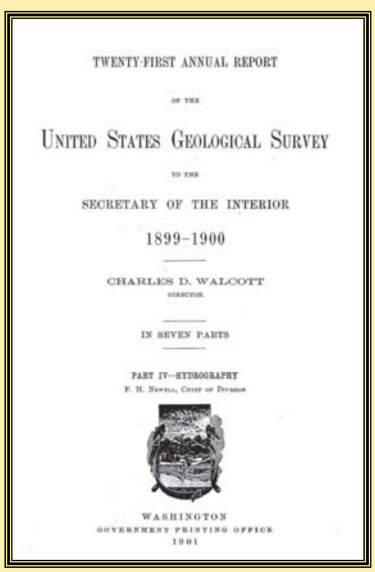
**APPENDIX**
for ANSAC report
NAVIGABILITY ALONG THE NATURAL CHANNEL OF THE
SAN PEDRO RIVER, AZ
From Mexico to mouth at the
Gila River at Winkleman, AZ

By Win Hjalmarson, PE
for ACLPI


**ANSAC**
May 2013

Note: program must be manually advanced


TWENTY-FIRST ANNUAL REPORT

OF THE

UNITED STATES GEOLOGICAL SURVEY

TO THE

SECRETARY OF THE INTERIOR

1899–1900

CHARLES D. WALCOTT
DIRECTOR

IN SEVEN PARTS

PART IV—HYDROGRAPHY
F. H. NEWELL, CHIEF OF DIVISION

WASHINGTON
GOVERNMENT PRINTING OFFICE
1901

Historic diversions and other conditions.

(Next 10 slides)

SAN PEDRO RIVER.

This stream rises in Sonora, Mexico, crossing the national boundary into Cochise County, Arizona. Thence it flows in a northerly direction, entering Gila River at Dudleyville, 50 miles above Florence, Arizona. The drainage area in Mexico, as determined from existing maps, is 120 square miles. The total area drained at its mouth is 3,456 square miles. The basin is a long and narrow one, bordered by mountains with an elevation of from 5,000 to 6,000 feet. The river receives



its principal supply from the rainfall in the headwater canyons. The period of greatest precipitation is in the months of July and August, when floods of considerable size come down San Pedro River. During the rest of the year the stream is small, winding back and forth in its sandy bed.

The valley of this river is comparatively wide and is occupied by ranches. In its upper half the chief industry is stock raising and the principal crop raised is alfalfa. Lower down, however, more diversified farming is practiced. Beginning about 12 miles south of the railroad and going upstream, most of the valley lands are included in two Spanish claims. The title to the lower claim has been in litigation for a long period, and the land has been taken up by a number of settlers. A very recent decision, however, confirms the original land grant, and, as a consequence, it is the property of a few individuals. It is reported that the small ranchers who were so unfortunate as to locate within its boundaries are now abandoning their homes and moving elsewhere.

The following is a list of the canals in San Pedro Valley, furnished by Mr. T. E. Farish in 1889:

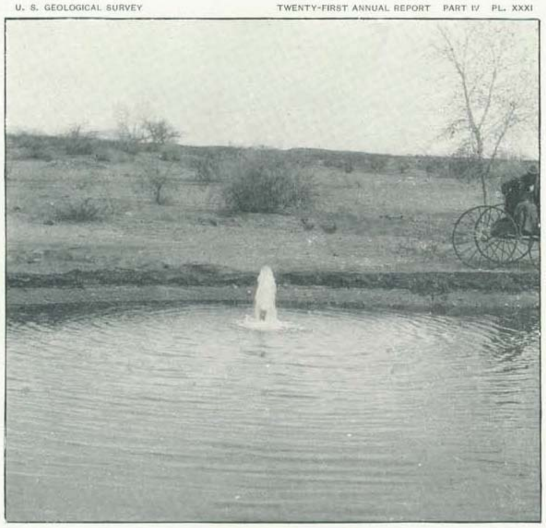
*Canals in San Pedro Valley, Arizona.*

| Canal. | Length. | Area covered. | Canal. | Length. | Area covered. |
|---|---|---|---|---|---|
| | *Miles.* | *Acres.* | | *Miles.* | *Acres.* |
| Brown | 1¼ | 160 | Watterman No. 2 | 1½ | 320 |
| Cook | 1½ | 200 | Watterman No. 1 | 1½ | 320 |
| Dodson | 2 | 320 | Swingle | 2 | 480 |
| Push | 2 | 640 | Harrington | 1¾ | 480 |
| Bates | 1½ | 160 | Lattin | 1 | 80 |

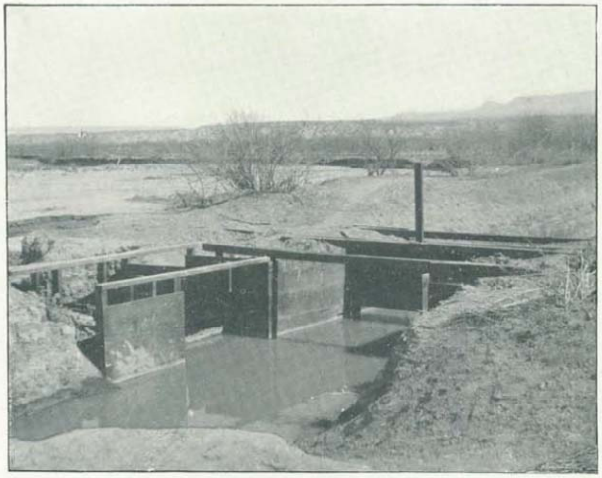
In the lower portion of its course the river is in places dry, owing to the diversions made by a large number of small canals. In addition to the main stream there are in the mountains, at the outlets of various canyons, a number of small springs whose waters have been used for agricultural purposes and which are of considerable value to the owners; but these do not form a notable feature in the water supply of the district. The total area upon which crops were raised in this district during the census year 1890, was 2,672 acres, or nearly 4.2 square miles, being 0.15 per cent of the area of the entire basin.

The Mormon settlement of St. David, from 4 to 8 miles above Benson, Arizona, is interesting on account of the artesian wells that have been sunk there. The total number of wells is 55. Of these, 9 occur in sections 33, 34, and 35, township 17 S., range 21 E. The remainder occur in townships immediately south, in sections 3, 4, 5, 8, 9, 10,

U. S. GEOLOGICAL SURVEY TWENTY-FIRST ANNUAL REPORT PART IV PL. XXXI



*A.* ARTESIAN WELL NEAR ST. DAVID, ARIZONA.



*B.* HEAD GATE OF SAN PEDRO DITCH, ARIZONA.

NEWELL.] COLORADO RIVER DRAINAGE. 353

15, and 16. They vary in depth from 150 to 450 feet, the average being 350 feet. The two largest wells are located in township 18 S., range 21 E., and have a depth of 275 feet and 450 feet, respectively. The former is located in the northeast quarter of section 5 and the latter in the northwest quarter of the northeast quarter of section 16 and within a half mile of Old St. David. They each discharge 85 gallons per minute from a 2-inch pipe. The average flow of the other wells is 40 gallons per minute. The formations passed through are, first, soil and gravel to a depth of from 50 to 150 feet, and then a very impervious red clay, with a thickness of 75 to 150 feet, which evidently forms the impervious strata over the water-bearing gravel immediately beneath. This red clay does not have to be cased. The water obtained is excellent for domestic purposes.

