recharge basins already exist and projects are in the planning stage for instream recharge from that area to Valencia Road. The Pima Mine Road Recharge Project (PMR) was developed by CAP jointly with the City of Tucson Water Department as a State Demonstration Recharge Project for the underground storage of Colorado River water. A 2-mile long, 36-inch diameter pipeline will convey water by gravity from CAP's aqueduct to the recharge basins. The project occupies 14 acres, with basins excavated twelve feet below the surface. Up to 10,000 acre-feet of CAP water can be recharged during the pilot phase. CAP pipeline reaches this area from the Altar Valley through the San Xavier District and could possibly be extended to Green Valley and the copper mine.

Another recharge proposal involves in-channel recharge through the San Xavier District. This proposal would require agreement between the Tohono O'odham and the City of Tucson. Approval of this project would also require approval of the U.S. Fish and Wildlife Service in light of possible impacts that organisms introduced by CAP water might have on threatened and endangered species.

## **EXISTING PUBLIC LAND USES**

The upper watershed is in the Coronado National Forest which includes the popular Madera Canyon Recreation Area, with its trails, picnic areas and campground. Private residences in the Canyon have been phased out. Grazing is allowed in parts of the National Forest.

The 530,811 acre Santa Rita Experimental Range is between the Madera Canyon area and Green Valley. This land is owned by the State of Arizona and managed by the University of Arizona for long-term grassland studies. This area is not open for grazing or recreational use.

## **HISTORIC LAND USES**

Parts of this area are the most historic in the region. People have used the area for at least 2,000 years. The course of the river south of this subarea was a shallow, marshy creek with perennial water. At the present county line the geology changes from high bedrock to the south and deep alluvium to the north. The river was historically normally dry between the county line and the springs in the Martinez Hill region, although the water table was very close to the surface. The springs provided a dependable supply of water for Indians and attracted Spanish

missionaries to the area where they established the San Xavier Mission and grew crops. The Tohono O'odham farmed the region around the mission for many years, but sinkholes have developed in the former agricultural land making this land unusable.

Spanish miners worked in the Santa Rita Mountains as did Anglo miners starting in the mid-nineteenth century and there are still remains of historic mines in the area. The river became a major transportation corridor for gold seekers going to California and many other travelers.

The Continental-Green Valley area has been used for farming for almost one hundred years. Pecan groves have replaced crops such as corn and cotton grown on family farms.

## **EXISTING PRIVATE LAND USES**

### **The Santa Cruz River Region**

The only incorporated town in the subarea is Sahuarita. Sahuarita's current population is less than 3,000, but is projected to increase to about 9,000 by 2015. Continental is a small agricultural community. Green Valley which has a much larger population has repeatedly rejected attempts at incorporation. The Tucson City limits reach the northern edge of the subarea.

The primary agriculture in the area is in the FICO pecan groves along the river in the Green Valley/Continental area. Although some new groves have been recently planted, some of the older groves have been converted to residential use.

The San Xavier portion of the subarea is largely used for ranching, some residential use, and tourism at the Mission. The ASARCO copper mine extends onto the San Xavier District. Although most of the land along I-19 has been left undeveloped down to Sahuarita, the tribe is currently constructing a new casino and connecting road on the east side of I-19 at the southern boundary of the tribal property.

Large open pit copper mines are very significant features in this area, extending from within the San Xavier district where land is leased for mining, all the way to Green Valley and for many miles west. The mining which has occurred on the foothills terrace between Green Valley and the Sierrita Mountains and up into the San Xavier District of the Tohono O'odham Nation has resulted in the trapping of most of the mountain runoff in the tailings ponds associated with the mines. For the most part the effect of these mines on drainage through Green Valley has been to reduce flooding. However, mining operations are exempt from coverage under most floodplain management regulations in Arizona. Hence, the effectiveness and safety of the tailings mines as flood control structures is undocumented.

The mining operations may have water quality impacts. Water is used in the process of removing copper and other minerals from the ore and the resulting contaminated water is reused to some extent, but then disposed of in tailings ponds where the water evaporates and reject materials remain. Tailings ponds loom behind Green Valley and to the north. The USGS is currently conducting a study of the potential impacts to water quality of mining operations in the Upper Santa Cruz watershed (see <http://minerals.cr.usgs.gov/santacruz/index.htm> for more information on this project).

### **The East Terrace**

The east terrace on the north side of the Santa Rita Mountains slopes gently toward the flat valley. A granite mine on this side provides construction materials for a growing Tucson metropolitan area. In some areas wildcat development has occurred and there are a few small neighborhood developments near the eastern boundary of the subarea, most notably Corona de Tucson. Many acres of land are advertised for sale, both as large acreages and as developed lots within planned subdivisions. Sycamore Ridge, for example, to the west of Corona de Tucson, has lots for sale of minimum 4 acres with utilities. South of I-10 in the Wilmot area is a State Prison, and the Pima County Fairgrounds.

## **PROJECTED LAND USES**

The Pima County Comprehensive Plan allows for commercial and residential zoning on the west side of the River from the county line through Sahuarita and for mixed uses north of the mountains to I-10. Green Valley is expected to continue to grow at a rate of 2-3 percent annually. The incorporated town of Sahuarita is currently considering additional high density land use rezonings, commercial uses, golf courses and a community lake which will use groundwater. Because the lake is designated as a town lake, rather than a private lake, it is exempt from state laws governing use of groundwater on new lakes.

An attempt to rezone the Canoa Ranch on the southern boundary of the subarea failed and the area is under consideration for a historical and natural preserve, although additional rezoning applications may be submitted. The Santa Cruz County portion of the river is also experiencing population growth pressures and a continuous population corridor from Nogales to Marana is possible in the future.

Several attempts have been made to rezone the Canoa Ranch, near the Santa Cruz County line, for relatively high density development and resort facilities. The Board of Supervisors denied a major rezoning request, but new requests are rumored. Current county policy is to attempt to protect as much of this area as possible as open space. Private citizen groups are actively working to raise the necessary funds to preserve the historic and natural features of the area as a park, living history museum, or other format.

Additional residential or commercial uses in this area would have impacts on water supplies if groundwater pumping is the water source and on drainages and flooding potential as new impervious surfaces are constructed, drainages altered, and flood control structures built. This will especially be a problem if construction occurs on the broad floodplain. Expansion of Sahuarita Road or any other new road needed for an expanding population would impact drainages in the many ways described in Chapter III.

There may be demands to widen Sahuarita Road as more and more truckers use the road as a bypass between I-10 and I-19 and as more housing development occurs. This would probably involve changing the dip crossings to all-weather crossings. This in turn would probably lead to additional residential and commercial use of that area.

Copper mining in this area was projected to have diminished by now, but new processing techniques have extended the life of the mine. This copper will eventually be mined out and active operations will cease, but the long term land use and watershed impacts of the open pit mine and the tailings ponds will remain.

The granite mine at the north end of the Santa Ritas has a much longer projected lifetime, keeping pace with the demand for construction materials. Because of the provisions of the 1872 Mining Laws, it is possible that the Santa Rita Mountains may be the location of new mining operations, although the only recent proposal has been on the east side of the range, outside this subarea.

Agriculture (traditional crops as well as crops such as alfalfa) will return to San Xavier when the CAP pipeline reaches the area in 2001. The Tohono O'odham also have plans to restore parts of the Santa Cruz River as well as a number of washes, using their allocation of CAP water. They are also considering using CAP water to reconstruct the mesquite bosque that was once south of the mission, possibly solving the sinkhole problem in the process.

## **ISSUES FOR DISCUSSION**

### **POPULATION GROWTH ALONG THE RIVER**

With the projected population growth in Green Valley and Sahuarita additional pressures will be put on the water supplies of the area as well as the drainage features. How should these pressures be handled? Should growth be limited to reasonably available groundwater supplies or should CAP water be brought farther south for use on turf and/or treated for municipal use?

### **POPULATION GROWTH ON THE NORTH SIDE OF THE SANTA RITAS**

How should the distributary flow issues be handled as the east terrace is developed? Should the trend be towards planned subdivisions, wildcat development, or towards minimal further development?

### **CANOA RANCH**

What should be done at Canoa Ranch? Should it be zoned for higher density residential development or should it be preserved as open space? Is a park or museum a good use for that land? If developed what measures should be implemented to preserve overbank capacity.

### **WATER SUPPLIES**

If the CAP pipeline is extended to Green Valley, enough water would be available for more population growth without using additional groundwater. Is this a desirable goal? Additional land will be used for recharge projects if the current projects prove to be successful. Is this a desirable land use for the area?

**EFFLUENT USE**

Should better use be made of wastewater produced in this area? What kinds of uses are preferable: constructed wetlands, riparian restoration, and/or application to golf courses or the pecan groves with corresponding reduction of groundwater use? How should any such projects be implemented?

**WIDENING OF SAHUARITA ROAD**

Should Sahuarita Road be widened and made into an all-weather road?

**CONVERSION OF SANTA RITA EXPERIMENTAL RANGE**

Although there are currently no plans for the University to abandon the Range, this is possible in the future. As this is State Trust Land, it would be available for sale at some time in the future. What should be the long-term plan for this land? Should it remain as open space?

**EXPANSION OF TOURISM AT MADERA CANYON**

Increasing tourism will place pressures to provide more services in Madera Canyon and to improve the road into the canyon. What measures should be taken to assure that the adverse impacts are minimal?



Region Within the Subarea	Grazing	Wildcat Subdivision	Planned Subdivision	Copper Mine	Sand & Gravel Mine	Pumping	Agriculture	Recreation
Santa Cruz River vicinity		X	X+		X	X+-	X-	X+
Piedmonts	X	X+	X+			X+		X+
Mountains	X			X-				X+

**Key:** X = Existing    X+ = Existing with potential to increase    X- = Existing with potential to decrease  
X+- = Existing with potential to increase or decrease    P = Potential

**Fig. 6-3. Generalized Matrix of Potential and Existing Impacts on Watercourses in the Upper Santa Cruz Subarea**

Region Within the Subarea	Alternate Water Less Pumping	More Non-structural Floodplain Management	Stricter Land Use Management	Federal Public Lands Expansion	State Trust Land Preserved	Other Preserves Increase	Better Grazing Management
Santa Cruz River vicinity	X	X	X			X	
Piedmonts	X	X	X		X		X
Mountains							X

**Key:** X = Is possible and could have significant impact if it occurred.

**Fig. 6-4. Generalized Matrix of Potential Options for Reducing Stress on Watercourses in the Upper Santa Cruz Subarea**

# Chapter 7

## Subarea 4 - Middle Santa Cruz

### WATERSHED/WATERCOURSE CHARACTERISTICS

#### THE WATERSHED

The Middle Santa Cruz Subarea includes that portion of the Santa Cruz River Watershed that lies between Martinez Hill to the south and the Rillito River confluence to the north. It is downstream of the Upper Santa Cruz Subarea described in Chapter 6 and the Cienega-Rincon Subarea described in Chapter 5. The subarea includes the Rillito River-Pantano Wash system and its watershed upstream to Rincon Creek. Pantano Wash becomes Rillito Creek at Craycroft Road where Tanque Verde Creek joins Pantano Wash. The subarea encompasses much of the Tucson Metropolitan area and extends to the crest of the Tucson Mountains on the west, to the crest of the Santa Catalina Mountains on the north and to the crest of the Rincon Mountains on the west. Elevations along the Santa Cruz River in the subarea range from approximately 2200 feet at the Rillito River confluence to 2500 feet where the river passes Martinez Hill. Elevations within the watershed range up to almost 4,700 feet at Wasson Peak in the Tucson Mountains, almost 9,200 feet at the peak of Mt. Lemmon in the Catalina Mountains and almost 8,400 feet at Rincon Peak in the Rincon Mountains. Fig. 7-1 shows the subarea. Fig. 7-2 depicts the watershed.

#### Central region

The subarea consists of a broad alluvial plain between the Middle Santa Cruz and Rillito River-Pantano Wash system flanked by relatively steep foothills and mountains lying west of the Santa Cruz River, north of the Rillito River and east of the Pantano Wash. The alluvial plain between the Santa Cruz and Rillito-Pantano consists primarily of the urbanized Tucson Metropolitan area. In this area, drainage consists largely of urbanized (i.e., channelized and bank protected) watercourses. The Alamo Wash is an example of a largely urbanized wash within this area. In many cases drainage is carried within street sections which were built along historic natural drainage paths. Alvernon Way from Speedway to Ft. Lowell Road is a good example of this type of drainage. In a few cases

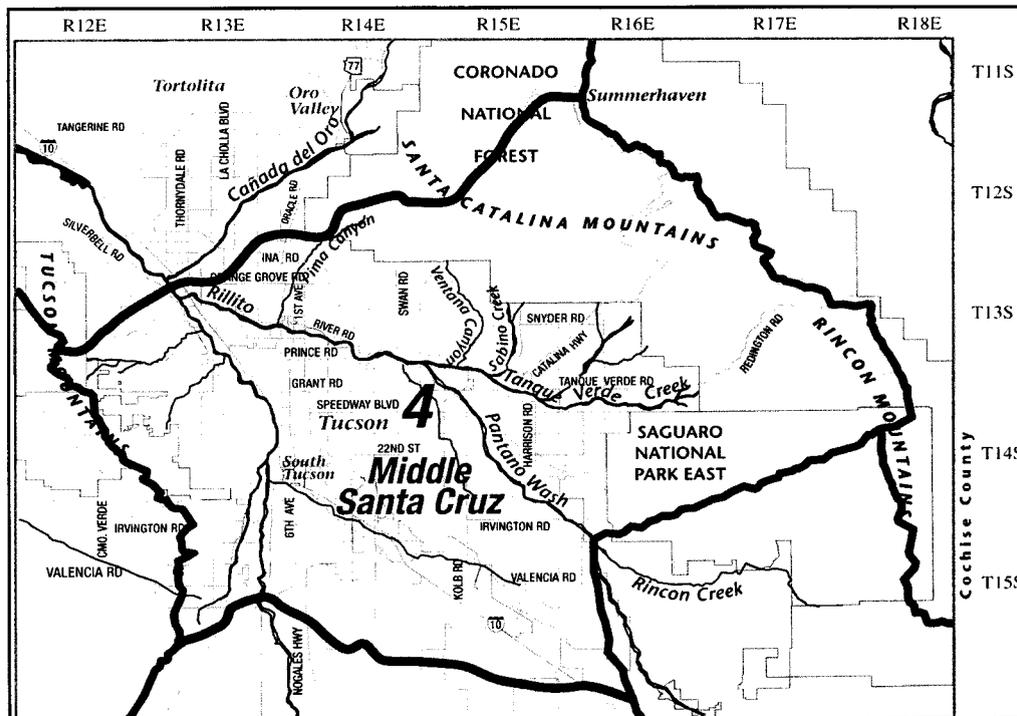


Fig. 7-1. The Middle Santa Cruz Subarea.

some washes have been preserved in their natural state or have been enhanced to provide a vegetated riparian environment. The Arroyo Chico west of Randolph Park is an example of such a wash. South of the Tucson Metropolitan area this alluvial plain exists as relatively natural drainage paths from the foothills of the Santa Rita Mountains to the south. Drainage in this area is generally well defined although some of the drainage south of the airport is almost sheet flow-like in nature.

In the 1800's the Santa Cruz and Rillito Rivers within the subarea existed as shallow meandering streams where the groundwater level sometimes reached or exceeded the wash bed level, resulting in stream flow and occasional marshy areas. During the late 19<sup>th</sup> century and early 20<sup>th</sup> century, a combination of conditions occurred which resulted in entrenchment of these rivers into much deeper channels. It is not entirely clear what caused this to happen but the entrenching of the rivers is generally attributed to a combination of climate changes, man-made diversions along the rivers, overgrazing and perhaps some geologic activity in the Tucson area.

Today, the Santa Cruz and Rillito Rivers are very well-defined, channelized and bank protected washes. The Santa Cruz River once flowed above ground in a few spots within the subarea, most notably at the base of "A" Mountain. However, excessive groundwater pumping has lowered the water table so that the river now flows only in response to direct rainfall runoff or discharge of effluent from wastewater treatment facilities. Channelization and erosion control of the river began in the early 1970's as development encroached upon the floodplain. The channelization process gained momentum in response to the flood and erosion damage which occurred during the floods of the late 1970's and 1983. The 1983 flood alone caused more than 64 million damage to roads, bridges, and public utilities, not to mention private property damage. By the early to mid 1990's nearly all segments of the Santa Cruz and Rillito Rivers in the Tucson area had been channelized and stabilized using soil cement or other treatments. As a result of this effort, the January 1993 flood, considered to be similar in magnitude to the October 1983 flood in some respects, caused considerably less damage. Included with or added onto many of these flood control projects were recreational improvements such as biking or walking paths, parks and playgrounds.

The Pantano Wash (i.e., the upstream extension of the Rillito River) was somewhat less impacted during the Tucson urbanization process. The wash is protected with soil cement, rock and other stabilization materials in some, but not all, locations. This stream has been most adversely affected by the practice of upstream mining for sand and gravel needed for construction. This practice has contributed substantially to downcutting of the channel bottom as channels are eroded into and out of the relatively deep pits dug into the channel as a part of the mining effort. In recent years the Pima County Flood Control District has taken a more restrictive approach generally to managing this type of activity, but the pits along the Pantano Wash were annexed by the City of Tucson.

### **Foothills regions**

The portions of the subarea west of the Santa Cruz River, north of the Rillito River and east of the Pantano Wash include the foothills of the Tucson Mountains, the Santa Catalina and the Rincon Mountains, respectively. These three foothills areas consist of well defined washes coursing through the ridges of the foothills. These washes are generally in their natural condition and serve as a conduit for wildlife to travel into the mountains. These washes generally have adequate flood storage capacity and development has tended to stay up on the ridges away from the wash bottoms. Erosion hazards are relatively limited in these areas as the geology of the foothills ridges generally rises above the alluvium of the plain between the rivers and has a hard surface, not easily eroded.

The subarea is home to well-known riparian areas associated with the Tanque Verde Creek, and its tributaries, Bear Canyon, and Sabino Creek. Tanque Verde Creek is a tributary to the Rillito River located in the valley between the Santa Catalina and Rincon Mountains. Although Tanque Verde Creek is generally dry, it is home to a wide variety of vegetation including cottonwoods and sycamores. The density of vegetation along the creek is well-known in the area and is easily observed from aerial photography. Sabino Creek is a tributary of Tanque Verde Creek. Sabino Creek has its headwaters in the upper reaches of the Santa Catalina Mountains and receives considerable runoff from spring snowmelt and mountain rainfall. As a result, Sabino Creek is often a running stream. The upper portions of the creek are located within the National Forest Service where the creek exists as a steep boulder strewn stream with dense vegetation. The creek attracts thousands of visitors each year looking for an oasis of water and vegetation in the desert.

### **TRIBUTARY CHARACTERISTICS**

The characteristics of tributary washes within the subarea vary considerably. This change is largely a function of slope, geology and vegetation cover/type. Tributary washes which emanate from the Catalina Mountains are generally well defined until reaching their confluence point with Rillito Creek or the Canada del Oro Wash. Today

distributary flow occurs only at the confluence of Finger Rock Wash with Rillito Creek, but historically this type of form was more common where tributaries entered the Rillito Valley. The area roughly bounded on the north by Rillito Creek, on the south by Interstate 10, on the east by Harrison Road and on the west by the Canada del Oro Wash is highly urbanized. Several of the washes within this area have been channelized. Most were channelized thirty to forty years ago, are under capacity, and subject to overbank flooding through residential areas. Many of the washes are earthen and have experienced bed degradation and erosion. The City of Tucson has modified some of the channels by increasing their capacity and installing bank protection.

The area south of Interstate 10 and east of the Alvernon Way alignment contains a wash planform that is different than observed in other areas of Pima County. This region of the valley is comparatively flat having slopes generally in the range of 1 percent. The cross-slope from ridge to valley floor is also very mild. Vegetation cover throughout the area consists primarily of creosote and desert grasses. The mild slopes combined with denser vegetation cover results in less runoff. The lower runoff volume combined with the more passive landform fails to yield sufficient energy to cut sand bed channels which are so common throughout the rest of the county. Runoff from the watersheds in this area creeps overland to settle into the low lying areas or percolates into the ground. The low lying area where flow settles are usually quite wide which provides significant runoff storage capacity. This storage capacity is important to reducing flood peaks along downstream channels such as Airport Wash and Rodeo Wash. These washes are also geologically stable yielding little sediment even during high magnitude storms.

### **MAJOR WASH CHARACTERISTICS**

The major washes within this subarea include segments of Pantano Wash, Tanque Verde Creek, Agua Caliente Wash, Sabino Creek, Rillito Creek, and the Santa Cruz River. Pantano Wash has been channelized and stabilized with soil cement bank protection along most of the reach between the Rillito Creek confluence and Golf Links Road. Significant channel bed degradation has occurred along the Pantano Wash during past decades requiring periodic grade control structures to prevent undermining of bridges and utilities which cross the channel. South of Golf Links Road the Pantano Wash exists primarily in a natural condition. There is a grade control structure at the Harrison Road dip crossing that functions to reduce bed degradation along the upstream reach.

Channel bed degradation continues to occur along the reach upstream of Houghton Road. This degradation has been due to urbanization effects along downstream reaches and due to sand and in-stream gravel mining that has occurred since the 1950's. Degradation has increased channel depth by several feet and narrowed the floodplain, caused higher flow velocities and has increased bank erosion. Stream capture of some of the gravel pits has, at some locations moved the channel across the valley floor by several hundred feet.

Tanque Verde Creek exists primarily in a natural condition east of Tanque Verde Road. Soil cement bank protection has been installed between the confluence with Sabino Creek and a point about 1/4 mile upstream of Tanque Verde Road, and along portions of the bank adjoining Tucson Country Club Estates. The depth of the low flow channel has increased due to degradation along the reach between the Rillito Creek confluence and a point about one mile upstream of Tanque Verde Road (a total distance of about 4 miles). The degree of bed degradation has not been as severe as along Pantano Wash but overbank flow depths and storage capacity is limited. Bank erosion has increased as a result of higher flow velocities associated with channel incisement. Significant overbank flooding and storage capacity still exist along the upstream reaches east of Houghton Road and the Agua Caliente confluence.

The Agua Caliente Wash is a major tributary to Tanque Verde Creek. Agua Caliente has experienced major floods in 1983 and 1993. A significant amount of residential development has occurred within the floodplain. The channel was generally shallow and braided until it was excavated through the Belaire Ranch Estates subdivision in the 1970's in an attempt to contain flows and allow development adjoining the channel. The Belaire Ranch excavation started a geomorphic phase of arroyo cutting and entrenchment along the wash. The banks of this excavated channel have been eroded during past floods and the capacity of the channel has been inadequate to contain flows experienced in 1983 and 1993.

Pima County channelized Agua Caliente Wash along the reach beginning about one half mile upstream of Tanque Verde Road to direct flow through a new bridge. The new bridge was constructed after the 1993 flood which isolated residents east of Agua Caliente Wash and north of Tanque Verde Creek for a period of three to four days. This channelization collects all but about 2000 cubic feet per second (cfs) of the 100 year flow and directs it through the bridge opening. The 2000 cfs flow outflanks the east end of the bank protections and passes over Tanque Verde Road. Flow that passes through the bridge opening then flows toward another bridge at Houghton Road. Some of the flow passes through the bridge at Houghton Road while most of it drains along the east side of

Houghton Road toward Tanque Verde Creek. This results in a large sheetflow floodplain area on the east side of Houghton Road extending south to Tanque Verde Creek. This sheet flooding area probably functions to some degree to reduce downstream peaks flows. Currently there is a proposal by area land owners to channelize the wash from Houghton Road to the Tanque Verde Creek confluence.

The floods of 1983 and 1993 have made it evident that the reach of Agua Caliente Wash downstream of Tanque Verde Road has been aggrading. This aggrading is due to slope reduction and the dispersion of flow onto the overbank areas.

Except for a dam in the Sabino Canyon Recreation Area, Sabino Creek has not been modified by man-made changes other than at the confluence with Tanque Verde Creek. The stream bed matrix for Sabino Creek is a gravel/cobble complex which resists movement except during high magnitude storms. As such, bed degradation has been limited and has occurred only in the vicinity of the Tanque Verde Creek confluence. Upstream reaches are naturally armored with cobbles and bedrock outcrops. The degree of development within the Sabino Creek floodplain is isolated and of low density.

The reach of Rillito Creek within the boundary of the subarea exists primarily as an urban flood control channel. The banks have been lined with soil cement along the entire length except one mile reach of the south bank between Swan Road and Dodge Blvd. Grade control structures have been installed by Pima County and the Corp of Engineers to prevent further degradation and stabilize the vertical profile. The 100 year floodplain limits are contained within the banks except along the aforementioned Camino de la Tierra area and between Dodge Blvd. and the Country Club Road alignment.

The Santa Cruz River has been channelized and stabilized with soil cement along most of the reaches within this subarea except,

- (1) a two mile reach beginning ½ mile north of Valencia Road extending to Irvington Road,
- (2) a one mile reach from Ajo Way to the 36<sup>th</sup> Street alignment,
- (3) along the one mile reach beginning one fourth of a mile north of Grant Road to the Ft. Lowell Road alignment, and
- (4) from a point approximately one fourth of a mile north of Camino del Cerro to the confluence with Canada del Oro Wash.

Construction plans are presently being prepared by Pima County for installation of soil cement bank protection along the reach between Grant Road and Ft. Lowell Road. This reach contains a severe meander bend where bank erosion has been significant during past floods. During the 1983 flood the west bank moved approximately 600 feet west.

The degree of channel incisement that has occurred along the Santa Cruz River has eliminated almost all overbank flooding within this subarea. Degradation of the bed continues to occur but not to the degree experienced between the 1950's and 1990's. Grade control structures have been installed along some reaches to stabilize the vertical profile.

## **HUMAN IMPACTS ON THE WATERCOURSES**

### **FLOOD MANAGEMENT STUDIES AND ACTIVITIES**

Extensive studies and control projects have been implemented on the Santa Cruz and Rillito rivers. In addition the majority of washes in the urban area have been treated for flood control in some manner. These treatments range from full straightening and cementing of the wash on sides and bottom (e.g., Arroyo Chico under Kino Boulevard), to leaving the wash relatively natural in places with dip crossings (e.g., Arroyo Chico north of Reid Park).

As described above the Rillito is soil cemented or planned for soil cement for its entire distance to the confluence with the Santa Cruz, including parts of the Pantano Wash.

### **Pima County Studies and Projects**

Pima County projects and studies are conducted both within and without city limits, as the property tax levy that funds the district comes from all landowners in the county. A more complete list of Pima County studies is in Appendix C. The ones described below are representative of problems in this subarea.

The City of South Tucson Drainage Study looked at drainage problems in this area and examined how improvements in adjoining areas could mitigate serious street flooding problems in South Tucson. This study was in response to a request from South Tucson for an \$11 million project that would have funneled much of the stormwater into storm sewers. The Pima County study looked at other alternatives and recommended a less costly

one that would utilize a retention basin near 36<sup>th</sup> Avenue and Park Avenue and would combine the flood control features with recreational features, including a ball field.

A plan for the Santa Cruz River from Valencia to Irvington calls for two new miles of soil cement bank stabilization on both banks to tie into existing bank stabilization to control erosion. Matching funds will be required from property owners.

The Tucson Mountain Basin Management Study completed in 1986 looked at the channels tributary to the Santa Cruz River and found then that there was sufficient capacity in the channels upstream of Silverbell Road, but the channels downstream were undersized. Development policies were recommended that included building setbacks, channelization of tributaries and all weather access provisions as well as preservation of natural watercourse characteristics upstream of Silverbell Road. Some road improvements have been made since that time. Most of the upstream watercourses are still relatively natural as recommended.

The River Management Plan for Rillito River and Major Tributaries establishes floodplain objectives for Pantano Wash from Speedway Boulevard downstream, Tanque Verde Creek, Agua Caliente Wash and Sabino Canyon Wash. Bank stabilization and grade control structures were recommended for all of Rillito Creek and for Pantano Wash from Speedway to Glenn. Non-structural approaches were recommended for the other areas, with emphasis on natural channel overbank storage capacity. After severe erosion during the 1993 flood some property owners along Tanque Verde Creek called for reconsideration of the non-structural approach and a new study was undertaken. Only one structural measure was initially found feasible, a levee at the Forty-niners Country Club, but at the request of homeowners this was dropped and only nonstructural approaches are under consideration. The management plan for the Cienega Creek Preserve prohibits channelization and sand and gravel mining. .

A network of flood and precipitation sensors warns of floods coming down the Santa Cruz from Nogales, and down the Rillito River system with thirteen sensors at Tanque Verde Creek, Sabino Canyon, Agua Caliente, and Ventana Canyon.

Pima County has acquired four acres along the Tanque Verde Creek for floodplain management and other acreage along Pantano Wash, the West Branch of the Santa Cruz River, and the Rillito River.

#### *Critical and Balanced Basins*

The county has declared many parts of the urban area outside city limits as critical basins (See Chapter 3). The Riverside Terrace area on the northwest side near Orange Grove Road was declared critical because it poses flooding problems with existing development. A portion of the Ruthrauff Road area has very poor drainage and drainage facilities are almost nonexistent. The Friendly Village and Northmanor areas have drainage problems because of poorly constructed drainageways.

Along the Catalina Foothills, the Finger Rock Wash and Valley View Wash areas are considered critical basins because of flooding and erosion problems caused by inadequate channels, diverted floodwaters, and homes within the floodplain. Ventana Canyon is a balanced basin because the terrain is steep and further development would cause flooding problems.

Farther east the Tres Hombres, Woodland Wash, Tanque Verde Wash, Fortyniners Wash and Hidden Hills Wash basins are critical because of severe drainage problems because natural and manmade channels are incapable of conveying discharges. In the Tres Hombres watershed poorly defined channels on the fan surface complicate the issue. The Agua Caliente at Melpomene is balanced because the channel cannot handle the discharges and further development would complicate the picture.

On the south side of the area, parts of Earp Wash, Airport Wash, Julian Wash, Valencia Wash, and Rodeo Wash are considered balanced because there is potential for serious flood problems.

On the east side of the Tucson Mountains the area is not designated, but it is included in the Tucson Mountain Management Area in which each proposed development is evaluated as to its needs to be considered critical or balanced.

#### **City of Tucson Studies and Projects**

Tucson divides the city into nine hydrologic units as shown in Fig. 7-2. The City's of Tucson's Stormwater Management Plan looked comprehensively at 59 watersheds which comprise the City's stormwater system. Nonstructural stormwater management is recommended within 55 percent of these 59 watersheds. This type of management includes recommending purchase of flood insurance, new studies, and preservation of naturally vegetated watercourses. For the other 45 percent combination or structural approaches are recommended, including

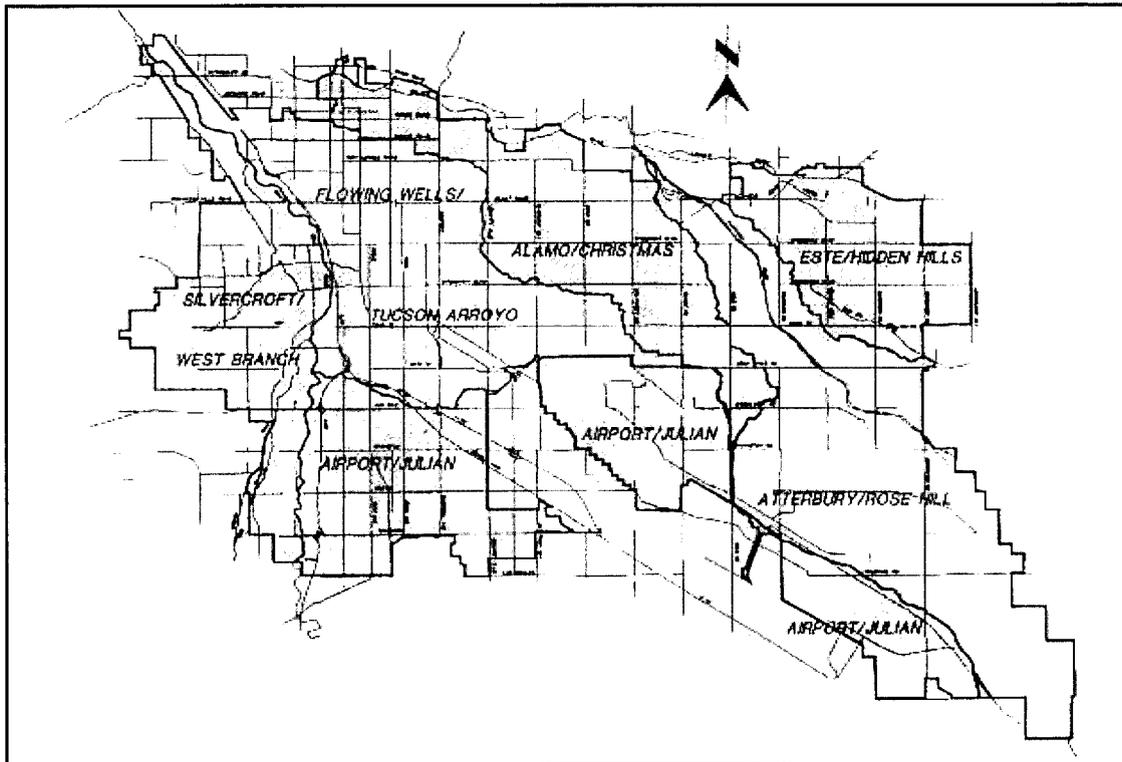


Fig. 7-2. City of Tucson Hydrologic Units. Source City of Tucson Stormwater Master Plan.

structural improvements for homes, storm drains, concrete or soil cement lining, riprap or gabion banks, vegetated or earthen banks and mitigation of riparian habitat. Flood hazard studies were considered of highest importance for the "A" Mountain/Menlo Park area, Alverson Wash, High School Wash and others as listed in Appendix D.

The City's study prioritized watercourses according to condition of the natural vegetation, with Atturbury Wash, Civano Wash and Anklam Wash having the highest value and Escalante Wash, Camino Seco Wash, and Alamo Wash having the lowest. For a complete list see Appendix D. Riparian habitats recommended for preservation with potential disturbed areas were Airport/Julian, Alamo/Christmas, Atturbury/Rose Hill, Este/Hidden Hills, Flying Wells/Tucson Arroyo and Silvercroft/West Branch.

In the structural program, potential localities for stormwater projects include portions of Valencia Wash, Airport Wash, Downtown, West University, Grant Road, Flying Wells Wash, Alamo Wash, and others as Listed in Appendix D. Grade control structures are recommended on fourteen watercourses.

## WATER AND WASTEWATER-RELATED LAND USES

### Water Supply

Depth to water in the valley ranges from 150 feet near the Santa Cruz River to almost 400 feet in central Tucson, with a few areas of shallow groundwater in the outlying areas. Most of the groundwater pumping in the area is done by Tucson Water, but other water providers also pump a significant amount of water within this subarea. Some of the major providers are Metropolitan Domestic Water Improvement District, Flying Wells Irrigation District, The University of Arizona, and Davis-Monthan Airforce Base. See Chapter 3 for a map of water providers.

For the most part the water table has already dropped so far that any connection between groundwater and surface water does not exist, but in a few localized portions of this subarea, there is shallow groundwater and excessive pumping can affect riparian vegetation. This is especially true along parts of the Tanque Verde, Sabino Creek, Bear Canyon, and Agua Caliente. Continued growth in this area could have detrimental effects on watercourses unless the water supplies are brought in from elsewhere. Reduction of current pumping levels in some

of these areas would also benefit the riparian areas. In the mountains a number of perennial streams still flow without competition from water users.

Subsidence from excessive groundwater pumping is already occurring in central Tucson and around the airport. This is expected to worsen unless pumping in the vulnerable areas is stopped. Subsidence would seriously affect buildings, roads, pipelines, and other facilities. It could also affect how and where flooding occurs. While the City of Tucson will be taking steps to reduce pumping in the central area once CAP water is introduced into the system, other pumpers will probably continue their pumping unless management changes are made.

The Summerhaven area on Mt. Lemmon gets its water from the headwaters of Sabino Creek. In a drought year water supplies on the mountain are restricted and the flow in Sabino Creek below is much less than in normal to wet years.

## **Wastewater**

Pima County operates two major sewage treatment plants that treat the vast majority of the wastewater from this subarea. These are located downstream of most of the population at Roger Road (the northern edge of the metropolitan area at one time) and Ina Road. The wastewater supports riparian vegetation along parts of the river downstream, although the value of the habitat is somewhat limited by other factors. For more information on these facilities, see Chapter 3.

## **Recharge**

### *CAP Recharge Projects*

Several recharge projects have been proposed for this subarea. An important factor that influences the location of instream recharge is the presence of landfills close enough to water courses to pose a water quality threat as discussed in Chapter 3. The Rillito River system is one possible recharge site. Potential locations for CAP recharge occur along Tanque Verde Creek, Pantano Wash and the Rillito from Swan downstream beyond Oracle. None of these have been fully studied or approved. One major concern relating to recharge in the Pantano Wash area is a plume of contaminated groundwater emanating from the landfills between Broadway and Speedway. Groundwater recharge in this area could push the plume in the direction of major City of Tucson wells as well as some private wells. Recharge projects along the Upper Santa Cruz River are discussed in Chapter 6 and along the Lower Santa Cruz in Chapter 8.