Pl. XXXI, *A*, is a view of the flowing well of Peter Gould, near St. David, Arizona. It is 500 feet deep, has a 2-inch pipe, and flows 50 gallons per minute. John S. Merrill also has a flowing well near St. David 295 feet deep, with a pipe $1\frac{1}{2}$ inches in diameter, which flows 45 gallons a minute. It was put down in three days, at a cost of $3.50 per day. The pipe cost 16 cents per foot, making a total of less than $55. It is claimed that this well has sufficient water to irrigate 20 acres of land.

This Mormon settlement also irrigates a maximum of 300 acres from the St. David canal, which was built in 1881. The only canal above St. David is the one irrigating the Spanish claims mentioned.

In T. 12 S., R. 19 E., San Pedro River passes through what is known as The Narrows. At this point are cliffs 25 feet high, the width of the river being 225 feet. Above the perpendicular height of 25 feet the slope on either side is very gradual. The width at the 50-foot elevation is about 800 feet. As the fall of the river is about 18 feet to the mile, the site would accommodate a reservoir of very small capacity. A number of small canals, aggregating 41, take water from the river. They all are individual concerns, serving one or two, and in a few cases three, ranches. There can not be more than 75 ranches served by them, and probably 3,500 acres would represent the amount that is actually irrigated in San Pedro Valley. Fig. 203 is a map of the San Pedro, showing the ditches diverting water from it. The table on the next page is an enumeration of these canals, with the amount of water carried in each, as measured in March, 1899, beginning at the head of the river and following downstream.

21 GEOL, PT IV—00——23

354 PROGRESS OF STREAM MEASUREMENTS FOR 1899.

*Canals diverting water from San Pedro River, Arizona.*

| Canal. | Location. | Discharge. |
|---|---|---|
| | | *Second-feet.* |
| St. David Canal Co.'s | East side | 7.3 |
| Etts | do | 1.2 |
| Chisholm | West side | 2 |
| Gibson | do | 2 |
| Tres Alamosa | do | 2 |
| Dunbar | East side | 1 |
| Lopnaw | West side | 1 |
| Aperdiser | do | 1 |
| Bohn | East side | 2 |
| Blanchard | do | 2 |
| Mexican | do | 2 |
| Frenchman | do | 2 |
| Pantano | do | 1 |
| Mange | do | 2 |
| Soso | West side | 2 |
| Do | East side | 2 |
| Los Angeles | West side | 4.2 |
| Warner | East side | 2 |
| Patton | do | 3 |
| Bayless & Berkalow | West side (from a spring) | 3 |
| Do | do | 3 |
| Do | East side | 3 |
| Miley | do | 2 |
| Clark | do | 2.3 |
| Acton | do | 2 |
| Figueroa | West side | 3 |
| Brown | East side | 9.1 |
| Busand | do | 3.4 |
| Brown & Wills | do | 5 |
| Cook | do | 6.4 |
| Push | do | 4 |
| Dodson | West side | 7.6 |
| Indian | East side | 1 |
| Finch & Draper | West side | 2.8 |
| Swingle | do | 3.7 |
| Scott & Cunningham | East side | 6.6 |
| Young | do | 2 |
| Lattin | do | 2 |
| Bates | West side | 2 |
| Piercy | do | 2 |
| Total | | 117.6 |

Note:

A second-ft = 1 cfs

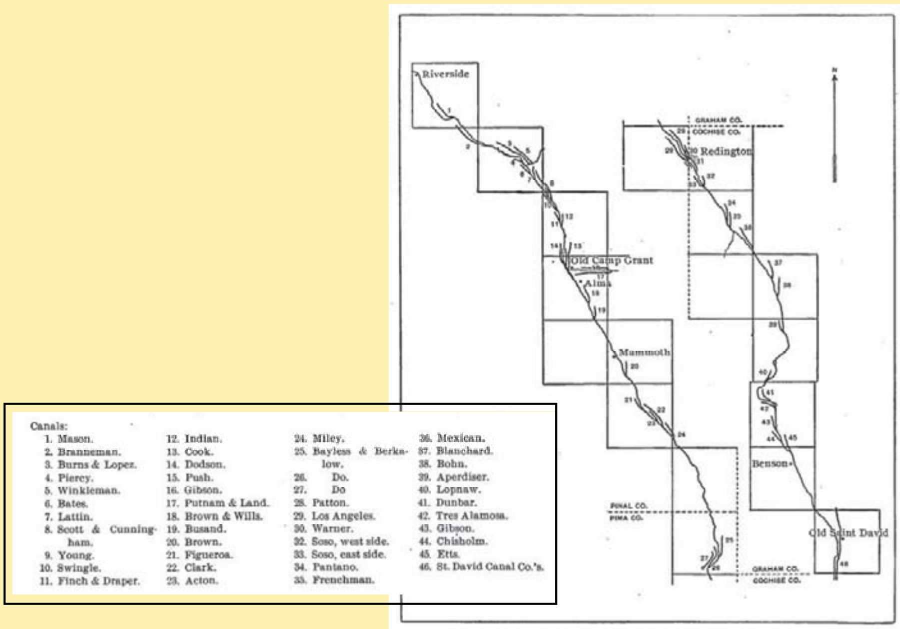



FIG. 203.—Map showing location of canals diverting water from San Pedro River.

The San Pedro contributes a very large percentage of the sediment of lower Gila River. The basin of the former stream, as already stated,

356 PROGRESS OF STREAM MEASUREMENTS FOR 1899.

is largely occupied as cattle ranges, and for ten months of the year the cattle graze over the hills, cutting and loosening the soil, so that when the heavy rains of the summer season arrive the gulleys contain volumes of what may be called liquid mud, which finds its way to the main stream. Probably the percentage of sediment for the San Carlos reservoir site is not so great as for the Buttes. The elevation at the mouth of the river is approximately 1,900 feet, while at Benson, 90 miles upstream, it is 3,550 feet. The distance between the two points being 90 miles, the average slope of the river is 18 feet to the mile.

Note: With all the channel downcutting, a considerable amount of sediment entered the Gila River.

# San Pedro River Watershed Subflow Zone Delineation Report

ADWR

Appendix B

June 2009

**Diversions for irrigation**

**(next 8 slides)**

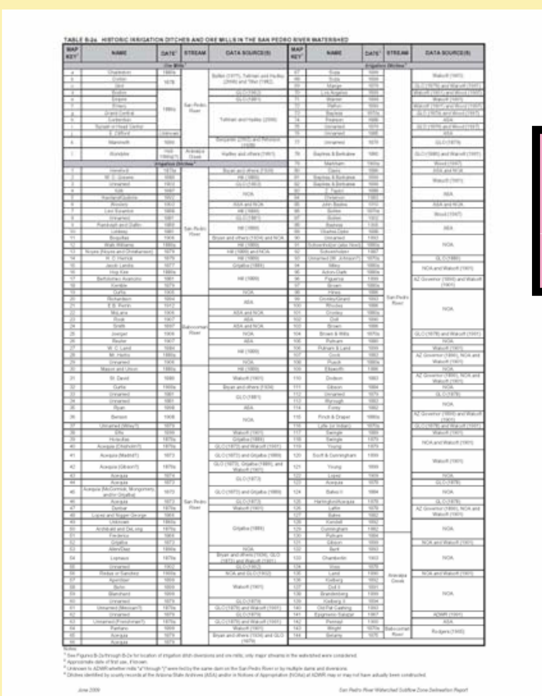
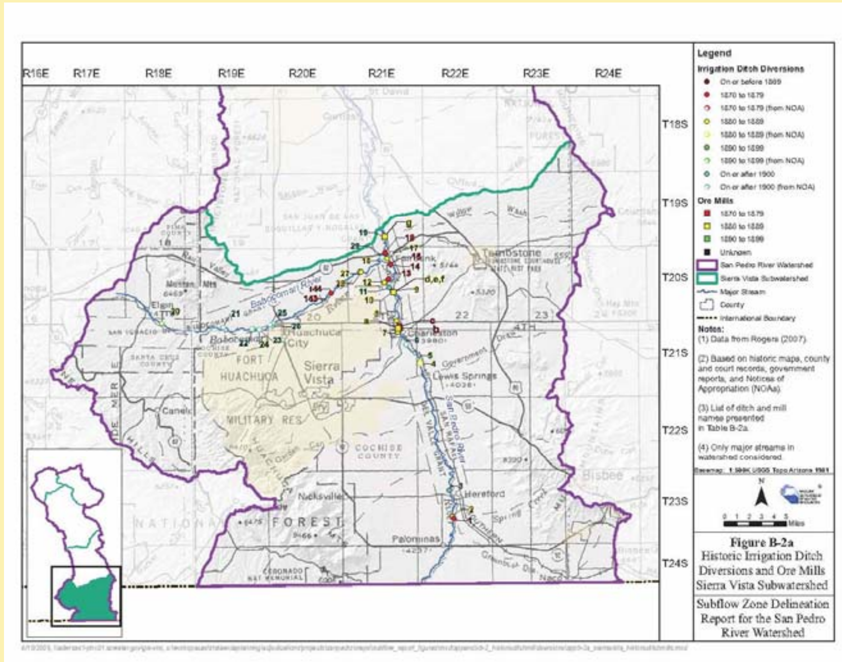
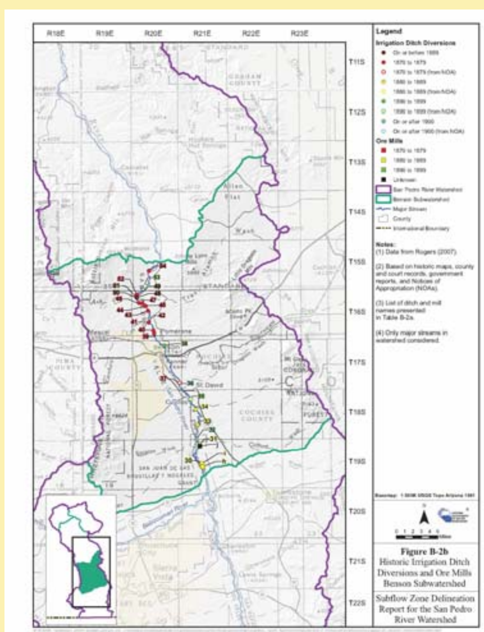


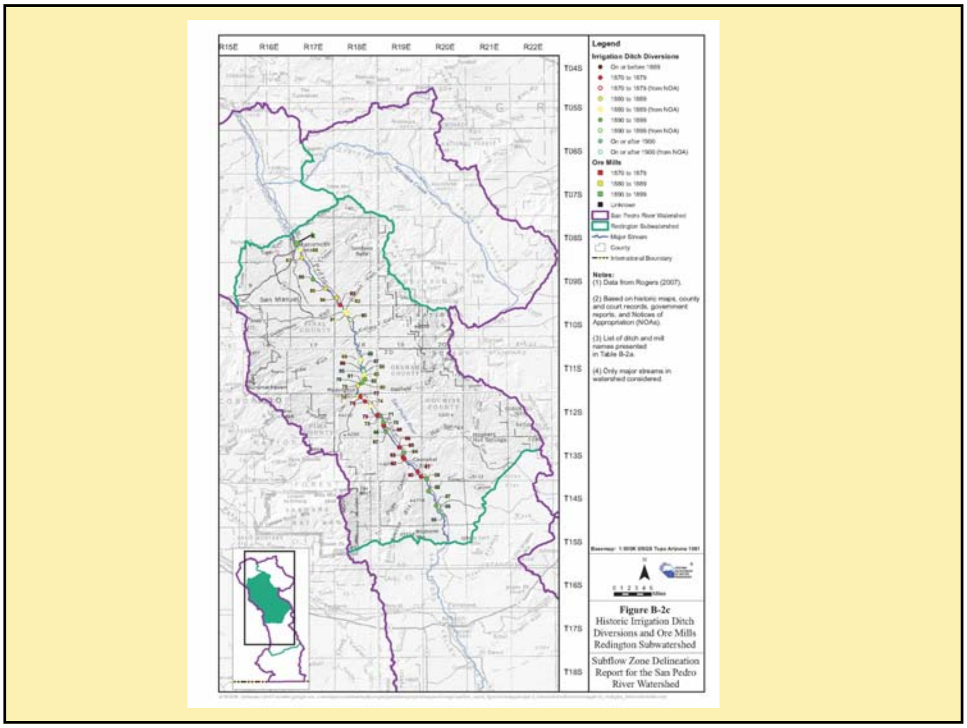
TABLE B-2a HISTORIC IRRIGATION DITCHES AND ORE MILLS IN THE SAN PEDRO RIVER WATERSHED

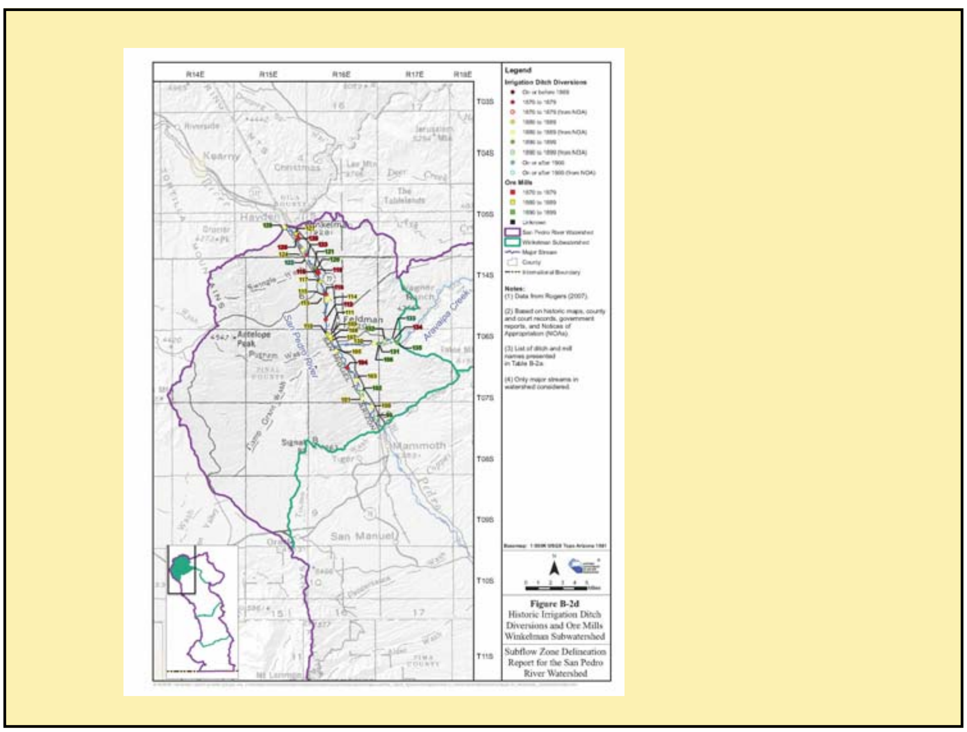
| MAP KEY | NAME | DATE | STREAM | DATA SOURCE(S) | MAP KEY | NAME | DATE | STREAM | DATA SOURCE(S) |
|---|---|---|---|---|---|---|---|---|---|

ADWR has records of 144 diversions along the San Pedro and major tributaries. Some of these diversions may not have been built.