### *Wastewater Recharge Projects*

The City of Tucson has wastewater recharge projects along the Santa Cruz River near the Roger Road Wastewater Treatment Plant, in conjunction with its reclaimed water system. This system consists of a tertiary treatment plant which treats Roger Road Treatment Plant water to a higher level of cleanliness. The water is recharged into basins on the west side of the river and then retrieved for use on turf during the summer high water demand season. The reclaimed system extends all the way to the southeast side of the basin. There is also a recharge project in connection with the Sweetwater Wetlands described below. The recharge basins are periodically dried out to maximize recharge potential and are not used for other purposes such as wildlife habitat.

## **The Tucson Airport Remediation Project (TARP)**

The City of Tucson operates a treatment facility to remove TCE (trichloroethylene) from contaminated groundwater near the Santa Cruz River near Irvington Road. This project resulted from an agreement between EPA, the City of Tucson, the Airport Authority and others and is jointly funded. TARP produces high quality water through an air-stripping process. What can be done with this water is limited by the agreement, EPA regulations and voter preferences expressed with the passage of Proposition 200 in 1995. An early option to release the water into the Santa Cruz River or into a constructed wetland near the river was halted partly by those factors and partly by neighborhood opposition to a possible mosquito-breeding area. The water is combined with other water currently and put in the city system.

## **Constructed wetlands and riparian rehabilitation projects**

### *City of Tucson Projects*

Sweetwater Wetland was Tucson's first full-scale constructed wetland. It was built in response to an ADEQ directive and is described in Chapter 3. The Atturbury Wash Wetland Project is a very different project, an attempt to rehabilitate a wash with a small wetland using reclaimed water. It is less than 5 acres in size and located in

Lincoln Regional Park near Pantano and Escalante Roads. The treated water will flow down about one half mile of a tributary to the Atturbury Wash and will be recharged into the aquifer by way of a "dry well."

The Rio Nuevo Project was approved by voters in 1999 and is an ambitious effort to develop a cultural and commercial center focused on Tucson's history. Included in this project are museums, park facilities, landfill remediation, and water features including rehabilitation of the Santa Cruz River in the downtown area. For more information see [www.ci.tucson.az.us/transport/engineering/](http://www.ci.tucson.az.us/transport/engineering/)

#### *Pima County Projects*

Pima County's Paseo de las Iglesias Project is in the early planning stages and involves a stretch of the Santa Cruz River between San Xavier and "A" Mountain. It will combine recharge, low-flow bank protection, trails, and preservation of cultural resources. This project will be done in connection with the City's Rio Nuevo Project. The U.S. Army Corps of Engineers is conducting studies of options which could be built using federal and local funds.

The County proposes to use reclaimed wastewater for recharge and recreation in the Rillito River Recharge and Habitat Restoration Project. The water is to cycle through wetlands before reaching the river bed for recharge. The City and County are cooperating on two other related projects along the Rillito.

Arroyo Chico is a largely manmade wash with native vegetation in central Tucson. Flooding problems have developed as urbanization proceeded in the watershed. Rather than build more standard bank protection and channelization, the County proposes to use detention basins instead. One such basin has already been built in Reid Park and others are planned along Park Avenue to detain peak flows and create a native plant habitat.

The County will create 27 acres of wetlands and riparian habitat at the new Ajo Detention Basin near Julian Wash and extend the Tucson Diversion Channel. This project is located near Ajo Way and County Club Road and is part of a larger recreational complex including Tucson Electric Park and the Kino Sports Complex. The water supply for this project is captured urban storm water for use in turf irrigation and in the water features.

#### **TRANSPORTATION**

The entire area is laced with roads. Interstate 10 cuts through the area from the northwest side to the southeast side. I-19 joins Nogales with I-10. The railroad roughly parallels I-10 through the area. The Tucson International Airport is at the southern boundary of the subarea.

#### **EXISTING PUBLIC LAND USES**

This subarea is surrounded by public lands, some of which are in adjoining subareas. The Coronado National Forest occupies the Catalina Mountains to the north and parts of the Rincon Mountains to the east. The forest is used for grazing and recreation, with some areas such as Mt. Lemmon and Sabino Canyon very intensively used for recreational purposes. Perennial and intermittent streams in the Catalina Mountains include parts of Ventana Canyon, Finger Rock Canyon, Pima Canyon, Bear Canyon, Sabino Canyon, and Rose Canyon Creek. There are popular hiking trails along each of these watercourses.

Saguaro National Park occupies part of the Rincon Mountains and foothills to the east and the Tucson Mountains to the west, in the Avra Subarea. The Park gets more than three million visitors annually. There is no camping within the Park, but a scenic drive takes the visitor around the park to trails, picnic areas and view spots. This road follows natural contours and utilizes dip crossings. Rincon Creek, which is perennial almost to the lower boundary of this subarea. There are also several intermittent streams in the eastern part of the Park.

Pima County's Tucson Mountain Park occupies much of the southern portion of the Tucson Mountains and abuts Saguaro National Park. This is described in the Avra Valley Subarea chapter.

The City of Tucson and Pima County own much of the land along the Rillito and Santa Cruz Rivers in this subarea, which are used for floodplain management, recreation (including 23 miles of river park), wastewater treatment, and other public purposes. The paved public hiking and biking trails along the banks of the Rillito and Santa Cruz River are widely used.

The Davis-Monthan Air Force Base extends north of I-10 from Alvernon Road to Harrison Road. It is used for military training, housing for personnel, and storage of aircraft. The Base has a golf course and its own water system.

#### **EXISTING PRIVATE LAND USES**

Most of the land in the lower elevations of the subarea is either privately owned or is State Trust Land which can be sold and developed. Approximately one third of the land within city limits is classified as "vacant" but most

of this land is on the outskirts of town. (See Appendix F for lands uses in the city). The City of Tucson's growth has increased dramatically since the last century when only a few hundred people lived in the area. Today's population of 474,457 is projected to increase to 565,735 people within city limits by 2015. The population of the one square mile City of South Tucson, on the other hand has remained stable for years and is projected to continue to do so since it entirely surrounded by Tucson. Much of this subarea is in unincorporated Pima County. Tucson has actively worked to annex more of the subarea but, although it has been successful on the east side of town, annexations north of the Rillito River have been opposed.

### **Foothills Regions**

The Tucson Mountains Foothills region includes the lower regions of the Tucson Mountain Park and Saguaro National Park as well as private lands outside those boundaries down to Silverbell and Mission Roads. The Town of Marana extends into the northern part of this region, the City of Tucson into the southern part, but the majority of the region is unincorporated. The Continental Ranch Subdivision within the town limits of Marana lies near the Santa Cruz River and is growing rapidly. Most of county portion is zoned for low density use and the boundaries of the public lands are designated on the Comprehensive Plan as Resource or Resource Transition zones, which call for very low density. As described above, a number of well-defined washes traverse this area. For the most part they have been left natural, affected more by road or utility crossings than other actions. There are some notable exceptions, however to this generalization.

The Starr Pass Resort (within Tucson city limits) is located between Anklam Road and 22<sup>nd</sup> Street, adjoining Tucson Mountain Park. A golf course occupies much of the lower portions of the land. Homes and apartments line the edges of the golf course and the roads. The washes have been left relatively natural in most places up to the turfed areas.

The southern portion of the Tucson Mountains region has some wildcat development, although development is relatively sparse. Only the area near Valencia Road near the river is densely developed.

The Catalina Mountains Foothills region includes the foothills all the way to Rillito Road and Tanque Verde Creek. Tucson City limits generally start south of the Rillito and most of the area north of the river is unincorporated.

### **The Central Region**

The Central core area south of the Rillito River is densely populated, while the foothills areas are usually zoned at a lesser density, with some dense spots and commercial areas. The southern part of the area, around the Tucson International Airport is the most industrialized portion of the subarea. Approximately 70 percent of the 162 square miles within the boundaries of the city were developed, and approximately 30 percent are classified as vacant.

The floodplains of the Santa Cruz, Rillito, Pantano and Tanque Verde traverse this area. An important private use in some of these floodplain areas is sand and gravel mining. As the population increases the demand for these construction and landscape materials also increases. Significant sand and gravel operations are along the Santa Cruz River north of San Xavier, at Camino del Cerro, Orange Grove Road, and near the Rillito Cement Plant south of Marana. There are also major sand and gravel operations on Pantano Wash south of 22<sup>nd</sup> Street and farther upstream. (See discussion and map in Chapter 3). Sand and gravel operations are regulated differently within the city than outside it. In particular, the City allows mining within the active channel of the watercourse while the County does not.

### **PROJECTED LAND USES**

Much of the central core is built out, although vacant lands do remain scattered at places throughout the area.

A large shopping center is proposed for the Campbell-Skyline Road area and major development has begun nearby at the mouth of Pima Canyon in the Catalina Foothills. Additional construction can be anticipated in undeveloped areas in the foothills of both the Catalina and Tucson Mountains, extending to the Forest boundaries. Following the success of the Starr Pass development, the area along Anklam Road and the natural area between Anklam and Speedway can be expected to fill in.

Probably the fastest population and commercial growth in this subarea can be expected on the southeast side of town as Rocking K Ranch and nearby properties are developed. It is in this area that some of the most environmentally sensitive lands occur in the subarea. These areas have an uneven terrain and pose special problems

for providing all-weather roads and solving drainage problems. Development of this area will require sand and gravel mining which has the potential to degrade the Pantano Wash.

## **ISSUES FOR DISCUSSION**

### **URBAN WASHES**

The vast majority of the washes in this subarea have been modified to a greater or lesser extent by human activities. The City has prioritized the washes with riparian values within city limits as described above. How should the higher priority washes be protected or rehabilitated? Are stronger city or county ordinances needed to restrict development of vegetated washes both inside and outside the city?

### **RIO NUEVO PROJECT**

What water-related features should be included in the Rio Nuevo Project? Are portions of the Santa Cruz River good places to use CAP water for vegetation rehabilitation? What kinds of projects should be emphasized?

### **FLOOD AND EROSION CONTROL ON THE SANTA CRUZ RIVER**

What kind of floodplain management should be utilized on the portions of the Santa Cruz River without soil cement? Should it be left relatively natural as it is now, or should the bank protection upstream and downstream be joined?

### **GROUNDWATER PUMPING**

Should any measures be taken to ensure that groundwater pumping by Tucson Water or other water providers does not affect the remaining shallow water portions of the subarea?

### **CITY-COUNTY COORDINATION**

Should more efforts be made to coordinate the county's approach to watercourse preservation with the city's approach? Should provisions be made when the City annexes an area to coordinate with the County?

### **FLOODPRONE LAND ACQUISITION**

Should the City be more involved in floodprone land acquisition? Are there important floodplain properties that either City or County should acquire?

### **ROAD ACCESSIBILITY ISSUES**

What should be the policy on all-weather roads in the more remote areas? Does government have a responsibility to build culverts and bridges to ensure access? Should road accessibility policies be coordinated with watercourse preservation policies?

### **SAND AND GRAVEL MINING**

Should city and county sand and gravel mining policies be coordinated, especially with regard to areas likely to be annexed?

Region Within the Subarea	Grazing	Wildcat Subdivision	Planned Subdivision	Copper Mine	Sand & Gravel Mine	Pumping	Agriculture	Recreation
Mountains	X			P				X+
Foothills		X+	X+			X		X+
River and Tributaries		X+	X+		X+	X-		X+
Central Core			X+			X-		
<p><b>Key:</b> X = Existing    X+ = Existing with potential to increase    X- = Existing with potential to decrease  X+- = Existing with potential to increase or decrease    P = Potential</p>								

**Fig. 7-4. Generalized Matrix of Potential and Existing Impacts on Watercourses in the Middle Santa Cruz Subarea**

Region Within the Subarea	Alternate Water Less Pumping	More Non-structural Floodplain Management	Stricter Land Use Management	Federal Public Lands Expansion	State Trust Land Preserved	Other Preserves Increase	Better Grazing Management
Mountains				X			X
Foothills	X	X	X	X	X	X	
River and Tributaries	X	X	X			X	
Central Core	X	X	X				

**Key:** X = Is possible and could have significant impact if it occurred.

**Fig. 7-5. Generalized Matrix of Potential and Existing Impacts on Watercourses in the Tortoita Subarea**

# Chapter 8

## Subarea 5 - Tortolita Fan

### WATERSHED/WATERCOURSE CHARACTERISTICS

The Tortolita Fan Subarea consists primarily of the tributary drainage to the Santa Cruz River which emanates from the Tortolita Mountains and associated foothills/piedmont area along the northern boundary of Eastern Pima County and flows from the Catalina Mountains western flanks. The subarea also includes the Santa Cruz River downstream of the Cañada del Oro Wash Confluence near Ina Road. The subarea is bounded by the Tortolita Mountains to the northeast, the Cañada del Oro Wash to the southeast, the Santa Cruz River floodplain to the southwest and the Pinal County line to the north. The primary physiographic features of the subarea are the Tortolita Piedmont and the Lower Santa Cruz River and its floodplain. Fig. 8-1 shows the subarea. Fig. 8-2 depicts the watershed.

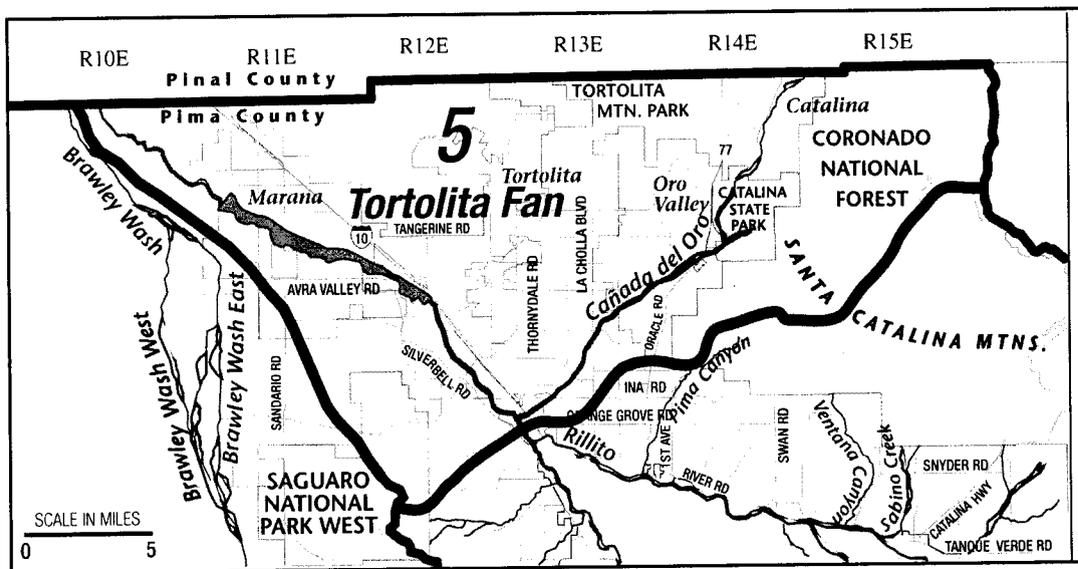
#### The Tortolita Piedmont

The Tortolita Piedmont consists of a coalescing series of geologically ancient alluvial fan surfaces between Interstate 10 and the Tortolita Mountains. These alluvial surfaces cover a relatively large area extending from near the Cañada del Oro Wash to the Pinal County line. A substantial portion of this area is currently shown on flood insurance maps as alluvial fan flood hazard areas. The Federal Emergency Management Agency (FEMA) treats flood hazards in alluvial fan areas differently from other flood hazard areas in that property cannot be removed from the floodplain simply by elevating the ground above the flood level. In alluvial fan areas, the regulatory presumption is that all portions of the fan are subject to erosion hazards as well. However, intensive study of the area, which has occurred during the last ten years, has cast considerable doubt on the validity of the alluvial fan designation because of the apparent stability of the geology of the area. For this reason it is possible that the area may be designated as non-alluvial fan in the future. Because of the designation of extensive portions of the subarea as alluvial fan, development has been slow to occur in this area.

Romero Creek and the Cañada del Oro are perennial in places as they descend from the National Forest into the State Park. A portion of Honeybee Wash, through the Rancho Vistoso area is also classified as perennial

#### Santa Cruz River Floodplain

The balance of the subarea is located primarily within the floodplain of the Lower Santa Cruz River through the



**Fig. 8-1. The Tortolita Fan Subarea.**

Town of Marana. This area has long been used primarily for agricultural purposes and has been prone to extensive flooding. The area was hard hit by flooding which covered thousands of acres in both October 1983 and January 1993. During the 1983 flood, three people died in Marana due to flood-related accidents and residences, businesses, agricultural fields, and public transportation infrastructure suffered extensive damage. During the 1993 floods, approach roads to two bridges in Marana, and several agricultural fields and residences were damaged. The Santa Cruz River in this area is an effluent dominated stream through Marana, with some riparian sections.

### **Major Wash Characteristics**

The two major washes within this subarea are the Cañada del Oro Wash and the Santa Cruz River. The Cañada del Oro Wash has been channelized and stabilized with soil cement bank protection. The only reach which remains somewhat natural is along the  $\pm 1.0$  mile reach between La Cholla Blvd. and La Canada Drive.

The Cañada del Oro Wash was excavated through Tucson National Country Club in the 1960's. This excavation along with channelization along downstream reaches initiated severe degradation. This degradation has generally been controlled by installation of grade control structures which occur periodically along the reach between the Santa Cruz River confluence and just downstream of La Cholla Blvd. Degradation is still occurring along the reach upstream of La Cholla Blvd. Floods that occurred in the 1990's resulted in about four to five feet of degradation at the Overton Road dip crossing. It is expected that this degradation will continue to propagate upstream during future floods. This may ultimately pose a threat to existing bank protection that has been constructed east of La Canada Drive (adjoining Oro Valley Country Club Estates).

The reach of the Canada del Oro Wash in the vicinity of the town of Catalina is entrenched a few feet below adjoining overbank elevations, however, the channel capacity is limited and a significant amount of overbank flow occurs during high magnitude floods. The overbank floodplain has gradually developed at low density and there continues to be development pressure because the area is so attractive for rural residence. This reach of the wash has been mapped as a federally delineated floodplain and floodway. The floodway occupies a width of about 1000 feet of the floodplain area. There are several residential structures located within this floodway which were there prior to the federal designation. The restrictions placed on new development by the floodway designation have rendered some parcels unusable and required some new homes to be raised two to four feet above natural grade.

The Santa Cruz River has been channelized through the Continental Ranch development between Cortaro Road and a point about 1.7 miles south of the Avra Valley Road bridge. This channelization contains the 100 year flood within a two tiered channel. The upper tier is inundated with flow only during floods with a return period greater than 10 years. The upper tier may be developed in the future with recreational uses such as a park and/or golf course.

Pima County is presently constructing a levee along the east bank of the Santa Cruz River between the north end of Continental Ranch and Sanders Road (a total distance of approximately six miles). The overbank floodplain area on the west side of the river across from the levee as well as along both overbanks north of Sanders Road presently function to provide overbank storage capacity. This storage capacity acts to decrease downstream flood peaks.

The vertical profile of the Santa Cruz River channel has been experiencing significant aggradation along the reaches north of Trico-Marana Road. This aggradation may be in part due to perineal sewage effluent flows which support phreatophyte vegetation growth and, infiltration of the effluent which attenuates the flow and drops sediment. Severe aggradation is also occurring at the Trico Road bridge due to the vegetation and due to a narrow bridge opening which blocks the flow.

The reach of the Santa Cruz River extending south of Trico-Marana Road to Avra Valley Road has generally been stable. No significant aggradation or degradation has been identified along this reach. Some degradation is occurring along the south end of the Continental Ranch reach in the vicinity of Cortaro Road. Recently a five foot drop in the channel was protected from further deterioration by a grade control structure. The degradation is believed to be due to perineal sewage effluent flows which has been gradually and continuously degrading the bed elevation. Some of the degradation may have also been the result of sand and gravel mining that occurred in the vicinity of Ina Road and Cortaro Road during the late 1970's and early 1980's. The flood of 1983 captured a gravel pit just north of Ina Road. This may have disrupted sediment transport and initiated degradation along the near upstream and downstream reach.

### **Tributary Characteristics**

The wash characteristics throughout the subarea are quite diverse. This diversity is related to topography (slope and landform) and geology. The two most notable sub-regions are the Tortolita piedmont and the Tucson Mountain foothills. The Tortolita Mountains are composed of a soft granite which weathers rapidly and lends to high sediment

production. This sediment is delivered via the drainage systems to the piedmont where slopes decrease, deposition occurs, and distributary drainage patterns form.

The soils created by decomposition of granite are coarse grained and non-cohesive. They are easily entrained (carried in suspension) and transported downslope until slope decreases and the sediments are deposited. This deposition eventually fills in a wash, forcing flow to seek and alternate path that creates distributary flow patterns.

Erosion and degradation are a frequently observed consequence of urbanization and man-made modifications to washes in distributary flow areas. Collection of the flow often results in higher velocities which entrains more sediment and initiates the erosion process. The area where this erosion has most frequently been observed is within the Town of Oro Valley along the fringe of the Cañada del Oro Wash. This is an area characterized by steep slopes and loose sandy soils. Development in this area has modified flow conditions by increasing runoff and confining flow to excavated channels. This has frequently resulted in erosion along the wash reaches where the development occurred and deposition along downstream reaches.

The distributary washes which exist on the western flank of the Tortolita piedmont have not been significantly affected by man-made modifications or development. The extent of development within this region is confined to the valley floor adjoining Interstate 10 and to the Dove Mountain master planned community. Land development within the Dove Mountain project has been limited and has been structured to avoid modifications to the washes, except where road crossings (culverts) are necessary. The north boundary of the distributary flow region extends southwesterly from the mountain front until slope decreases enough to initiate sediment deposition. Washes remain well defined between topographical highs for distances of one to three miles from the mountain front. In general, it appears that distributary wash patterns begin to develop when the slope of the piedmont decreases to less than about three percent.

Future development along the valley floor adjoining Interstate 10 will not affect the stability of washes on the piedmont. The most significant challenge will be to define adequate measures for collection and conveyance of floodwaters and sediment to an outfall such as the Santa Cruz River.

The largest tributary to the Canada del Oro Wash is Big Wash. This watercourse has a 100 year discharge rate of 18,000 cfs. Big Wash remains as a braided channel system which has not been significantly affected by man-made change.

Washes emanating from the Tucson Mountain are well defined throughout most of the foothills area flanking the east side of the mountains. Distributary wash patterns develop within some small areas near the north end of the mountains. The distributary wash patterns are confined to areas where surface slopes decrease below three percent. The Tucson Mountains are composed primarily of igneous (volcanic) rock which is much less erodible than the granite of the Tortolita Mountains. The soil yielded by these mountains is also more conducive to cohesion which is another factor increasing erosion resistance.

## **HUMAN IMPACTS ON THE WATERCOURSES**

### **FLOOD MANAGEMENT STUDIES, PLANS AND ACTIVITIES**

#### **Pima County studies and projects**

Because of the complex flood problems in this area, there are quite a few studies and management plans. The largest project in the area is construction of a 7.36 mile levee along the north/east bank of the Santa Cruz River starting south of Avra Valley Road and proceeding downstream through Marana. The river side of the levee will be reinforced with soil cement to protect the levee from being undermined. The project will satisfy FEMA requirements, allowing additional development near the river in Marana. It is expected to remove approximately 4,468 acres from flood hazard or floodplain status. This was in response to a series of past flooding problems, especially the 1993 flood in which bridges, agricultural fields and residences were damaged. The project is funded jointly by Pima County, The Arizona Department of Water Resources, U.S. Bureau of Reclamation, and benefitting properties.

Pima County completed an area-wide study of the Tortolita Fan in 1987 and included interim floodplain management policies which were adopted by the Board of Supervisors. In 1991 the second phase was completed. This had an analysis of watersheds impacting the Tangerine Road, including Ruelas Canyon, Prospect Canyon, Canada Agua, North Ranch and portions of Wild Burro Wash. The recommendations included both structural and non-structural alternatives. A 1996 study by the U.S. Army Corps of Engineers examined a variety of structural flood control measures to channelize washes to maximize development potential. This project was not implemented because the Corps found that the costs far outweighed the benefits and the program was not environmentally sound.

The report states that if the growth rate in the area exceeded 7 percent, another economic evaluation should be made. The current approach is not to channelize the washes, but to require that any development not be placed so as to require major structural controls.

The Cañada del Oro River Management Plan dealt with the floodplains between Catalina State Park and the Santa Cruz River confluence. A combination of structural and non-structural policies were proposed including acquisition, bank stabilization, floodplain rezoning, and financing. Much of the bank stabilization was completed and acquisition continues, and about 24 acres have been purchased.

A very different problem occurred along Highland Wash in Oro Valley. The pre-development drainage in this area was about 3,000 cfs and the existing channel and culvert under Lambert Lane were undersized for that amount of water. Upstream development has increased that flood flow to about 5,000 cfs, far too much for the drainage system to handle. An agreement calls for upstream developers to install on-site retention basins as development occurs. In addition, a developer was supposed to do floodplain improvements, but this did not occur. The recommended solution included dedication of the wash to the county with continued improvements to the drainage system, including retention basins.

A study of the Cañada del Oro Wash at Catalina was completed in 1991 with recommendations to acquire floodprone land. About 7 acres were acquired under this program.

Pima County bond funds are earmarked for several locations in Oro Valley in the Rancho Feliz subdivision, areas along La Canada Drive between Naranja and Lambert Lane, parts of Lambert Lane, and Linda Vista Boulevard. These are primarily improving road crossings and correcting drainage problems that contribute to flows that affect traffic.

Pima County has acquired 27 acres of flood prone land along the Cañada del Oro in the Catalina area to reduce flood damage.

A network of flow and precipitation sensors have been installed to provide early warning of flood potential in the Cañada del Oro drainage.

The Town of Oro Valley has begun an intensive study of flooding problems in the city.

#### *Balanced and critical basins*

Most of the Tortolita Fan area outside Oro Valley has been declared a critical basin because of widespread overbank flooding from natural channels originating on the fan; unpredictable flow paths for major floods originating at the fan apex; a potential for flooding across watershed boundaries; rapid and unpredictable erosion and deposition along streams; flooding due to inadequate culvert drainage capacity under the railroad and impassable dip crossings. The Loma de Oro Wash is declared critical because the existing channel is inadequate. In the town of Catalina the basin to the east of Twenty-seven mile wash was declared balanced because further development would increase drainage problems as was the drainages flowing east in the Cañada del Oro because of severe erosion potential. (See Chapter 3 for an explanation of critical basins).

#### **TRANSPORTATION**

Interstate 10 runs along the western boundary of the subarea and Highway 77 along the eastern side of the valley along the foot of the mountains. Numerous streets and roads run through the area, with Tangerine being the farthest north paved road that connects I-10 and Highway 77. There is a small airport for private planes west of Oro Valley.

#### **EXISTING PUBLIC LAND USES**

Pima County's Tortolita Mountain Park occupies 3,446 acres in the Tortolita Mountains at the northern end of the subarea. This park is kept natural and recreational use is very low. There are no facilities such as picnic areas or paved roads.

Catalina State Park occupies 5,493 acres along the Sutherland Wash and Cañada del Oro Wash (which join in the Park) and adjoins the western part of the Coronado National Forest. The park has horseback trails and facilities, picnic and camping areas, and trails that lead to the higher elevations of the Catalina Mountains. The Cañada del Oro is left natural and public roads do not cross it or Sutherland Wash within the park.

The Pusch Ridge Wilderness Area occupies 55,992 acres within the upper elevations of the Coronado National Forest, traditional bighorn sheep winter habitat in this and in the Middle Santa Cruz Subarea. The Pima Canyon Trail leads into this area with limits on visitation to protect the few remaining sheep. The Pusch Ridge Estates in

this area was designed with provisions to protect the sheep, such as not allowing dogs, but the sheep have continued to decline for a variety of reasons.

Parts of the northern end of the Tucson Mountains are within the Saguaro National Park boundary. The northernmost tip is State Trust Land.

## **WATER AND WASTEWATER- RELATED LAND USES**

### **Water Supply**

Private water companies serve much of the area and there are many private domestic and irrigation wells. The Town of Oro Valley's water utility serves much of the Oro Valley area. The Metropolitan Domestic Water Improvement District (Metro) serves the southeastern part of the area and Marana has its own company. In addition, there are some smaller private water providers and the City of Tucson provides water to some areas. Oro Valley and Metro have CAP allocations, although there are currently no facilities to provide CAP water to their customers.

### **Wastewater**

Because Marana is downstream of the Ina Road Treatment Plant the community has had problems deciding how deal with wastewater. Pima County operates one facility in Marana, the School District has its own facility and the remainder are private facilities to serve specific subdivisions. A regional facility is planned at the Pinal County line at some future date when increased population growth warrants it.

Dove Mountain and most of the Tortolita Fan, Catalina, and Oro Valley are at a higher elevation than the Ina Road Treatment Plant, so they can more easily be incorporated in that system. The area, including Dove Mountain is already connected to Ina Road Treatment Plant by pipeline. Four small plants in the area were closed when the connection was made.

### **Recharge and habitat**

Depth to water ranges from 50 feet along the upper sections of the Cañada del Oro to more than 450 feet in the Tortolita foothills, with some surface flows in the mountains and upper foothills. Wells are located throughout the area for agricultural, municipal and domestic purposes. Much concern has been expressed about the impacts that pumping in the Rancho Vistoso area could have on Honeybee Wash.

The water table in the Marana area has remained high in spite of extensive agricultural pumping. This is largely because of the steady flow of effluent that serves to recharge the basin near the river. Recently farmers in the Marana area started to use CAP water for agriculture, lessening their pumping.

Pima County is currently developing recharge projects along the Santa Cruz River in the Marana area which would have wildlife habitat potential. A facility permit has been issued for the Lower Santa Cruz Replenishment Project, which would have a capacity of 12,000 to 13,000 acre feet in its first phase. Later phases would increase this potential. While this location has a lot of benefits, it is in an area of already relatively high groundwater levels downstream of the main wells from which groundwater is withdrawn for municipal use in the Tucson basin.

Oro Valley is studying the potential for a CAP recharge and recovery project along the Cañada del Oro. The Bureau of Reclamation is examining the possibility of a CAP turnout from the canal on the west side of the Tortolita Mountains and a pipeline extending into the Oro Valley area for this purpose. There has also been discussion of a treatment facility so the CAP water could be used for municipal purposes.

## **EXISTING PRIVATE LAND USES**

Marana is the largest town in the area in terms of acreage, but Oro Valley is the largest in terms of population. The small town of Catalina at the northern part of the area is unincorporated. The towns of Tortolita and Casas Adobes were formed by residents, but the formation was challenged in court and their status is as yet undetermined. Pima County continues to perform the appropriate governmental functions, such as sheriff's service, in these areas until the matter is finally resolved. Saddlebrooke, a resort community designed largely for retired people is in this vicinity in the Catalina Mountains foothills and has experienced continual growth.

The western part of the Marana area has long been used for agriculture in this and the adjoining Avra Valley, with most of the agriculture on the west side of the river. Agriculture in this area has depended mostly on cotton, alfalfa, and some vegetable crops such as lettuce. Agricultural activities are discussed in more detail in the Avra Valley Subarea chapter.

Since Marana began annexing large areas to the south and east of its traditional area, extensive urban lands are now also included in the town. An industrial area parallels I-10. Marana's population grew from a few thousand people in the 1980s to 14,700 in 2000 and is projected to increase to 52,328 by 2015.

The eastern side of the subarea, on the other hand, is largely residential and commercial in character. The burgeoning town of Oro Valley has experienced rapid population growth in the past fifteen years, with much of that happening in the planned resort community of Rancho Vistoso. From a 1997 population of 37,800 the population is projected to increase to 51,200 by 2015. The Oro Valley Land Use Plan provides for an increase to 125,000 people by 2020. Most of the housing in the Oro Valley area is within the higher cost range of housing in Pima County, with some homes selling in the million dollar range. Commercial activity is common along Highway 77 which has a series of shopping centers from Ina Road through Oro Valley. There is a state juvenile detention center south of Catalina. Development in Catalina has largely been through wildcat subdividing and lot-splitting which has in places.

Most of the land between Oro Valley and I-10 is as yet only lightly populated, except for the Dove Mountain subdivision, which is in the Town of Marana. This area is planned for 9,159 homes on 5,600 acres. The entire area contains ancient ironwood trees with their special habitat as described in the SDCP report, Desert Ironwood Primer. Rapid growth was projected in this part of the subarea and a new highschool planned to accommodate past and projected growth, but possible designation as critical habitat for the pygmy owl has slowed rezonings and subdivision starts drastically. As indicated above, the flooding problems of this area require that if the lot is developed it be done carefully.

There are many golf courses in the subarea, most of which use groundwater, although the County's Arthur Pack Golf Course and the Heritage Highlands Golf Course use effluent.

## **PROJECTED LAND USES**

The Pima County Comprehensive Plan calls for the Tortolita Mountains and the floodplains of major washes coming from those mountains to be left as Resource Conservation Areas. The more remote parts of the area are planned for rural and low density uses, while the towns of Marana and Oro Valley are zoned for low to high density and commercial uses. The plan calls for commercial activity centers along Highway 77.

### **Private land development**

Large portions of this area have been designated as potential habitat for the endangered cactus-ferruginous pygmy owl. This is discouraging development of the area, although much of the land is already zoned for residential and commercial purposes in Marana and Oro Valley. However, there has already been development of some areas along the mountain fronts along the south portion of the subarea. The Dove Mountain project is a 5,600-acre master planned golf-resort community located near the mouth of Ruelas Canyon in the Tortolita Mountains. Pressure to develop in this area will likely continue as this area represents a relatively large open area that is primarily under state land ownership and is uphill from existing wastewater treatment facilities at Ina Road and proposed facilities in Marana.

The Marana area is also experiencing development pressure. The Continental Ranch development has resulted in construction of hundreds of homes within the geologic floodplain south of the river just north of Cortaro Road. The homes are protected by channelization and bank stabilization along the Santa Cruz River. Currently, the Pima County Flood Control District is constructing a flood control levee along the northeast side of the Santa Cruz River between Avra Valley Road and Sanders Road. Just over seven miles of new earthen levee will be constructed along the north bank of the Santa Cruz River, and the side of the levee that faces the river will be stabilized with soil cement. The design includes protection from 100-year Santa Cruz River flooding, eight feet of toedown below the channel invert to protect the levee from being undermined by scour, and three feet of freeboard above the 100-year water surface elevation to satisfy federal floodplain regulations. Once completed the project will remove thousands of acres of property from the floodplain thereby enabling development of the area.

Potential impacts of development in the subarea are numerous. Proper development of the Tortolita Piedmont area will require careful planning of through drainage improvements to insure that individual development projects do not result in wholesale alteration of drainage patterns on the ancient alluvial fans. This may need to be accomplished by establishing flood/drainage corridors such as the desert brown belt approach currently being pursued in similar areas in Scottsdale, Arizona. Other approaches may include large scale stormwater detention basin, however, such basins must be carefully designed and sited so as to avoid creating downstream erosion problems along major channels. Development of the area will also be complicated somewhat by the existence of the

Central Arizona Project canal which traverses the piedmont. The CAP forms a virtual dam across the piedmont which drainage must collect against until reaching one of the through cross-drainage structures along the canal. Planning of regional-scale flood control facilities will need to take the location of these crossings into account. Proper development of the Lower Santa Cruz River floodplain behind the planned flood control levee will also require careful planning. The areas behind these levees will still be subject to inundation from the Tortolita Piedmont flow sources even after completion of the levee. Proper through drainage of the piedmont flow sources into the Santa Cruz River must be provided to insure safe construction in the area.

#### **Proposed water delivery projects**

The Bureau of Reclamation is studying alternative ways to bring CAP water to the Oro Valley-eastern Marana area. Total annual water use in the area is about 15,500 acre feet, with turf accounting for about 6,500 of that amount. This usage is projected to reach 47,600 acre feet by 2018. One alternative would bring unprocessed CAP water for use on turf in Marana and Oro Valley and for recharge projects. The 30" pipeline would travel along the Moore Road alignment from the CAP canal to Big Wash. Two pumping stations would be needed - at the canal and in the vicinity of Blue Bonnet Road. Two storage tanks would be located along the system. At Big Wash the water would be recharged in four basins and in the wash. A gravity pipeline would transport the water to its intended use downstream. The amounts of water under discussion range from 17,400 acre feet to 30,000 acre feet. The amount not used on turf would be recharged. The Bureau estimates total construction costs at more than \$43 million.

#### **Preservation Proposals**

The state's Growing Smarter Initiative (See Chapter 3) would designate parts of the Canada del Oro in the Catalina Area, parts of Big Wash and parts of the Tortolita Mountains as State Trust Lands that should be preserved. Pima County has a proposed mesquite bosque restoration project along the Santa Cruz River near Cortaro Road.

### **ISSUES FOR DISCUSSION**

#### **Development of the Tortolita Fan**

Should the Tortolita fan be developed for urban uses or left a rural open space? If the Tortolita fan is developed, what flood precautions should be taken in light of its characteristics described above? Should they be largely non-structural (e.g., keep structures away from the floodways) or should the washes be channelized to maximize development potential? How should the flows be conveyed to the Santa Cruz River.

#### **Roads and Bridges**

To what extent should the roads with dip crossings be converted to all weather roads with culverts or bridges? Should Tangerine Road, in particular, be expanded or designed for all-weather travel? Are other roads needed in the area?

#### **Options for the Effluent-dominated Stream**

If flows continue to the Santa Cruz River from the wastewater treatment plants, what efforts if any, should be made to improve the habitat and/or recreational value of the river?