Legend
Irrigation Ditch Diversions
On or before 1869
1870 to 1879
1870 to 1879 (from NOA)
1880 to 1889
1880 to 1889 (from NOA)
1890 to 1899
1890 to 1899 (from NOA)
On or after 1900
On or after 1900 (from NOA)
Ore Mills
1870 to 1879
1880 to 1889
1890 to 1899
Unknown
San Pedro River Watershed
Sierra Vista Subwatershed
Major Stream
County
International Boundary
Notes:
(1) Data from Rogers (2007).
(2) Based on historic maps, county and court records, government reports, and Notices of Appropriation (NOAs).
(3) List of ditch and mill names presented in Table B-2a.
(4) Only major streams in watershed considered.
Figure B-2a
Historic Irrigation Ditch Diversions and Ore Mills Sierra Vista Subwatershed
Subflow Zone Delineation Report for the San Pedro River Watershed
R16E R17E R18E R19E R20E R21E R22E R23E R24E
T18S T19S T20S T21S T22S T23S T24S
Tombstone
Charleston
Lewis Springs
Hereford
Palominas
Sierra Vista
Huachuca City
FORT HUACHUCA MILITARY RES.
COCHISE COUNTY
Nicksville
FOREST
Babocomari River
Miles


Legend
Irrigation Ditch Diversions
Ore Mills
Notes:
(1) Data from Rogers (2007).
(2) Based on historic maps, county and court records, government reports, and Notices of Appropriation (NOAs).
(3) List of ditch and mill names presented in Table B-2a.
(4) Only major streams in watershed considered.
Figure B-2b
Historic Irrigation Ditch Diversions and Ore Mills Benson Subwatershed
Subflow Zone Delineation Report for the San Pedro River Watershed
R18E R19E R20E R21E R22E R23E
T11S T12S T13S T14S T15S T16S T17S T18S T19S T20S T21S T22S


Legend
Irrigation Ditch Diversions
Ore Mills
Notes:
(1) Data from Rogers (2007).
(2) Based on historic maps, county and court records, government reports, and Notices of Appropriation (NOAs).
(3) List of ditch and mill names presented in Table B-2a.
(4) Only major streams in watershed considered.
Figure B-2c
Historic Irrigation Ditch Diversions and Ore Mills
Redington Subwatershed
Subflow Zone Delineation Report for the San Pedro River Watershed


Legend
Irrigation Ditch Diversions
Ore Mills
Notes:
(1) Data from Rogers (2007).
(2) Based on historic maps, county and court records, government reports, and Notices of Appropriation (NOAs).
(3) List of ditch and mill names presented in Table B-2a.
(4) Only major streams in watershed considered.
Figure B-2d
Historic Irrigation Ditch Diversions and Ore Mills
Winkelman Subwatershed
Subflow Zone Delineation Report for the San Pedro River Watershed

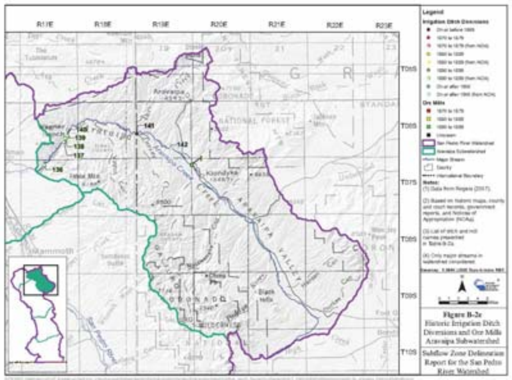
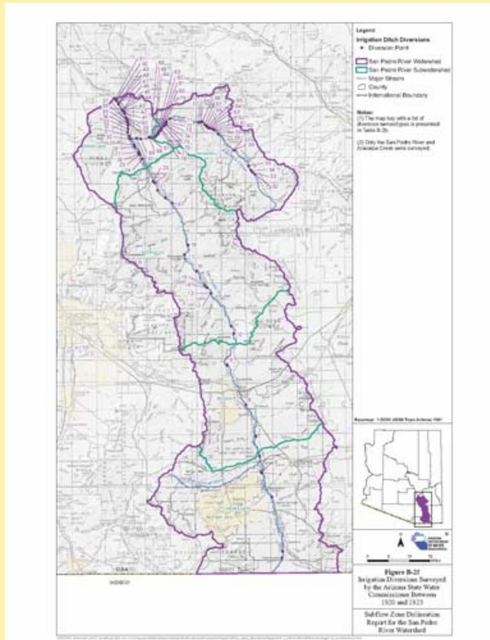



TABLE B-2b. IRRIGATION DIVERSIONS SURVEYED IN THE SAN PEDRO RIVER WATERSHED BY THE ARIZONA STATE WATER COMMISSIONER BETWEEN 1920 AND 1923

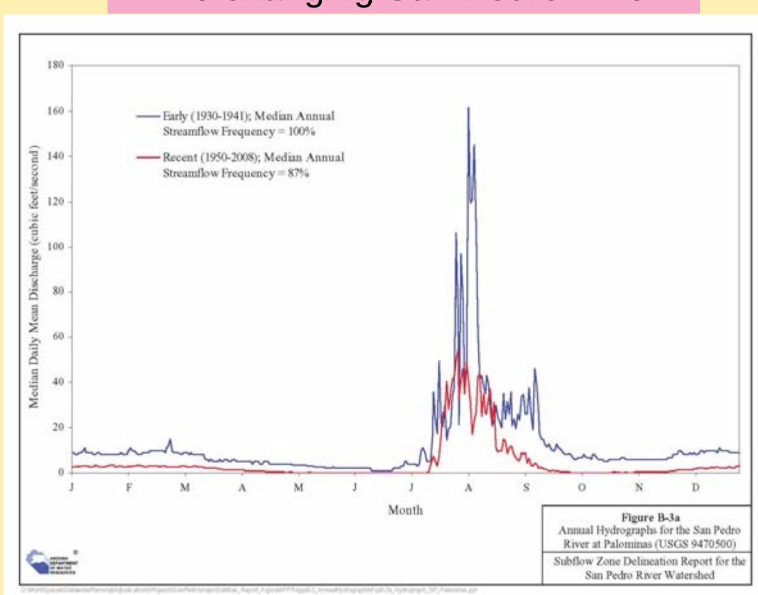
| MAP KEY[1] | DIVERSION NAME/TYPE | SURVEY DATE | STREAM | MAP KEY[1] | DIVERSION NAME/TYPE | SURVEY DATE | STREAM |
|---|---|---|---|---|---|---|---|
| 1 | Pump Plant (direct) | 1921 | San Pedro River | 46 | Pump Plant (direct) | 1920 | San Pedro River |
| 2 | Ditch | | | 47 | Ditch | 1921 | |
| 3 | Ditch | | | 48 | Ray Con Ditch | | |
| 4 | Bogallas Ditch | | | 49 | Valdez Canal | | |
| 5 | Bogallas Ditch | | | 50 | Upshaw Ditch | | |
| 6 | Curtis Ditch | | | 51 | Hardwick Ditch | | |
| 7 | St. David Canal | 1923 | | 52 | Whelan Ditch | 1921 | Aravaipa Creek |
| 8 | Benson Canal | | | 53 | Kennedy Bros. Ditch | | |
| 9 | Pump Plant (direct) | 1921 | | 54 | Valenzuela Ditch | | |
| 10 | Apodaca Ditch | | | 55 | Eureka Springs Cattle Co Ditch | | |
| 11 | Sanchez Ditch | | | 56 | Rolen Ditch | | |
| 12 | Vasquez Ditch | | | 57 | Haby Ditch | | |
| 13 | Gamez Ditch | | | 58 | Ditch | | |
| 14 | Munguia Ditch | | | 59 | Ditch | | |
| 15 | Soza Ditch | | | 60 | Ditch | | |
| 16 | Bayless Ditch | | | 61 | Ditch | | |
| 17 | Vasquez Ditch | | | 62 | Trail Ditch #1 | | |
| 18 | Vasquez Ditch | | | 63 | Trail Ditch #2 | | |
| 19 | Amado Ditch | 1920 | | 64 | Ditch | | |
| 20 | Acton Clark Ditch | | | 65 | Trail Ditch #3 | | |
| 21 | Smith Ditch #1 | | | 66 | Trail Ditch #4 | | |
| 22 | Daily Ditch | | | 67 | Salazar Ditch | | |
| 23 | Smith Ditch #2 | | | 68 | Trail Ditch #5 | | |
| 24 | Zapata Ditch | | | 69 | Trail Ditch #6 | | |
| 25 | San Pedro Ranch Ditch | | | 70 | Trail Ditch #7 | | |
| 26 | Buzan Ditch | | | 71 | Buzan Ditch | | |
| 27 | Pump Plant (direct) | | | 72 | Stewart Ditch | | |
| 28 | Stewart Ditch | | | 73 | Kielberg Ditch | | |
| 29 | Pusch Ditch | | | 74 | Brandenberg Ditch #1 | | |
| 30 | Pusch Ditch | | | 75 | Brandenberg Ditch #2 | | |
| 31 | Pusch Ditch | | | 76 | Brandenberg Ditch #3 | | |
| 32 | Ditch | | | 77 | Zapata Ditch 1 | | |
| 33 | Ditch | | | 78 | Zapata Ditch 2 | | |
| 34 | Brooks Ditch | | | 79 | Zapata Ditch 3 | | |
| 35 | Finch Ditch #1 | | | 80 | Row Ditch | | |
| 36 | Indian Ditch | | | 81 | Baker Ditch | | |
| 37 | Ditch | | | 82 | Flannery Ditch | | |
| 38 | Finch Ditch #2 | | | 83 | Salathile Ditch | | |
| 39 | Finch Ditch #3 | | | 84 | Indian Ditch #1 | | |
| 40 | Bittick Ditch | | | 85 | Indian Ditch #2 | | |
| 41 | Drake Ditch | | | 86 | Indian Ditch #3 | | |
| 42 | Wilcox Ditch | | | 87 | San Pedro Ranch Ditch | | |
| 43 | Reay Ditch | | | 88 | Stewart Ditch | | |
| 44 | Wilcox Ditch Heading | | | 89 | Ditch | | |
| 45 | Pump Plant (indirect) | | | 90 | Ditch | | |

Notes:
[1] See Figure B-2f for location of irrigation diversions; only the San Pedro River and Aravaipa Creek were surveyed.

June 2009 · San Pedro River Watershed Subflow Zone Delineation Report




## The changing San Pedro River



## Predevelopment Evapotranspiration

Not included in the analysis of navigability was the possibility the base runoff was greater because the predevelopment evapotranspiration rates may be as little as 40 percent of post-1970 rates.

(see next slide).

"The predevelopment rate of ground-water discharge is poorly defined. Previous investigations of the Upper San Pedro basin in the United States and Mexico have estimated about 26,400 m3/d of ground-water discharge through riparian evapotranspiration (Freethey, 1982; Esparza, 2002; table 2). Previous investigations of changes in the riparian area in the San Pedro Valley (Reichardt and others, 1978) and recent comparisons of repeat aerial photographs in the Sierra Vista subwatershed (Russ Scott, Research Hydrologist, Agriculture Research Service, written commun., 2005) indicate that predevelopment evapotranspiration rates may be as little as 40 percent of post-1970 rates."

Pool, D.R., and Dickinson, J.E., 2007, Ground-water flow model of the Sierra Vista Subwatershed and Sonoran portions of the Upper San Pedro Basin, southeastern Arizona, United States, and northern Sonora, Mexico: USGS SIR 2006-5228, 48 p.

Following 5 slides from:

Muffley, B.W., 1938. *The History of the Lower San Pedro River Valley in Arizona*.
M.A. Thesis, University of Arizona, Tucson.

“The health condition at Camp Grant was also a disturbing factor. At that time the San Pedro was swampy. There were numerous beavers that dammed up the streams and made small lakes. This encouraged mosquitoes which in turn made malaria common.” (p. 13)

“A post office was established below the junction of the San Pedro River and Aravaipa Creek in 1878. It was known as Mesaville and had J. N. Dodson as postmaster. Above and below this small post office and store several farms and ranches were developed. The largest of these holdings were those of George Pusch. This place, later known as Feldman, eventually embraced the holdings of Mr. Dodson. Nearby, George Cook held a small farm which for a short period was noted for its productivity.” p. 30-31.

"East of Mesaville in Aravaipa Canyon several small fruit ranches were established. Unlike most parts of Arizona, water was plentiful, and land was scarce." p. 31-32

"The number of farms above and below Reddington continuously decreased during the last decade of the nineteenth century. This did not mean that less land was being cultivated, but instead that the property was being concentrated into larger ranches. As was mentioned in the last chapter, the company of Bayless and Berkalew was gradually acquiring more land. This process was speeded up by the drought of 1891, 1892, and 1893." p. 52-53.

THE DECLINE OF THE LOWER SAN PEDRO VALLEY 1904-1920

"The story of the farms was the saddest part of the history of the lower San Pedro Valley. Once a hardy, ambitious, energetic class wrested many fertile acres from the mesquite and rocks. By 1904 the river had carved away the choice pieces of land. The more energetic of the settlers had moved on to places of greater promise. Ditches from the river were difficult to keep in place, and many an acre of land was allowed to grow into a mesquite thicket. Farmers found it easier to keep a few head of range cattle and forget about tilling the soil." p. 57.