#### **Loss of overbank storage along Cañada del Oro**

How should the problem of loss of overbank storage area along the Cañada del Oro be addressed - through structural or non-structural approaches, including land acquisition?

#### **Use of CAP in area - including instream recharge**

Should CAP water be brought into the area? If so, how should it be used? Should it be treated for municipal use? Used for golf courses? Used for recharge projects? Used to riparian uses along the Cañada del Oro or other watercourses? What precautions are needed in infrastructure construction through the alluvial fan area, if that is the chosen route?

**Use of Wastewater**

Should a program be developed for use of wastewater on golf course or for other purposes? Should a treatment facility be built in the Marana or Oro Valley areas? Should the use of septic systems be discouraged in all or parts of the area?

Region Within the Subarea	Grazing	Wildcat Subdivision	Planned Subdivision	Copper Mine	Sand & Gravel Mine	Pumping	Agriculture	Recreation
Santa Cruz River		X	X		X+	X-	X-	
Tortolita Fan	X-	X	X			X+		
Oro Valley			X		P	X-		
Catalina		X	X			X+		
Public Lands	X							X+

**Key:** X = Existing    X+ = Existing with potential to increase    X- = Existing with potential to decrease  
X+- = Existing with potential to increase or decrease    P = Potential

**Fig. 8-3. Generalized Matrix of Potential and Existing Impacts on Watercourses in the Tortolita Subarea**

Region Within the Subarea	Alternate Water Less Pumping	More Non-structural Floodplain Management	Stricter Land Use Management	Federal Public Lands Expansion	State Trust Land Preserved	Other Preserves Increase	Better Grazing Management
Santa Cruz River	X	X	X				
Tortolita Fan	X	X	X		X	X	
Oro Valley	X	X	X		X	X	
Catalina	X	X	X		X	X	
Public Lands							X
Key: X = Is possible and could have significant impact if it occurred.							

Fig. 8-4. Generalized Matrix of Potential Options for Reducing Stress on Watercourses in the Tortolita Fan Subarea

# Chapter 9

## Subarea 6a - Altar Valley

### WATERSHED/WATERCOURSE CHARACTERISTICS

#### THE WATERSHED

The Altar Valley Subarea of the watershed of the Brawley Wash upstream of Mile Wide Road. The subarea is bounded by the Baboquivari, Coyote and Roskrige Mountain ranges to the west and the Tucson, Sierrita, Cerro Colorado, Las Guijas and San Luis Mountain ranges to the east.

The Altar Valley consists of a long north-draining valley with tributary drainage into the Brawley Wash from the mountain ranges to the east and west. The foothills tributary areas generally consist of well-defined washes which drain in a tributary manner into the Brawley Wash. Washes on the flat valley floor tend to be ill-defined and shifting, with sheet flooding occurring in many areas. See Fig. 9-1. for a map of the subarea and Fig. 9-2 for a map of the watershed.

#### BRAWLEY WASH

The main drainage feature of the subarea is the Brawley Wash which flows from south to north along the axis of the valley starting near the Mexican border. The Brawley Wash is also known as the Altar Wash south of State Highway 86 (Ajo-Tucson Highway). This wash has experienced considerable entrenchment during the last century, largely in response to overgrazing, especially in the southern portions of the wash.

Brawley Wash has a wide geologic floodplain which varies in width from 0.5 to 1.0 miles along the reaches through and south of Township 15 South. The floodplain width along the reach through Township 14 South ranges in width from 2.0 to 4.0 miles. Historically, the floodplain was occupied by a series of distributary channels which functioned to slow velocity and spread flow across the floodplain. The floodplain environment was generally aggradational but sediment transport capacity changed with flood volume to maintain a quasi-stable channel system. The channel entrenchment that has occurred in more recent times is probably associated with overgrazing of the watershed, wagon road ruts, and the construction of farm levees which narrowed the floodplain and increased flow velocity. (Also see Fig. 3-5 in Chapter 3). The result of entrenchment is an increase in flood peaks, sediment conveyance and bank erosion, all of which translate to channel instability and higher flood stages along downstream reaches. A continuation of the entrenchment would lead to further loss of overbank storage capacity, more downstream flooding, and the possible propagation of the entrenchment toward tributary washes in some locations. The area should be studied to determine the likelihood that entrenchment will continue based on future practices in the watershed and in the wash itself. Other measures such as check dams or bank

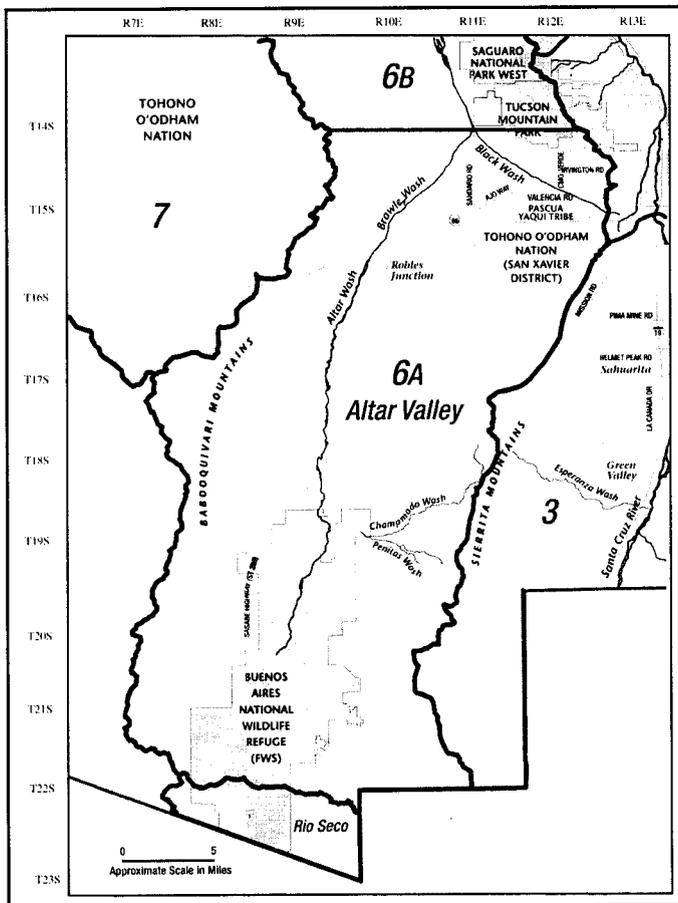


Fig. 9-1. The Altar Valley Subarea.

stabilization may help to reduce the entrenchment if the underlying causes are corrected . These measures are critical not only to Brawley Wash but also to tributary watersheds which support riparian vegetation and wildlife. Severe, unrecoverable degradation to the quality of these resources will occur if entrenchment is allowed to propagate into the tributary washes and the sub-watersheds which they support.

### **BLACK WASH**

A major tributary to the Brawley Wash is the Black Wash located between the Tucson Mountain and Sierrita Mountain foothills. The Black Wash is a poorly defined drainage path with flow splits and flat areas causing widespread flooding in times of heavy rains. Black Wash remains a stable geomorphic environment not having been subjected to the entrenchment associated with man-made changes within the Brawley Wash watershed. This is probably due to the geology of the contributing watershed and the mild slope of the valley floor. Future change should be limited because of these factors.

### **TRIBUTARY WASHES**

Tributary washes are generally well defined throughout most of the watershed. Drainage density on the alluvial pediments between mountain front and valley floor is relatively high because of the steep surface slopes and soil type. A large area (approximately 100 square miles) of distributary washes occurs along the north and west slopes of the Sierrita Mountains within Township 15 South, Range 11 East and 12East, and within Township 16 South Range 10 East and 11 East. This distributary flow area extends from the mountain front to confluence with Brawley Wash or Black Wash. Distributary drainage systems commonly occur upon the pediments adjoining mountainous areas. A distributary channel form evolves as a result of sediment deposition induced by slope reduction. The washes aggrade which in-fills the channel and forces flow to spread onto adjoining areas of the pediment. Flood peaks dissipate as the distance from the mountain front increases (via surface storage and infiltration) ultimately leaving little or no trace of a channel.

### **DISTRIBUTARY WASHES**

Distributary washes add an element of uncertainty to land use planning. The uncertainty is the inability to predict future flow paths and sediment loads. Usually, the uncertainty to predict flow patterns is dealt with by constructing a collector channel and/or berm along the upstream side of a land use area.. This channel/berm functions to intercept, then route the flow around the area being protected. The approach has been used many times throughout Pima County to provide flood protection for residential, commercial, and agricultural development as well as transportation facilities. Degree of success has varied depending upon design factors such as slope and stabilization measures and upon watershed size and sediment load. This is because a collector channel introduces an abrupt change to the hydraulic and geomorphic characteristics of distributary washes. The most commonly observed change is sediment deposition within the collector channel, then erosion along the downstream reaches where flow is returned to natural wash.

## **HUMAN IMPACTS ON THE WATERCOURSES**

### **FLOOD MANAGEMENT ACTIVITIES**

In 1990 the Flood Control District issued a study of the Southwest Basin which includes most of the area between Tucson Mountain Park and the San Xavier District, extending almost to Sandario Road. A further study in 1994 addressed flooding problems in the Tierra Conita/Camino Verde area and Tucson Estates. Floodplain maps and policies were developed.

Drainage and flooding along the Black Wash has historically been a problem. In July 1990 numerous homes were flooded in response to a high-intensity summer monsoon storm in the area. To address flooding problems in the Black Wash area, the Pima County Flood Control District adopted the Black Wash administrative floodway in 1991 to set aside a corridor associated with the heaviest concentration of flow during storms where residential construction would not be permitted. The district also acquired about 70 acres of floodprone land along Black Wash to protect it and downstream land from flood damage. Pima County has designated the portion of the Black Wash watershed upstream of Ajo Way a critical basin because flooding is severe and occurs annually. (See Chapter 3 for information on this designation).

## **TRANSPORTATION**

Highway 86 (Ajo Way) is the main east-west thoroughfare in the area, going from Tucson to Why, through the Tohono O'odham Nation. Highway 256 extends from Robles Junction on Highway 86 to the Mexican border. The Arivaca Road connects Highway 256 with Interstate 19 at Amado. Sandario Road is a major north-south road on the north side of Highway 86 extending to Marana. Gates Pass Road connects Tucson with the area and meets Kinney Road which goes to the Arizona Sonora Desert Museum and Saguaro National Park to the northwest and Highway 86 to the south. Other roads, mostly unpaved, intersect the area. Roads can affect drainages in ways described in Chapter III.

Along two-lane Highway 256, for example, most of the crossings are dip crossings with minimal impact on the watercourses. At some locations, however, these crossings create a point where the wash cannot erode naturally. When flows reach the downstream side of the road erosion occurs, creating a big drop off on the downstream side of the road. Asphalt or rocks then protect the road from erosion. In another location a culvert diverts the water under the road. Where the culvert discharges rushing flood waters, a deep arroyo has been cut which extends all the way to Brawley Wash. The Ajo Highway, on the other hand which is wider and much more heavily used, has been designed with more complex crossing structures, culverts and bridges that span the floodplain of the wash. Other roads in the area rely mainly on dip crossings, especially the unpaved roads and the roads within the County Park and the National Park. Many of these roads are sometimes inaccessible at flood time, creating safety problems for residents especially when emergency vehicles cannot reach them. Pima County has installed precipitation and flood sensors in Brawley and Black washes to give advance warning of flows that might make those roads impassable.

## **WATER AND WASTEWATER-RELATED LAND USES**

### **Water Supply**

Depth to water in the Altar valley ranges from 150' along the sections of Brawley Wash south of Ajo Way to more than 400' in the wellfield area, with a very high water table in the Arivaca area and at places between Arivaca and Arivaca Junction.. There are numerous shallow wells south of Arivaca, indicating a high water table there also. Two intermittent streams flow down from the Baboquivari Mountains in the subarea. The Arivaca Watershed Education Taskforce has calculated that the average annual renewable water supply for that area is no more than 645 acre feet, and probably about half that, while water use would increase to about ten times the safe yield amount if all the potential uses within the AMA were realized there.

Starting in the 1960s, the City of Tucson began to purchase farms in order to use the water underneath them for municipal purposes. Most of the approximately 10,000 acres are now abandoned farm land and not being used for other purposes since the water is reserved for use in the city. The Avra Wellfield provided about 18 percent of Tucson Water's 1999 water supply. A pipeline extends underground to Tucson along Ajo Way. There are also many private wells in the region and a private water company. There has been some land subsidence in the heavily pumped portions of the valley.

In the 1980s, the Bureau of Reclamation began construction of the Pima County portion of the Central Arizona Project which comes through this area as an underground pipeline. The City's Hayden-Udall Water Treatment Plant is located at the intersection of Ajo Way and Tucson Estates Parkway, where there are also a number of homes. An underground pipeline extends from the treatment plant to Cat Mountain and under Starr Valley, a large valley within Tucson Mountain Park adjacent to Cat Mountain, to the eastern side of the Tucson Mountains. Another pipeline extends south towards the San Xavier District and Pima Mine Road. As mitigation for habitat loss when building the CAP, the Bureau of Reclamation established a Wildlife Mitigation Corridor at the eastern boundary of the Tohono O'odham Nation in the planning unit.

In the 1980s and early 1990s the Bureau of Reclamation examined possible sites for a terminal storage facility (reservoir) for CAP water. The original proposal involved a large reservoir in Starr Valley, within Tucson Mountain Park. This project was dropped because of protests from people who did not want to see such encroachment into the park. Other proposals included a multi-purpose lake in this valley that could have recreational uses. Tucson Water did not encourage the concept of a recreational lake related to a water supply system. There is currently a proposal to build a terminal storage reservoir near Black Wash and the Pasqua Yaqui Reservation where there is a turnout to the reservation.

### **Wastewater**

Most of the region depends on septic systems for wastewater treatment. Pima County operates a facility at Arivaca Junction and in the Avra Valley.

## **Recharge**

Many acres of land in this area have the appropriate properties for recharge projects. The CAVSARP (Central Avra Valley Storage and Recovery Project) is located to the northwest of the treatment plant in the Avra Subarea (See Chapter 9). If the initial project is found to accomplish the goals as projected, additional acreage in the Altar and Avra subareas will probably be devoted to recharge. (Also see recharge discussion in Chapter III)

## **EXISTING PUBLIC LAND USES**

Much of the valley is in public ownership: City of Tucson, Pima County, state or federal, with some Tohono O'odham land projecting into the region from the west (Shuck Toak) as well as the San Xavier District on the east side of the subarea. In the last century, the Altar Valley was an open grassland with wildlife such as pronghorn antelope, Aplomado falcons, masked bobwhite quail, Mexican wolves, black bear, and an occasional jaguar traveling between mountain ranges.

The 121,308 acre Buenos Aires National Wildlife Refuge occupies a considerable part of the south end of the valley, abutting a section of the Coronado National Forest. The Refuge was created in the 1985 to preserve the grasslands environment of the upper Altar Valley as a refuge for unique wildlife in the area. A cienega and creek-based wildlife area are located near the town of Arivaca. Seven springs form this rare desert wetland. Arivaca Creek flows downstream from the wetland seasonally with a high enough water table to support giant cottonwoods and lush vegetation. The refuge also includes Aguirre Lake which was built in the 1880s to water fields and stock. Migrating waterfowl, wading birds, and shorebirds use the seasonal lake today. The most recent addition to the refuge is Brown Canyon, at the foot of the Baboquivari Mountains. This canyon features sycamores and live oaks and a 47-foot natural bridge in the upper canyon. This area is only open for scheduled tours.

As settlements sprang up in the Altar Valley in the 1860s, the delicate balance of the ecosystem was changed. Overgrazing, water diversion projects, and other human activities left the ground bare, exposing it to torrential summer rains that quickly eroded the soil. A major wagon road ran along the wash and ruts deepened into gullies. With the grass gone and natural fires suppressed, mesquite gained a foothold. An erosion process began which continues to this day.

More than 320 species of birds have been recorded at Buenos Aires NWR. Antelope (reintroduced) mule deer, coyote, and javelina are some of the mammals seen today along refuge roads. Mountain lion, coatimundi, ring-tailed cats, and badger are also present. In addition to the masked bobwhite quail, Buenos Aires NWR protects habitat for six other endangered species (cactus ferruginous pygmy-owl, Pima pineapple cactus, Kearney bluestar, peregrine falcon, southwest willow flycatcher, and razorback sucker). Bullfrogs, introduced from the eastern United States have reduced populations of native amphibians and fish. A Heritage Fund sponsored program is attempting to reduce their numbers.

The Pima County-owned Tucson Mountain Park and the federally-owned Saguaro National Park (initially established in the 1930s) preserve a good portion of the Tucson Mountains, their western foothills and a part of the valley floor in this region, but are mostly in the adjoining Avra Subarea and are more fully described in that chapter. The Tucson Mountain Park and Saguaro National Park in the Avra and Altar Valleys include many miles of trails, a campground, and picnic areas. In the past there have been proposals for other activities within the park, such as a tourist railway or mining, but these have been rejected. If the land within Tucson Mountain Park is used for other than the originally intended purposes, parts are subject to reversion to BLM ownership. Visitor use of the area has increased dramatically in recent years.

The area also includes many acres of State Trust Land. Many of these lands are leased for grazing, especially in the grasslands regions of the subarea. State Trust Land is generally available for lease or sale and could eventually be used for subdivisions and other purposes.

The BLM Coyote Mountain Wildlife area (5,103 acres), and Baboquivari Wilderness Area (currently claimed by the Tohono O'odham), and the Bureau of Reclamation's Wildlife Mitigation Corridor (2,717 acres) are managed for wildlife benefits and have very little recreational use. The Wildlife Corridor was located at a strategic location to maintain a wildlife corridor from the Tohono O'odham Nation to the Tucson Mountains. Clearing of land for agriculture on the area adjacent to the wildlife corridor may diminish its value somewhat.

## **EXISTING PRIVATE AND INDIAN LAND USES**

The primary private land uses in the valley are ranching, agriculture, tourism, and residential, some commercial uses, and the Ryan Airfield. The only active mining in the area currently is a gravel pit, although parts of the area

were heavily prospected in the past and some historic mines and ghost towns occur in the southeastern section. Parts of the area are within the "copper belt" and could possibly be mined in the future.

This area has three small unincorporated communities: Sasabe, at the Mexican border crossing, Arivaca, and Robles Junction (also called Three Points) and a large mobile home development at Tucson Estates. Sasabe is a small remote town at the Mexican border on Highway 256, whose economic base depends on the lightly-used border crossing. Arivaca, too, is a small community, but its economic base is ranching and tourism to the Buenos Aires Wildlife Refuge. Residents of Robles Junction at the intersection of Highways 86 and 256 commute to Tucson, and work in small local businesses.

The Altar Valley has been grazed since the late nineteenth century and some of the grassland ranches are still in the ownership of the original pioneer families. Part of the grazed land is privately owned, but the majority is leased from the State Land Department. Although overgrazing caused severe problems in the past, grazing management has improved and rules have become more stringent and the impacts of today's grazing are less severe. Some of the ranchland in the area is in excellent condition. Some ranchers feel that their management is more protective of the land than management of the wildlife refuge.

The valley to the north of the grasslands was at one time more intensively farmed than it is today. There is still some agriculture north of State Highway 86. The largest remaining farm is the well-known Buckelew Farms on Route 86 which grows cotton and where hundreds of school children visit each year to collect Halloween pumpkins.

The Tohono O'odham Nation is developing 2,668 acres of land for irrigated agriculture in the Shuk-Toak farming district in order to utilize a portion of its CAP allocation. The CAP line was designed with a turnoff for that purpose. No groundwater pumping is involved, but desert vegetation is being cleared for this project and drainages are being collected and channelized in this sheet flow area. This is expected to affect flooding conditions downstream.

Many people who live in the Altar Valley choose to do so because they prefer a low-density rural lifestyle. In some cases this results in houses or mobile homes on large lots, sometimes bunched together to share services. Some large-lot wildcat subdivision development (often mobile homes) has occurred in the part of the valley north of State Highway 86 and near Black Wash.

Some people prefer to live in planned subdivision settings. Several small subdivisions have developed south of the Highway between Kinney Road and Robles Junction, most notably Diamond Bell Ranch (south of Robles Junction) which has zoning and provisions for utilities for many more homes than now exist there. This subdivision has a checkered past. A 1994 Star article predicted that "Diamond Bell Ranch may come out of its long sleep when home building and lot sales get underway later this year. ..." This was twenty five years after its opening. At some time in the future this development will probably be a major feature in the area.

Tucson Estates is a mobile home area at the foot of Cat Mountain occupied largely by retirees and winter visitors. New subdivisions are being constructed near the Tucson Estates Mobile Home Park as a result of a 1998 rezoning, and some commercial development is occurring in connection with that development and at the intersection of Kinney Way and Ajo Way. There are currently no large shopping centers or supermarkets in the area, but this could change as the population increases.

Millstone Manor is a subdivision in the northwestern part of the subarea. When platted in the 1950s, little consideration was given to drainage patterns even though it is in a floodprone area. A map for this area identified special permit conditions for new construction.

### **PROJECTED LAND USES**

The Pima County Comprehensive Plan designates a large swath of land running along the drainages between Saguaro National Park and the Tohono O'odham Nation as low to medium density residential and commercial areas along Ajo Way and Kinney Road. Resource Transition Zones buffer the public lands.

Change is liable to come to much of the area in future years. Arivaca is a somewhat remote part of this subarea, but its beauty and its access to I-19 and the rapidly growing parts of Santa Cruz County and southern Pima County make it a likely site for population growth. Although Arivaca is currently a small community, privately owned land is available for development as is some state land, as illustrated by the numerous "for sale" signs in the area. If pumping increased significantly, the water table would be lowered and the cienega and creek affected. When the Fish and Wildlife Service considered applying for an instream flow permit for the cienega and creek, questions arose about whether a permit would actually protect the area from pumping and some local landowners feared that their right to develop would be affected. Survival of the cienega is a delicate issue which would have to be addressed, especially since the options for other water sources are very limited.

With the passage of the North American Free Trade Agreement (NAFTA) border activity throughout the Southwest generally increased. Nogales has become a very busy crossing point. Some people project that the Sasabi crossing could be expanded and more heavily used, especially by truck traffic. If this happened it would probably lead to pressures for road improvement and additional services (both in Arizona and Sonora). It is possible that in the distant future Sasabi could be a link between Mexican Highway 2 and I-10 near Marana. All of this activity could affect the town and the valley.

As the density in the Tucson Estates area increases, based on approved rezonings as well as possible additional rezonings, there are impacts on the watercourses. Additional paved areas and land grading, especially on slopes, change the runoff patterns as discussed in Chapter III and may contribute to downstream flooding, depending on how they are designed. Since this area tends to be subject to flash floods with little warning, drainage problems need to be carefully handled. Additional residential development will also lead to the demand for community wastewater treatment facilities with possible reuse options. Road construction, widening, or paving, to serve these developments also has impacts on the drainages, whether the water is directed through dip crossings, culverts, or bridges.

Wildcat subdivision is liable to continue to occur throughout the area and rezonings for additional subdivisions may well be sought throughout the flatter portions of the valley.

Most of this population growth will have to be served by additional or improved roads including all-weather crossings, water, wastewater, and other public services as well as more places for shopping. These will, in turn, require adaptation to the floodplain whether in the sheet flow areas or the areas with more defined washes.

## **ISSUES FOR DISCUSSION**

### **POPULATION GROWTH AND ARIVACA CIENEGA/ARIVACA CREEK**

Arivaca is the only populated area in this subarea with groundwater near the surface. The Arivaca Cienega and Arivaca Creek are dependent on a high water table. At the present rate of pumping this is not endangered, although water levels do decline in very dry years. If groundwater pumping in this area were to increase significantly, the cienega and creek would be threatened. Should measures be taken to limit new pumping in this area? If so, what measures such as importation of water, strict conservation rules, or limits on construction are appropriate? While it is technologically possible to import water from outside the subbasin, the cost would probably be prohibitive.

### **SUBDIVISION AND WILDCAT DEVELOPMENT ISSUES**

If any of the large ranches (probably including State Trust Land) in the grasslands areas south of Ajo Way were to be available for sale, what would be the best use of the land? Options could include county purchase as open space land, expansion of Buenos Aires Wildlife Refuge, planned subdivision development, or piecemeal development. If areas are developed, what measures should be taken to reduce the impacts on the watercourses? Are current county floodplain management strategies adequate to deal with potential flooding problems and road access problems caused by increased growth?

North of Ajo Way, near the Tucson Mountains, and in the Robles Junction area the predominant pattern of wildcat and small subdivision development could continue or it could change character to larger planned subdivision development, following the example of Diamond Bell Ranch. Some State Trust Land in the valley could be sold for these purposes. Is continued population growth in this area desirable? Should additional restrictions be placed on construction? If the population continues to grow, how should wastewater be managed?

Should rezonings be allowed for large commercial development, such as a shopping center or "large box stores" to serve residents? If so, how should the watercourse and flooding issues be addressed with the addition of impervious surfaces such as parking lots and buildings in mind?

### **EXPANSION OF RYAN AIRFIELD**

As the Pima County population grows there may be more demand for airport space. With its large flat area and existing airfield, some of the Tucson Airport traffic, such as private planes, military training, or shipping, could be diverted to an expanded Ryan Airfield. Further paving of the area for parking or runways would alter drainage patterns. Is this a desirable land use? How should drainage issues be managed?

### **ABANDONED FARMLAND ISSUES**

What should be done with abandoned farmland in this area? Should these lands be available for other uses such as residential development, commercial uses (using CAP water), or preserves? Should projects be undertaken to rehabilitate any of those lands towards native habitat?

### **RECHARGE AND TERMINAL STORAGE PROJECTS**

The City of Tucson has examined several possibilities for constructing additional CAP recharge projects in this valley. These could occupy many acres of land, making it unavailable for other kinds of development. The current design for recharge projects does not include public recreational use or wildlife habitat. Recharge projects in some other places do have these features. Should some recharge projects be multiple purpose? Is recharge a good use for land in this valley? If a terminal storage facility is built near Black Wash, how should it be designed?

### **TUCSON MOUNTAIN PARK ISSUES**

Tucson Mountain Park was established to preserve a significant scenic and wildlife area from housing development. How should increasing tourism be handled? Should additional land be acquired for the park or more strict buffer requirements be established to separate the park from the kind of dense development occurring near Tucson Estates?

### **ROAD EXPANSION ISSUES**

Since signing of the NAFTA Treaty there has been some talk of expanding the border station at Sasabe to accommodate more traffic. Such expansion could be accompanied by additional use of Highway 256, especially by truckers, and the road might then require widening as well as all-weather crossings or bridges instead of the current dip crossings, which themselves create problems as described above. Is this a good option for the valley? Should road crossings be designed with more attention paid to minimizing impacts on the watercourses?

Additional park and scenic area visitation could necessitate road and parking area expansions within the Tucson Mountain Park and its access roads. The road currently uses dip crossings for the most part with some impact on the many washes as described above. Other types of crossings as part of road improvements could negatively impact the washes in other ways or could improve the situation. How can these demands best be accommodated? Should road widening be encouraged or allowed within the Park?

As population growth continues, pressures are liable to develop to pave some currently unpaved roads or to widen access roads such as Tucson Estates Parkway, Sandario Road or Kinney Road. This would probably impact the drainages in the area as well as attract population growth and land use in some areas. The same road-related questions arise as mentioned above. How should these impacts be managed?

### **BRAWLEY WASH RESTORATION**

At several times in recent years the Natural Resources Conservation Service (formerly Soil Conservation Service) has proposed building a series of check dams along Brawley Wash and some tributaries, in an attempt to reduce the incision of the wash. These dams would be designed like check dams in the San Simon Valley which have managed to halt the severe erosion and add sediment to the channel to build it back up to its former level. Most ranchers were in favor of this project, but funding was not available. Should efforts be renewed to restore the wash by this or other methods?



Region Within the Subarea	Grazing	Wildcat Subdivision	Planned Subdivision	Copper Mining	Sand & Gravel Mining	Pumping	Agriculture	Recreation
Arivaca & Buenos Aires Refuge	X-	X+	X+	X		X+		X+
Brawley Wash Ranchland Area	X-		P			X		
Remainder of Valley	X-	X+	X+			X	X+-	X+

**Key:** X = Existing    X+ = existing with potential to increase    X- = Existing with potential to decrease  
X+- = Existing with potential to increase or decrease    P = Potential

**Fig. 9-3. Generalized Matrix of Potential Impacts on Watercourses in the Altar Valley Subarea**

Region within the Subarea	Alternate Water Less Pumping	More Non-structural Floodplain Management	Stricter Land Use Management	Federal Public Lands Expansion	State Trust Land Preserved	Other Preserves Increase	Better Grazing Management
Arivaca & Buenos Aires Refuge	X*		X	X			X
Brawley Wash Ranchland Area	X*			X	X		X
Remainder of Valley	X	X	X			X	

Key: X = Is possible and could have significant impact if it occurred. X\* = Technically possible but very costly.

Fig. 9-4. Generalized Matrix of Potential Options for Reducing Stress on Watercourses in the Altar Valley Subarea

# Chapter 10

## Subarea 6B - Avra Valley

### WATERSHED/WATERCOURSE CHARACTERISTICS

#### THE WATERSHED

The Avra Valley Subarea consists of the watershed of the Brawley Wash downstream of Mile Wide Road. The subarea is bounded by the Silverbell, Waterman and Roskrige Mountain ranges to the west and the Tucson Mountains to the east. The subarea extends north to the confluence with the Santa Cruz River which occurs near the Pima-Pinal County line. On most maps the Brawley Wash changes names to the Los Robles Wash shortly before joining the Santa Cruz River. The subarea is shown on Fig. 10-1 and the watershed on Fig. 10.2.

The Avra Valley Subarea consists of a wide north draining valley with tributary drainage into the Brawley Wash from the mountain ranges to the east and west. The west foothills (i.e., Roskrige and Silverbell Mountain foothills) tributary areas generally consist of well-defined washes until they reach the valley floor where they lose much of their definition. Much of the tributary drainage on this side of the valley drains into the Blanco Wash before reaching the Brawley Wash. The Blanco Wash is a major tributary to the Brawley Wash which runs parallel to the Brawley on the west side of the valley floodplain before joining it about three miles from the Pima-Pinal County line. Tributary drainage of the Tucson Mountain foothills is somewhat less defined than the Roskrige-Silverbell foothills with some of the drainage following a distributary or sheet-flow like pattern in the Picture Rocks area just north of Saguaro National Monument.

Much of the valley floor of the subarea consists of braided channels running generally north across a wide shallow floodprone area. Historically mapping of flood hazards in this area has been difficult because of the poorly defined, almost sheet-flow type nature of the drainage in the valley. In addition, the Brawley Wash itself typically exists as more than one branch along the valley floor.

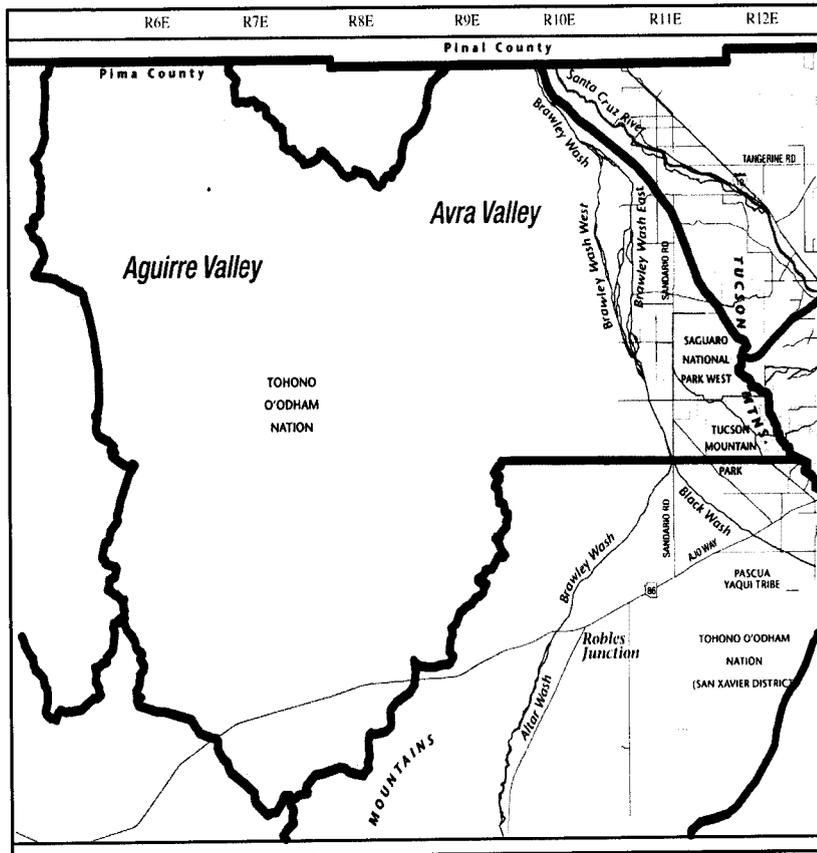


Fig. 10-1. The Avra Valley Subarea.

The Avra Valley subarea also includes an area known as the Aguirre Valley. This area is located west of the Silverbell Mountains and consists primarily of Township 11 South, Range 6 East. This area is very remote with no paved roads into the area from other portions of Pima County. Primary access is by way of Night Sky Street in Pinal County. The area is physically quite similar to other portions of the Avra Valley subarea. The Aguirre Wash, which is the primary flow path through the valley, consists of poorly defined braids, which lose and gain definition intermittently. These braids are located within a broader valley that exhibits characteristics of shallow sheet flow conditions. Tributary drainage to the area is reminiscent of the Picture Rocks portion of the Avra Valley Subarea with poorly defined but generally tributary drainage forms. Development of the Aguirre Valley consists almost exclusively of agricultural fields that nearly span

the valley within Township 11 South, Range 6 East. Occasional, isolated stock tanks and ponds dot the landscape in the areas tributary to the valley. No development of any other type is discernable from 1992 aerial photography. This condition is supported by a complete lack of permits on file at the Pima County floodplain office.

### **TRIBUTARY WASH CHARACTERISTICS**

Tributary washes are generally well defined along the upper reaches where they begin to emanate from the mountain fronts then move downslope towards the valley. The degree of entrenchment between adjoining topographical high points decreases with distance from the mountain front as channel slope becomes milder. The slope reduction ultimately results in a depositional environment which develops distributary channel patterns. These patterns are evident throughout the lower reaches of the piedmont on both sides of the valley.

### **DISTRIBUTARY WASHES**

Distributary drainage systems commonly occur upon the pediments adjoining mountainous areas. A distributary channel form evolves as a result of sediment deposition induced by slope reduction. The washes aggrade which infills the channel and forces flow to spread onto adjoining areas of the pediment. Flood peaks dissipate as the distance from the mountain front increases (via surface storage and infiltration) ultimately leaving little or no trace of a channel.

Distributary washes add an element of uncertainty to land use planning. The uncertainty is the inability to predict future flow paths and sediment loads. Usually, the uncertainty to predict flow patterns is dealt with by constructing a collector channel and/or berm along the upstream side of a land use area. This channel/berm functions to intercept, then route the flow around the area being protected. The approach has been used many times throughout Pima County to provide flood protection for residential, commercial, and agricultural development as well as transportation facilities. Degree of success has varied depending upon design factors such as slope and stabilization measures and upon watershed size and sediment load. This is because a collector channel introduces an abrupt change to the hydraulic and geomorphic characteristics of distributary washes. The most commonly observed change is sediment deposition within the collector channel, then erosion along the downstream reaches where flow is returned to the natural wash.

### **MAJOR WASH CHARACTERISTICS**

There are two major washes which drain north through Avra Valley. Brawley Wash is the largest of the two washes having a drainage area of about 1165 square miles at the south boundary of this subarea. Black Wash is a major tributary to Brawley Wash which collects runoff from the west slopes of the Tucson Mountains and portions of the Sierrita Mountains.

The 100-year floodplain covers just about all of the Avra Valley bottom land. Brawley Wash has a wide geologic floodplain which vary in width from one to four miles, generally increasing in the downstream direction. The floodplain is occupied by a series of distributary channels which functioned to slow velocity and spread flow across the floodplain. The floodplain environment is generally aggradational but sediment transport capacity changed with flood volume to maintain a quasi-stable channel system. The channel entrenchment evident along the upper reaches of Brawley Wash through Altar Valley has not occurred along the Avra Valley reach, except for one segment near the CAVSARP project, probably a result of agricultural activity. Portions of the valley floor have been farmed during past decades. This farming usually included the construction of diversion berms along the south, east and west boundaries of the fields to divert flow away from the crops. Many of these berms still exist but are generally in a state of disrepair.

Black Wash remains a stable geomorphic environment not having been subjected to the entrenchment associated with man-made changes within the Brawley Wash watershed. This is probably due to the geology of the contributing watershed and the mild slope of the valley floor. Future geomorphic change should be limited because of these factors.

The floodplains in Avra Valley have restricted development. A few subdivisions which were constructed decades ago usually have inadequate drainage facilities. There has been periodic flooding within these subdivisions which has damaged property and the drainageways which were intended to floodproof the homes. Past flooding in these areas has increased Pima Counties awareness of flooding and flood damage potential in this valley. An administrative floodway was developed and adopted to assist Pima County with regulating future development within the Brawley and Black Wash floodplain areas.

## **HUMAN IMPACTS ON THE WATERCOURSES**

### **FLOOD CONTROL PLANS AND PROJECTS**

Pima County has acquired 263 acres of floodprone land along Brawley Wash near Mile-Wide Road for flood control purposes.