"Soon, however, when the grass on the hills had been eaten away, and the beaver on the river had been trapped, the soil began to erode. That process continued without interruption after it started in the late 1880's. Farm after farm washed away leaving only sand. The banks became higher thus making it more difficult to take water out of the river by the use of ditches. For many years this erosion did not reduce the agricultural prosperity of the valley because of the great demand for farm products. Eventually, however, when the mines at Mammoth closed, farming decreased to relative unimportance." p. 70.

Simulated changes of base flow along reach between Mexico headwaters and USGS Redington gage (1940-2020)

Next 6 slides

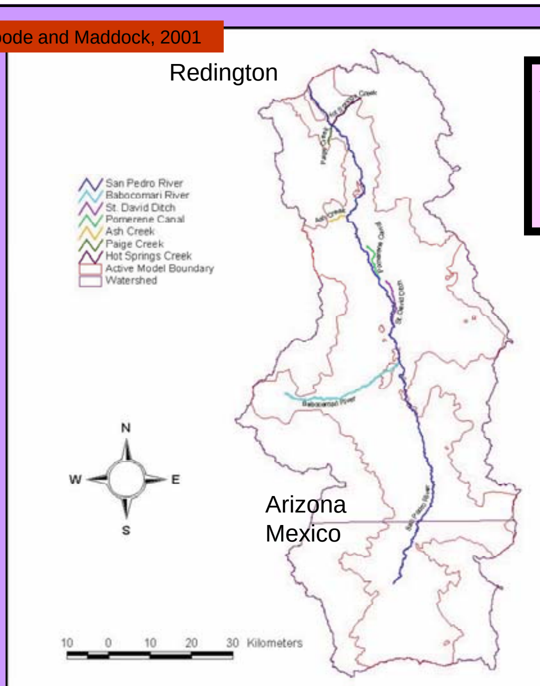
Goode, T.C., and Maddock, Thomas III, 2000, Simulation of groundwater conditions in the Upper San Pedro Basin for the evaluation of alternative futures: University of Arizona, Tucson, Arizona, Department of Hydrology and Water Resources, HWR No. 00–030, 113 p.

This study also took a different approach to previous model layering for the area. Although the same conceptual model used by previous authors was used as a basis for the model structure, the numerical model created a new Layer 1 to accommodate steep hydraulic gradients and perched conditions along mountain front areas. This layer was assigned the same hydraulic properties of the regional aquifer system, with hydraulic conductivity ranging from 0.03 to nearly 4.0 meters per day. Vertical conductivities were held very low to reflect clay lenses and shallow bedrock which restrict vertical flow of water in these areas.

After calibrating the model to natural system inputs (recharge) and outputs (evapotranspiration, baseflow) and available data on aquifer characteristics, Goode and Maddock (2000) applied pumping stresses representative of actual well information for the entire Upper San Pedro Basin through the year 1997. Goode and Maddock provide a detailed description of the groundwater modeling done as part of this study. Simulations were conducted with the USGS MODFLOW finite-difference numerical simulation program using a baseline (pre-development) condition of 1940.

www.epa.gov_region9_nepa_epa-generated_huachuca_AppendixF

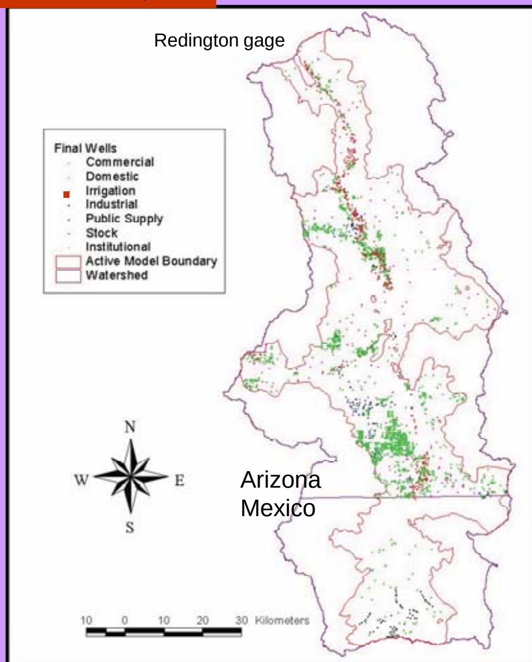
Goode and Maddock, 2001




## Streams and Diversions in the Upper San Pedro Basin

Goode and Maddock, 2001

## Wells




- **Well Registry 1980-1997**
- **GWSI 1940-1979**
- **Water Use Type**
  - Public Supply, Irrigation, Domestic, Stock, Industrial, Commercial, Institutional
- **Unknown/Unused Wells**
  - Unused wells within 1000m of the floodplain, having greater than or equal to 100 gallon per minute (gpm) test pumping rate were considered irrigation wells
  - Unused wells with less that 100 gpm test pumping rate were considered domestic wells outside of the floodplain
  - All other unused wells with no associated test pumping rate were assigned as domestic wells
  - Unknown wells within the floodplain are considered irrigation wells
  - All other unknown wells are considered domestic wells
- **Mexican Wells**
  - Observation wells removed
  - Unknown wells assumed to be domestic
  - All known wells belong to Cananea mine

Goode and Maddock, 2001

Baseflows Estimated by Previous Studies (cfs) (Vionnet, 1992 and Jahnke, 1994)

| Name of Gaging Station | 1940 | 1950 | 1960 | 1970 | 1980 | 1990 | 1997 |
|---|---|---|---|---|---|---|---|
| Palominas | 4.27 | * | * | * | * | * | * |
| Charleston | 14.47 | * | * | * | * | * | * |
| The Narrows | * | * | * | 4.40 | * | * | * |
| Redington | * | * | * | 5.50 | * | * | * |

Model Computed Baseflows (cfs)

| Name of Gaging Station | 1940 | 1950 | 1960 | 1970 | 1980 | 1990 | 1997 |
|---|---|---|---|---|---|---|---|
| Palominas | 4.00 | 3.64 | 3.33 | 2.91 | 2.35 | 2.09 | 2.01 |
| Charleston | 13.24 | 12.22 | 11.49 | 10.34 | 9.03 | 8.83 | 8.87 |
| The Narrows | 13.61 | 11.19 | 9.03 | 6.17 | 2.98 | 1.38 | 0.88 |
| Redington | 14.67 | 11.85 | 9.40 | 6.17 | 2.59 | 0.82 | 0.62 |

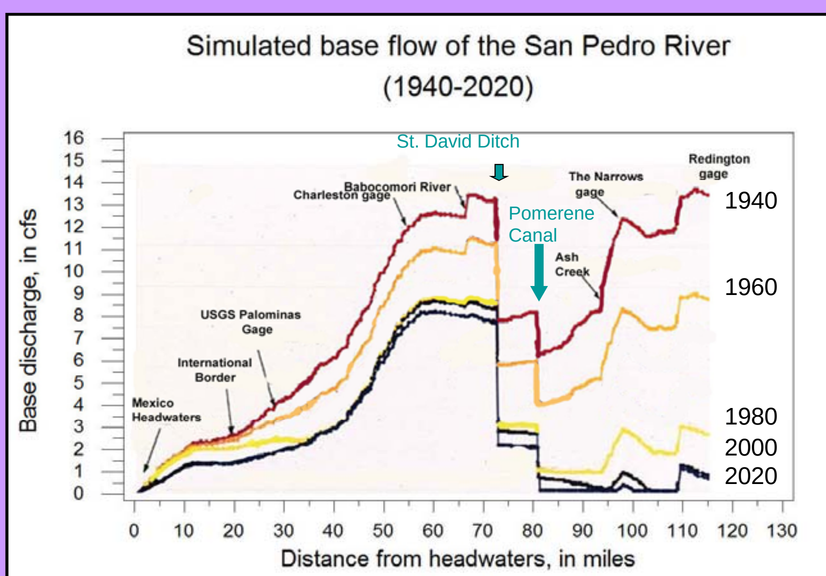
Simulated base flow along the San Pedro River is shown on the following slide. Its important to note:

(1)In 1940, a total of 7 cfs was diverted from the river at the St. David ditch and the Pomerene canal. This suggests the flow at Reddington would have been more than 20 cfs had there been no diversions for irrigation and assuming no return flow.