### **TRANSPORTATION**

Interstate 10 is just beyond the eastern boundary of the subarea, connecting Tucson with Phoenix and points west. The railroad parallels the interstate to the east. Within the subarea the major north-south road is Sandario Road which connects with the Ajo Highway to the south. Picture Rocks Road connects the Valley with Ina Road and partially traverses Saguaro National Park. Avra Valley Road crosses the Santa Cruz River south of the Rillito Cement Plant and continues west. Most of the other roads in this (CAVSARP) area (Sanders Road, Greer Road, for example) are unpaved, or are paved for only a short distance. There are numerous urban streets in town.

The Avra Valley Airport handles small planes only. Farther west is a small gliderport.

### **WATER AND WASTEWATER- RELATED USES**

#### **Water Supply**

Depth to water ranges from 200 feet near the Santa Cruz River to more than 400 feet to the south near the City's well fields. There are several shallow groundwater areas in the Waterman Mountains.

The Cortaro-Marana Irrigation District provides agricultural and domestic water and several water companies provide domestic water. Many water users in the area have their own wells.

The Central Arizona Project (CAP) enters Pima County in this area on the east side of I-10 and goes towards the Avra Valley in an underground conduit beneath I-10 and the railroad. It turns south along the center of the valley and proceeds into the Altar Valley subarea. There are three pumping stations to lift the water along this route (Sandario, Twin Peaks and Brawley).

#### **Wastewater**

Most of the population of the area has septic systems. The Arizona Sonora Desert Museum has its own system as does the Gilbert Ray Campground. For a description of wastewater issues in the Marana area, see Chapter 8.

#### **Recharge**

The Lower Santa Cruz River Recharge Project (LSCRPP) is being developed jointly by Central Arizona Project (CAP) and the Pima County Flood Control District as a State Demonstration Recharge Project for the underground storage of Colorado River water. The agencies share construction costs while CAP operates the project. The project is designed to recharge 30,000 acre feet of water per year through eight basins covering approximately 77 acres.

The Avra Valley Recharge Project (AVRP) was developed by Central Arizona Project (CAP) as a State Demonstration Recharge Project for the underground storage of Colorado River water. CAP operated the project as a pilot facility from July 1996 to December 1997 and, in early 1998, was awarded a permit to operate the project full-scale for 20 years. The basins are located on a river terrace in an abandoned gravel pit adjacent to the Santa Cruz River. CAP designed, constructed and operates the facility, while BKW Farms, Inc. constructed and operates the pump station and delivery canal. The Metropolitan Domestic Water Improvement District leased project storage capacity and earned storage credits for 6,200 acre-feet of water stored underground at the facility. The project consists of four infiltration basins with a combined surface area of 11 acres. Up to 11,000 acre-feet of CAP water per year may be recharged to the aquifer.

At the southern end of the Avra Valley, the City of Tucson operates the Central Avra Valley Storage and Recovery Project for CAP water (CAVSRP). This a pilot project with three 20-acre basins, along with pipelines to transport CAP water from the CAP canal to the recharge basins. The pilot project permit allows up to 10,000 acre-feet of CAP water to be recharged over a two year period. This facility was designed to deal with the requirements of Tucson's Proposition 200, an initiative passed by voters in 1992. This law resulted from consumer dissatisfaction with direct delivery of CAP water to homes. Recharge was a one option recommended by the voters. The facility is located on former agricultural land and is designed to recharge CAP water and recover it for municipal use. Recharge of this type removes some of the potential pollutants in the water, but does not affect the salinity and the water still requires treatment in the Hayden-Udall Water Treatment Plant before being put in the municipal system.

If studies of this project show promise, the project will be expanded or additional sites chosen so that even more water can be recharged. Since the Tucson area does not yet need all the CAP water to which it is entitled, recharge projects will continue to be in demand here and elsewhere. Under current Arizona law it is possible for a developer or municipality without an assured long-term water supply to participate in the Central Arizona Water Conservation District which administers recharge programs which are actually run by local entities. By buying into recharge projects somewhere in the Active Management Area, the assured water supply designation may be granted even if the recharge does not occur near the development. Affected homeowners must make annual payments for the project. The demand is expected to continue for additional recharge sites in this area and elsewhere. The Altar Valley is especially attractive as a recharge location because of the quality of its soils, the availability of vacant land, and its proximity to City of Tucson wellfields.

Effluent flows into the area play a major role in recharging the aquifer as well as the growth of vegetation along the river. (See Chapter 8 for more information).

### **EXISTING PUBLIC LAND USES**

The Saguaro National Park occupies the southeastern portion of the subarea and a portion of the Altar Subarea, with a total of 23,425 acres. This adjoins the Tucson Mountain Park with a total of 18,122 acres in the Altar, Avra, and Middle Santa Cruz subareas. Hiking trails, picnic areas, a campground and a Visitor Center are used by more than 3 million people annually.

The Arizona Sonora Desert Museum is within the Tucson Mountain Park, near the Saguaro National Park boundary, along the edge of King Canyon. More than half a million people visit the museum annually. The museum has worked to be sensitive to the environment and minimize any changes to the watercourses, although parking areas and other structures inevitably have an impact. Water harvesting and water conservation are important to the museum which depends on pumped groundwater.

The Old Tucson Studio is also within the Tucson Mountain Park and attracts more than half a million visitors annually.

The BLM Silverbell Resource Conservation Area occupies 100,369 acres of mountainous land in the Silverbell Mountains. This area is protected from residential development, but mining, grazing, and recreational activities are allowed. BLM also manages the Waterman Mountains Area of Critical Environmental Concern which covers 3,245 acres. This area is primarily managed to protect the endangered Nichol's Turk's Head Cactus. Mining is not allowed. Neither of these areas has intermittent or perennial streams, but both have numerous ephemeral washes.

Tucson Water owns approximately 20,000 acres of farmland in the Avra and Altar valleys in order to use the water in the city water system. For the most part these farms are not used for other purposes. Tucson Audubon has a grant from the U.S. Army Corps of Engineers to conduct a pilot Revegetation project on a 270-acre site on the Simpson Farm, a City of Tucson farm property. It is near a popular birding spot, a pecan grove near the Pinal Air Park. (which is just across the line in Pinal County). This area receives effluent from the County's wastewater treatment plants. The flow that reaches the Simpson farm currently nourishes cottonwoods and willows and a thriving bird population. The project is designed to plant drought-tolerant native plants on the old farm land.

### **EXISTING PRIVATE USES**

Historically agricultural uses have predominated in the valley and these uses have included construction of berms and ditches to channel and direct water around and away from farm fields. In the past the lack of defined drainage and limited development also resulted in a general lack of good floodplain mapping. The Cortaro-Marana Irrigation District, BKW Farms and Avra Irrigation District are the major farming areas in the Avra Valley. The AMA sets conservation goals for various kinds of crops and has been working to reduce water use for agriculture. The percentage of water used in the Tucson AMA for agricultural purposes has declined from 84 percent of total water used to less than 50 percent today. This is partly through better irrigation methods and partly through conversion of farmland to urban uses. Farm acreage declined steadily until the late 1990s when it again climbed, probably due at least in part to a legal option offered by the AMA, groundwater savings facilities (also called "in lieu recharge."). In return for subsidized agricultural use of CAP water, the farms agree to pump less groundwater. All three Avra Valley farming areas listed above used a total of approximately 25,000 acre feet of CAP water 1997 under that program. Cortaro-Marana Irrigation District also uses about 3,000 acre feet of effluent.

ASARCO operates the Silver Bell Copper Mine on 18,000 acres in the northwestern part of the subarea. There are three open pits which produce about 55 tons per day of copper. Copper was first produced here in the 1880s, halted in 1915 and resumed again in 1954. In 1992 a land exchange with BLM was completed and additional areas

were available for mining. In 1997 construction of the new facilities was complete and mining commenced there. As part of the land exchange, the Waterman Mountains Area of Critical Environmental Concern was set aside.

More recently, development in the area, particularly near the Picture Rocks area, has prompted the Pima County Flood Control District to develop better regulatory tools for the area, including the Brawley Wash Administrative Floodway Maps. These maps define a corridor set aside to allow for through passage of the highest concentration of flood flow and maintain overbank flood storage levels. The floodway corridors insure a future path for flood waters and are unavailable for development.

### **PROJECTED LAND USES**

The Pima County Comprehensive Plan calls generally for low density land use except for an area west of Marana and another south of Marana, with a transition zone to buffer the Saguaro National Park. Much of the area on both sides of the Brawley Wash are designated for agriculture and resource conservation. The Marana Town Plan calls for medium to high density in the town itself.

Most recent development in the area has been in the form of large-lot parcel splitting resulting in unregulated subdivision-type development. As a result, access to many residential areas may be severely limited in times of flooding. This condition currently exists for many homes built along the Blanco Wash on the west side of the valley floor. This area was subdivided many years ago before current floodplain regulations required adequate elevation of floors above flood level and set back of construction from watercourses to prevent erosion damage.

Development in this area can be expected to continue as other parts of the metropolitan area become built out or too expensive to develop. However, much of the valley floor has been purchased by Tucson Water for its water rights. These areas may also be used in the future for groundwater recharge projects similar to Tucson Water's existing Central Avra Valley Storage and Recovery Project (CAVSARP) which was constructed to recharge Central Arizona Project water. Additional floodplain management tools are needed for this planning area, particularly better floodplain mapping of the areas tributary to the Brawley Wash.

A Ironwood Forest National Monument has been proposed for the Silverbell portion of the subarea. This includes land most likely to be subjected to mining in the future. The proposal necessarily excludes areas already being mined or for which mining rights have already been established, but includes BLM lands where claims might be filed in the future.

## **ISSUES FOR DISCUSSION**

### **SUBDIVISION DEVELOPMENT**

Requests for subdivision rezonings are liable to increase in coming years in the incorporated and unincorporated areas as are implementation of existing zoning classifications. What measures, if any, should be taken to minimize the impacts on watercourses and flooding, especially in light of the special problems of the sheet flow areas? Should both structural and non-structural solutions be required? How should flood problems in the sheet flood areas be resolved?

### **WILDCAT DEVELOPMENT**

Should wildcat development be allowed to continue in the area? Should greater controls be placed on this type of development, especially as it affects watercourses and downstream flooding?

### **PICTURE ROCKS ROAD, SANDARIO ROAD, OTHER roads**

As the population of the area increases, the demand for better transportation corridors is also expected to increase. What kinds of drainage crossings should be utilized? Should all major roads be all-weather roads? Should Sandario Road be allowed to become the major north-south road in the area?

### **IMPACTS OF EXPANDED TOURISM**

If tourism to the Desert Museum, Saguaro National Park and Old Tucson were to continue to increase, what provisions, if any, should be made for all-weather roads that can carry more traffic? Should the roads through the Park continue to remain open for general traffic?

### **INCREASED USE OF LAND FOR RECHARGE**

In order to maximize its use of CAP water, the City of Tucson is liable to build more recharge facilities in the Avra Valley. Is this a good use of the land? What other uses should be considered for abandoned farm land in this area? Should the recharge basins be designed to accommodate other uses such as wildlife?

### **EXPANSION OF AGRICULTURE AT SHUK TOAK**

Expansion of agriculture at Shuk Toak is expected to impact the downstream areas where flows have been channelized for release north of the district. What measures, if any, should Pima County take to minimize the impacts of the concentrated flows on areas which previously were sheet flow areas with ill-defined drainage patterns?

Region Within the Subarea	Grazing	Wildcat Subdivision	Planned Subdivision	Copper Mine	Sand & Gravel Mine	Pumping	Agriculture	Recreation
Tucson Mountain Foothills		X+	X+			X+-		X+
Marana West of River		X	X+			X+-		
Valley Floor		X+	X+		P	X+	X-	
Silverbell, Aguirre, Waterman Area	X			X		X	X	

Key: X = Existing    X+ = Existing with potential to increase    X- = Existing with potential to decrease  
X+- = Existing with potential to increase or decrease    P = Potential

Fig. 10-3. Generalized Matrix of Potential and Existing Impacts on Watercourses in the Avra Valley Subarea

Region Within the Subarea	Alternate Water Less Pumping	More Non-structural Floodplain Management	Stricter Land Use Management	Federal Public Lands Expansion	State Trust Land Preserved	Other Preserves Increase	Better Grazing Management
Tucson Mountain Foothills	X	X	X	X	X		
Marana West of River	X	X	X			X	
Valley Floor	X	X	X		X		
Silverbell, Aguirre, Waterman Area				X	X	X	X

**Key:** X = Is possible and could have significant impact if it occurred.

Fig. 10-4. Generalized Matrix of Potential Options for Reducing Stress on Watercourses in the Avra Valley Subarea

# Chapter 11

## Subarea 8 - Western Pima County

### WATERSHED/WATERCOURSE CHARACTERISTICS

#### THE WATERSHED

The area consists of low lying southeast to northwest trending mountain ranges with wide alluvial valleys in between. Few of the mountains in the area rise to more than 3,000 feet in elevation and most of the valley areas lie at or below 1,000 feet in elevation. The most notable mountain ranges in the area are the Ajo Mountains located in the Organ Pipe Cactus National Monument, and the Growler and Granite Mountain ranges, between which lies the Growler Valley and the Growler Wash. The subarea is shown on Fig. 11-1 and the watershed on Fig. 11-2.

The Town of Ajo is located along a saddle in a smaller mountain range known as the Little Ajo Mountains. The town is located on high ground relative to the valley drainage in the area. Only one wash of notable size, the Gibson Arroyo, passes through the existing town site. The Gibson Arroyo is a sand bed channel typical of many in the area. However, the arroyo has been modified and rerouted in places to accommodate development of the town. The reaches of Gibson Arroyo upstream (south and east) of Ajo through Township 12 South, Range 5 West contain broad areas of distributary sheet flow. The washes associated with this distributary flow area spread across the valley floor to widths ranging between one to 3 miles. This area provides a significant amount of overbank storage which reduces downstream peak flow rates and sediment transport volume. Pima County designated Gibson Arroyo in the Ajo area as a critical basin because of drainage problems in the Homer Brown Subdivision.

The area is notable for its relatively low rainfall, which measures about nine inches per year in Ajo. The

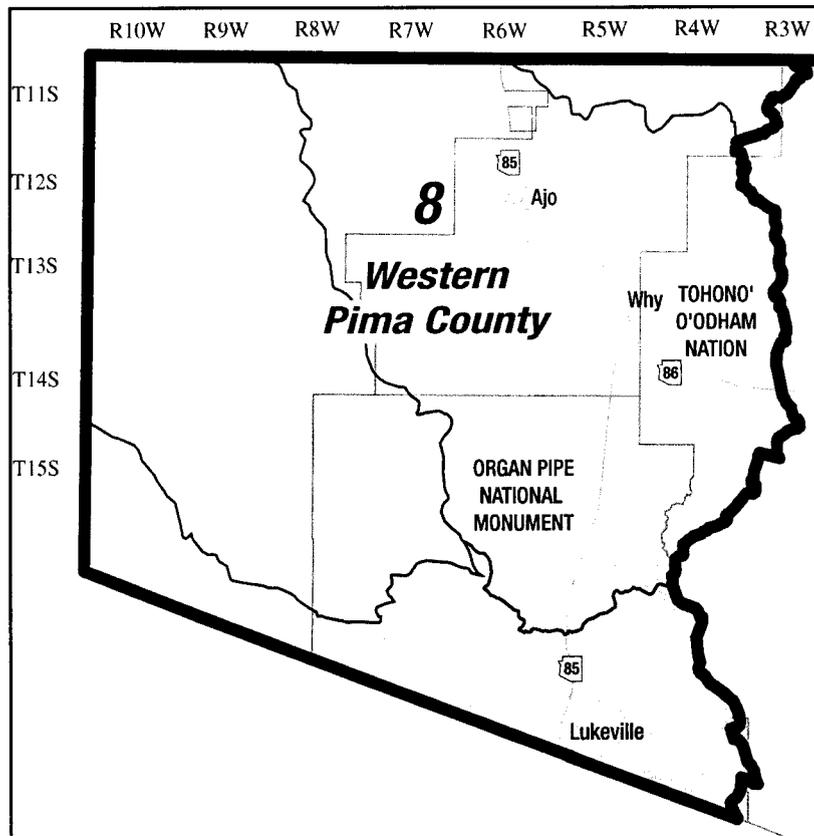


Fig. 11-1. The Western Pima County Subarea.

low density of vegetation of most of the landscape reflects the lower rainfall. The Growler Wash through the Growler Valley, located within the Cabeza Prieta National Wildlife Refuge is one of the larger drainages within the area. However, the lack of vegetation along this wash is remarkable given the size of the upstream watershed.

## **HUMAN IMPACTS ON THE WATERCOURSES**

### **TRANSPORTATION**

The main road through this area is Highway 85 which connects with Mexican Highway 8 which goes to Rocky Point and with Mexican Highway 2, the major east-west Mexican highway in the area. Highway 85 goes from the border town of Lukeville to Interstate 8 at Gila Bend and Interstate 10 Buckeye. It also connects to Highway 86 which goes through the Tohono O'odham Nation to Tucson. Most of the watercourse crossings are dip crossings, with some bridges and culverts. There is a small airport in Ajo.

### **WATER AND WASTEWATER-RELATED LAND USES**

#### **Water Supply**

Water is supplied from private wells and from a private water company in Ajo. ASARCO has its own wells and Organ Pipe National Monument has its own wells and water system for visitors.

#### **Wastewater**

Ajo's wastewater is treated in a private facility. A proposal is pending to expand the size of this facility. Organ Pipe National Monument has its own treatment facility. The rest of the region is on septic systems.

### **EXISTING PUBLIC LAND USES**

The Western Pima County Subarea is a vast area consisting primarily of public lands. Organ Pipe Cactus National Monument occupies 320,800 acres at the southeast portion of this subarea. A large campground, capable of handling large RVs, is situated near the Visitor Center. Informal camping is allowed elsewhere in the Monument. Two scenic drives allow the visitor access to trails and picnic areas. The eastern drive is paved, while the western one is unpaved. Both routes follow land contours and depend on dip crossings to traverse the many small watercourses.

The Cabeza Prieta National Wildlife Refuge occupies 860,010 acres in Pima and Yuma Counties, with 429,750 of those acres in Pima County. This area is only accessible to 4-wheel vehicles by permit. The road is unpaved and often unpassable during downpours. Use during wet periods can seriously degrade the road through creation of ruts.

The 2,700,000 acre Goldwater Air Force Gunnery Range (44,279 acres in Pima County) extends partially into Pima County, but is mostly in Yuma and Maricopa Counties. Most of this area is closed to the public and used primarily for military training activities. Parts are accessible by permit and are used to access the Yuma County parts of the Wildlife Refuge. Military use of the area is periodically reviewed and is not authorized indefinitely. Grazing is not allowed in the Monument, Refuge, or Gunnery Range, although some cattle do reach the range across the international border.

To the east of this subarea is the 2,490,105 acre Tohono O'odham Nation. The remaining lands between the above public areas are held by the Bureau of Land Management where grazing is allowed. The sources of water and forage are very limited in this dry portion of the state and grazing tends to degrade the land near the few water sources unless carefully managed.

### **EXISTING PRIVATE LAND USES**

There are roughly fifty square miles of non-federally owned lands in the subarea, the majority of which are located near the Town of Ajo and north of the town along the Maricopa-Pima County line. The unincorporated town of Ajo is at an elevation of 1,798 feet. Today's population is almost 3,500, but at its peak in the 1960s when the copper mine was in full production, the population topped 7,000. The community is served by four water companies and has community wastewater treatment. It also has a country club and golf course. Although the town faced serious economic problems when the mine closed, it recovered and today's economic base is largely based on retirees and tourism going to the nearby Organ Pipe National Monument and attractions in Sonora, especially Rocky Point.

The Town of Ajo is largely as it has existed since the height of mining in the area in the 1960's. The Town consists primarily of small lot residential development originally constructed as housing for those working in the mines and now serving as housing primarily for retirees who moved to the area after closure of the mines in the 1980's. Development of the surrounding area has consisted primarily of large lot development with conventional residential and manufactured housing. Review of files at the Pima County Floodplain Management office revealed instances of problems with drainage in the area but these were generally minor in nature.

Why is a small unincorporated area at the junction of Highways 85 and 86. The area has seen a small boom in RV parks and facilities to serve tourists. The Tohono O'odham Nation has a gambling casino at the edge of town.

Mining began in Ajo in earnest in the early 1900s when John Greenway began investing in the area. By 1916 the town of Cornelia (just north of present-day Ajo) had a population of 5,000 and mining was booming. Ajo was founded in 1920 and the New Cornelia mine became the mainstay of the economy. The peak years were in the 1960s, but in 1985 ASARCO (American Smelting and Refining Company) closed the mine because it was no longer profitable. The existing tailings ponds and open pits are a significant feature of the town. In 1997, however, the company decided to reopen the mine using new technologies that make it possible to extract copper profitably from ore with low concentrations. Once the various permits have been attained, the company projects that the mine will employ about 400 people and have an annual production of 135 million pounds of copper and 25,000 ounces of gold. Groundwater is the source of water for the mining operation and the town.

### **PROJECTED LAND USES**

With the reopening of the mine, the population of the town can be expected to grow to accommodate the new employees. The 400 employees projected, however, are far less than the employment in the 1960s. Whether a town with active mining operations will prove to continue to be appealing to retirees is unknown.

Increased recreational use of the nearby areas may also affect some land uses in the area. A citizen group has a proposal to join the existing National Monument, the Wildlife Refuge and parts of the military bases into a National Park which would be coordinated with areas in Mexico, including the existing Pinacate National Park. While this would give added protection to the area it could also greatly increase tourism and the facilities demanded by park visitors in Ajo, Way and in the public lands themselves.

With the passage of NAFTA and the increase in tourism to Rocky Point and Organ Pipe National Monument there has been discussion of widening the highway and raising the speed limits. One alternative includes routing a new highway through the Tohono O'odham Nation instead of using the present alignment. The National Park has been opposed to widening the road or increasing the speed limit because of possible damage to wildlife and vegetation.

## **ISSUES FOR DISCUSSION**

### **MINE EXPANSION**

When the mine reopens, what measures, if any, should be taken to protect the water supply and drainages in the area?

### **WIDENING OF HIGHWAY**

How should increased traffic between Lukeville and I-10 be handled? Should the current road be widened and made all-weather? Should a new road be constructed outside the National Park boundary?

### **INCREASED LAND PRESERVATION MEASURES**

Should a National Park be established in the region?

### **INCREASED RECREATION**

As recreational use of the area increases, are new measures needed to minimize the impacts of activities such as recreational vehicle camping and offroad vehicle use?

### **GRAZING MANAGEMENT**

Are changes needed in how grazing is managed in the area to ensure that watercourses are not degraded?

Region Within the Subarea	Grazing	Wildcat Subdivision	Planned Subdivision	Copper Mine	Sand & Gravel Mine	Pumping	Agriculture	Recreation
Ajo-Why		X+	X+	X+		X+		
Public Lands	X							X
<b>Key:</b> X = Existing    X+ = Existing with potential to increase    X- = Existing with potential to decrease X+- = Existing with potential to increase or decrease    P = Potential								

**Fig. 11-3. Generalized Matrix of Existing and Potential Impacts on Watercourses in the Western Pima County Subarea**

Region Within the Subarea	Alternate Water Less Pumping	More Non-structural Floodplain Management	Stricter Land Use Management	Federal Public Lands Expansion	State Trust Land Preserved	Other Preserves Increase	Better Grazing Management
Ajo-Why			X				
Public Lands							X

Key: X = Is possible and could have significant impact if it occurred.

Fig. 11-4. Generalized Matrix of Potential Options for Reducing Stress on Watercourses in the Western Pima County Subarea

# Chapter 12

## Summary and General Issues for Discussion

### THE MOST FREQUENT PROBLEMS

Some themes are repeated throughout the subareas and some are unique to one or a few of them. What happens in one subarea often affects the watercourses in another subarea downstream. Activities in the Upper Santa Cruz subarea, or even upstream of that area in Santa Cruz County may be felt in the Middle Santa Cruz and Tortolita Fan subareas. Activities in Santa Cruz County and in the Cienega-Rincon subarea also have impacts downstream in the Middle Santa Cruz and Tortolita Fan subareas. The Altar and Avra subareas are also closely related to each other and to the lower reaches of the Santa Cruz River. The Middle San Pedro subarea is hydrologically isolated from the rest of Pima County, but is strongly affected by what happens in Cochise County upstream. Solutions to floodplain management and to riparian preservation, thus are interrelated. Some decisions will be made on a case by case basis and others will require a regional approach, or legislation to implement. This chapter looks at common themes in the subareas and at kinds of activities that impact more than one subarea.

Almost all the subareas experience flood problems created or exacerbated by human activity and have watercourses that are very different from pre-Anglo settlement conditions. In almost all of them public and private funds have been spent to repair damage from past flood and erosion incidents and to prevent future problems. The impacts are summarized generally in Fig. 12-1 and options for protection in Fig. 12-2. The following are the most common themes.

#### **Flooding**

##### *Bank Erosion*

Erosion of banks of dry watercourses is a major problem in this area and is often exacerbated by human activity. Erosion has occurred in most of the subareas on curving banks of the watercourses and in places that receive heavy discharges from sources such as culverts and storm drains. Erosion at spots in the Santa Cruz River from downstream of San Xavier to Marana has involved loss of many acres of land and major channel shifts. Erosion of the Rillito caused major damage in several floods. Erosion on many smaller watercourses has led to localized damage throughout the region.

##### *Flooding in Sheet Flow Areas*

Sheet flow areas offer special problems for development. The drainages are ill-defined and flooding problems are minimal and short-lived in any one part of a natural sheet-flow region. Sheet flow provides water and nutrients for natural vegetation over a large area. Once development takes place, however, the roads, buildings, and flood control structures tend to concentrate flows into more clearly defined channels which may cause flood problems for downstream landowners and at road crossings. These changes are liable to be felt all the way to the downstream areas where channels are well established and are liable to lead to increased erosion as the flood waters are concentrated into smaller areas. The native vegetation, too, may be affected by changes in the water distribution patterns.

Should development in sheet flow areas be restricted to maintain as much natural flow as possible, or should the flows be channelized into discreet flow patterns by proposals such as the Corps of Engineers proposal for the Tortolita area discussed in Chapter 8, and in the Shuk Toak area discussed in Chapter 9, or should each problem be treated on a case-by-case basis? Should government be responsible for construction and/or maintenance of such projects?

##### *Flooding in Distributary Flow Areas*

Distributary flows areas offer similar problems for development. While the drainages are better defined than in sheet flow areas, they tend to change with each major flow. The floodprone areas are difficult to map. These problems can be solved by keeping development off areas currently serving as a drainage, by keeping development off all areas susceptible to becoming drainages, or by channelizing the flows so that drainages are well-defined, allowing more land to be used by people.

Should non-structural approaches be used in distributary flow areas, and development be prohibited or restricted in areas where flows are liable to occur?

Should structural approaches be used to maximize usable land? If so, what conditions should be imposed on the builder? Should government be responsible for their construction and/or maintenance?

#### *Flooding in Tributary Flow Areas*

In many of the subareas some neighborhoods have had repeated flooding problems, usually because homes were built in floodprone areas or because the areas became floodprone after upstream development increased the intensity of flows to the areas or changed the path of the flow. Most of these problems are solved by city or county through structural solutions, although in some cases home buyouts are necessary. The development of stricter floodplain regulations has lessened the number of new problems, although problems from older construction continue to require solutions.

#### *Street Drainage and All-Weather Access*

How roads are integrated into the landscape can have a great effect on what happens downstream in a watercourse. Properly designed dip crossings on lightly used roads generally have the least impact on the watercourse, but are liable to be impassable when the watercourse is flowing and sometimes divert flows down roadways if improperly designed or aligned. The more heavily used the roads, the more demand there is for all-weather crossings. Properly designed culverts and bridges can have minimal impacts on the watercourses, especially when they are sized adequately. Major thoroughfares require bridges properly protected from flood and erosion damage. This protection may result in the need for additional protection downstream if it impedes the flow.

Oversizing roads and crossings to anticipate future demand may lessen the future flood problems but may also contribute to further development of an area which brings about its own problems.

In most of the subarea drainage problems occur because of undersized culverts and storm drains. This inadequate sizing most often happens because of upstream construction that has increased peak flows, the magnitude of which was not anticipated when the drainages were designed. In some cases the lack of drainage capacity has caused backup of floodwaters into neighborhoods. In the more remote parts of the subareas as well as in parts of the urban area, streets are not able to handle the flows and streets are dangerous or impassable for short periods of time. Where dip crossings are used, homes may be inaccessible for hours or even days when precipitation is high. In some cases lives have been lost because people tried to drive in flooded washes. Installation of crossing features has also lead to downstream erosion in many of the subareas.

#### **Land Uses Issues**

##### *Planned Subdivision vs. Wildcat Development*

Houses or mobile home built one at a time (wildcat development) generally have less impact on the watercourses than large numbers of homes, but the cumulative effect of many such homes can be at least as great as the impacts from a subdivision on which restrictions have been placed as a condition of rezoning. These homes generally use septic systems which may benefit a high water table through recharge, but may also create water quality problems. Most ordinances have specific exemptions for small or individual construction, although a floodplain permit would be required. The County's Buffer Ordinance, for example, exempts developments of less than 80 acres from the buffer requirements.

Government has experienced increasing demands from people in wildcat developments for flood protection or rescue, all-weather roads, and other services. Providing such services piecemeal is usually costly.

Subdivision development, on the other hand, may involve large-scale structural flood control measures that seriously alter watercourses and the presence of a large number of homes impacts the riparian areas and wildlife. Many of the flood control structures and wastewater treatment distribution systems are usually paid for by the developer (ultimately the home buyer), not the county taxpayer and are done in a planned coordinated manner. All-weather roads within the development are usually a condition of rezoning. Flood control structures, wastewater facilities, and roads must be approved by the governing agency.

##### *Natural Recharge and Overbank Storage*

In some cases, residential and commercial development or road construction may result in loss of overbank storage capacity and recharge capability. This can result, in turn, in community-wide problems including more violent floods downstream and diminished long term water supplies.

### *State Trust Land*

State Trust Land is scattered among most of the subareas and much of that land includes watercourses. How that land is used will impact many of those watercourses. The Arizona Preserve Initiative and the Growing Smarter Program (described in Chapter 3) offer possibilities for preserving some of that land. While some state funds are available, most of the costs of purchasing the land must be found locally. The state has designated certain specific areas as eligible for protection.

### **Riparian Values**

It is almost always more expensive to restore a damaged area than to prevent damage. Areas that have been degraded through erosion or loss of water supply, are generally more difficult to rehabilitate than areas with minimal damage. Watercourses naturally go through cycles where floods may wipe out some of the vegetation in some years but normal conditions restore the vegetation. If the basic conditions remain undamaged the watercourses can usually repair itself. It is only when additional strains such as land clearing are placed on the watercourse, that it has difficulty recovering. Too much stress, such as loss of the water supply, may render the area unrecoverable.

### *Loss of Riparian Vegetation*

Many of the watercourses in the subareas have much less vegetation than they did in the past due to dewatering of the watercourse, clearing of land near, up to and even in the channel, bank stabilization measures and direct flood damage. This can lead both to loss of wildlife habitat and to increased erosion, sedimentation, and downstream flooding.

### *Defined Xeroriparian Washes with Native Vegetation*

There are many xeroriparian washes, especially in the foothills areas where the channels are clearly defined and the concentration of water allows for vegetation such as acacia trees along the channel. These channels benefit wildlife as well as provide broad areas for flows of water. Their sandy or rocky bottoms provide some recharge benefits and lessen downstream flow.

### *Dewatering of streams*

In several subareas, groundwater is close enough to the surface in one or two localized places that streamflow and/or cienegas still occur. There are currently no provisions in Arizona state water law to restrict pumping for the purpose of preserving these areas.

## **THE RANGE OF SOLUTIONS AND ISSUES FOR DISCUSSION**

Solutions to these problems range widely and sometimes solve more than one problem, but, on the other hand, some solutions create new problems of their own.

### **Flooding Issues**

#### *Structural vs. Non-structural Flood Control*

Throughout eastern Pima County the question of whether to deal with flooding problems comes down to whether structural or non-structural approaches are the most effective and/or desirable. The City of Tucson's Stormwater Management Plan emphasizes non-structural approaches where feasible and Pima County has a floodprone land acquisition program. All entities have floodplain ordinances and several have riparian habitat ordinances, yet structural approaches continue to be funded and built. In some cases this is because activities in parts of the watershed have contributed to serious downstream flooding problems which must be addressed structurally in built-up areas. In other cases, new residential and commercial developments are going in with concreted floodways, usually to maximize the amount of buildable land.

"After a \$50 million dollar bond sale in '84, the City of Tucson thought it had the solution to its storm water drainage problems. "We took that \$50 million and started cutting down trees and grading channels and putting down concrete like nobody's business," said Jim Glock, the city's transportation planning administrator and project manager for the Tucson Stormwater Management Study. "We were getting that water out of your backyard.

'But people (in the community) started scratching their heads and going, 'Now, wait a minute, I liked those trees - and I liked the way those water courses looked.'

The city soon discovered that Tucsonans had some very particular ideas of how they wanted to handle those infrequent bursts of rain in the desert."

**Source:** City of Tucson Stormwater Management Study web site. [www.ci.tucson.az.us/transpor](http://www.ci.tucson.az.us/transpor)

Should structural solutions be encouraged or allowed if they increase the buildable land area? Should structural flood control solutions be allowed in new construction where there are feasible nonstructural alternatives? Should the county and/or city riparian protection ordinances be revised to further encourage or require non-structural solutions in some circumstances? Should more controls be placed on structural solutions to ensure that they do not adversely impact downstream landowners? Who should be liable for any adverse downstream flooding impacts of development upstream or in the watershed?

#### *Special Flooding Problems*

Should development in sheet flow areas be restricted to maintain as much natural flow as possible? Or should structures be built to channel the sheet flows into areas where they can be controlled? Should government be responsible for construction and/or maintenance of such structures?

Should non-structural approaches be used in distributary flow areas, and development be prohibited or

restricted in areas where flows are liable to occur? Should structural approaches be used to maximize usable land? If so, what conditions should be imposed on the builder? Should government be responsible for their construction and/or maintenance?

#### *Road Crossings*

What criteria should be implemented for making roads accessible in all weather? What criteria should be implemented for minimizing adverse impacts of road crossings on watercourses?

#### **Land Use Issues**

##### *Wildcat Development Vs. Planned Subdivisions*

Should further restrictions be placed on wildcat development to assure that the cumulative effect of individual homes does not increase flooding potential or damage watercourses? Should the small development exemptions to various ordinances be reconsidered? What responsibility does government have to provide services to people in outlying areas when not provided by the builder? Are additional regulations needed to assure that the impacts of subdivision development on watercourses and downstream flooding is minimal?

##### *Natural Recharge and Overbank Storage*

How should potential loss of overbank storage capacity be managed? Should it be a factor in land use planning?

##### **The Fate of State Trust Lands**

Should local government (possibly in cooperation with non-profit groups) participate more actively in the State Land Department programs which provide for preservation of certain State Trust Lands? Should government be proactive in designating lands most in need of protection? Should the State Constitution be changed to make it easier to trade or preserve environmentally sensitive lands.

#### **Riparian Area Issues**

##### *Groundwater Pumping Affecting Streamflow*

Should measures be taken to restrict development without an alternate water source in area with shallow water tables? Should measures be taken to provide alternate water sources for these areas? Should Pima County residents seek to change the water law at least for the Tucson AMA? Should government purchase land in critical areas to prevent new pumping?

*Preservation of Natural Watercourses*

In washes with existing native vegetation, should a buffer area be established between development and the wash to preserve the native vegetation? If so, what kinds of structures, if any, should be allowed in the buffer area?

If structural solutions are allowed to maximize usable land, what restrictions, if any, should be placed on them? Should government be responsible for their construction and/or maintenance? Are the current city and county ordinances adequate?

*Rehabilitation of Watercourses*

What is the value of rehabilitating damaged watercourses? Should public funds be spent to recreate riparian habitat? If so, what criteria should be used to decide which areas are rehabilitated? Should wastewater or CAP water be used for this purpose?

*Use of CAP Water and Wastewater*

Should CAP water be used for in-channel recharge and to rehabilitate washes or major watercourses? Should CAP water be used for additional constructed wetlands alone or in connection with recharge projects? If it is used in watercourses, what precautions should be adopted to minimize adverse impacts on native species?

*Watercourses near Public Lands*

Are new measures needed to protect watercourses near public lands? Are the current buffer ordinances adequate?

**Coordination Between Jurisdictions**

Is more coordination needed among governmental entities in Pima County and between Pima County and each of the three counties sharing watersheds with Pima County? Is a basin-wide water management authority needed?