(2)The predevelopment base runoff was equal to or greater than the base flow for 1940.

(3)The simulated base flow at the upper part of hydrologic 15050203 is about 3 times the base flow used for the study of navigability.

Modified from Goode and Maddock, 2001

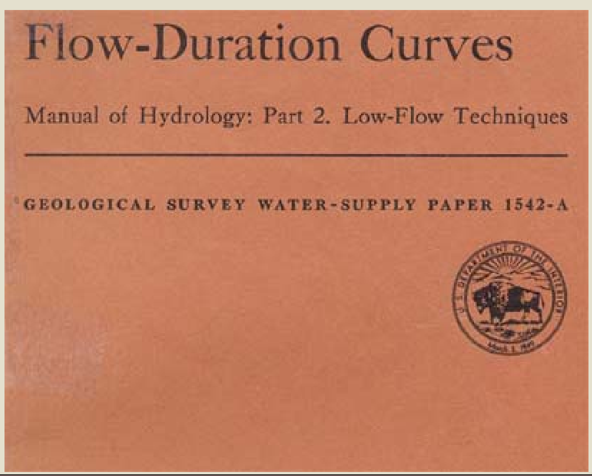


# Flow Duration

Further description for ANSAC

San Pedro River

Used by engineers for more than 100 years




Searcy, J. K., 1959, Flow-duration curves: U. S. Geological Survey Water-Supply Paper 1542-A, 33 p.

Perennial runoff along the entire study reach obviously is needed for continuous navigability throughout the year.

Although perennial runoff is not considered a requirement for navigability, it is considered ideal for this assessment.

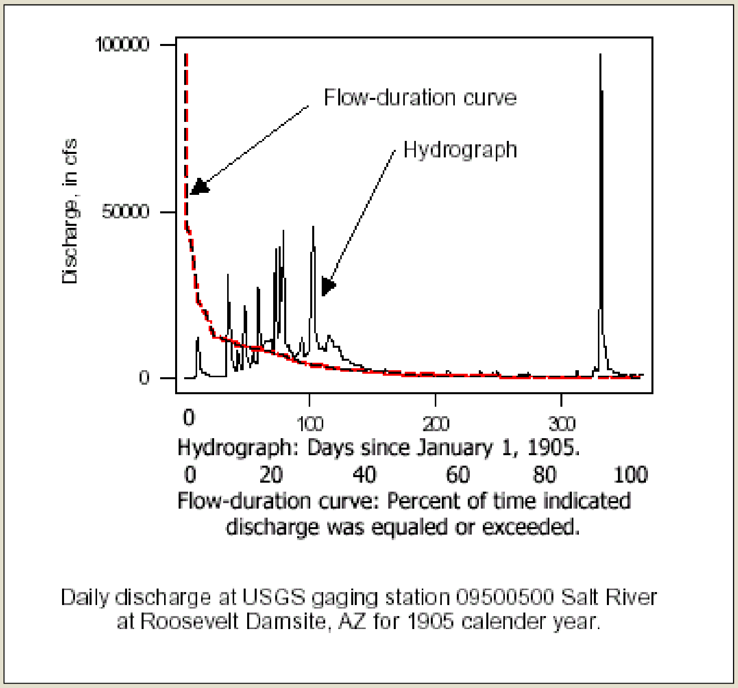
Because precipitation is seasonal, the river would have needed to receive water from ground-water storage during seasonal dry periods.

Also, water stored in the ground during wet years and carried over and released during dry or drought years would enhance navigability.

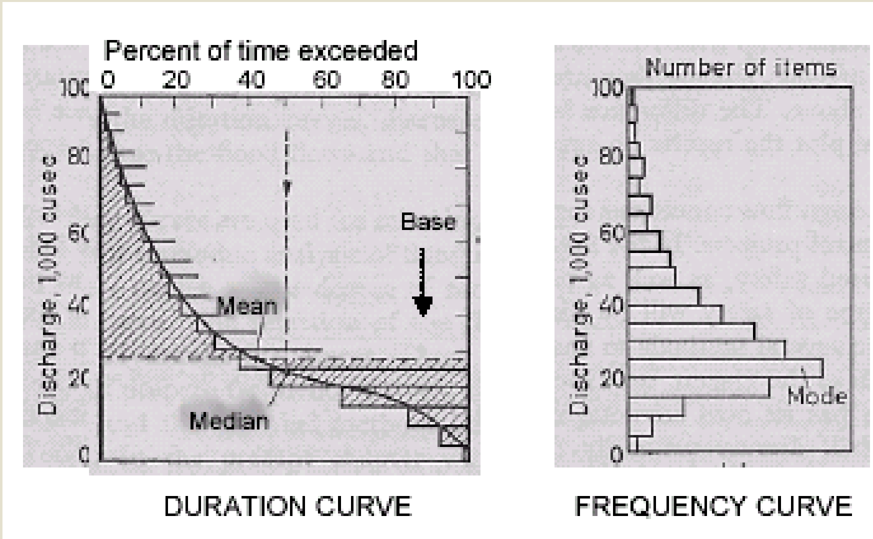
Therefore, the base runoff of the San Pedro River is important for this study of navigability.

**Runoff hydrograph and flow-duration**

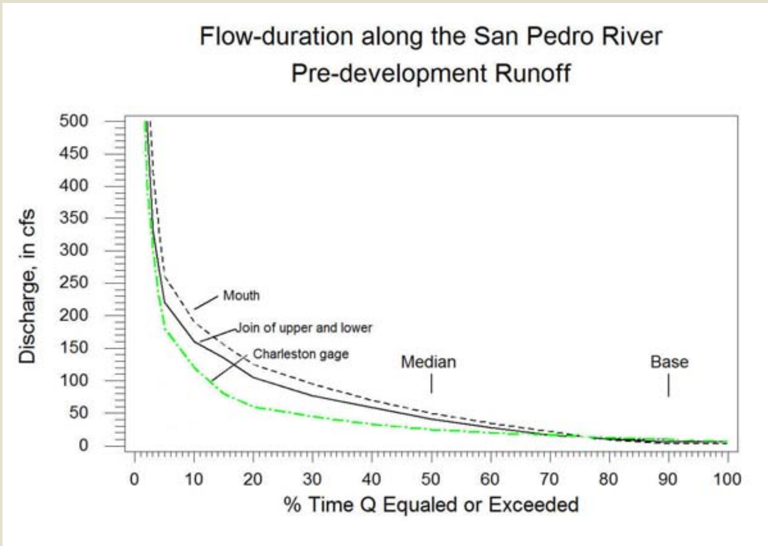
A flow duration curve of daily mean discharge is simply the ranking of the discharges according to magnitude. The ranked mean daily discharges are plotted on the block diagram with the ordinate in discharge units of cfs as was done for the hydrograph on the following:




The flow-duration curve is a cumulative frequency curve that shows the percent of time specified discharges were equaled or exceeded during a given period.




**Cumulative frequency histogram with flow duration curve and frequency histogram (bell-shaped curve).**



# Base runoff from alluvial basins (regional aquifers) along the San Pedro River

Supplemental information

"Ground-water outflow from the alluvial basins (aquifers) along the San Pedro River occurs through three basic mechanisms:

(1) discharge to springs and streams,

(2) evaporation and transpiration from the water-table zone, and

(3) underflow to adjacent basins."

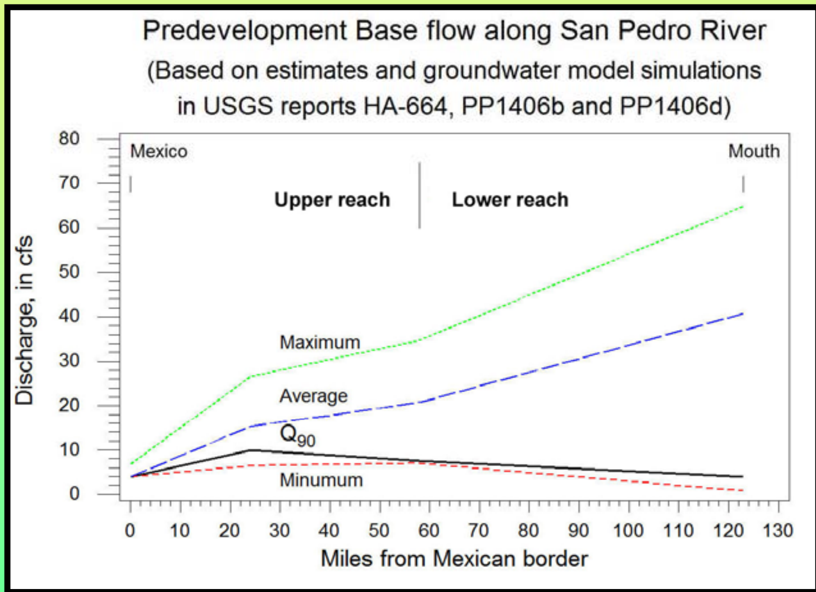
Anderson, T.W, Freethey, G.W, 1995, Simulation of Ground-Water Flow in Alluvial Basins in South-Central Arizona and Parts of Adjacent States : U.S. Geological Survey Professional Paper 1406-D, 78 p.

"The quantity of natural discharge from each basin probably was nearly constant from year to year before development. The influence of wet and dry years was dampened by the large quantity of ground water stored in the basin."

Anderson, T.W, Freethey, G.W, 1995, Simulation of Ground-Water Flow in Alluvial Basins in South-Central Arizona and Parts of Adjacent States: U.S. Geological Survey Professional Paper 1406-D, 78 p.

Base runoff that discharges to the San Pedro River from the alluvial basins was used for this assessment. Discharge to springs in the lower reach was not considered to produce a conservative result.

The base runoff along the river is shown on the following slide.




The $Q_{90}$ used for this analysis is from USGS HA-664. Based on more recent reporting by Anderson and Freethey (e.g. the average annual base runoff from PP1406d) a greater amount of $Q_{90}$ is suggested.

The smaller estimate of $Q_{90}$ is used for this analysis to account for natural and ordinary alternating gaining and losing reaches along the river (typical of meandering alluvial rivers like the San Pedro), possible short reaches with two channels and losing reaches associated with deposited sediment from occasional storm runoff at the mouths of tributary streams.

The exclusion of spring flow and the use of the lowest likely $Q_{90}$ results in a conservative analysis of navigability. This approach recognizes the natural variable nature of the flow and geometry of the river channel. ANSAC can rest assured that a conclusion of navigability is conservative and soundly based.

# Cienegas

The natural inner valley of the San Pedro River was characterized as a broad, low-gradient valley with a shallow, meandering stream flowing through a generally marshy environment.

These bottomland marsh areas, termed *cienegas* by the early Spanish settlers, were widespread and nearly continuous along the length of the San Pedro River.

Fogg, J., Elmore, J., Gonzale, M., 2012, RIPARIAN CONDITIONS ALONG THE SAN PEDRO RIVER: POTENTIAL NATURAL COMMUNITIES AND FACTORS LIMITING THEIR OCCURRENCE, For BLM by Lowclouds Hydrology, Inc.

"Prior to the late 1800's the San Pedro River was a relatively low-energy, unentrenched fluvial system with extensive marshy reaches, or cienegas (Hereford, 1993)."

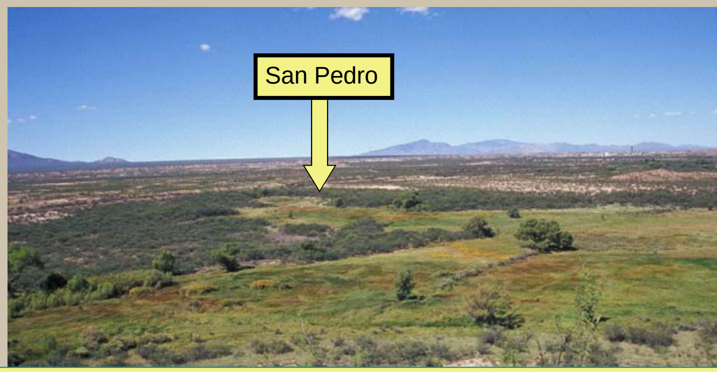
Cook, Joseph P., 2009, and others, Mapping of Holocene River Alluvium along the San Pedro River, Aravaipa Creek, and Babocomari River, Southeastern Arizona, Arizona Geological Survey, 76 p and 6 maps.

The widespread occurrence of cienegas from this earlier time is evident in the cutbanks of the present-day San Pedro.

Dark paleosols (see arrow) indicative of cienega conditions exposed in the cutbank on the San Pedro River.

Fogg, J., Elmore, J., Gonzale, M., 2012, RIPARIAN CONDITIONS ALONG THE SAN PEDRO RIVER: POTENTIAL NATURAL COMMUNITIES AND FACTORS LIMITING THEIR OCCURRENCE, For BLM by Lowclouds Hydrology, Inc.

The presence of the dark paleosoils is indicative of wet conditions during stable channel conditions. Human activity destabilized the relatively stable natural riverine environment. Remnant cienegas still exist along the San Pedro, albeit in peripheral positions disconnected from the river and in very limited extent (e.g., the St. David cienega shown on the next slide).




Cienegas are mid-elevation wetlands characterized by permanent, scarcely fluctuating water sources and semi-arid surroundings. The saturated soils produce an organic muck that precludes colonization of all but specialized organisms. The St. David Cienega is a located at the northern end of the SPRNCA, a portion shown here. Photo taken September, 2003, looking northwest, from top of nearby butte. (ASU Life Sciences study)

**Significance of Cienegas**

(natural conditions)

There was spring flow along the entire San Pedro River.

There was little channel entrenchment along the river.