Subarea	Grazing	Wildcat subdivision	Planned subdivision	copper mine	sand & gravel mine	Pumping	Agriculture	Recreation
Upper San Pedro	X	P	P	P	P	X	X	X+
Cienega-Rincon	X-	X+	X+	P	X+	X+		X+
Upper Santa Cruz	X-	X+	X+	X-	X+	X+-	X-	X+
Middle Santa Cruz		X+	X+		X+	X+-		X+
Tortolita	X-	X+	X+		X+	X+-	X-	X+
Altar Valley	X-	X+	X+			X+	X+	X+
Avra Valley	X-	X+	X+	X+	P	X+-	X-	X+
Western Pima County	X	X+	P	X+		X+		X+

**Key:** X = Existing X+ = Existing with potential to increase X- = Existing with potential to decrease  
X+- = Existing with potential to increase or decrease P = Potential

**Fig. 12-1 Generalized Matrix of Existing and Potential Impacts on Watercourses in the Subareas**

Subarea	Alternate Water - Less Pumping	More Non-structural Floodplain Management	Stricter Land Use Management	Federal Public Lands Expansion	State Trust Land Preserved	Other Preserves Increase	Better Grazing Management
Upper San Pedro			X	X		X	X
Cienega-Rincon	X	X	X	X	X	X	X
Upper Santa Cruz	X	X	X			X	X
Middle Santa Cruz	X	X	X	X		X	X
Tortolita	X	X	X		X	X	X
Altar Valley	X	X	X	X		X	X
Avra Valley	X	X	X			X	X
Western Pima County			X				X

Key: X = Is possible and could have significant impact if it occurred.

Fig. 12-2. Generalized Matrix of Potential Options for Reducing Stress on Watercourses

# APPENDIX A

## GLOSSARY

**100-year flood** - The term refers to a flood level that statistically has a one in one hundred chance of occurring in any given year, or on an average once every 100 years. This does not imply that there are 100 years between floods, but is a statistical estimate of probability.

**Acre-foot** - The amount of water needed to cover an acre of land one foot deep, equal to 325,851 gallons.

**Aggradation** - Buildup of the channel and/or banks from deposition of sediment during flows.

**Alluvial fan** - An gently sloping area at the base of a mountain range where alluvium has been deposited over many years, spreading out as flows have spread out and channels have shifted. True alluvial fans are areas of extreme unpredictability in channel location changes.

**Alluvium** - Debris from erosion, consisting of some mixture of clay particles, sand, pebbles, and larger rocks.

Usually a good porous medium for groundwater movement and storage.

**Aquifer** - One or more geological formations containing enough saturated porous and permeable material to transmit water at a rate sufficient to feed a spring or for economic extraction by a well. The word comes from a combination of two Latin words, aqua (water) and ferre (to bring), literally something that brings water.

**Arroyo** - A watercourse that is dry almost all the time. The term is most often used to describe a dry wash with steep sides cut by erosion, but is also used to describe any dry wash.

**Bank protection** - Structural flood control measure to keep the banks from eroding. Bank protection can take various forms from concrete to relatively inconspicuous structures.

**Bankful stage** - The stage at which a stream first overflows its natural banks.

**Base flow** - Streamflow derived from groundwater seepage into the stream; water that flows on the surface independent of precipitation.

**Bed load** - Large or heavy sediment particles that travel near or on the stream bed when water flows.

**Bed rock** - Solid rock that lies under the soil, generally limiting the downward flow of water.

**Braided stream** - A network of interconnected rivulets or shallow channels spread out over a broad floodplain. The channels often shift during flow events.

**Channel** - The primary area within a watercourse through which water flows.

**Channel stability** - The ability of the walls of the channel to withstand erosion and change of course.

**Channelization** - A form of flood control that involves excavating a channel and sometimes in stabilizing the banks to protect them from erosion. Channelization can be accomplished by various methods including concreting the entire channel or soil cementing the banks.

**Cienega** - A marshy area.

**Cone of depression** - A depression of the water table formed around a well when water is pumped out.

**Constructed wetland** - A wetland constructed usually to give final water quality treatment to wastewater from municipal or industrial water treatment plants.

**Culvert** - A passageway under a road to allow conveyance of water.

**Degradation** - Deepening of the channel or loss of soil along the banks due to erosion during flows.

**Deposition** - Dropping of sediment in a streambed or floodplain. The slower-moving parts of the watercourse generally receive the most deposition.

**Discharge** - The amount of water that passes a specific point on a watercourse over a given period of time. Rates of discharge are usually measured in cubic feet per second (cfs).

**Discontinuous ephemeral stream** - An ephemeral stream that has some combination of a channel, sheet flow and/or distributary flow.

**Distributary flow** - Flow of water that spreads out in more than one channel, the position and length of which sometimes change over time.

**Downcutting** - A valley or streambed deepening process caused by erosion of the streambed.

**Effluent** - Water that has been collected in a sewer for subsequent treatment. The term also refers to water that has been treated and released from the treatment plant.

**Effluent dominated stream** - A watercourse the flow of which is predominately made up of effluent from a wastewater treatment plant.

**Ephemeral stream** - A watercourse that flows only in direct response to precipitation, whose channel is at all time above the water table, and is dry most of the time.

**Erosion** - Wearing away of soil by water or wind.

**Erosion hazard area** - A section of a watercourse that is particularly vulnerable to erosion. The outside curve of a watercourse, for example, is more likely to be an erosion hazard area than a straight stretch. The legal definition is land adjoining a watercourse regulated by this title which is deemed by the county engineer to be subject to flood-related erosion losses.

**Evapotranspiration** - The amount of water that is transpired through pores and evaporated by vegetation.

**Exotic species** - Species of plants or animals that did not evolve in the area or nearby, but were introduced by humans intentionally or accidentally. Exotic species especially become problems in disturbed areas.

**FEMA** - Federal Emergency Management Agency. This agency is responsible for overseeing floodplain mapping, for administering a flood insurance program, and for some flood control programs.

**Flash Flood** - A flood of very high discharge and short duration, sudden and local in extent.

**Flood** - Streamflow that goes beyond the normal channel limits. This term is also used to describe any usually large amount of water in a watercourse. "Flood" or "floodwaters" means a temporary rise in water level, including groundwater or overflow of water onto lands not normally covered by water

**Flood Control District** - A governmental entity with responsibility for preventing flood damage and providing floodplain management. In Pima County, the Board of Supervisors performs the function of a Flood Control District.

**Flood insurance** - Insurance which covers damages from floods. This is from private companies or and may be federally subsidized.

**Floodplain** - The area in and near a watercourse that may be inundated during floods. Portions of the floodplain may be designated at 50-year floodplain (2% probability of occurring in any year, which averages out to one year in 50, hence the name), 100-year floodplain (1% probability) or even 500-year floodplain. These lines are officially designated on FEMA maps for most watercourses in the area.

**Floodplain acquisition** - Obtaining floodprone lands through purchase or donation for the purpose of precluding development of those lands and reducing the need for structural flood control measures. Such lands are often also used for recreational purposes or wildlife habitat preservation.

**Floodway area** - The channel of a watercourse and the adjacent land areas necessary in order to discharge the base flood without cumulatively increasing the water surface more than one foot above the base flood elevation and without creating hazardous velocities of floodwaters.

**Floodway fringe area** - Land outside the floodway but within the regulatory floodplain and below the base flood elevation.

**Flow event** - A period in which water flows in a normally dry watercourse, whether or not the level reaches flood stage. In common parlance the word "flood" is often used to describe a flow event.

**Gaining stream** - A stream that receives water from the saturated zone of the water table.

**Geologic floodplain** - that portion of the land that has, in the geologic past, been subject to fluvial processes. The geologic floodplain may be different than the regulatory floodplain.

**Gradient** - The slope of the bed of a watercourse. In general, the steeper the slope, the faster the water will travel in a watercourse. A lower area of a watercourse is "downgradient" or "downstream" from a higher area.

**Groundwater** - Subsurface water in the zone of saturation, or more commonly, available groundwater is defined as that portion of the water beneath the earth's surface that can be collected by various means or that flows to the surface through springs or seeps.

**Headcutting** - Erosion of a watercourse in the upstream direction, caused by lowering of the channel through downstream erosion.

**Hydroriparian area** - An ecosystem associated with perennial watercourses characterized by dense coverage of wetland plant species. Cottonwood and willow trees are commonly found in hydroriparian areas.

**Intermittent stream** - A watercourse where some sections are normally dry and others normally have some flow because groundwater flows into the stream from springs or a surface source such as melting snow.

**Interrupted stream** - A watercourse that in places has a combination of perennial, intermittent or ephemeral characteristics.

**Losing stream** - A watercourse that loses water through the streambed to the underlying aquifer or unsaturated zone. In these areas the water table is not high enough to support stream flow.

**Meander** - A pronounced sinuous curve along a watercourse.

**Mesoriparian area** - An area supported by perennial or intermittent streams, or areas of shallow groundwater. They are similar to Hydroriparian habitats but with less dense plant communities. Typical species in this class include mesquite, ash, netleaf hackberry and sycamore.

**Overbank** - The area beyond the channel on which floodwaters may flow.

**Overbank storage** - The capacity of the overbank area to retain water.

**Perennial stream** - A watercourse that has at least a little water all year round. This is usually because the water table in the area is so high that it intercepts the channel, providing water to the watercourse.

**Piedmont** - The area between the mountain front and the valley, the foothills area.

**Reach** - A term used to describe a specific length of a stream or watercourse. For example, the term can be used to describe a section of a stream or watercourse between two bridges.

**Recharge** - Augmentation of the groundwater by addition of water. This may be accomplished naturally through precipitation or artificially through several types of recharge structures.

**Reclaimed water** - Water that has been treated beyond the secondary treatment level and is available for use on turf or other facilities.

**Regulatory floodplain or flood-prone area** - That portion of the geologic floodplain associated with a watercourse or that area where drainage is or may be restricted by man-made structures and that would be inundated by the base flood where the peak discharge of the flow is one hundred cubic feet per second (cfs) or greater, or those areas which are subject to sheet flooding, or those areas mapped as being floodprone on existing recorded subdivision plats.

**Rehabilitation** - Treatment of a damaged watercourse or other area so that it partially retains its former characteristics.

**Restoration** - Treatment of a damaged watercourse or other area to return it to its approximate historic condition.

**Revegetation** - Planting of trees and shrubs in an area where the vegetation has been lost or damaged.

**Riparian area** - The area in and near a watercourse including the vegetation dependent on water in and beneath the area, and including any wildlife using the area, a water-dependent ecosystem .

**Riparian obligate plant** - A plant that can only grow in a riparian area.

**Riprap** - A type of flood control structure which uses large angular rocks sometimes set in a metal framework.

**Runoff** - Drainage or flood discharge which leaves an area as surface flow or as pipeline flow, having reached a channel or pipeline by either surface or subsurface routes.

**Saturated zone** - An area in which all the pore spaces are filled with water.

**Section 404 permit** - A permit required from the U.S. Army Corps of Engineers before certain alterations can be made to a watercourse. (See Chapter 3).

**Sheet flow** - those areas which are subject to flooding with depths of one-half foot or greater during the base flood where a clearly defined channel does not exist and the path of the flooding is often unpredictable and indeterminate.

**Soil Cement** - A type of bank protection structure that utilizes a combination of cement and soil from the watercourse to obtain a somewhat natural looking appearance.

**Stormwater** - Water that flows after a rainstorm in the streets, storm sewers and watercourses.

Stormwater permit - A permit required of any entity which is responsible for stormwater releases. (See Chapter 3).

**Stream** - Technically, a flowing body of water, but the term is also used in Arizona for watercourses that are normally dry.

**Subsidence** - Downward movement of the land surface associated most often with excessive groundwater pumping. (See Chapter 2).

**Surface water** - Water that flows on the surface in watercourses.

**Suspended particles** - Particles that are light enough to remain suspended in the water rather than sink to the bottom.

**Threatened & Endangered Species** - Species designated by the U.S. Fish and Wildlife Service as needing special protection because of severe decline of numbers and/or imminent threats. Candidate species are those which are under consideration for this listing, but have not been designated. All of these together are referred to sometimes as "listed species." (See Chapter 3).

**Tributary** - A watercourse that flows into another larger watercourse. The Rillito, for example, is a tributary of the Santa Cruz River and Tanque Verde Creek is a tributary of the Rillito.

**Tributary plan form** - Areas that have a well-defined channel bed and banks with adjoining overbank floodplain areas. Channels join in the downstream direction.

**Water table** - The upper level of the zone of saturation in an aquifer.

**Watercourse** - any lake, river, stream, creek, wash, arroyo or other body of water or channel having banks and bed through which waters flow at least periodically.

**Watershed** - The area which contributes water to a watercourse, including lands on which rain or snow falls that subsequently reaches some watercourse. (See Chapter 2).

**Wetland** - An area that always has water at or very near the surface and supports vegetation or wildlife that can only grow in such an environment. Also called "cienega," "swamp," or "marsh." Also see Constructed Wetland.

**Xeroriparian area** - an area with habitats associated with intermittent water supplies that may include species from adjoining upland areas. Typical species include palo verde and mesquite, along with occasional mesoriparian species. Pima County maps classify these areas A-D according to the amount of vegetation.

# APPENDIX B

## LAWS AND REGULATIONS

The following appendices include citations for the federal, state and local laws most pertinent to watercourse management. Only the most pertinent portions of the various laws are cited and described in these appendices. All State laws may be found on the State's web site [www.state.az.us](http://www.state.az.us).

### STATE LAWS

#### WATER

The following is a section from Title 45 which contains Arizona's water laws. This section, 108, prescribes ways in which assured water supply may be shown for subdivisions.

#### Evaluation of subdivision water supply

A. In areas outside of active management areas established pursuant to chapter 2, article 2 of this title, the developer of a proposed subdivision including dry lot subdivisions, regardless of subdivided lot size, prior to recordation of the plat, shall submit plans for the water supply for the subdivision and demonstrate the adequacy of the water supply to meet the needs projected by the developer to the director. The director shall evaluate the plans and issue a report on the plans.

B. The director shall evaluate the proposed source of water for the subdivision to determine its ability to meet proposed uses for a period of years commensurate with normal practices in other areas of the state and shall forward a copy of such evaluation to the state real estate commissioner.

C. The director may designate cities, towns and private water companies as having an adequate water supply by reporting that designation to the water department of the city or town or private water company and the state real estate commissioner.

D. The director may designate a city or town that does not directly supply water to customers as having an adequate water supply by reporting that designation to the city or town and the state real estate commissioner if all of the following apply:

1. The city or town has entered into a contract with the United States secretary of the interior or a county water authority established pursuant to chapter 13 of this title for permanent supplies of Colorado river water for municipal and industrial use.

2. The city or town has entered into a contract with each private water company that serves water within the city or town to provide Colorado river water to those private water companies.

3. The Colorado river water for which the city or town has contracted is sufficient together with other water supplies available to the private water companies that serve water within that city or town to provide an adequate supply of water for the city or town.

4. The director finds that new subdivisions within the city or town will be served primarily with Colorado river water by one of the private water companies that serve water within that city or town.

E. The director shall not require a developer to submit plans for the water supply pursuant to subsection A of this section if either:

1. Both of the following apply:

- (a) The developer has obtained a written commitment of water service from cities, towns or private water companies that have been designated as having an adequate water supply.

- (b) That city, town or private water company has been designated as having an adequate water supply pursuant to subsection C of this

2. All of the following apply:

- (a) The city or town has been designated as having an adequate water supply pursuant to subsection D of this section

- (b) The developer has obtained a written commitment of water service from a private water company that serves water within that city or town

- (c) The developer has obtained the written concurrence of the city or town that has been designated.

F. The director may revoke a designation made pursuant to this section when the director finds that the water supply may become inadequate.

## **ARTIFICIAL LAKES**

### **Filling large bodies of water for landscape, scenic or recreational purposes prohibited; exceptions; preemption**

A. Except as provided in subsection B of this section, in an Active Management Area established under chapter 2 of this title, a person shall not use any water for the purpose of filling or refilling all or a portion of a body of water.

B. This section does not apply to a body of water if any of the following applies:

1. The body of water was filled before January 1, 1987. If the surface area of the body of water is increased on or after January 1, 1987, this exception does not apply to the quantity of water that is added.

2. The director has determined that substantial capital investment has been made in the physical on-site construction of the body of water before January 1, 1987. If the surface area of the body of water is increased after it is initially filled, this exception does not apply to the quantity of water that is added.

3. The body of water is located in a recreational facility that is open to the public and owned or operated by the United States, this state, a city, town or county, a flood control district established under title 48, chapter 21 or a multi-county water conservation district established under title 48, chapter 22.4. The body of water is filled and refilled exclusively with any one or any combination of the following:

(a) Effluent.

(b) Storm water runoff that is not subject to appropriation under section 45-141.

(c) Poor quality water used pursuant to a permit issued under subsections C and D of this section.

(d) Groundwater withdrawn pursuant to a drainage water withdrawal permit issued under section 45-519.

(e) Groundwater withdrawn in the first year of a temporary dewatering permit issued under section 45-518.

(f) Groundwater withdrawn as part of a remedial action under title 49, chapter 2, article 5.

(g) Water used pursuant to a permit for interim water use issued under section 45-133.

(h) Surface water except central Arizona project water that, as determined by the director, physically occurs at such times, in such quantities or under such other circumstances that it cannot be physically captured and beneficially used by any other holder of an appropriative right.

5. The body of water is an integral part of a golf course which complies with any applicable conservation requirements in the management plan for the active management area adopted under chapter 2, article 9 of this title.

6. The body of water is unsealed and is an integral part of an underground storage facility for which the director has issued a permit under chapter 3.1 of this title.

7. The body of water is a swimming pool that is owned and operated by a hotel, motel, country club or resort and has a surface area equal to or less than forty-three thousand five hundred sixty square feet. If a hotel, motel, country club or resort has more than one swimming pool, only one of those swimming pools may have a surface area greater than twelve thousand three hundred twenty square feet.

C. A person who seeks to use poor quality groundwater to fill or refill all or a portion of a body of water shall apply to the director for a permit to use the groundwater for that purpose. The director may issue a permit if the applicant demonstrates that all of the following apply:

1. The applicant otherwise has a right to use the proposed source of groundwater for the proposed purpose.

2. The groundwater because of its poor quality cannot be used for another beneficial purpose at the present time and it is not economically feasible to treat and transport the groundwater and use it for another beneficial purpose.

3. The withdrawal of the groundwater is consistent with the management plan and achievement of the management goal for the active management area.

D. A permit issued pursuant to subsection C of this section may be issued for a period of up to thirty-five years. The director shall determine the duration of the permit on the basis of the estimated life of the source of poor quality groundwater and the potential for future beneficial use. The director shall monitor the use of groundwater pursuant to the permit and shall terminate the permit if any of the conditions for issuance of the permit no longer applies. A permit may be renewed subject to the same criteria used in granting the original permit.

...

A. A person otherwise subject to the prohibitions of section 45-132 may use groundwater withdrawn pursuant to a type 1 or type 2 non-irrigation grandfathered right or water other than groundwater to fill or refill all or a portion of a body of water until sufficient effluent is available to fill or refill the body of water if the person applies for and obtains a permit for interim water use from the director. The director may issue a permit if the applicant demonstrates to the satisfaction of the director that all of the following apply:

1. The applicant otherwise has a right to use the water for the proposed purpose.

2. Sufficient effluent to fill or refill the body of water is not reasonably available but it has been demonstrated by clear and convincing evidence that sufficient effluent will be available no later than five years from the date the permit is issued.

3. The applicant has:

(a) Provided the necessary easements for an on-site treatment facility or access to an off-site treatment facility and for transportation of a permanent effluent supply to the body of water.

(b) Provided the site location for the facility and received approval for the facility from the department of environmental quality, if an on-site treatment facility will be used.

(c) Recorded the easements and any site location for an on-site treatment facility on the plat of record for the subdivision or development within which the body of water is located.

4. The body of water will store effluent that will be applied to grow landscaping plants on common areas or will be used for other beneficial purposes that would otherwise require use of surface water or groundwater.

5. The development or facility in which the body of water is located will include an effective water conservation program. The specific conservation requirements in the water conservation program shall be consistent with and shall not by this paragraph be required to be more strict than any specific conservation requirements in the applicable management plan. 6. The body of water otherwise complies with this article. ...

### **STATE TRUST LANDS ARS Title 37**

**State lands subject to sale;** rights reserved in lands sold; state lands not subject to sale; development agreements

A. All state lands, except as otherwise provided for in this title, including all improvements made or placed on or connected with state lands, shall be subject to appraisal and sale as provided in this title.

B. Any person over eighteen years of age is entitled to purchase any of the state lands. ...

E. Notwithstanding the provisions of subsection C of this section, all state lands sold after March 18, 1968 shall be sold with the reservation that all oil, gas, other hydrocarbon substances, helium or other substances of a gaseous nature, geothermal resources, coal, metals, minerals, fossils, fertilizer of every name and description, together with all uranium, all thorium or any other material which is or may be determined by the laws of the United States or of this state, or decisions of court, to be peculiarly essential to the production of fissionable materials, whether or not of commercial value, and the exclusive right thereto, on, in, or under such land, shall be and remain and be reserved in and retained by the state, regardless of any sale under this section and the issuance of any certificate of purchase to any purchaser of state lands pursuant to this section, provided, that the reservation shall not include common variety minerals as defined in section 27-271, subject to the following: ...

2. The mineral rights reserved to the state in the lands sold shall be closed to entry and location as a mineral claim or claims, but the department may issue, upon application, mineral exploration permits embracing the reserved mineral rights when such issuance is deemed in the best interest of the state, provided that the surface owner or owners shall have the first right of refusal to acquire such mineral exploration permits.

### **37-258. Sale of rights in dry riverbed**

A. Upon receipt of the appraisal and when it is in the best interests of this state and of the trust, the commissioner may cause rights of the state in any dry riverbed on the land described in the application to be put up for sale to the highest bidder. This sale may include the state's interest in oil, gas, other hydrocarbon substances, helium or other substances of a gaseous nature, geothermal resources, coal, minerals, fossils and fertilizer of every name and description together with all uranium, thorium or other materials peculiarly essential to the production of fissionable materials. ...

C. The sale is subject to all existing leases, covenants, conditions, restrictions, easements, encumbrances, rights and rights-of-way against the land described in the application. The state may sell its rights in an entire section in any one year. No sales shall be deemed to be agricultural land for purposes of section 37-234. At least ten per cent, but not more than twenty-five per cent, of the appraised value, as stated in the auction notice, which shall be applied to principal, together with the prescribed fee under section 37-108 shall be paid by cashier's check upon announcement of the successful bidder. The balance of the purchase price shall be paid by cashier's check within thirty days of the date of the sale and no interest shall be charged. In other respects, the sale shall be conducted as specified in this article. The minimum price at the sale shall be the value of Arizona's interest in the land as determined by the preceding appraisal, including the increased value resulting from the development or improvements made by the applicant and his predecessors in interest.

### **Lease of state lands for certain purposes without advertising; terms and conditions**

A. All state lands are subject to lease as provided in this article for a term of not more than ten years for agricultural, commercial and homesite purposes, without advertising. The leases shall be granted according to the constitution, the law and the rules of the state land department.

B. No lease shall be granted as provided by this section without application. All applications for leases shall be made upon forms prepared and furnished by the department, shall be signed and sworn to by the applicant or his authorized agent or attorney and shall be filed with the department. In lieu of signing and swearing to the application before a notary public or other person authorized to take acknowledgments, the applicant may affix his signature to the application, accompanied by a certification, under penalty of perjury, that the information and statements made in the application are to the best of his knowledge and belief true, correct and complete, and the application shall be accepted as duly executed. ...

D. No lessee shall use lands leased to him except for the purpose for which the lands are leased.

E. No lessee shall sublease lands leased to him without written permission of the state land department.

### **Nominating and classifying trust land as suitable for conservation purposes**

A. On the commissioner's initiative, or on petition as provided by subsection C of this section, the commissioner may nominate certain trust lands as being under consideration for classification as trust lands suitable for conservation purposes. The commissioner shall not nominate trust lands as being under consideration for classification as trust lands suitable for conservation purposes unless the trust lands are eligible for classification under this section and are located within:

1. One mile of the corporate boundaries of an incorporated city or town having a population of less than ten thousand persons according to the most recent United States decennial census.

2. Three miles of the corporate boundaries of an incorporated city or town having a population of ten thousand persons or more according to the most recent United States decennial census.

3. Ten miles of the boundaries that are established in paragraph 1 or 2 of this subsection and that are located within counties with a population greater than five hundred thousand persons according to the most recent United States decennial census and are adjacent to lands that are eligible for conservation and share with them a specific physical characteristic such as a reach of a river, a mountain slope or an archaeological feature.

B. In addition to the lands identified in subsection A, paragraphs 1 through 3 of this section, the following lands may be nominated for reclassification by the commissioner:

1. Those lands within the Tortolita mountain park in Pinal county located within T10S, R12E and T10S, R13E.

...

C. The commissioner shall receive a petition to nominate trust lands as being under consideration for classification as trust lands suitable for conservation purposes from:

1. A state agency that leases the land or intends to lease or purchase the land.

2. The board of supervisors of the county in which the land is located.

3. The governing body of a city or town if the land is located within:

(a) The corporate boundaries of the city or town.

(b) One mile outside the corporate boundaries and the city or town has a population of less than 10,000

persons.

(c) Three miles outside the corporate boundaries and the city or town has a population of 10,000 persons or

more.

4. Ten or more private individuals who:

(a) Reside in the county in which the land is located.

(b) Have the financial capability to lease or purchase the land.

5. A nonprofit corporation or trust, the purpose or powers of which include conservation of natural, scenic, open space or other conservation values.

6. The current lessee of the land.

7. A business or corporation that is legally empowered to own or manage real property in this state and that intends to lease or purchase the land. ...

E. The commissioner shall not nominate or classify trust land as suitable for conservation purposes if a development plan was approved for the land pursuant to article 5.1 of this chapter before July 26, 1996. The commissioner may nominate and classify trust land as suitable for conservation purposes in an area within a development plan approved after July 26, 1996 if appropriate conservation purposes are incorporated within the development plan prepared for the commissioner's approval. ...

H. In determining whether reclassification is in the best interest of the trust, the commissioner shall:

1. Consult with the governing body of each city or town in which the land proposed for reclassification is located or to which the land is contiguous, the county board of supervisors of each county in which the land is located if the land is not located within the boundaries of a city or town and the local planning and zoning authorities, including the affected regional planning authorities.
2. Consider recommendations of the conservation advisory committee.
3. Consider all evidence and testimony that are submitted at the hearing under subsection G of this section.
4. Consider the physical and economic impacts that the reclassification would have on other lands owned or controlled by the current lessee and the physical and economic impacts on the local community.
5. Consider the existence of any holding lease on the lands.
6. Consider the existence of any planning permit issued by the commissioner for the lands pursuant to article 5.1 of this chapter.
7. Consider the amount of progress on any development plans being completed for the lands pursuant to article 5.1 of this chapter.
8. Evaluate the mineral potential of the land.

I. The commissioner shall determine whether the reclassification is in the best interest of the trust and, in making the determination, shall state in writing the reasons why the classification is or is not in the best interests of the trust.

J. If the commissioner reclassifies the trust land as suitable for conservation purposes, the commissioner shall adopt a plan to allow existing and conservation uses to be coordinated in a manner that will protect both existing uses and conservation and open space values. If the reclassified trust land is unleased or the petitioner is the lessee pursuant to subsection C, paragraph 6 of this section, the commissioner may require a plan from the petitioners describing how the property is to be managed. In adopting the plan, the commissioner shall consult with:

1. The conservation advisory committee.
2. The governing body of the city or town if the land is located in a city or town.
3. The county board of supervisors if the land is not located in a city or town.
4. Existing lessees of the trust land, local and regional planning authorities and owners of private land that is located within three hundred feet of the trust land.
5. Any other person or entity that the commissioner considers to be necessary.

K. The classification of state land as suitable for conservation does not affect the designation or use of adjacent federal, state or private land.

L. A person who is adversely affected by the commissioner's decision to reclassify land as suitable for conservation purposes may appeal the decision to the board of appeals pursuant to section 37-215.

M. On classifying trust lands suitable for conservation purposes, existing leases shall not be canceled or modified as a result of any actions taken pursuant to this article, and renewals of existing leases shall be pursuant to section 37-291. ...

#### **Designation of state lands as urban lands on request**

A. The governing body of a city, town or county may request that the commissioner designate as urban lands state lands that are located within:

1. One mile of the corporate boundaries of an incorporated city or town having a population of less than 250,000 people.
2. Three miles of the corporate boundaries of an incorporated city or town having a population of 250,000 people or more.

B. The commissioner shall provide notice of a request made pursuant to subsection A of this section to all local governing bodies within three miles of the land in question.

C. The commissioner shall designate as urban lands those state lands requested pursuant to subsection A of this section unless the commissioner determines that the designation is an inappropriate categorization of the lands. When the commissioner makes a designation, he shall provide notice of the designation of the lands as urban lands to all local governing bodies within three miles of the lands so designated. If the commissioner determines that the designation would be inappropriate, he shall state in writing his reasons, and shall provide a copy of this statement to the requesting local governing body. The local governing body may appeal this decision to the board of appeals as provided in section 37-215.

**Conceptual urban state trust land use plans; five year state trust land disposition plans; definitions**

A. The commissioner shall create conceptual land use plans for all urban state trust land in this state and other state trust lands the commissioner considers to be appropriate. The commissioner shall:

1. Prioritize the creation of conceptual plans to the extent possible to:

(a) Correlate with the rate of population growth in the urban areas in this state.

(b) Coincide with the production of municipal general plans under title 9, chapter 4, article 6 and county plans under title 11, chapter 6, article 2.

2. Revise and update each plan at least every ten years.

3. Consult with the city, town or county in which the land is located and with any regional planning organization regarding integrating the conceptual plan into the general land use plan of the city, town or county.

4. Submit each plan, and revision of the plan, to the urban land planning oversight committee for review. ...

C. The commissioner shall create five year disposition plans for all state trust land in this state, based at a minimum on market demand, anticipated transportation and infrastructure availability. The commissioner shall:

1. Review and update each plan each year as may be necessary.

2. Consult with the city, town or county in which the land is located and with any regional planning organization.

3. Submit each plan and revision to the urban land planning oversight committee to ensure conformity with the conceptual plan under subsection A. ...

**Designation of lands; development or secondary plan; requirements; approval**

A. The commissioner may designate certain urban lands as suitable for a development plan. The designation may be made only for lands for which a state general plan has been approved under section 37-332. The designation shall specify the boundaries of the urban lands and that a development plan is to be prepared for those lands.

B. After designating certain urban lands as suitable for a development plan, the commissioner may cause a development or secondary plan to be prepared. The development or secondary plan may be submitted to the department, after a development planning permit or secondary planning permit is issued, or may be prepared by a planning contract to the lowest and best bidder, with monies appropriated by the legislature for the purpose of urban lands development planning. A secondary planning permit is a planning permit issued for a parcel or parcels of state land that have not yet been disposed of to prepare a secondary plan which supplements and implements an approved development plan.

C. The development or secondary plan shall contain specific provisions for the use, development and management of the urban lands in accordance with the state general plan as approved under section 37-332.

D. The development or secondary plan shall contain provisions as are necessary to implement the purposes of this section, including:

1. Provisions for allocation and location of specific uses of the land, including residential, commercial, industrial, recreational or other appropriate uses.

2. Provisions for acceptable densities and concentrations of the designated land uses.

3. Provisions for the timing and rate of development.

4. Provisions for the delivery of an adequate or assured water supply as specified in title 45, chapter 1 or 2.

5. Provisions for public facilities and resources, including water supply delivery systems, wastewater collection and treatment systems, parks and public recreational facilities, school sites, roads and other elements of a transportation system and other necessary facilities and services.

6. Provisions for needed zoning and other land use control mechanisms.

7. Provisions for resource conservation and the use of alternate sources of energy.

8. Other provisions deemed relevant by the commissioner.

E. To the extent the proposed development plan would require zoning inconsistent with any existing zoning, the commissioner shall submit a request to the local government with jurisdiction over the lands in question for either rezoning consistent with the development plan or approval of a land use plan pursuant to statute or ordinance that would include designations of proposed zoning categories and land use intensity and that would be consistent with the development plan. The local government shall act upon the request within six months, notifying the commissioner as to the acceptance or rejection of the commissioner's request for rezoning or plan approval. Rejection of a request for rezoning or plan approval may, at the commissioner's discretion, be appealed in the manner provided to any owner of land affected by a zoning decision. The local government's zoning decision shall govern the use of the lands unless the commissioner determines that such zoning or plan is detrimental to the interests of the trust. If the commissioner so determines, the commissioner shall prepare a written statement of the

reasons for the determination and shall within ten days of such decision provide a copy of the written statement to the local planning authority. The local government within whose jurisdiction the lands are located has thirty days from receipt of this statement to appeal the commissioner's decision to the board of appeals as provided for in section 37-215. If the local government fails to act upon the commissioner's request for rezoning or plan approval within the time provided in this subsection, the commissioner may adopt the development plan, noting that the requested rezoning or plan approval has not been obtained from the local government. The commissioner may, after compliance with the requirements of section 37-335, reclassify the lands and proceed with their sale or lease, noting in the call for bids that the requested rezoning or plan approval has not been obtained.

F. The commissioner shall not approve the development or secondary plan until the director of water resources has either evaluated the plans for an adequate water supply for the proposed development of lands outside a groundwater active management area as required by section 45-108 or has certified that there is an assured water supply for the proposed development of lands in a groundwater active management area as required by section 45-576. ...

#### **Section 4.**

All lands, lease-holds, timber, and other products of land, before being offered, shall be appraised at their true value, and no sale or other disposal thereof shall be made for a consideration less than the value so ascertained, nor in any case less than the minimum price hereinafter fixed, nor upon credit unless accompanied by ample security, and the legal title shall not be deemed to have passed until the consideration shall have been paid. ...

#### **ARIZONA PRESERVE INITIATIVE**

The following description is from the State Land Department web site.

The Arizona Preserve Initiative (API) was passed by the Arizona State Legislature as HB 2555 and signed into law by the Governor in the spring of 1996. It is designed to encourage the preservation of select parcels of state Trust land in and around urban areas for open space to benefit future generations. The law lays out a process by which Trust land can be leased for up to 50 years or sold for conservation purposes. Leases and sales must both occur at a public auction.

Conservation is defined in the law as "protection of the natural assets of state Trust land for the long-term benefit of the land, the beneficiaries, lessees, the public, and unique resources such as open space, scenic beauty, protected plants, wildlife, archaeology, and multiple use values." Under the original legislation, only Trust land within incorporated cities and towns, within one mile of incorporated municipalities of less than 10,000 persons, or within three miles of municipalities equal to or greater than 10,000 persons may be reclassified for conservation purposes.

In 1997, 1998, and 1999 amendments to the API were passed and signed into law. The revisions expanded the applicable area in Maricopa County and Pima County up to an additional ten miles beyond the 1996 boundaries and made specific Pinal and Coconino County lands adjacent to the Superstition Mountains and the San Tan Mountains near Metro Phoenix, within the Tortolita Mountains near Tucson, and southwest of Flagstaff eligible for conservation consideration. Among other provisions, a public-private matching grant program was created under the auspices of the State Parks Board for acquisition or lease of state Trust lands for conservation. Proposition 303, passed by voters in November, 1998, funds the grant program for 11 years beginning in July, 2000. Also clarified was the establishment of a lower bond for sale or lease applications and changes in the appraisal process.

A state or local government, business, state land lessee or a group of citizens may petition the State Land Commissioner to have certain Trust land nominated and reclassified for conservation purposes. After all appropriate notifications, public hearings, consideration of physical and economic impacts to lessees and the Trust, the Commissioner may reclassify the subject land as suitable for conservation purposes. The Commissioner must consider recommendations from a five-member Conservation Advisory Committee that was established by law, as well as consult with local and regional planning authorities. Existing leases on any land reclassified for conservation purposes may not be canceled or impaired in any way.

Once the land is reclassified, the Commissioner may adopt a coordination plan for the property to protect conservation values. The statute authorizes the Commissioner to withdraw land from sale or lease for three to five years (with the possible extension for up to three more years) to allow prospective lessees or purchasers time to prepare the plan for the property and to raise funds.

With one independent appraisal and an independent review appraisal of the fair market value and required legal notice, a conservation lease or sale may be auctioned. The land value cannot be reduced because of the conservation purpose.

If an existing lease is not renewed because a conservation lease is issued, the former lessee must receive compensation for the loss of lease and reimbursable improvements. If the land is sold for conservation purposes, the lease must be allowed to continue to the end of its term. If that lease were to be modified or canceled by the new owner, the law provides for compensation by the new owner to the lessee. To date, the Land Commissioner has received 15 petitions for reclassification, and has reclassified seven properties. One application to purchase has been received.

## LOCAL FLOODPLAIN ORDINANCES

All the local jurisdictions have very similar floodplain ordinances. Many of the provisions are directed by state law. All ordinances have definitions, provisions for mapping, variances, appeals, and procedures. These are not included in the descriptions below, but may be found in the full versions of the ordinances which may be found on the web sites for Pima County, Tucson, and Oro Valley (Marana's laws are not yet on the web site).

The ordinance quoted in part below is the Pima County ordinance. Where the jurisdictional ordinances differ, their versions are included below the relevant section, with the indication of jurisdiction denoted by bold italics. Note that in some cases the ordinances are very similar, but the way they are interpreted may be quite different. An example of this is the section dealing with sand and gravel operations. The Pima County and City of Tucson ordinances appear to be quite similar, but when Tucson annexed a portion of the Pantano Wash, the rules for the sand and gravel companies there were relaxed.

### **Floodway Requirements**

#### *Uses allowed.*

Except as provided for in this chapter, no other use shall be allowed in any floodway. The following open space uses shall be permitted within a floodway to the extent that they are not prohibited by any provision of this title or any other ordinance, law or regulation, and provided they do not require fill, excavation, or the storage of materials or equipment:

- A. Agricultural uses, including general farming, pasture, grazing, outdoor plant nurseries, horticulture, truck farming, sod farming, and wild crop harvesting;
- B. Industrial-commercial uses such as loading areas, airport landing strips, parking areas;
- C. Private and public recreational uses, including golf courses, tennis courts, driving ranges, archery ranges, picnic grounds, parks, wildlife and nature preserves, game farms, shooting preserves, target ranges, trap and skeet ranges, hunting and fishing areas, hiking and horseback riding trails;
- D. Accessory residential uses, including lawns, gardens, parking areas and play areas.

#### *Limited and unallowed uses.*

No use shall be allowed which:

- A. Acting alone or in combination with existing or future uses creates danger or hazard to life or property. In determining whether a use creates a danger or hazard to life or property, the county engineer may require a certification by an Arizona registered professional civil engineer that the proposed use will not result in any increase in the floodway elevations during the occurrence of the base flood, nor will the proposed use divert, retard or obstruct the flow of floodwaters:
- B. Increases the floodway elevations;
- C. Adversely affects groundwater recharge;
- D. Increases erosion potential upstream and/or downstream;
- E. Places a waste disposal system wholly or partially in a floodway.

#### *Flood control structures.*

Flood control structures designed to protect life or property from the dangers or hazards of floodwaters are permitted provided all other provisions of this title are met.

#### *Sand, gravel and other excavations.*

Sand and gravel excavations, including proposed operations and existing operations subject to permit renewal, are subject to the following:

A. Extraction of sand, gravel and other materials is allowed within a floodway, provided that excavations are not so located nor of such depth, or width or length, or combination of depth-width-length as to present a hazard to structures (including but not limited to roads, bridges, culverts and utilities), to the banks of water courses, to other property, or which adversely affect groundwater recharge.

B. Within a floodway there shall be no stockpiling of materials or tailings that may obstruct, divert or retard the flow of floodwaters except as reviewed and approved by the Pima County engineer on an individual floodplain use permit basis.

C. Excavations may be allowed only in those reaches of watercourses which have, at a minimum, a balanced sediment system, i.e. the sediment coming into the reach is equal to or greater than the sediment leaving the reach and the long term sediment balance for the entire river system indicates that the stream channel will aggrade.

D. Due to the rapidly changing hydraulic characteristics of watercourses in Pima County, and the effects excavations have on these characteristics, floodplain use permits for excavations shall only be issued for a limited time period, not to exceed one year, subject to annual renewal upon review by the county engineer.

E. In addition to those conditions provided for elsewhere, floodplain use permits for excavations may impose conditions regarding the area and location in which excavations are allowed, the maximum amount of material to be excavated, and other reasonable restraints on the methods of operating, including time restraints.

F. Any extraction of sand and gravel or related materials in a floodway shall be allowed after the effective date of the ordinance codified in this title only if a reclamation plan is also provided for the extraction operation. The reclamation plan shall show in sufficient detail the actions which are proposed to reclaim the excavated areas so that all adverse effects of extraction are mitigated. The plan shall also contain a timetable and financial assurances for accomplishing reclamation.

G. The county engineer may require bonds or other financial assurances appropriate for the sand and gravel extraction operation.

H. The county engineer may require hydrologic, hydraulic and geomorphic analyses addressing the existing conditions as well as the impacts under the proposed method of operation. I. The floodplain management board may grant variances as provided by Chapter 16.56 of this title.

### **Exemptions and Nonconforming Uses**

#### *Exemptions from Title 16 regulations.*

As specified in Arizona Revised Statute (A.R.S.) Section 48-3609, the provisions of this title shall not affect or prohibit: A. Existing legal uses of property or the right to continuation of such legal use. However, if a nonconforming use of land, or a building or structure is discontinued for twelve consecutive months or destroyed to the extent of fifty percent of its value, as determined by a competent appraiser, any further use shall comply with this title; B. Reasonable repair or alteration of property for the purposes for which the property was legally used on December 16, 1974, except that any alteration, addition or repair to a nonconforming building or structure which would result in increasing its flood damage potential by fifty percent or more shall be either flood proofed or elevated to, at or above the regulatory flood elevation; C. Reasonable repair of structures constructed with the written authorization required by A.R.S. Section 48-3613 and Section 16.12.020 of this chapter; D. Facilities constructed or installed pursuant to a certificate of environmental compatibility issued pursuant to Title 40, Chapter 2, Article 6.2 of A.R.S. Section 40-360, et seq.

#### *Review of plans--Uses authorized without permit.*

As specified in A.R.S. Section 48-3613, before construction of the following may begin, plans floodplain management board for review and comment; however, the following shall not be prohibited and shall not require a floodplain use permit or other written authorization:

A. The construction of bridges, culverts, dikes and other structures necessary for the construction of public highways, roads and streets intersecting or crossing a watercourse;

B. The construction of storage dams for watering livestock or wildlife and structures on banks of a watercourse to prevent erosion of or damage to adjoining land if the structure will not divert, retard or obstruct the natural channel of the watercourse or dams for the conservation of floodwaters as permitted by Title 45, Chapter 6 of A.R.S. Section 45-1201, et seq.;

C. Construction of tailing dams and waste disposal areas used in connection with mining and metallurgical operations. This subsection does not exempt those sand and gravel operations which will divert, retard or obstruct the flow of waters in a watercourse from complying with and acquiring authorization from the floodplain management board pursuant to the regulations adopted by the floodplain management board under this title; D.

Other construction, if it is determined by the floodplain management board that written authorization is unnecessary; E. Construction by any flood control district, county, city, town or other political subdivision exercising powers granted to it under Title 48, Chapter 21, Article 1 of A.R.S. Section 48-3601, et seq.; F. The construction of streams, waterways, lakes and other auxiliary facilities in conjunction with development of public parks and recreation facilities by a public agency or political subdivision; G. The construction and erection of poles, towers, foundations, support structures, guy wires, and other facilities related to power transmission as constructed by any utility, whether a public service corporation or a political subdivision.

**Use permit required when.**

This chapter shall not exempt any person from obtaining a floodplain use permit as set forth in this title for any use which diverts, retards or obstructs the flow of water and creates a danger or hazard to life or property in the area.

**Liability for increasing flood hazards.**

These exemptions do not preclude any person from liability if that person's actions increase flood hazards to any other person or property.

**Nonconforming uses permitted when.**

A. Improvements to or Reconstruction of Existing Nonconforming Uses.

1. Any structure which is repaired, reconstructed, or substantially improved at a cost equal to or exceeding fifty percent of the value of the structure as shown on the latest assessment rolls of the Pima County assessor either

(a) before the improvement or repair is started; or

(b) if the structure has been damaged and is being restored, before the damage occurred, shall conform to the provisions of this title. For the purpose of determining the value of any such construction, repair or alteration, the normal retail value of the materials and the reasonable value of the labor performed shall be used. No person shall repair or alter property in a piecemeal manner so as to avoid the provisions of this section.

2. For the purpose of this chapter, substantial improvement is considered to occur when the first alteration of any wall, ceiling, floor or other structural part of the building commences, whether or not that alteration affects the external dimension of the structure. The term does not, however, include any project for improvement of a structure to comply with existing state or local health, sanitary or safety code specifications which are solely necessary to assure safe living conditions.

B. Discontinuance of Nonconforming Use. In the event that the use of a nonconforming use is discontinued for a period of twelve consecutive months, any further use thereof shall be in conformity with the provisions of this title.

**Floodway Fringe Area Requirements**

*Uses allowed.*

Any use, to the extent not prohibited by this title or any other ordinance or law, is allowed within the floodway fringe area.

*Conditions applicable to all uses.*

A. The following general conditions set out in Sections 16.28.030 through 16.28.070 shall apply to all uses within the floodway fringe area:

B. No development, storage of materials or equipment, or other uses shall be permitted which, acting alone or in combination with existing or future uses, create a danger or hazard to life or property.

C. Consideration of the effects of a proposed use or development shall be based on the assumption that there will be an equal degree of encroachment extending for a significant reach on both sides of the watercourse.

*Fill and fill materials.*

A. Any fill proposed to be deposited in the floodway fringe must be shown to have some beneficial purpose and the amount thereof not greater than is needed to achieve that purpose, as demonstrated by a plan submitted by the owner showing the uses to which the filled land will be put and the final dimensions of the proposed fill or other materials.

B. Such fill or other materials shall be protected against erosion by riprap, vegetative cover, bulkheading, or other approved methods.

*Structures--Construction restrictions.*

A. Structures shall be constructed so as to offer the minimum obstruction to the flow of floodwaters. Wherever possible, structures shall be constructed with the same alignment as the direction of flood flow and so far as practicable shall be placed approximately on the same alignment as those of adjoining structures.

B. All structures shall be firmly anchored to prevent their flotation, which might otherwise result in damage to other structures or restriction of bridge openings and other narrow sections of the watercourse.

C. Service facilities such as electrical and heating equipment shall be constructed at or above the regulatory flood elevation for the particular area, or be adequately flood proofed.

D. Any structure designed or utilized for human habitation, whether full-time or part-time, shall have the lowest floor elevated at or above the story flood elevation. Prior to the pouring of the first slab or finish floor inspection, the applicant shall submit to the county engineer certification by an Arizona registered land surveyor that the elevation of the lowest floor is in compliance with the floodplain use permit.

E. Enclosed areas within the regulatory floodplain and below the regulatory flood elevation shall be designed to equalize hydrostatic flood forces on exterior walls by allowing for the entry and exit of floodwaters.

F. If fill is used to elevate any structure, the minimum elevation of the fill shall be at or above the base flood elevation and shall extend at such elevation for a distance of at least twenty-five (25) feet beyond the outside limit of the structure unless a study/analysis prepared by an Arizona registered professional civil engineer demonstrates that a lesser distance is acceptable.

G. Structures designed or utilized for human habitation, whether full-time or part-time, shall only be permitted where the product of the flow depth  $d$ , in feet, times the square of the flow velocity  $v$ , in feet per second, of the surrounding floodwaters of the base flood does not exceed the numerical value of eighteen for a period in excess of thirty minutes, or the surrounding floodwaters of the base flood do not exceed three feet in depth.

#### *Storage of materials and equipment.*

A. The storage and/or processing of materials that are buoyant, flammable, explosive or that could be injurious to human, animal or plant life in time of flooding is prohibited.

B. Storage of other material or equipment may be allowed if it is not subject to major damage by floods and is firmly anchored to prevent flotation or is readily removable from the area within the limited time available after flood warning.

#### *Utilities and sanitary facilities.*

A. Water supply, water treatment, and sewage collection and disposal systems built in a regulatory floodplain shall be designed to prevent or minimize infiltration of floodwaters into these systems and discharge of materials from these systems into floodwaters.

B. On-site sanitary waste disposal systems shall be located to avoid impairment to them or contamination from them during flooding.

#### *Sand, gravel and other excavations.*

A. Extraction of sand, gravel and other materials is allowed within the floodway fringe and erosion hazard areas, provided that excavations are not so located nor of such depth, or width, or length, or combination of depth-width-length as to present a hazard to structures (including but not limited to roads, bridges, culverts and utilities), to banks or watercourses, to other property, or which adversely affect groundwater recharge.

B. There shall be no stockpiling of material or tailings within the floodway fringe areas that may obstruct, divert or retard the flow of floodwaters except as reviewed and approved by the Pima County engineer or an individual floodplain use permit basis.

C. Due to the rapidly changing hydraulic characteristics of watercourses in Pima County, and the effects excavations have on these characteristics, floodplain use permits for excavations shall only be issued for a limited time period, not to exceed one year, subject to annual renewal upon review by the county engineer.

D. In addition to those conditions provided for elsewhere, floodplain use permit for excavations may impose conditions regarding the area and location in which excavations are allowed, the maximum amount of material to be excavated, and other reasonable restraints on the methods of operation, including time restraints.

E. Any extraction of sand and gravel or related materials in the floodway fringe or erosion hazard areas shall be allowed after the effective date of the ordinance codified in this title only if a reclamation plan is also provided for the extraction operation. The reclamation plan shall show in sufficient detail the actions which are proposed to

reclaim the excavated areas so that all adverse effects of extraction are mitigated. The plan shall also contain a timetable and financial assurances for accomplishing reclamation.

F. The county engineer may require bonds or other financial assurances appropriate for the sand and gravel extraction operation.

G. The county engineer may require hydrologic, hydraulic and geomorphic analyses addressing the existing conditions as well as the impacts under the proposed method of operation.

H. The floodplain management board may grant variances as provided by Chapter 16.56 of this title.

### **Manufactured Homes and Manufactured Home Parks and Subdivisions**

Permit requirements and exemptions.

A. From the effective date of the ordinance codified in this title, it shall be unlawful to place a manufactured home within a regulatory floodplain, as described in Chapters 16.24 and 16.28 of this title, or erosion hazard areas as described in Chapter 16.20, for more than one hundred eighty consecutive days without first applying for and obtaining a floodplain use permit from the county engineer, and thereafter complying with each and every written term of the permit. However, no such floodplain use permit shall be required for any repairs or alterations for which the value of the materials and labor thereon does not exceed one thousand five hundred dollars, except for those improvements which obstruct the flow of floodwaters. For the purpose of determining the value of any such repairs or alterations, the normal retail value of materials and the reasonable value of labor performed shall be used. Although no floodplain use permit is required, all other provisions of this title shall be observed in the performance of said repairs or alterations.

B. Repairs or alterations shall not be done in a piecemeal fashion for the purpose of avoiding applying for a permit when the total cost of said work is in excess of one thousand five hundred dollars. (Ord. 1999-FC-1 § 1 (part) 1999;

### **Anchoring requirements.**

All manufactured homes and additions to manufactured homes located within a regulatory floodplain or erosion hazard area shall be anchored to resist flotation, collapse or lateral movement by one of the following methods: A. By providing an anchoring system designed to withstand horizontal forces of twenty-five pounds per square foot and uplift forces of fifteen pounds per square foot; or

B. By providing over-the-top and frame ties to ground anchors. Specifically:

1. Over-the-top ties be provided at each of the four corners of the manufactured home, with two additional ties per side at intermediate locations, except that manufactured homes less than fifty feet long require only one additional tie per side, and

2. Frame ties be provided at each corner of the home with five additional ties per side at intermediate points, except that manufactured homes less than fifty feet long require only four additional ties per side, and

3. All components of the anchoring system be capable of carrying a force of four thousand eight hundred pounds. Location and placement conditions. Where any of the following:

A. Manufactured homes not placed in manufactured home parks or subdivisions;

B. New manufactured home parks or subdivisions;

C. Expansions to existing manufactured home parks or subdivisions; and

D. Repair, reconstruction or improvements to existing manufactured home parks or subdivisions that equal or exceed fifty percent of the value of the streets, utilities and pads before the repair, reconstruction or improvement commenced; are located within a regulatory floodplain or erosion hazard area, the following standards shall apply:

1. Adequate surface drainage and access for a hauler shall be provided,

2. All manufactured homes shall be placed on pads or lots elevated on compacted fill which shall be, at a minimum, at or above the base flood elevation or on a stem wall or on pilings so that the bottom of the structural frame or the lowest point of any attached appliances, whichever is lower, is at or above the regulatory flood elevation. If elevated on pilings:

a. The lots shall be large enough to permit steps,

b. The pilings shall be placed in stable soil no more than ten feet apart, and c.

Structures designed or utilized for human habitation, whether full-time or part-time, shall only be permitted where the product of the flow depth  $d$ , in feet, times the square of the flow velocity  $v$ , in feet per second, of the surrounding floodwaters of the base flood does not exceed the numerical value of eighteen for a period in excess of thirty minutes, or the surrounding floodwaters of the base flood do not exceed three feet in depth.

## **Subdivisions and Development**

### *Suitability of land.*

Land may not be parceled or subdivided in such a manner as to create lots unsuitable for development because of flood or erosion hazards. Plans and plans to show areas subject to flooding and erosion. All tentative plats and development plans submitted shall show location, by survey or photographic methods, of streams, watercourses, canals, irrigation laterals, private ditches, culverts, lakes and other water features, including those areas subject to flooding or erosion. The plats/plans shall also include the direction of any flow and drainage area, as well as water surface elevations and the limits of inundation for the base flood if such a flood has a peak flow rate equal to or greater than one hundred (100) cfs.

### *Grading and drainage improvement.*

A. All tentative plats and development plans shall show proposed grading and improvements for areas which are subject to flooding or which have drainage problems, and shall also show a description and location of all facilities proposed to alleviate flooding or drainage problems within or outside the boundaries of the subdivision or development.

B. All development plans and tentative plats must be accompanied by conceptual grading plans and conceptual drainage improvement plans as neck to demonstrate:

1. The methods for flood proofing and/or drainage control for the development, including sufficient lot grading information to demonstrate adequate finished pad elevations and/or drainage slopes to protect building foundations;
2. That improvements are compatible with the existing upstream and downstream drainage conditions and that any proposed grading and/or grade change will not have an adverse impact on surrounding property;
3. The methods of erosion and sediment control;
4. The methods of mitigating increased urban peak and volumetric flood water runoff or discharge on downstream properties created as a result of the development.

C. Prior to commencement of any site improvements or grading, a grading plan must be submitted to the Pima County department of transportation and flood control district for review and approval. Detailed improvement plans for storm drains or channel improvements must also be submitted to the same department for review and approval.

### **Floodplain and floodway boundaries--Drainage areas.**

A. All final plats and development plans shall indicate the limits of the regulatory floodplains, erosion hazard boundaries and the limits of the federally established regulatory floodplains and floodways (if applicable), and be delineated in a surveyable manner and certified by an Arizona registered land surveyor.

B. All final plats shall indicate both the drainage areas and their respective base flood peak discharges, with a note contained on the final plat that the drainage areas and base flood peak discharges are provided by the owner only for information purposes.

### **Development plan--Advisories to other jurisdictions.**

A. The district shall advise any city or town which has assumed jurisdiction over its regulatory floodplains in accordance with Arizona Revised Statute 48-3610 in writing, and provide a copy of any development plan or any application which has been filed with the county for a floodplain use permit or variance to develop land in a regulatory floodplain or floodway within one mile of the boundary between the district's area of jurisdiction and the jurisdiction of that city or town.

B. The district shall also advise any city or town in writing and provide a copy of any development plan of any major development proposed within a regulatory floodplain or floodway which could affect flood-prone areas or watercourses within that city's or town's area of jurisdiction.

C. Written notice of a copy of the plan of development shall be sent to any adjacent jurisdiction no later than three working days after having been received by the district.

### **Street elevation requirements.**

Streets required for paved permanent access shall be designed and constructed so that the flow depths over them do not exceed one foot in depth during the base flood. At least one paved permanent access shall be provided to each lot over terrain which can be traversed by conventional motor vehicles in times of flooding. In specific instances at drainage crossings where it can be demonstrated that this requirement is either impractical, based upon low hazard to life and property, or where construction of a drainage crossing may create problems which override the

corresponding benefits, this requirement may be waived by the county engineer. Fill may be used for streets in areas subject to flooding provided such fill does not unduly increase flood heights. The developers may be required to provide profiles and elevations of streets for areas subject to flooding.

**Building site location restrictions.**

A. Land which contains areas within a regulatory floodplain or erosion hazard area shall not be platted for residential occupancy or building sites unless each lot contains a building site, either natural or man-made, which is not subject to flooding or erosion by the base flood.

B. It is preferred that building sites be located outside of the regulatory floodplain.

C. In regulatory floodplain areas where fill is to be used to raise the elevation of the building site, the building shall be located not less than twenty-five feet landward from any edge of the fill unless a study/analysis prepared by an Arizona registered professional civil engineer demonstrates a lesser distance is acceptable. No fill shall be placed in any regulatory floodplain or floodway, nor shall any fill be placed where it diverts, retards or obstructs the flow of water to such an extent that it creates a danger or hazard to life or property.

D. Any dwelling unit built within a regulatory floodplain shall be constructed so as to place the minimum floor elevation of the dwelling unit at or above the regulatory flood elevation.

**Setbacks from channels.**

Along reaches of watercourses where hazards from eroding banks or channel meandering are considered by the county engineer to be severe, special engineering studies prepared by an Arizona registered professional civil engineer shall be required of the property owner or developer, and requirements for setbacks from banks of watercourses and/or other protection measures shall be established in accordance with those approved studies. Also see Chapter 16.40 of this title.

**Setbacks on all other watercourses.**

When the banks are stabilized to the level of the base flood (plus an appropriate freeboard) the setback to structures shall be a minimum of twenty (20) feet for access and maintenance. When access and maintenance easements are not required by the city engineer, the minimum setback may be reduced to ten (10) feet at the discretion of the city engineer. When banks are not stabilized, the setback to structures shall be as calculated from guidelines in the Standards Manual.

**Pima County Ordinance**

**Rights-of-way for drainage.**

A. Whenever a subdivision plat or development plan contains a watercourse which is regulated by this title, all rights-of-way associated with the watercourse shall be designated "Drainageway."

B. If the watercourse is an improved major watercourse, the drainageway shall include the channel, the channel improvements, and a fifty-foot-wide area measured outward from the front face of the top of the bank protection for Pima County or for Pima County flood control district use.

C. If the watercourse is an improved minor watercourse, the drainageway shall include the channel, the channel improvements, and necessary maintenance access.

D. If the watercourse is to remain natural, the drainageway shall be the boundaries of the regulatory floodplain.

E. Along major watercourses where the peak discharge during the base flood is ten thousand cubic feet per second or greater, the drainageway shall be dedicated in fee simple to the Pima County flood control district. F.

Along other watercourses, the county engineer shall determine whether it is necessary for Pima County or the Pima County flood control district to have control of the drainageway. If the county engineer determines that public control is necessary, the owner shall dedicate the drainageway in fee simple or grant an easement.

**Detention/retention systems.**

*Cost recovery for drainage or flood control improvements.*

The floodplain management board may establish a cost recovery system or fee system for the improvement or installation of public flood-control systems. The purpose of the fee is to provide a method for off-site improvements necessary to mitigate the effect of urbanization and to provide a systematic approach for the construction of public flood-control improvements. If such a system is adopted it shall demonstrate that the fee will in some manner benefit the property from which the fee is collected and be applied equitably to all property in proportion to floodwaters

generated by urban use of the property. The fees will also be restricted to providing flood control improvements necessary for the allowed use of the properties from which the fee is collected, and the fees shall be reasonably related to the actual cost of providing flood control improvements beneficial to the site or surrounding area. The fees will be reviewed by the flood control district advisory committee prior to action by the board of directors of the Pima County flood control district.

*Drainage Channels.*

- A. Drainage channels shall not be fully lined. Improved channel bottoms shall remain natural.
- B. Perimeter channels that route flow around the outer edge of the development should be prohibited in all areas where there is an established natural channel.
- C. In unusual conditions on a case-by-case basis, lined and/or perimeter channels may be approved for use by the county engineer.

**Erosion Hazard Areas and Building Setbacks**

*Building setback requirements.*

In erosion hazard areas where watercourses are subject to flow-related erosion hazards, building setbacks are required as set out in Sections 16.40.020 and 16.40.030.

*Setbacks near major watercourses.*

For major watercourses, with base flood peak discharges of two thousand cfs or greater, the following building setbacks shall be required where approved bank protection is not provided:

A. Along the following major natural watercourses where no unusual conditions exist, a minimum building setback, as indicated below, shall be provided at the time of the development unless an engineering analysis which establishes safe limits is performed by an Arizona registered professional civil engineer and is approved by the county engineer. Unusual conditions include, but are not limited to, historical meandering of the watercourse, large excavation pits, poorly defined or poorly consolidated banks, natural channel armoring, proximity to stabilized structures such as bridges or rock outcrops, and changes in the direction, amount and velocity of the flow of waters within the watercourse.

1. The building setback shall be five hundred feet along the Santa Cruz River, Rillito Creek, Pantano Wash, Tanque Verde Creek and the Canada del Oro Wash downstream of the confluence with Sutherland Wash;

2. The building setback shall be two hundred fifty feet along major watercourses with base flood peak discharges greater than ten thousand cfs; 3. The building setback shall be one hundred feet along all other major watercourses with base flood peak discharges of ten thousand cfs or less, but more than two thousand cfs.

B. Along major watercourses where unusual conditions do exist, building setbacks shall be established on a case-by-case basis by the county engineer, unless an engineering study which establishes safe limits is performed by an Arizona registered professional civil engineer and is approved by the county engineer. When determining building setback requirements, the county engineer shall consider danger to life and property due to existing flood heights or velocities and historical channel meandering. Unusual conditions include, but are not limited to, historical meandering of the watercourse, large excavation pits, poorly defined or poorly consolidated banks, natural channel armoring, proximity to stabilized structures such as bridges or rock outcrops, and changes in the direction, amount, and velocity of the flow of waters within the watercourse.

***Tucson Ordinance Setbacks***

***Table I***

<b><i>Watercourse</i></b>	<b><i>Minimum Setback</i></b>	<b><i>Minimum setback in in Curved Section (Feet) Straight Section(Feet)</i></b>
<i>Pantano Wash</i>	350	870
<i>Rillito Creek</i>	360	895
<i>Santa Cruz River</i>	490	1,220

## **MARANA ORDINANCE SETBACKS**

### **A. Major watercourses**

*For major watercourses, with 100-year peak discharges of 2,000 cfs or greater, the following building setbacks shall be required where bank protection is not provided.*

*1. Along the following major natural watercourses where no unusual conditions exist, a minimum setback measured from the primary channel bank or 100-year floodway, where the channel does not contain the 100-year discharge, shall be provided at the time of the development unless an engineering analysis which establishes safe limits is performed by a Registered Professional Civil Engineer and is approved by the Town Floodplain Administrator.*

- a. Santa Cruz River requires a setback of 500 feet.*
- b. All other major watercourses with 100-year discharges greater than 10,000 cfs shall require a setback of 250 feet.*
- c. Major washes with 100-year discharges of 10,000 cfs or less, but more than 2,000 cfs will require a setback of 100 feet.*

### *Setbacks from minor washes.*

For minor washes with a base flood peak charge of two thousand (2000) cfs or less, the following building setbacks shall be required where approved bank protection is not provided:

A. Along minor watercourses where no unusual conditions exist, a minimum setback of fifty feet shall be provided at the time of development unless an engineering analysis which establishes safe limits is performed by an Arizona registered professional civil engineer and is approved by the county engineer. Unusual conditions include, but are not limited to, historical meandering of the watercourse, large excavation pits, poorly defined or poorly consolidated banks, natural channel armoring, proximity to stabilized structures such as bridges or rock outcrops, and changes in the direction, amount, and velocity of flow of the waters in the watercourse.

B. Along minor washes where unusual conditions do exist, building setbacks shall be established on a case-by-case basis by the county engineer, unless an engineering study which establishes safe limits is performed by an Arizona registered professional civil engineer and is approved by the county engineer. When determining building setback requirements, the county engineer shall consider danger to life and property due to existing flood heights or velocities and historical channel meandering.

### **Runoff Detention and Retention Systems**

*Runoff reduction required when--Specifications adopted.*

All proposed residential densities of three or more units per acre and all proposed commercial and industrial developments greater than one acre in size shall provide some method of peak or volumetric runoff reduction. The amount of reduction is stipulated within the Stormwater Detention/Retention Manual. The Stormwater Detention/Retention Manual approved for use by the board of supervisors as of the effective date of the ordinance codified in this title is made a part of this title. Any revisions to the Stormwater Retention/Detention Manual will be reviewed by the flood control district advisory committee.

### **Balanced and critical basins--Development conditions.**

Balanced and critical drainage basins which have been identified by the county engineer as unsuitable for added development because of the high probability of increased flooding, or flooding of existing improvements or property not previously flooded, or ponding of floodwater, may be developed further only upon the incorporation of adequate detention/retention systems or flood control facilities, as reviewed and approved by the county engineer. Drainage basins which have not been previously identified as unsuitable for additional urban development but upon any study are so identified shall be subject to the provisions of this chapter. These detention or retention systems or flood control facilities shall be incorporated into any and all future basin-development proposals regardless of size or land use density.

### **Structural flood control measures.**

A. Structural flood control measures may be proposed in conjunction with or in place of detention/retention systems if it can be clearly demonstrated that such measures will not alter the water and sediment equilibrium of the affected watercourse and will mitigate environmental impacts.

B. Appropriate structural flood control measures, such as channelization to a logical conclusion downstream of the proposed development and/or improvements to existing off-site flood control systems within the effected drainage or stream reach, shall be completed in accordance with plans reviewed and approved by the county engineer.

*Fee in lieu of detention/retention requirements.*

A fee may be utilized in place of a detention/retention system when it can be clearly demonstrated that detention at the site does not provide off-site flood relief due to the parcel size, location within the drainage basin, or other factors. The fees collected will be used to construct public flood-control improvements which will mitigate the potential damage of floodwaters originating from the property contributing the fees. In balanced and critical basins, and where development is less than three units to the acre, use of a fee system will be encouraged in lieu of a detention system in order to preserve the natural drainage patterns.

*Maps of balanced and critical basins.*

The county engineer shall prepare and retain for public inspection and use an official map designating balanced and critical basins within Pima County.

A. This title is one aspect of land and resource management planning for Pima County. Floodplain management must be seen in perspective, not only as flood hazard minimization, but as one element of an integrated program of natural resource management and flood and erosion hazard reduction.

B. The floodplain management board recognizes that it is both necessary and desirable to maintain a balanced and cooperative relationship between human communities and the land and resources which sustain them. Maintaining the stability, health, diversity and natural flora and fauna of the environment is essential.

C. It is the intent of the floodplain management board that:

1. The highest and best use of regulatory floodplains in Pima County be for maintenance of hydrologic and hydraulic processes, with consideration for groundwater recharge, aesthetics, natural open space, recreation areas and wildlife habitat;

2. Any human habitation or structural developments which limit natural processes within flood-prone or erosion hazard areas be discouraged and limited to the extent allowable by law;

3. The county acquire, by appropriate means, lands within the regulatory floodplain and erosion hazard areas, and that these lands be managed by the Pima County flood control district to preserve or enhance natural values and expressed resource management goals;

4. Regulatory land use control for floodplain management emphasize overall watershed management, and that floodplain management be used to prevent unwise human occupation or encroachment into regulatory floodplain and erosion hazard areas;

5. Natural flood-prone areas, streams, washes, arroyos, rivers and drainage courses, whenever possible, be preserved in their natural riverine condition and that any land use proposal which utilizes this approach be considered superior to all others;

D. The purpose of this title is to protect the public health, safety, and general welfare of the citizens of Pima County by adopting regulations designed:

1. To minimize flood and erosion damages;

2. To meet or exceed state and federal requirements relating to floodplain management, thereby enabling Pima County residents to purchase low-cost flood insurance, receive disaster relief should the need arise, and to seek residential and commercial real estate loans;

3. To establish minimum flood protection elevations and damage prevention requirements for structures and other types of development which may be vulnerable to flood and erosion damage;

4. To regulate encroachment and building development within areas subject to flooding or erosion, and to assure that the flood-carrying capacity within the altered and/or relocated portion of any watercourse is maintained;

5. To encourage the most effective expenditures of public money for flood control projects;

6. To minimize the need for rescue and relief efforts associated with flooding and erosion, generally undertaken at the expense of the general public;

7. To minimize damage to public facilities and utilities such as water and gas mains, electric, telephone and sewer lines, streets and bridges located in regulatory floodplain and erosion hazard areas;

8. To help maintain a stable tax base by providing for the protection of regulatory floodplain and erosion hazard areas;

9. To inform the public when property is in a regulatory floodplain or erosion hazard area;
10. To insure that those who occupy the areas within a regulatory floodplain and erosion hazard area assume the responsibility for their actions;
11. To protect, preserve and enhance groundwater recharge; 12. To encourage the preservation of natural washes and enhance the riverine environment.

*Application and enforcement.*

A. The ordinance codified in Title 16 of this code shall apply only within regulatory floodplain and erosion hazard areas.

B. This title shall be applicable and enforceable in the incorporated as well as the unincorporated areas of Pima County, including public lands, but excluding Indian and military reservations and those incorporated areas of cities or towns which have elected to assume separate floodplain management powers and duties pursuant to Section 48-3610 of the Arizona Revised Statutes.

*Performance standards.*

The performance requirements as specified in this title are minimum standards and address general floodplain management requirements. Specific projects may warrant additional requirements. The floodplain management board and the county engineer have the authority to establish standards and/or policies as necessary to carry out the provisions of this title. All drainage design standards, river and basin management plans, or other land use plans approved by the board of supervisors or floodplain management board are hereby incorporated into this title.

*Interpretation of provisions--Conflict resolution.*

A. In the interpretation and application of this ordinance, all provisions shall be:

1. Considered as minimum requirements;
2. Liberally construed in favor of the governing body; and 3. Deemed neither to limit nor repeal any other powers granted to Pima County under any state statute.

B. Where this title conflicts with or overlaps any other ordinance or regulation, whichever imposes the more stringent restrictions for the health, safety and welfare of the public shall prevail.

**Sediment and Erosion Control**

Application of chapter provisions. Any activity which may have an effect on the floodwater-carrying capacity of any watercourse regulated by this title is subject to the provisions of this chapter.

*Soil investigations.*

The county engineer may require appropriate soil investigation reports for the purpose of determining the erosive properties of areas or lands to be graded or disturbed which may create sediment deposition or erosion in any watershed regulated by this title.

*Grading or alteration of watercourses.*

Any grading or alteration of any watercourse regulated by this title shall be controlled to minimize the loss of soil through erosion from rainfall or stormwater flowage. Methods to control erosion and sedimentation must be demonstrated to the satisfaction of the county engineer prior to the granting of a floodplain use permit for any work in any floodplain. Both temporary and permanent measures for sediment and erosion control must be clearly delineated on plans or other written documents prior to receiving a floodplain use permit. The Grading Design Manual prepared pursuant to Chapter 18.81 of the zoning code shall be used to prepare these plans or documents.

## **RIPARIAN HABITAT ORDINANCES**

### **PIMA COUNTY WATERCOURSE AND RIPARIAN HABITAT PROTECTION AND MITIGATION REQUIREMENTS**

**Purpose.**

The purpose of this chapter is to enhance wildlife and recreation values where appropriate by preserving riparian vegetation along watercourses and floodplains and:

- A. Protect the valuable, limited and endangered natural riparian habitat resources of Pima County;
- B. Provide an ecologically sound transition between riparian habitat communities and developed areas;
- C. Assure the continuation of existing or natural functions, values and benefits provided by riparian habitat resources;
- D. Promote an economic benefit to Pima County by providing the aesthetic, recreation and wildlife values of riparian habitat for the enjoyment of residents and visitors;
- E. Promote natural erosion control; and
- F. Promote continuity of xeroriparian habitat.

**Description.**

For purposes of this chapter, "riparian habitat" is defined as plant communities occurring in association with any spring, cienega, lake, watercourse, river, stream, creek, wash, arroyo, or other body of water, either surface or subsurface, or channel having banks and bed through which waters flow at least periodically. These habitats are generally characterized or distinguished by a difference in plant species composition or an increase in the size and/or density of vegetation as compared to upland areas. These communities represent a continuum of plant species' response to available moisture and can be subdivided into hydroriparian, mesoriparian, and xeroriparian.

A. Hydroriparian. Riparian habitats generally associated with perennial watercourses. Plant communities are dominated by obligate or preferential wetland plant species such as willow and cottonwood. The Cottonwood/Willow Forest is a typical example of this habitat type.

B. Mesoriparian. Riparian habitats generally associated with perennial or intermittent watercourses or shallow ground water. Plant communities may be dominated by species that are also found in drier habitats (e.g. mesquite) but contain some preferential riparian plant species such as ash or netleaf hackberry. The mesquite bosque and sycamore-ash association are examples of this community type.

C. Xeroriparian. Riparian habitats generally associated with an ephemeral water supply. These communities typically contain plant species also found in upland habitats, however, these plants are typically larger and/or occur at higher densities than adjacent uplands. Xeroriparian habitat is further divided into four sub-classes based on total vegetative volume (TVV):

- 1. Xeroriparian A: TVV greater than 0.850 cubic meters per square meter (m<sup>3</sup>/m<sup>2</sup>).
- 2. Xeroriparian B: TVV less than or equal to 0.850 m<sup>3</sup>/m<sup>2</sup> and greater than 0.675 m<sup>3</sup>/m<sup>2</sup>.
- 3. Xeroriparian C: TVV less than or equal to 0.675 m<sup>3</sup>/m<sup>2</sup> and greater than 0.500 m<sup>3</sup>/m<sup>2</sup>.
- 4. Xeroriparian D: TVV less than or equal to 0.500 m<sup>3</sup>/m<sup>2</sup>.

**Applicability.**

This chapter shall apply to all properties within unincorporated Pima County which contains riparian habitat as delineated on riparian habitat maps adopted by the floodplain management board. This chapter shall apply to Pima County and parties acting on behalf of Pima County. This chapter shall apply to individual building permits issued under zoning existing as of the effective date of the ordinance codified in this chapter or lot splits which are not subject to subdivision regulation. All requirements of this chapter shall apply to hydroriparian, mesoriparian and xeroriparian Classes A, B, and C. Xeroriparian Class D habitat shall not be included in the riparian habitat areas which, when altered, will trigger mitigation plan requirements under Section 16.54.050 of this chapter. At the option of the property owner, xeroriparian Class D habitat may be included in the preserved area for the purpose of relying on flexible development standards identified in Section 18.07.080 of the Pima County Zoning Code.

**Permits.**

A. As part of the floodplain use permit process for property subject to provisions of this chapter, the proposed development will be reviewed for impacts to existing riparian habitat. A floodplain use permit shall be required:

- 1. When a total of one third (1/3) acre of the riparian area of a subject property is to be altered; or
- 2. When any hydroriparian and/or mesoriparian habitat is to be altered; or
- 3. When, in order to avoid such alteration of the riparian habitat area on the subject property, a modification of development standards under Section 18.07.080 of the Pima County Zoning Code is necessary.

B. Permits for disturbance of hydroriparian and/or mesoriparian habitat will require a habitat mitigation plan approved by the flood control district board of directors prior to the issuance of the required permit(s).

C. Submittals. Permit applications shall include:

- 1. A map delineating riparian habitat boundaries and the areas where riparian habitat will be altered;

2. On-site vegetation volume surveys for developments of 3.3 acres (144,000 square feet) or larger;
3. A description of the vegetation that will be altered;
4. Evidence that the impact on vegetation will be minimized and that no reasonably practicable alternative to the impact exists;
5. Such additional supporting information as the district determines necessary to carry out review under this chapter.

D. Permit Conditions. Conditions may be placed on the permit that, to the extent reasonably practicable, require preservation of or mitigate the impact on riparian habitat. If mitigation is required, compliance with an approved mitigation plan shall be made a condition of the permit.

#### **Mitigation.**

A. Mitigation Plan. If an applicant demonstrates to the satisfaction of the district that alteration of riparian habitat areas exclusive of xeroriparian Class D cannot reasonably be avoided, a mitigation plan shall be submitted for approval by the district. Hydroriparian and/or mesoriparian habitat mitigation plans shall be approved by the flood control district board of directors.

B. Mitigation Plan Requirement. The mitigation plan shall delineate all mitigation measures to be taken by the owner and shall include a schedule of completion. The mitigation plan shall be consistent with any riparian habitat mitigation standards adopted by the floodplain management board, and shall be prepared in accordance with best available scientific or management practices. Mitigation may be incorporated into measures taken to satisfy other requirements of the district. Where appropriate, the mitigation plan shall at a minimum provide for:

1. Construction methods that identify and protect riparian habitat that is to be left unaltered;
2. Selective clearing or other habitat manipulation;
3. Replacement of affected vegetation with appropriate plant species in ratios which will result in simulation of the prealteration vegetation within five years;
4. Irrigation with passive water harvesting where possible, or installation and maintenance of irrigation methods, until plantings are established;
5. Periodic monitoring of mitigation features;
6. Maintenance and replacement of damaged plantings.
7. Posting a performance bond or financial assurances.

C. Mitigation Banking. At the request of the property owner and with district board approval, the mitigation plan requirement under this chapter may be waived by contributing funds to an account established and administered by the district solely for the purpose of purchasing high value riparian habitat which shall include hydroriparian, mesoriparian, and xeroriparian Class A.

#### **Riparian habitat maps.**

A. The riparian habitat maps and Ordinance 1994-FC2, adopted by the board on July 19, 1994, are hereby amended by adopting the revised riparian habitat maps prepared by the flood control district which detail on a parcel level, and more precisely delineate the location of riparian habitat areas subject to the requirements of the riparian habitat ordinance, and which are incorporated in this section by reference.

B. The riparian habitat maps shall be kept on file and made available to the public in the offices of the Pima County flood control district.

### **TUCSON WATERCOURSE AMENITIES, SAFETY AND HABITAT (WASH ORDINANCE)**

#### **Purpose and Intent.**

Washes within the urbanized areas of the city in which existing vegetation is maintained are valuable nature resources that contribute to the health and well-being of the residents of the city. Such washes assist in groundwater recharge, support wildlife habitat, and provide natural open space areas. These regulations are specifically intended to accomplish the following:

- (a) Maximize opportunities for groundwater recharge through the preservation of specific washes with earthen channels and banks.
- (b) Protect existing vegetation found within and near specific washes.
- (c) Provide for the restoration of vegetation disturbed as a result of development in and adjacent to specific washes.
- (d) Assist in the reduction of the urban heat island effect by retaining existing vegetation and minimizing structural improvement of urban washes.

**Applicability.**

(a) These regulations apply to all lots or parcels of land existing as of April 25, 1991, that are adjacent to the washes listed in table 1.

(b) These regulations do not apply to the following:

(1) A lot or parcel existing on April 25, 1991, to be developed with one (1) single-family residence or single-family residence accessory structure.

(2) A subdivision plat, development plan, or site plan approved prior to April 25, 1991, provided that construction occurs within five (5) years of the effective date of this article [April 24, 1991].

(c) The term "city limit line," as used in Table 1, means the city limits as existing on the effective date of an ordinance, adopted subsequent to an annexation, which specifically extends the applicability of these regulations to the newly annexed wash reaches. Notice and hearing for adoption of an ordinance establishing the applicability of these regulations to annexed areas shall be in the same manner as for adoption of an ordinance establishing original zoning boundaries for newly annexed areas.

**TABLE 1  
Washes Subject to the Watercourse Amenities, Safety, Habitat Regulations**

Airport Wash, Santa Cruz River to city limit line	Naylor Wash, Arroyo Chico to Columbus Blvd
Alamo Wash, city limit line to Escalante Rd.	Nebraska Wash (East), Airport Wash to 12th Ave.
Arcadia Wash, Glenn Street to 22nd Street	Pima Wash, Rillito Creek to Oracle Rd.
Arroyo Chico, Park Avenue to Alvernon Way	Powderhorn Wash, Anklam Road to Tumamoc Hill
Arroyo Chico, 10th Street to First Ave.	Racetrack Wash, Rillito Creek to River Rd.
Atturbury Wash, Pantano Wash to Irvington Rd.	Railroad Wash, Arroyo Chico to Country Club Rd.
Cholla Wash, West Branch Santa Cruz River to City limit line	Robb Wash, Tanque Verde Creek to 22nd ST.
Christmas Wash, Rillito Creek to Tucson Blvd.	Rodeo Wash, Santa Cruz River to Alvernon Way
Citation Wash, Arroyo Chico to Alvernon Way	Rolling Hills Wash, Pantano Wash to Harrison Rd.
Civano Wash, Pantano Wash to city limit line	Rose Hill Wash, Pantano Wash to 22nd St.
Earp Wash, Julian Wash to city limit line	Sabino Creek, Tanque Verde Creek to city limit line
Este Wash, Tanque Verde Wash to Broadway Blvd	Sentinel Wash, Cedar Street to Sentinel Peak
Fahringer Wash, between Sabino Creek & Tanque Verde Rd.	Spanish Trail Wash, Pantano Wash to Houghton Rd..
Globeberry Wash, Silvercroft Wash to Headwaters	Tucson Park Wash, Silvercroft Wash to Greasewood Rd.
Hidden Hills Wash, Tanque Verde Creek to city limit line	Valencia Wash (East), Santa Cruz River to I-19
High School Wash, Tucson Arroyo to Plumer Ave.	West Branch Santa Cruz River, Santa Cruz River
Julian Wash, Tucson Diversion Channel to city limit line	to Valencia Rd.
Kinnison Wash, Atturbury Wash to Irvington Rd.	Wyoming Wash, Santa Cruz River to 17th Ave.
Maxwell Wash, Silvercroft Wash to Anklam Rd.	

**Development in the study area.**

(a) Study Area Established. A study area consisting of the channel, the banks, and the land area extending fifty (50) feet from the banks of the washes listed in table 1, is hereby established.

(b) Required Study Area Information. If alterations to the study area are proposed, the following information shall be submitted to the city engineer prior to the issuance of a permit for development in the study area:

(1) Hydrology/hydraulic study. A study of the wash and its hydrology and hydraulics is required. In addition to the information required by Chapter 26, Floodplain and Erosion Hazard Area Regulations, the hydrology/hydraulics study shall contain the following elements:

- a. The location of the 100-year floodplain on, adjacent to, and a minimum of two hundred (200) feet upstream and downstream of the proposed development.
- b. Soil conditions in and adjacent to the watercourse, and the erosion potential.
- c. Existing rights-of-way or easement dedication along the wash for a distance of five hundred (500) feet upstream and downstream of the proposed development.
- d. The existing and proposed ownership of any drainageway facilities on or adjacent to the site and identification of the persons responsible for the maintenance of such facilities.
- e. Previous hydraulic/hydrology studies or maps prepared for the watershed.
- f. Groundwater recharge potential at this location.
- g. Sediment transport characteristics along the watercourse centered on this location.

- h. Existing and proposed utilities to and across the site.
- i. Any other elements that may be characteristic of the watercourses on or adjacent to the site.
- (2) Plant/habitat inventory. All development proposals shall be accompanied by an inventory of the existing vegetation and wildlife habitats within the study area.
- (3) A copy of the plant/habitat inventory shall be submitted to the planning director for review.
- (c) Basin Management Plan. Development on a lot or parcel which is located within the boundaries of an approved basin management plan shall be in conformance with the plan.

**Development requirements for resource areas.**

(a) Resource Area. The resource area consists of the channel and banks of a wash, and those portions of the study area containing vegetative resources and wildlife habitat areas. Where alteration to any portion of the resource area is proposed, the applicant for a development permit is required to demonstrate why the resource area cannot be left in its natural condition.

(b) Alteration of Resource Area. No development, including grubbing, grading, removal of vegetation, channelization, or other type of alteration of the land, shall occur in the resource area unless a mitigation plan, which includes a plan for the proposed wash treatment and a preservation/revegetation plan, is submitted to the city engineer and approved as provided for in section 29-17 below.

(1) Mitigation plan. The mitigation plan must demonstrate that the loss of existing vegetation and wildlife habitat as a result of development in the resource area is minimized, and that lost vegetation and wildlife habitat are restored or recreated through the specific wash treatment and the preservation/revegetation plan. If a vegetated area is altered, the site must be revegetated to the same or greater density, diversity, and volume of vegetation as existed prior to the alteration. The mitigation plan shall demonstrate the following:

a. Wash treatment. The treatment of the watercourse must be done in a manner which maintains the existing appearance or predevelopment condition of the resource area by using one (1) or a combination of the following methods, in order of priority. Alternative structural solutions consistent with the intent of these regulations are encouraged and may be proposed by the owner.

- 1. Earthen channel.
- 2. Retention of stormwater runoff to reduce the impact on an earthen channel.
- 3. Structural materials conducive to retaining existing vegetation or revegetation, including any use of a soil filter blanket.
- 4. Compound channels.
- 5. Riprap, whether exposed or buried.
- 6. Gabions.

b. The following wash treatments may be used only if the city engineer determines that an existing safety hazard warrants such treatment, and the wash treatment method is approved by the mayor and council.

- 1. Rock veneer.
- 2. Soil cement.
- 3. Reinforced concrete, including textured, tinted, or colored concrete.

c. Preservation/revegetation plan. The preservation/revegetation plan must demonstrate that any vegetation removed from the resource area is replaced as closely as possible to the predisturbance condition in terms of plant type, density, and diversity. Plant types not currently existing on the site may be included in the preservation/revegetation plan if they are listed on the low water use/drought tolerant plant list in development standard 9-06.0. The preservation/revegetation plan shall contain the following information:

- 1. A preservation plan for native vegetation in the resource area.
- 2. The proposed location of vegetation after development, including the location of salvaged materials.
- 3. An access plan and maintenance schedule for the vegetation in the resource area.

(2) A copy of the preservation/revegetation plan shall be submitted to the planning director for review.

**CITY OF TUCSON LAND USE CODE - ENVIRONMENTAL RESOURCE ZONE (ERZ)**

**Purpose.**

These regulations are intended to recognize the value of Tucson's natural open space resources, particularly the critical and sensitive wildlife habitat of eastern Pima County associated with public monuments, forests, and preserves. These regulations relate to areas associated with Tucson's public lands and preserves, including Saguaro National Park, Coronado National Forest, and Tucson Mountain Park. It is the intent of these regulations to protect

valuable habitat resources to the greatest extent possible. Development, compatible with these public resources, is allowed.

This overlay zone specifically serves to:

A. Recognize the social, economic, environmental, biologic, and cultural importance of Saguaro National Park and Tucson Mountain Park to the city of Tucson.

B. Buffer Saguaro National Park and Tucson Mountain Park from the impacts of new development by allowing development which is compatible with preservation of critical wildlife habitat and the Park environs.

C. Conserve certain designated washes which extend from the Parks as areas of natural and scenic and provide valuable wildlife habitat.

D. Complement the City of Tucson Interim Watercourse Improvement Policy which provides for flood control, erosion mitigation, and groundwater recharge through the preservation of designated washes in natural and undisturbed states.

E. Assist in implementing the Tucson General Plan policies which call for the preservation of Tucson's significant natural areas along designated watercourses where identified in adopted area and neighborhood plans.

#### **Applicability.**

A. *Areas Mapped.* Parcels which may contain critical riparian habitat are shown on a series of maps approved by the Mayor and Council called the Environmental Resource Zone Overlay Maps (ERZ Maps) which are an exhibit to this ordinance incorporated herein by reference and kept on file in the Planning Department. ERZ Maps will include all parcels along the subject washes which may contain riparian habitat, including those parcels that are not vacant. These maps are based on the Critical and Sensitive Wildlife Habitat Map which the Mayor and Council adopted by Resolution #15149.

B. *Resource Corridors.* Critical riparian habitat is associated with resource corridors along the following washes which are shown on the ERZ Maps:

- |                     |  |
|---------------------|--|
| 1) Agua Caliente;   | 11) San Juan;  |
| 2) Ajo;             | 12) Silvercroft;                                       |
| 3) Anklam;          | 13) Tanque Verde Creek;                                |
| 4) Coronado Ridge;  | 14) portions of the West Branch of the Santa Cruz;     |
| 5) Enchanted Hills; | 15) Camino de Oeste;                                   |
| 6) Escalante;       | 16) unnamed washes in the Flato-Franco Drainage Basin; |
| 7) Este;            | 17) Race Track; and                                    |
| 8) Greasewood;      | 18) Rincon Creek.                                      |
| 9) Painted Hills;   |  |
| 10) Reyes;          |  |

C. *New Development.* New development which occurs on parcels shown on the ERZ Maps will be reviewed for compliance with these regulations.

D. *Rezoning.* Rezoning applications for parcels adjacent to the washes listed above, but not shown on the ERZ Maps, are subject to these regulations.

E. *Approved Subdivisions.* Where a recorded plat shown on the ERZ Maps is resubdivided, it must comply

F. *Annexation.* As annexation occurs, additional resource corridors or extensions of resource corridors may be added to the ERZ Maps.

#### **Exceptions.**

These regulations do not apply to the following.

A. Any single-family residence or other development existing as of July 3, 1990, or any expansion of up to twenty-five (25) percent of either an existing residence or other development.

B. Any lot or parcel to be developed with one (1) single-family residence where all development and the residence and any accessory structures are located outside of the critical riparian habitat area.

C. Any subdivision which was recorded prior to August 3, 1990, as long as:

1. Substantial construction occurs within five (5) years after August 3, 1990, and
  2. Construction occurs in accordance with the approved plat.
- D. Where these regulations affect a parcel which is also subject to the Hillside Development Zone regulations, these regulations do not apply as long as there is no encroachment into the one hundred (100) year floodplain.

**Review and Approval Required.**

Two (2) options are available for development under these regulations.

A. *No Encroachment in Floodplain.* Where the owner of a lot or parcel affected by these regulations chooses to leave the one hundred (100) year floodplain undisturbed, the Environmental Resource Zone (ERZ) does not apply except that temporary fencing will be placed between the project site and the floodplain area as provided in Sec. 2.8.6.6.B; where permitted by the floodplain ordinance, development in this floodplain area is allowed as provided in Sec. 2.8.6.6.

B. *Study of Resource Corridor.* Where the owner of a lot or parcel affected by these regulations chooses to do a study of the resource corridor, a development submittal containing the following information is made to the Planning Department for review in accordance with Sec. 5.4.3.9, Type IX Administrative Procedure.

1. Submittal material will include an Environmental Resource Report as established in Development Standard 2-13.0. This Report presents a study of the resource corridor and documents locations of the resource corridor and critical riparian habitat.

2. If preservation of the critical riparian habitat cannot be accomplished as provided in these regulations, the submittal will include a mitigation plan as required in Sec. 2.8.6.5.D.

3. Permits for grubbing, grading, construction, or any other improvements will not be issued until all applicable requirements of Sec. 2.8.6.5 and Sec. 2.8.6.6 are met.

**Development Regulations.**

A. *Preservation of Critical Riparian Habitat.* Preservation of one hundred (100) percent of critical riparian habitat areas within the resource corridors for parcels shown on the ERZ Maps is required, except as provided in Sec. 2.8.6.4 and Sec. 2.8.6.6. The critical riparian habitat area may be included as part of any required open space on the site.

B. *Residential Development*

C. *Nonresidential Development.* Nonresidential development is allowed based on underlying zoning.

D. *Mitigation Plan.* Where preservation of the critical riparian habitat area cannot be accomplished as provided in these regulations, the owner is required to submit a mitigation plan, which will be reviewed in accordance with Sec. 5.4.3.9, Type IX Administrative Procedure, containing the following.

1. A statement of findings as to why one hundred (100) percent preservation of the critical riparian habitat area cannot be accomplished.

2. The plan will document the specific impact of the development on existing critical riparian habitat areas within the resource corridor.

3. The mitigation plan will present the techniques considered to lessen the impacts of the development on the critical riparian habitat areas. The techniques employed by the development project should protect remaining critical riparian habitat and restore critical riparian habitat areas disturbed during construction. This may be done through clustering development away from substantial amounts of critical riparian habitat, enhancement of degraded critical riparian habitat areas through revegetation or restoration, or other means appropriate to the type of project

4. The plan will provide for one hundred (100) percent restoration of the critical riparian habitat area disturbed during construction as detailed in Sec. 2.8.6.6.A.6, Sec. 2.8.6.6.A.7, and Sec. 2.8.6.6.A.8.

5. In reviewing the statement of findings and the mitigation plan, the Director will take into consideration such factors as the amount, quality, and predisturbance condition of the critical riparian habitat within the resource corridor; the contiguity of the critical riparian habitat; the presence of any endangered species; the upstream or downstream characteristics of the designated wash; the alternatives to the layout and design of the project; and any other pertinent factors relating to the proposed development or the critical riparian habitat that may be provided by the owner and the reviewing parties. (Ord. No. 9138, §1, 10/5/98)

E. *Temporary Fencing Required.* No grubbing, grading, or construction will occur on a project site which includes areas designated to be retained in a natural state, until those designated areas are temporarily fenced.

F. Inspection of Fencing. All temporary fencing will be field inspected by the Planning Department before any construction on the site begins. Fencing will be removed only on completion of construction.

**Standards for Roadway/Utility Encroachment.**

A. *Standards.* The following standards are required as part of the mitigation plan, where applicable. They are also required for any allowed encroachment into critical riparian habitat areas. Encroachment which may be allowed is limited to utilities, roadway improvements, walkways, or bike paths.

1. Roadway, bike path, and walkway improvements and utility encroachments into critical riparian habitat areas will be limited and approved only if there are no other alternatives in the design of the project. Where allowed, roadway, bike path, and walkway improvements and utility encroachments will cross critical riparian habitat areas, not run parallel to the critical riparian

2. Where roadway, bike path, and walkway improvements are allowed to encroach into critical riparian habitat areas, they are allowed only at the narrowest point of the critical riparian habitat

3. All utilities in critical riparian habitat areas will be located underground; utilities will be placed either along roadway, bike path, or walkway improvements or within approved easements.

4. Any roadway, bike path, or walkway improvement which impedes the movement of wildlife must be constructed in such a manner as to provide means for safe and accessible passage. Improvements or encroachments into critical riparian habitat areas should be constructed to minimize disruption of vegetation and critical riparian habitat. Where culverts are used, they should be box culverts a minimum of six (6) feet in height.

5. Where a roadway, walkway, or bike path improvement or utility encroachment occurs within the critical riparian habitat area, revegetation is required for any area disturbed because of such construction.

6. Revegetation should include plant material salvaged from the site.

7. Revegetation should recreate the critical riparian habitat through the planting of trees, shrubs, and seed mix native to the site and be equal to the predisturbance plant density, diversity, and volume on the net site.

8. A maintenance program is required for revegetation/restored or enhanced areas so that plant material is replaced as needed.

Other sections follow on fencing, walls, lighting and variances.

# APPENDIX C

## PIMA COUNTY FLOOD MANAGEMENT

### **BASIN MANAGEMENT PLANS**

#### **City of South Tucson Drainage Study, October 1992**

A Phase I report was completed in 1987 to identify existing drainage conditions within and impacting the one sq. mile City of South Tucson. Most water drains to the northwest through South Tucson in streets and undersized drainage swales. The report was updated in 1992.

#### **Highlands Wash Basin Management Plan, Jan. 1990**

The purpose of this study was to develop a plan for reducing existing flood hazard along the Highlands Wash, especially within the Highlands Manor Mobile Home Park, located north of Lambert Lane. Alternatives were formulated, and the recommended alternative was selected during the Phase 2 and 3 studies. A phased construction was recommended for improvement.

#### **Riverside Terrace Basin Management Plan, March 1987**

The report was undertaken to document existing hydrological and hydraulic conditions for the area, which drains southwest towards Rillito Creek. Nine watersheds were studied: Pima Wash, Roller Coaster Wash, Citrus Wash, Casas Adobes Wash, Nanini Wash, Pegler Wash, Carmack Wash, West Orange Grove basin and West Ina basin. Many of the roadway culvert crossings were found to be inadequate, and significant drainage improvements would be needed to accommodate the future River Road.

#### **Ruthrauff Road Basin Management Study, Jan. 1983**

The purpose of the plan was to develop policies and procedures to mitigate flooding in the Ruthrauff Road Critical watershed area. Phased structural improvements were recommended in five areas. In 1994 staff updated the study and re-evaluated structural opportunities in two areas.

#### **Southwest Basin Management Study, July 1990**

The first phase included an inventory of the drainage and policy recommendations. The phase 2 study addressed flooding and related problems in the Tierra Bonita/Camino Verde area and the Tucson Estates subdivision.

#### **Tortolita Basin Management Study, Nov. 1987**

The phase 1 study analyzed existing conditions along the Tortolita Fan area. Policies were developed to establish zoning conditions for rapidly expanding areas. These included channelization, preservation of spine washes, detention/retention basins, and other policies. In 1991 the second phase was completed. Watersheds impacting Tangerine Road were analyzed and the 100-year flood plains determined.

#### **Tucson Mountain Basin Management Study, March 1986**

Hydrological information was developed to manage floodplains in the Tucson Mountain foothills. Phase 1 efforts found that the channels tributary to the Santa Cruz River has sufficient capacity upstream of Silverbell Road, however most downstream channels were undersized. Development policies were recommended.

#### **Valencia Wash Basin Management Study, Sept. 1992**

Phase 1 studied existing conditions in this relatively flat area. In phase 2 structural and nonstructural alternatives were recommended to mitigate flooding along Valencia Wash between Valencia Road and Westover Avenue.

#### **Black Wash Drainage Analysis, Sept. 1990**

The purpose was to develop a floodplain management strategy to reduce flood hazards along Black Wash. An administrative floodway was established such that policies governing development in floodways could be applied. Land acquisition and an enhanced compliance program were recommended. Since the study several parcels of land have been acquired.

**Cañada del Oro River Management Plan, April 1983**

The purpose was to establish management objectives for the CDO between Catalina State Park and the Santa Cruz River confluence. A combination of structural and nonstructural policies were proposed, including acquisition, bank stabilization, floodplain rezonings and improvement financing.

**Cañada del Oro, Catalina, Arizona Flood Control Study, Nov. 1991**

The purpose was to assess the number of residents exposed to flood and erosion hazard and to estimate the costs of acquiring the floodway. Recommendations were made as to which parcels should be acquired.

**Pantano Wash River Management Plan, Dec. 1993**

This plan deals with sand and gravel mining activities and recommends alternatives for controlling the impacts of this mining on Pantano Wash.

**River Management Plan for Rillito River and Major Tributaries, March 1984**

The purpose was to establish floodplain management objectives for Rillito Creek and major tributaries. A primarily nonstructural approach was recommended. The policies were generally adhered to until May 1993 when the Board of Supervisors adopted a new policy in reaction to the 1993 flood;.

**Santa Cruz River Management Plan, April 1986**

The plan establishes floodplain management objectives for the Santa Cruz River between Martinez Hill and Avra Valley Road. Guidelines are proposed for constructing soil-cement bank stabilization, levees and grade control structures.

**Tanque Verde Creek Management Study, July 1993**

This study was undertaken in response to the 1993 flood in which severe bank erosion occurred. The study was undertaken to develop a comprehensive plan for addressing flood control needs along Tanque Verde Creek.

**PRESERVE MANAGEMENT PLANS****Bingham Creek Cienega Management Plan, 1992**

The District purchased this 300-acre parcel in 1989. According to a 25-year management agreement with the Nature Conservancy, the cienega will be maintained to "... protect, preserve, and restore riparian and aquatic habitat and other natural values." Policies for public use and scientific use are stated, and management goals are specified.

**Cienega Creek Natural Preserve Management Plan, 1994**

The Cienega Creek Natural Preserve is an approximately 4,000 acre parcel which includes a 12-mile stretch of Cienega Creek. The management plan was developed to preserve and protect the area and to provide opportunities for public recreation and education.

**BOND-FUNDED PROJECTS****Project: FC-1 -- Santa Cruz River, Grant to Ft. Lowell**

Location: Santa Cruz River, Grant Road to Fort Lowell alignment

Bond Funding: \$3,500,000

Scope: This area is subject to extensive lateral bank erosion. During the October 1983 Flood, approximately 300 feet of bank eroded; during the January 1993 Flood, up to 130 feet of bank eroded. One and-a-half (1-1/2) miles of new soil cement bank stabilization, which will fully contain the 100-year flow of the Santa Cruz River, will be constructed along both banks. This will tie into existing bank stabilization at the upstream and downstream ends. Sufficient toedown will be provided to protect the bank stabilization from failing due to channel bottom scour and three feet of freeboard above the 100-year water surface elevation will be provided to satisfy Federal Emergency Management Agency requirements.

Benefit: Properties protected include the I-10/Miracle Mile interchange; Arizona Department of Transportation (ADOT) maintenance yard; land, buildings and crops at the University of Arizona Agricultural Research Center; land owned by the City of Tucson, the Flowing Wells Irrigation District and private property owners; and a Tucson

Electric Power (TEP) transmission line, a Tucson Water mainline, two Santa Fe-Pacific petroleum pipelines, and two Southwest Gas pipelines.  
Other Funding: Matching funds from the Arizona Department of Transportation and University of Arizona will be required in the approximate amount of \$2,500,000.  
Implementation Period: 3

**Project: FC-2 -- Santa Cruz River, Valencia to Irvington**

Location: Santa Cruz River, Valencia Road to Irvington Road

Bond Funding: \$4,000,000

Scope: Although the Santa Cruz River 100-year flow is contained within the existing high banks, the earthen banks are unstable and are highly susceptible to lateral erosion during large flows. Two (2) miles of new soil cement bank stabilization will be constructed along both banks, which will tie into existing bank stabilization at the upstream and downstream ends.

Benefit: Areas to be protected from bank erosion include the Midvale Park residential and commercial subdivision along the west bank; Calle Santa Cruz along the east bank; and commercial development nodes at Irvington and Drexel Roads.

Other Funding: Matching funding from benefitting property owners in the amount of \$4,000,000 will be required.  
Implementation Period: 2, 3

**Project: FC-3 -- Lower Santa Cruz Levee, Interstate 10 to Sanders**

Location: Lower Santa Cruz River Levee, Interstate 10 (I-10) to Sanders Road

Bond Funding: \$6,000,000

Scope: Currently south of Avra Valley Road and east of the Tangerine landfill, the Santa Cruz River overtops its banks and causes extensive flooding between the Santa Cruz River and I-10, including the Town of Marana. During the 1983 flood, three people died in Marana due to flood-related accidents and residences, businesses, agricultural fields, and public transportation infrastructure suffered extensive damage. During the 1993 Floods, approach roads to two bridges in Marana, and several agricultural fields and residences were damaged. 7.36 miles of new earthen levee will be constructed along the north bank of the Santa Cruz River, and the side of the levee that faces the river will be stabilized with soil cement. The design includes protection from 100-year Santa Cruz River flooding, eight feet of toedown below the channel invert to protect the levee from being undermined by scour, and three feet of freeboard above the 100-year water surface elevation to satisfy Federal Emergency Management Agency (FEMA) requirements.

Benefit: Based on current FEMA flood hazard maps, the levee will remove approximately 4,468 acres from flood hazard or floodplain status. A significant number of homes and business will not be subject to flood hazard.

Other Funding: Matching funding in the approximate amount of \$1.9 million from benefitting properties will be required and collected. Additional funding of \$1.0 million and \$2.5 million will be provided to this project from the Arizona Department of Water Resources and the U.S. Bureau of Reclamation respectively. The remaining \$4.2 million will be funded by the Flood Control District Levy.

Implementation Period: 1, 2

**Project: FC-4 -- Mission Wash**

Location: Mission View Wash, Detention/Retention Basin

Bond Funding: \$1,000,000

Scope: Few drainage facilities exist in downstream areas, which includes portions of the City of Tucson and the City of South Tucson. Therefore, most flows are conveyed in the streets. As the streets have insufficient capacity to contain all but the smallest of flows, adjacent commercial and residential areas experience repeated flooding. This project will include design and construction of a regional detention/retention basin east of Park Avenue and south of 36th Street. Preliminary design of this new basin includes providing up to 43 acre-feet of floodwater storage, inlet structures to collect and concentrate sheet flow, and outlet works as needed to prevent adverse impacts downstream of the basin.

Benefit: The Tucson Stormwater Management Study identifies 44 existing homes that will be protected from flooding and roadway flooding would also be reduced, resulting in safer driving conditions. The detention basin could be developed for multi-purpose use, thereby providing park, recreation and open space benefits to the surrounding community.

Other Funding: \$0 Implementation Period: 2

**Project: FC-5 -- City of Tucson**

Location: Urban Drainage Improvements, City of Tucson

Bond Funding: \$2,000,000

Scope: Projects constructed will be those highest priority projects recommended in the City's Tucson Stormwater Management Study (TSMS). This study included an evaluation of drainage and flooding problems in each of the 59 watersheds that drain through the City. The most feasible solutions were recommended, consistent with goals established as part of the TSMS. Most of the highest priority projects are located in the central and south-central portions of the incorporated area. TSMS recommends preserving City watercourses in their natural state where feasible; however, some structural improvement projects are recommended to address long-standing flooding problems where residential and commercial properties have experienced repeated losses. Actual projects will be jointly selected by the Mayor and Council of the City of Tucson and the Pima County Flood Control District Board of Directors.

Benefit: The proposed improvements will either increase the flood protection provided by existing facilities, or will include new facilities that will alleviate chronic flooding problems.

Other Funding: \$0 Implementation Period: 1 through 5

**Project: FC-6 -- City of South Tucson**

Location: Urban Drainage Improvements, City of South Tucson

Bond Funding: \$900,000

Scope: Drainage improvements to be constructed include five separate projects located throughout the City of South Tucson, all located north of 36th Street and west of 6th Avenue. Two projects include covering existing concrete drainage channels and constructing new box culverts from the channel outlet to a downstream location, the first at the alley between 28th and 29th Streets at 7th Avenue, extending northwest to 28th Street and the second at the alley between 34th and 35th Streets, west of 6th Avenue, extending to 8th Avenue. A third project, at Rios Street west of 10th Avenue, includes constructing a new culvert system under Rios Street. A fourth project includes improving an existing cul-de-sac located west of 35th Street and 8th Avenue; vertical curbs will be installed, sidewalks constructed and that portion of the street repaved. The last project includes extending the existing box culvert that terminates at 8-1/2 Avenue to 9th Avenue, between 25th and 26th Streets, and backfilling over the vacant lot after the box culvert has been constructed.

Benefit: The proposed improvements will reduce chronic flooding problems in residential and commercial areas, and will make the streets safer for vehicular and pedestrian travel.

**Project: FC-7 -- Town of Sahuarita**

Location: Town of Sahuarita, Drainage Improvements

Bond Funding: \$500,000

Scope: Drainage crossings will be improved along La Cañada Drive and Camino de las Quintas, south of El Toro Road, located in the most populous parts of town. Washes draining from the west toward the Santa Cruz River on the east cross both of these roads, creating safety hazards and making them nearly impassable during summer monsoons. Five drainage crossings at each road will be improved. Pipe culverts will be constructed under both roads, and the drainageways between La Cañada Drive and the downstream Camino de las Quintas will be improved.

Benefit: These projects will improve the conveyance capacity of these drainageways, resulting in reduced flooding on these locally well-traveled roads, and making for safer driving conditions.

**Project FC-8 -- Town of Oro Valley**

Location: Town of Oro Valley, Urban Drainage Improvements

Bond Funding \$350,000

Scope: The proposed projects will address several drainage and flood control needs in the Town, some resolving long-standing drainage deficiencies in the community, others addressing problems which are the result of unprecedented growth in this area. Four areas will benefit from the proposed bond projects: 1) the Rancho Feliz subdivision, location southeast of the intersection of Lambert Lane and La Cañada Drive; 2) areas adjacent to La

Cañada Drive extending between Naranja Drive on the north and Lambert Lane on the south; 3) Lambert Lane at Pistachio Avenue; 4) Linda Vista Boulevard at Eggleston Drive.

Benefit: Improved drainage conditions for Town residents and safer driving conditions. In addition, future potential damage to major urban infrastructure in the area, including roadways, water delivery systems and electric lines, will be reduced.

**Project: FC-9 -- Green Valley Number 9**

Location: Green Valley Number 9, Drainageway Improvements

Bond Funding: \$1,000,000

Scope: Town homes along the north bank of this watercourse have long been susceptible to flooding. In the upstream reach, two new 12' x 13' cells will be added to the existing four-cell box culvert under Camino Portillo, to allow the 100-year flow to pass through the culvert. A new 160-foot long earthen dike protected by concrete will be installed on the north bank upstream of Camino Portillo, and a new 750-foot long earthen dike will be installed on the north bank upstream of the 160-foot long dike, to help keep floodwater in the main channel. In the downstream reach, plans call for excavating the channel and constructing new concrete bank stabilization along the entire 2300-foot reach. A new grade control structure will prevent erosion from undermining the bank stabilization. The excavated channel will have a 38-foot bottom width along the upper 700 feet, and a 50-foot bottom width along the lower 1600 feet.

Benefit: The threat of flooding and the erosion hazard will be reduced for residences and roadway maintenance needs near the undersized culvert will be reduced.

**Project: FC-10 -- Continental Vista**

Location: Continental Vistas, Green Valley - Drainageway Improvements

Bond Funding: \$250,000

Scope: This subdivision, located northwest of Continental Road and La Cañada Drive, is traversed by three drainageways. Bank erosion and over-bank flooding threaten residential structures, and bank erosion threatens Continental Road. Bank stabilization at four locations, and an earthen berm to contain flow, are proposed to reduce the erosion and flood hazard in this subdivision. Along the north wash, approximately 180 linear feet of placed rock rip-rap protection covering an earthen berm will divert flows away from this vulnerable area; on the opposite south bank, approximately 500 linear feet of rock rip-rap will be placed along the channel bank. Along the middle wash, approximately 150 linear feet of placed rock rip-rap or gabions are needed to reinforce the bank in this area. On the south wash, approximately 285 linear feet of stacked gabions are needed to protect this steep bank. Further downstream, an approximately 570-foot long earthen berm is needed to reduce the likelihood that dispersed flows will flood the homes.

Benefit: These improvements will protect residences in this subdivision from flooding and erosion hazards and will protect Continental Road from erosion hazards.

**Project: FC-11 -- South Tucson Fourth Avenue**

Location: Fourth Avenue Drainage Improvements, City of South Tucson

Bond Funding: \$500,000

Scope: In conjunction with planned roadway improvements to South Fourth Avenue, storm drain systems will be installed to reduce flooding in the streets and surrounding neighborhoods. Two storm drain projects are proposed: (1) construct a box culvert at 4th Avenue and 36th Street, extending northwest to 6th Avenue and 35th Street and tying into an existing storm drain system; and (2) construct a box culvert at 4th Avenue and 32nd Street, extending northwest to 6th Avenue and 29th Street.

Benefit: Both of these projects will reduce flooding in the streets and surrounding neighborhoods, and will improve the safety of vehicular travel. Construction of the storm drains in conjunction with the roadway improvements will reduce costs and lessen the disruption in the community due to construction.

**Project: FC-12 -- Fairview and Limberlost**

Location: Fairview Avenue and Limberlost Drive, Urban Drainage Improvements

Bond Funding: \$500,000

Scope: Following significant upstream development in the mid-1970's, the Fairview/Limberlost area has experienced repeated residential and roadway flooding. Approximately 1100 linear feet of new concrete-lined drainage channel

will be constructed along the east side of Fairview Avenue to collect and convey flows from Limberlost Drive to just south of Wetmore Road. The channel will have a 10-foot bottom width and variable depth. Seventy (70) linear feet of new box culvert will join the new channel to the existing box culvert underneath the Tucson Auto Mall.

Benefit: Reduced flooding of residential structures, including single family residences and manufactured homes. Travel on roadways downstream (northwest) of the intersection of Fairview and Limberlost would be made safer during rainfall events.

Other Funding: \$250,000 from private developers. Implementation Period: 3

**Project: FC-13 -- Holladay and Forrest**

Location: Holladay Street and Forrest Avenue, Drainage Improvements

Bond Funding: \$500,000

Scope: Drainage improvements are needed to eliminate repeated flooding of homes in this neighborhood, located northwest of the intersection of Mission and Drexel Roads. Due to the absence of conveyance facilities, most flow occurs over the land surface and concentrates in the streets. Proposed new improvements include constructing 1) a 2-foot high, 200-foot long berm on the south side of Canada Street at Westover Avenue; 2) a 25-foot wide, 1.5 foot deep, 700-foot long swale north of Canada Street and west of Westover Avenue, draining east to the Dakota Wash; 3) a berm along the west side of Westover Avenue north of Drexel Road; and 4) a 15-foot wide, 1.5-foot deep, and 500-foot long concrete drainage channel between Westover Avenue and Forrest Avenue. Other improvements include lowering the elevation of the intersection of Forrest Avenue and Holladay Street; and Holladay Street from Forrest Avenue to the Dakota Wash (approximately 600 feet). Holladay Street will be reconstructed as an inverted crown street, approximately 36 feet wide with 8-inch high curbs.

Benefit: Homes that are flooded during even relatively small rainfall events will be protected from the 100-year flood and safer vehicular access will be provided in this area. It should be noted an elementary school is located on Holladay Street east of Forrest Avenue.

**Project: FC-14 -- Tucson Diversion Channel**

Location: Tucson Diversion Channel, Drainage Improvements

Bond Funding: \$500,000

Scope: The proposed project is located along the Tucson Diversion Channel, which extends from Wilmot Road on the east to the channel outfall at the Santa Cruz River on the west. The Tucson Diversion Channel traverses the northern boundary of Davis Monthan Air Force Base, and extends through the City of Tucson and the City of South Tucson, intercepting flows draining from the southeast and delivering them to the Santa Cruz River. Proposed improvements to the Tucson Diversion Channel and its associated tributary drainage systems are needed to alleviate flood damage in surrounding areas.

Benefit: Improved drainage conditions and safer roadway travel for municipal and county residents in adjacent areas. In addition, potential flood damage to major urban infrastructure in the area, including several major roadway networks, the Southern Pacific Railway facilities, and the County's new Spring Training/Sports Park Development facility, will be reduced.

## PRIORITY STREAMS IN PIMA COUNTY

Prioritization of Streams for Conservation Pima County, Arizona (J. Fonseca and D. Scalero 2000, Pima County Flood Control District) prioritizes streams in each of the subareas according to their water supply and habitat value.

	Peren.	Inter.		Peren.	Inter.
<b>Subarea 1</b>			<b>Subarea 4-5</b>		
Buehmann Canyon	5.2	2.5	Santa Cruz River	6.8	15.7
Espiritu Canyon	2.2	2.4	<b>Subarea 5</b>		
Bingham Cienega	1.9	0.0	Canada del Oro	4.2	1.2
San Pedro River	1.3	10.6	Lemmon Creek	2.7	0.0
Youtcy Canyon	1.2	1.6	Wild Burro Canyon	0.7	0.0
Edgar Canyon	0.7	0.0	Palisade Canyon Creek	0.0	4.5
Bullock Canyon	0.7	3.1	Sutherland Wash	0.0	6.5
Miller Creek	0.0	4.1	<b>Subarea 6A</b>		
<b>Subarea 2</b>			Arivaca Creek	2.7	0.7
Cienega Creek (upper)	7.7	4.6	Arrieta Wash	0.0	0.0
Cienega Creek (lower)	2.7	4.8	Asolido Wash	0.0	0.0
Empire Gulch	1.4	0.0	Fresnal Wash	0.0	0.0
Wakefield Canyon	1.4	0.3	East Fork Apache Can.	0.0	0.0
Mattie Canyon	1.3	0.4	Fraguita Wash	0.0	0.0
Cinco Canyon	0.7	0.0	Las Moras Wash	0.0	0.0
Davidson Canyon	0.7	1.3	McCafferty Can.	0.0	0.0
Posta Quemada Canyon	0.3	0.0	Penitas	0.0	0.0
Nogales Spring	0.3	0.0	Pozo Hondo Wash	0.0	0.0
Little Nogales Spring	0.2	0.0	Sabino Wash	0.0	0.0
Agua Verde Creek	0.0	15.0	Brown Canyon	0.0	3.4
Gardner Canyon	0.0	0.5	Cedar Canyon	0.0	0.0
Rincon Creek	0.0	11.3	Sopori Wash	0.0	0.0
Mescal Arroyo	0.0	0.0	Thomas Canyon	0.0	3.0
Box Canyon	0.0	4.1	Saucito Wash	0.0	0.0
Chimineia Canyon	0.0	4.1	San Luis Wash	0.0	0.0
Madrona Canyon	0.0	3.4	Unnamed trib. to Arivaca Creek	0.0	0.0
<b>Subarea 3</b>			<b>Subarea 6B</b>		
Florida Canyon	0.0	3.4	Blanco Wash	0.0	0.0
Franco Wash	0.0	0.0	Cocio Wash	0.0	0.0
Madera Canyon	0.0	1.5	<b>Subarea 7</b>		
<b>Subarea 4</b>			Aguirre Wash	0.0	0.0
Sabino Canyon	15.0	3.4	<b>Subarea 8</b>		
Tanque Verde Creek	0.5	17.2	Quitobaquito	0.1	0.0
Romero Canyon	0.4	4.8			
Bear Canyon	0.0	12.3			
Agua Caliente Canyon	0.0	0.0			
Ventana Canyon	0.0	9.3			
Pantano Wash	0.0	0.0			
Rillito Creek	0.0	0.0			
Molino Canyon	0.0	5.2			

# APPENDIX D

## CITY OF TUCSON FLOODPLAIN PROJECTS AND POLICIES

### STORMWATER MASTER PLAN

The following text and tables are from the City of Tucson's 1995 Final Report: Tucson Stormwater Management Study, Phase II, Stormwater Master Plan. The entire report may be viewed on the City's web site.

#### Executive Summary

"Whenever and wherever practicable to do so, the emphasis of the recommended Stormwater Master Plan has been placed on implementing nonstructural stormwater management measures, with structural solutions proposed only for those areas where flooding was found to be a danger to human life, public health, and public safety. Table 1 of this report provides an overview of the recommended Stormwater Master Plan for the 59 watersheds which comprise the City's stormwater system. Nonstructural stormwater management is recommended within 33 of these 59 watersheds. The 33 watersheds constitute 55% of the total area under investigation. For the remaining 45% of the total area where either combination or structural approaches are recommended, structural solutions are proposed at various individual locations throughout the 26 watersheds.

"A wide variety of nonstructural, structural, and combination stormwater management alternatives have been formulated to address the stormwater needs for the 59 TSMS watersheds. Several stormwater management alternatives were formulated for each watershed to assure a comprehensive, watershed-wide approach for the management of the stormwater system. These stormwater management alternatives were first presented in the TSMS, Phase II, Task 8 document titled "Watershed-Specific Alternatives Formulation Report".

"The stormwater management alternatives were further refined for each watershed, and then analyzed and evaluated according to pre-determined social, environmental, economic, and technical factors. Based on the results of the analysis and evaluation process, a recommended stormwater management alternative was selected for each of the 59 TSMS watersheds. The results of the analysis and evaluation process, along with a recommended stormwater management alternative for each of the 59 TSMS watersheds, are presented in the TSMS, Phase II, Task 9 report titled "Watershed-Specific Alternatives Analysis and Evaluation Report".

"The recommended stormwater management alternative for each of the 59 TSMS watersheds forms the foundation for the recommended Stormwater Master Plan. The 59 watershed-specific stormwater management alternatives have certain common elements which can be grouped into five major categories of both nonstructural and structural stormwater management measures:

- (1) Preservation of Naturally Vegetated Watercourses (nonstructural);
- (2) Flood Hazard Studies (nonstructural);
- (3) Stormwater Quality Investigations (nonstructural);
- (4) Stormwater Capital Improvement Projects (structural); and
- (5) Miscellaneous Capital Projects (structural).

These major categories were compiled for the purpose of

- (1) identifying the relative significance of each component;
- (2) identifying the overall effects and potential impacts; and
- (3) assessing the implementation of each component; all on a City-wide basis. Since it may not be possible to implement all elements immediately, prioritization schemes for each of the five major categories were developed.

Selected tables from the report follow.

**TABLE 1. SUMMARY OF WATERSHED-SPECIFIC STORMWATER MANAGEMENT APPROACHES FOR CITY-WIDE STORMWATER MASTER PLAN**

	Number of Watersheds	Percent of Total Area
<b>TSMS Study Area</b>	59	100
<b>Nonstructural Approach</b>	33	55
<b>Structural Approach</b>	10	8
<b>Combined Structural-Non-Structural</b>	16	37

**TABLE 3. RIPARIAN HABITAT ALONG NATURALLY VEGETATED WATERCOURSES RECOMMENDED FOR PRESERVATION, WITH POTENTIAL DISTURBED AREAS**

**Riparian Habitat, by Class BL, BI, and BH**

Hydrologic Unit	Length (feet)			Total	Area (acres)			Total
	BL	BI	BH		BL	BI	BH	
Airport/Julian								
Preserved	18,453	22,877	2,110	43,440	41.8	47.6	5.2	94.6
Disturbed		2,100		2,100		2.9		2.9
Alamo/Christmas								
Preserved	11,320	16,710		28,030	10.8	18.3		29.1
Disturbed		2,000		2,000		1.1		1.1
Atturbury/Rose Hill								
Preserved	35,160	83,060	9,300	127,520	58.5	156.9	23.7	239.1
Disturbed								
Este/Hidden Hills								
Preserved	2,000	83,340	1,600	86,940	2.2	81.7	2.1	86.0
Disturbed		3,900		3,900		4.5		4.5
F. Wells/Tucson Arroyo								
Preserved	11,460	18,630	7,480	37,570	14.2	18.0	4.8	37.0
Disturbed	700			700	1.6			1.6
Silvercroft/West Branch								
Preserved	1,078	70,862	10,054	81,994	0.8	72.5	10.8	84.1
Disturbed								
<b>TOTALS</b>								
Preserved	<b>79,471</b>	<b>295,479</b>	<b>30,544</b>	<b>405,494</b>	<b>128.3</b>	<b>395.0</b>	<b>46.6</b>	<b>569.9</b>
Disturbed	<b>700</b>	<b>8,000</b>		<b>8,700</b>	<b>1.6</b>	<b>8.5</b>		<b>10.1</b>

BL = Xeroriparian, Low; BI = Xeroriparian, Intermediate; BH = Xeroriparian, High

**TABLE 4. PRIORITIZED LIST OF NATURALLY VEGETATED WATERCOURSES RECOMMENDED FOR PRESERVATION**

Name	Total Length	Vegetated Length	Name	Total Length	Vegetated Length
1 Atturbury Wash	51,540	45,960	35 Tucson Arroyo	12,200	5,100
2 Civano Wash	32,450	32,360	36 Mission View Wash	8,890	2,340
3 Anklam Wash	20,478	19,478	37 Lower Arroyo Chico	9,180	4,540
4 W. Branch Santa Cruz	15,496	12,776	38 Julian Wash Watershed, T1	7,000	2,400
5 Atturbury Wash Watershed, T2	7,800	7,800	39 Wrightstown Wash	10,630	2,700
6 Atterbury Wash Watershed, T1	10,200	10,200	40 Christopher City Wash	3,120	3,120
7 Rodeo Wash Watershed, T1	3,800	3,450	41 Mesquite Ranch Wash	5,500	2,500
8 Robb Wash	22,800	16,900	42 Julian Wash Watershed, T3	5,330	1,470
9 Kinnison Wash Watershed, T1	19,340	11,100	43 Este Wash Watershed, T3	2,280	2,280
10 Hidden Hills Wash	21,482	13,410	44 Cholla Wash	10,764	3,304
11 Enchanted Hills Wash	21,146	16,106	45 18th St Wash	7,400	1,950
12 Reyes Wash Watershed, S	110,660	10,660	46 Railroad Wash	9,760	5,320
13 Este Wash	14,535	8,510	47 Julian Wash Watershed, T4	3,560	900
14 Coronado Ridge Wash	11,400	9,480	48 W. Speedway Wash	10,930	2,000
15 Rodeo Wash Watershed, T2	4,130	4,130	49 Airport Wash Watershed, T1	6,300	1,500
16 Alamo Wash	39,240	12,690	50 Christmas Wash	9,220	2,000
17 Silvercroft Wash	23,952	8,160	51 Ajo Wash	10,140	2,700
18 Arcadia Wash	24,980	8,900	52 Rose Hill Wash	17,165	3,150
19 Reyes Wash Watershed, S2	8,990	8,990	53 Rolling Hills Wash	10,000	1,600
20 Earp Wash	6,210	3,020	54 Wyoming Wash Watershed, S2	5,340	2,050
21 Valencia Wash	12,020	4,140	55 Santa Clara Wash	4,750	250
22 High School Wash	10,625	7,480	56 Julian Wash Watershed, T8	5,540	900
23 Greasewood Wash	13,310	7,410	58 El Rio Wash	10,970	1,000
24 Atturbury Wash Watershed, T	35,400	4,000	59 Reyes Wash Watershed, S3	1,080	1,080
25 Farhinger Wash	7,450	5,900	60 Kinnison Wash	18,680	1,250
26 16th St Wash	4,750	2,700	61 Wrightstown Wash Watershed, T1	3,380	800
27 Julian Wash	8,050	6,230	62 Irvington Wash	1,850	1,850
28 San Juan Wash	10,260	9,060	63 Julian Wash Watershed, T2	700	700
29 Civano Wash Watershed, T1	4,950	4,950	64 Bronx Wash	5,620	2,300
30 Julian Wash Watershed, T9	5,370	5,370	65 Kinnison Wash Watershed, T3	5,750	2,100
31 Greyhound Wash	14,490	4,540	66 Nebraska Wash	13,060	1,040
32 Rodeo Wash Watershed, T5	6,720	1,340	67 Este Wash Watershed, T1	670	670
33 Old Julian Wash	3,000	4,000	68 Escalante Wash	550	550
34 Este Wash Watershed, T2	6,780	4,860	69 Camino Seco Wash1	1,036	700
			70 Alamo Wash Watershed, T9	6,900	1,320

T1, T2, etc. refers to numbered tributaries of the named watercourse.

**TABLE 6. PRIORITIZATION OF PROPOSED FLOOD HAZARD STUDIES**

<b>Watercourse</b>	<b>Estimated Study Cost</b>	<b>Priority</b>	<b>Watercourse Name</b>	<b>Estimated Study Cost</b>	<b>Priority</b>
"A" Mountain/Menlo Park	\$71,000	1	Enchanted Hills Wash	\$64,000	15
Alvernon Wash	\$16,000	2	Cholla Wash	\$43,000	16
High School Wash	\$46,000	3	Kinnison Wash	\$189,000	17
Bronx Wash	\$4,000	4	Anklam Wash	\$56,000	18
West Branch SCR	\$62,000	5	Railroad Wash	\$15,000	19
Alamo Wash	\$39,000	6	Greasewood Wash	\$20,000	20
Arroyo Chico	\$34,000	7	W. Speedway Wash	\$6,000	21
Arcadia Wash	\$20,000	9	18th St. Wash	\$14,000	22
Ajo Wash	\$11,000	10			
Lower Silvercroft Wash	\$44,000	11			
Creekside Wash	\$12,000	12			
San Juan Wash	\$41,000	13			
Tucson Arroyo	\$495,000	14			

\* "A" Mountain/Menlo Park includes Upper Silvercroft Wash, Sentinel Peak Wash, and El Rio Wash, in the area bordered by Anklam Rd./Fresno St. on the south, and Speedway Blvd. on the north.  
 \*\* Lower Silvercroft Wash extends from Speedway Blvd. to the Santa Cruz River.

**TABLE 9. SIX 5-YEAR CITY OF TUCSON STORMWATER  
CAPITAL IMPROVEMENT PROGRAMS (PRELIMINARY)**

**Program #1 = \$10,037,000**

Arroyo Chico (CW)	OC/C, STR
18th Street Wash (CL)	DET/RET
El Vado Wash (AG)	OC/SC, CBC
Wilson Wash (DG)	SD
Navajo Wash (DG)	SD

**Program #2 = \$6,907,000**

Arroyo Chico (CW)	OC/V, STR
Mission View Wash (CC)	DET/RET
Citation Wash (CW)	OC/C, CBC
Naylor Wash (CW)	OC/C
Santa Clara Wash (AH)	OC/CC, CBC
Alamo Wash (GC)	SD
Fahringer Wash (MN)	STR

**Program #3 = \$8,825,000**

Nebraska Wash (AW)	SD
Railroad Wash (CW)	OC/E
Tucson Gen Wash (GM)	DET/RET
High School Wash (CW)	Replace CLVT
Airport Wash (AW)	OC/CC, CBC
Alamo Wash (GC)	CBC (7)

**Program #4 = \$9,171,000**

Naylor Wash (CW)	OC/C, CBC
Citation Wash (CW)	OC/C, CBC
Christmas Wash (GL)	OC/V, CBC(3)
Cemetery Wash (DG)	SD
West University (DA)	SD
North Mountain Ave (GQ)	SD
High School Wash (CW)	Modify CLVT
Hidden Hills Wash (MR)	OC/C
Rolling Hills Wash (UC)	OC/C, CBC

**Program #5 = \$9,951,000**

Rodeo Wash (BR)	CBC (4)
Krueger Wash (DF)	OC/E, CBC
Christmas Wash (GL)	OC/SC
Christmas Wash (GL)	SD
El Vado Wash (AG)	SD, STR
North Mountain Ave (GQ)	OC/SC, CBC
Fahringer Wash (MN)	OC/G-R

**Program #6 = \$11,197,000**

Silverlake Wash (CW)	OC/C, CBC
Wetmore Wash (HR)	SD
Bronx Wash (DC)	OC/C
First Avenue Wash (GR)	SD
El Vado Wash (AG)	SD
Swan Park Wash (CW)	OC/C, CBC
Robb Wash (MW)	OC/C, OC/G
Stone Avenue Wash (HG)	SD
High School Wash (CW)	SD
Flowing Wells Wash(DG)	CBC
Valencia Wash (AL)	SD
Valencia Wash (AL)	SD
Racetrack Wash (GW)	OC/SC

**Total cost of all six programs = \$56,088,000**

Project Abbreviations:

**OC/SC**  
Open Channel with Soil Cement Bank Protection

**OC/V-E**  
Open Channel with Vegetative or Earthen Banks

**OC/C**  
Open Channel with Concrete Lining

**OC/G-R**  
Open Channel with Gabion or Riprap Banks

**OC/CC**  
Open Channel, Compound  
(low-flow bank protection)

**HDLU**  
Structures in high density land use categories

**SD**  
Storm Drain

**CBC**  
Concrete Box Culvert

**STR**  
Street Improvements

**DET/RET**  
Detention/Retention Facilities

**CLVT**  
Culverts



# **APPENDIX E**

## **RIPARIAN-RELATED HERITAGE FUND AND WATER PROTECTION FUND PROJECTS IN PIMA COUNTY**

### **Arizona Game and Fish Heritage Fund**

1. Pima County Flood Control District project to develop a management plan for the Cienega Creek Preserve.
2. BLM project to develop a low-water crossing of a tributary to Cienega Creek in the Empire Cienega Conservation Area
3. University of Arizona study of ways to incorporate wildlife into Tucson's river parkways.
4. City of Tucson project to design a project to utilize wastewater for wildlife habitat.
5. University of Arizona project to inventory riparian habitat along Rincon Creek
6. University of Arizona project to develop an outdoor classroom about using native vegetation for landscaping, including a mesquite bosque.
7. City of Tucson project to develop a wetlands on Atturbury Wash.
8. Pima County Flood Control District project to study feasibility of the development of shore bird habitat along Arroyo Chico.
9. University of Arizona project to investigate the diversity of species in the City of Tucson's Sweetwater Wetland.
10. University of Arizona project to inventory habitat along Rincon Creek.
11. City of Tucson project to design a habitat link from the Santa Cruz River to Silverbell Lake.

Source: Arizona Game and Fish Department, Funds/Planning Branch

### **Water Protection Fund**

1. U.S. Forest Service project to enhance habitat along the intermittent stream in Madera Canyon.
2. U.S. Forest Service project to stabilize ephemeral Oak Tree Gully in the Sonoita area.
3. Pima County Flood Control District project for restoration of Bingham Cienega along the San Pedro River near Redington.
4. City of Tucson project for enhancement of habit along Atturbury Wash.
5. BLM project to revegetate and restore habitat along Cienega Creek
6. San Xavier Indian Community project to do riparian restoration along the Santa Cruz River and ephemeral tributaries.
7. Hidden Valley Homeowner's Association project to analyze streamflow data along Sabino Creek in preparation for an instream flow permit application.
8. Arizona Geological Survey project to refine the geologic model of the Lower Cienega Basin to better determine the impacts of groundwater pumping on streamflow.
9. U.S. Fish and Wildlife Service project to Rehabilitate the ephemeral Puertocito Wash on the Buenos Aires National Wildlife Refuge.
10. U.S. Forest Service project to improve the riparian habitat along Paige Creek in Happy Valley (east of the Rincon Mountains), including instream flow control structure, fencing., and barriers to vehicle access.
11. Pima County Flood Control project to integrate riparian protection and enhancement with operation of a groundwater recharge facility utilizing treated wastewater along the Lower Santa Cruz River
12. Rincon Institute, Partnership for Riparian Conservation in Northeastern Pima County (PROPIMA) project to design and implement landowner-based strategies for protecting healthy riparian ecosystems from urbanization pressures in the Tanque Verde Creek and Rincon Creek watersheds.

Source: Water Protection Fund web site: [www.adwr1.state.az.us/awpf](http://www.adwr1.state.az.us/awpf)

# APPENDIX F

## LAND CLASSIFICATION IN INCORPORATED AND UNINCORPORATED PIMA COUNTY

### PERCENT LAND USE IN THE CITY OF TUCSON, 1990

<b>Developed Land</b>	
Residential	
Suburban Ranch	0.40
Single Family	20.44
Multiple Family	5.02
Mobile Home	1.54
Residential Total	27.40
Commercial	5.20
Industrial	3.67
Military and Reservation	10.76
Streets, Medians, and Alleys	9.88
Public*	4.00
Open Space**	3.59
Agriculture	0.93
Developed Land Total	65.44
<b>Undeveloped Land</b>	
Drainageways, Washes, & Riverbeds	3.01
Vacant Land	31.55
Undeveloped Land Total	34.56

\* Includes government property, miscellaneous public institutions and public use areas.

\*\* Includes natural areas and preserves, parks, and cemeteries.

Source: City of Tucson, Tucson, The People and the Place, Highlights from the 1990 Land Use Survey, July 1993.

### PERCENT LAND USE IN UNINCORPORATED EASTERN PIMA COUNTY, 1990 \*

<b>Developed Land</b>	
Residential	
<1 ac	6.85
1-3	3.25
3-6	0.88
6-10	0.28
10-24	0.12
>24	<0.01
Commercial/Office	0.21
Industrial	0.36
Mining	2.74
Institutional	0.77
Agricultural	
Active	3.07
Abandoned	3.31
Residential	0.01
Parks	2.76
Golf Courses	0.22
Transportation	0.97
Central Arizona Project	0.17
Undeveloped Land	
Public Preserves	3.06
Open Space (Rivers)	2.49
Vacant	68.45

\* Excluding all public lands. Includes State Trust lands. Source: Pima County Development Services Department, Planning Division.

# APPENDIX G

## REFERENCES AND

### SOURCES OF ADDITIONAL INFORMATION

Many of the general references listed for Chapters 2 and 3 were also used in the subarea chapters and are not listed separately again for those chapters. All references to federal, state and local laws and ordinances are listed in Appendices C and D and not repeated here.

#### **Chapter 2 Overview of Watersheds and Watercourses**

Anon. 1984. Drainage and Channel Design Standards for Local Drainage. Pima County Flood Control District. Tucson.

Anon. 2000. GIS Coverage of Perennial Streams and Areas of Shallow Groundwater. Final Project Report. Pima Association of Governments. Tucson.

Bull, William B. 1999. Discontinuous Ephemeral Streams. Unpublished. Geosciences Dept. University of Arizona.

Committee on Alluvial Fan Flooding. 1996. Alluvial Fan Flooding. National Research Council. National Academy Press. Washington D.C.

Graf, W. L. 1988. Science, engineering, and the law on western sunbelt rivers. Journal of Soil and Water Conservation.

Grimm, N.B.. 1992. Biogeochemistry of Nitrogen in Sonoran Desert Streams. Journal of the Arizona-Nevada Academy of Sciences 26: 139-155.

Hendricks, David M., et al, 1985. "Arizona Soils", College of Agriculture, University of Arizona National Weather Service, Tucson Web Site, <http://nimbo.wrh.noaa.gov/Tucson/climate/tus.html>

Plummer, Charles. C. and McGeary, David. 1979. Physical Geology. W.M. Brown Pub. Dubuque.

Tellman, Barbara, Yarde, Richard, and Wallace, Mary. 1998. Arizona's Changing Rivers: How People Have Affected the Rivers. Water Resources Research Center. University of Arizona. Tucson.

U.S. Forest Service, Coronado National Forest web site: [www.fs.fed.us/r3/coronado](http://www.fs.fed.us/r3/coronado)

U.S. Geological Survey. 1960. Manual of Hydrology. Water Supply Paper 1541-A and B. U.S. Government Printing Office. Washington D.C.

Webb, Robert H. and Betancourt, Julio L. 1992. "Climatic Variability and Flood Frequency of the Santa Cruz River, Pima County, Arizona", U.S. Geological Survey Water Supply Paper 2379.

#### **Chapter 3 Land Use and Watercourses**

##### *Flood Management*

Anon. 1997. Pima County Flood Control District Comprehensive Program Report FY 1990-91 to FY 1995-96.

Pima County Flood Control District web site: [www.dot.co.pima.az.us/flood/](http://www.dot.co.pima.az.us/flood/)

Tellman, Barbara. 1980. Flood and erosion hazards in the Tucson Area. Southwest Environmental Service. Tucson

##### *Land Use*

Anon. Pima County Comprehensive Plan. Rev. 1996. Tucson.

Anon. 1994. Integrating Land Use Planning and Water Quality Planning - A Guide for Planners and Local Officials Pima Association of Governments

Anon. 2000. Impact of Unregulated Development at the Community and Watershed Level. Pima County.

Anon. 1999. Biological Opinion On-going and Long-term Grazing on the Coronado National Forest. Arizona. Ecological Services Field Office US Fish and Wildlife Service. AESO/SE 2-21-98-F-399 July 29, 1999.

Connolly, Neva, Julia Fonseca, and John Regan. 2000. Land Stewardship in Pima County. Sonoran Desert Conservation Plan. Pima County.

Behlau, Frank, Matty, P., Veomett, J., and Bruwinski, K. 2000. History of Land Use in Eastern Pima County. Sonoran Desert Conservation Plan. Pima County.

U.S. Bureau of Land Management web site: [www.blm.gov](http://www.blm.gov)

U.S. Forest Service web site: [www.fs.fed.us](http://www.fs.fed.us)  
U.S. Forest Service web site: [www.fs.fed.us](http://www.fs.fed.us)

#### *Landfills*

- Anon. 1993. Environmental Assessment of Ten City-Operated Landfills, Tucson, Arizona Pima Association of Governments.
- Anon. 1995. Landfills and Waste Disposal Sites along the Lower Santa Cruz River Pima Association of Governments.
- Anon. 1995. Landfills along the Santa Cruz River in Tucson and Avra Valley, Arizona Pima Association of Governments.
- Anon. 1996. Identified Public Landfills (Excluding State and Federal Facilities) and Permanent Transfer Stations in Eastern Pima County and Ajo - Draft Pima Association of Governments.

#### *Stormwater*

- Anon. 1980. The Impact of Urban Runoff: Assessment of the Potential for Groundwater Pollution as a Result of Urban Runoff in the Tucson Area. Pima Association of Governments.

#### *Wastewater and Water Quality*

- Anon. 1978. Areawide Wastewater Management Plan. Pima Association of Governments.
- Anon. 1985. Areawide Wastewater Management Plan Point Source Update Pima Association of Governments
- Anon. 1989. Santa Cruz River, west Tucson Metropolitan Tucson Basin Water Quality and Pollution Source Assessment Pima Association of Governments.
- Anon. 1991 and 1994. City of Tucson Sweetwater Underground Storage and Recovery Facility. Tucson Water.
- Anon. 1993. An Assessment of Impacts from Septic Systems on Groundwater Quality in Hydrogeologically Sensitive Areas within the Tucson Basin Pima Association of Governments.
- Anon. 1996. Water Quality Assessment for the Tucson Active Management Area Northwest Replenishment Program Feasibility Study Pima Association of Governments.
- Dames and Moore. 1997. TARP In-channel Recharge Pilot Project Proposal. Prepared for Tucson Water.
- Malcolm Pirnie. 1995. Regional Effluent Utilization Plan. Multiple volumes. Prepared for Tucson Water.

#### *Water Resources and Riparian Areas*

- Anon. 1986. Santa Cruz River Alignment Recharge Study Pima Association of Governments.
- Anon. 2000. GIS Coverage of Perennial Streams and Areas of Shallow Groundwater. Final Project Report. Pima Association of Governments. Tucson.
- Anon. 1999. Water Resources and the Sonoran Desert Conservation Plan. Pima County.
- Anon. 1999. Focus on Riparian Areas. Sonoran Desert Conservation Plan Update. Pima County.
- Central Arizona Project web site: [www.cap-az.com](http://www.cap-az.com)
- CH<sup>2</sup>M Hill, Errol Montgomery & Associates and Wilson, L.G. 1998. Tucson Recharge Feasibility Assessment. Multiple volumes. Prepared for Tucson Water.
- Gelt, Joe, Henderson, J., Seasholes, K., Tellman, B. and Woodard, G. 1999. Water in the Tucson Area: Seeking Sustainability. Water Resources Research Center. University of Arizona. Tucson.
- Shafroth, Patrick, Tellman, B., and Briggs, M. 1999. Riparian Ecosystem Restoration in the Gila River Basin: Opportunities and Constraints. Water Resources Research Center. University of Arizona. Tucson.
- Tellman, Barbara. 1992. Arizona's Effluent Dominated Areas: Issues and Opportunities. Water Resources Research Center. University of Arizona. Tucson.
- Tellman, Barbara, Yarde, R. and Wallace, M. 1997. Arizona's Changing Rivers: How People Have Affected the Rivers. Water Resources Research Center. University of Arizona. Tucson.
- Wilson, L.G.

#### *Miscellaneous*

- Anon. 1999. Background information on the Central Arizona Project and Nonnative Aquatic Species in the Santa Cruz River Basin. U.S. Fish and Wildlife Service. Tucson.

Anon. 1999. Draft Biological Opinion on Impacts of the Central Arizona Project (CAP) to Gila Topminnow in the Santa Cruz River Basin through Introduction and Spread of Nonnative Aquatic Species.

Arizona Department of Economic Security web site: [www.de.state.az.us](http://www.de.state.az.us) (population statistics)

Arizona Department of Environmental Quality web site: [www.adeq.state.az.us](http://www.adeq.state.az.us)

Arizona Department of Water Resources web site: [www.adwr.state.az.us](http://www.adwr.state.az.us)

Langer, William and V.M. Glanzman. 1993. Natural Aggregate: Building America's Future. USGS Public Issues in Earth Science. Circular 1110. Washington DC.

Arizona Mining Association web site: [www.az.cu.org](http://www.az.cu.org)

Slaff, Steven. 1993. Land Subsidence and Earth Fissures in Arizona. Arizona Geological Survey. Tucson.

Tucson Electric Power web site: [www.tucsonelectric.com](http://www.tucsonelectric.com)

#### **Chapter 4 Middle San Pedro**

Harris, David. 2000. Resources of the Middle San Pedro Subarea. Arizona Nature Conservancy. Tucson.

#### **Chapter 5 Cienega-Rincon**

Anon. 1999. Cienega Creek Watershed: Proposed National Conservation Area Assessment. Sonoran Institute. Tucson.

Anon. Cienega Creek Management Plan. Pima County Flood Control District

Anon. Unique Waters Final Nomination Report for Cienega Creek Natural Preserve, Pima County, Arizona Pima Association of Governments November 1990

Briggs, Mark, Mary K. Schmid, and William Halvorson. 1997. Monitoring Riparian Ecosystems: an Inventory of Riparian Habitat along Rincon Creek near Tucson, Arizona. Usgs Cooperative Park Studies Unit. Technical Report 58. Tucson Az

The Friends of Cienega Creek Natural Preserve web site: <http://www.webofgibraltar.com/cienega/>

Fuller, Jonathan E. 1989, Pantano Wash River Management Plan Sediment Transport Analysis, Pima County Flood Control District

Gimblett, Randy. Monitoring Riparian Ecosystems: An Inventory of Riparian Habitat Along Rincon Creek, Near Tucson, Arizona web site: <http://srnr.arizona.edu/~gimblett/rinproj.html> 2000.

Saguaro National Park web site: [www.nps.gov/sagu/](http://www.nps.gov/sagu/)

U.S. Bureau of Land Management Empire-Cienega web site: [www.az.blm.gov:80/tfo/e-cinfo.html](http://www.az.blm.gov:80/tfo/e-cinfo.html)

Vail School District web site: <http://www.vail.k12.az.us/>

#### **Chapter 6 Upper Santa Cruz**

Anon. 1989. Final Environmental Impact Statement. San Xavier Development Project. A Feature of the Southern Arizona Water Rights Settlement Act. Boulder City.

Anon. Landfills and Waste Disposal Sites along the Upper Santa Cruz River Pima Association of Governments February 1995

Anon. An Assessment of Groundwater Quality near the Sahuarita Landfills, Sahuarita, Arizona - Phase II Report. Pima Association of Governments May 1993

Anon. Region Wide Groundwater Quality in the Upper Santa Cruz Basin Mines Task Force Pima Association of Governments September 1983

Condes de la Torre, Alberto, 1970, Streamflow in the Upper Santa Cruz River Basin, Santa Cruz and Pima Counties, Arizona: U.S. Geological Survey Water-Supply Paper 1939-A, 26p.

DeGroot and Fuller. 1988. Hydrologic Investigation for the Lee Moore Wash Watershed" Prepared for Pima County Flood Control District.

Green Valley web site: [www.greenvalleyarizona.com](http://www.greenvalleyarizona.com)

Medina, Alvin L. 1996. The Santa Rita Experimental Range: History and Annotated Bibliography (1903-1988). General Technical Report RM-GTR-276. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station. 67 pp.

Parker, J.T.C., 1995c, Channel change on the Santa Cruz River, Pima County, Arizona, 1936-86: U.S. Geological Survey Water-Supply Paper 2429, 58 p.

Sahuarita web site: <http://www.azplansite.com/city/index.htm?sahuarit>

Halpenny, L. Water Development Company

ASARCO web site: [www.asarco.com](http://www.asarco.com)

### **Chapter 7 Middle Santa Cruz**

City of Tucson stormwater web site: [www.ci.tucson.az.us/transport](http://www.ci.tucson.az.us/transport)

Lazaroff, David Wentworth, 1993. Sabino Canyon : the life of a southwestern oasis. University of Arizona Press. Tucson.

Sabino Canyon web site: <http://dizzy.library.arizona.edu/images/sabino>

Simons, Li, & Associates. 1995. Final Report. Tucson Stormwater management Study, Phase II, Stormwater Master Plan. Tucson.

### **Chapter 8 Tortolita Fan**

Anon. 1996. Tortolita Drainage Area Arizona. Reconnaissance Study. U.S. Army Corps of Engineers. Phoenix.

Arizona-Sonora Desert Museum. 2000. Desert Ironwood Primer. SDCP Report

Catalina State Park web site: [www.pr.state.az.us/park.html/catalina.html](http://www.pr.state.az.us/park.html/catalina.html)

Dove Mountain web site:

Saddlebrooke web site: [www.robson.com](http://www.robson.com)

Marana web site: [www.marana.com](http://www.marana.com)

Oro Valley web site: [www.ci.oro-valley.az.us](http://www.ci.oro-valley.az.us)

Phillips, Ann. 2000. North Simpson Farm Journal, January 2000. IN Vermillion Flycatcher. Vol. 44:4 (25).

### **Chapter 9 Altar Valley**

Anon. 1992. Brawley Wash Natural Resource Restoration Plan. Soil Conservation Service. Tucson

Arivaca Water Education Taskforce. 2000. Arivaca Resources Pima County Sonoran Desert Conservation Plan. Tucson.

USFWS Buenos Aires web site: [www.southwest.fws.gov/refuges/arizona/buenos](http://www.southwest.fws.gov/refuges/arizona/buenos)

### **Chapter 10 Avra Valley**

ASARCO web site: [www.ASARCO.com](http://www.ASARCO.com)

Malcolm Pirnie. 198. Central Avra Valley Storage and Recovery Project. Multiple volumes. Prepared for Tucson Water.

Marana web site: [www.marana.com](http://www.marana.com)

### **Chapter 11 Western Pima County**

Ajo web site: [www.ajoinaz.com](http://www.ajoinaz.com)

ASARCO web site: [www.ASARCO.com](http://www.ASARCO.com)

Cabeza Prieta National Wildlife Refuge web site: [www.fws.gov](http://www.fws.gov)

Organ Pipe National Monument web site: [www.nps.gov/orpi/](http://www.nps.gov/orpi/)