

**Arizona Stream Navigability Study  
for the  
San Pedro River:  
Gila River Confluence to the Mexican Border**

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*Comparison of Modern and Historical Record.* No systematic data exist by which to compare post-statehood flow rates with flow rates at the time of statehood. Secondary sources such as tree-ring data (Smith and Stockton, 1981) and precipitation analyses (Cooke and Reeves, 1976) indicate that the period around statehood was wetter and more flood prone than the most recent period of record. However, since no statistically significant climatic change has occurred since statehood (Sellers, 1960), streamflow records unaffected by development-related changes should adequately predict statehood streamflow rates. Some stations in the San Pedro watershed have shown declining flow rates, possibly due to increased ground water withdrawals. Therefore, use of long-term gage records may tend to under predict flow rates which occurred at statehood, but are broadly representative of that time period.

## Hydraulic Rating Curves

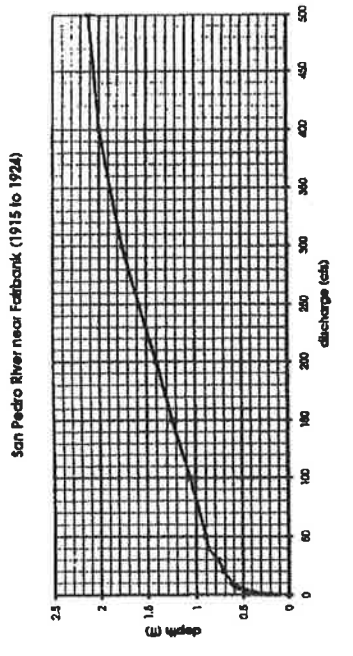
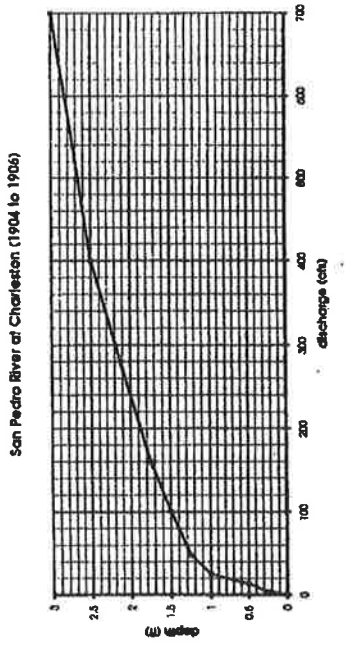
Hydraulic rating curves relate stream discharge to flow depth, width, and velocity. Two sources of information were used to develop rating curves for the San Pedro River: (1) historical measurements of stream stage, velocity, and discharge taken around the time of statehood by the USGS; and (2) recent streamflow characteristics recorded by USGS field personnel working at stream gage stations still in operation. A typical rating curve for the San Pedro River is shown in Figure 7-3; locations of San Pedro stream gages are shown in Figure 7-2; documentation on rating curves is attached in Appendix F.

Historical streamflow data were available from the Charleston (1904-1906), and (near) Fairbank (1915-1924), stations. To reconstruct rating curves, published stage, velocity, and discharge readings from the period of record closest to statehood were tabulated. Stream stage was then related to average stream depth. Finally, other streamflow parameters such as topwidth and velocity were estimated using Manning's equation<sup>4</sup>, assuming a rectangular channel. Rating curves were then developed and compared to monthly and annual streamflow statistics, as illustrated below.

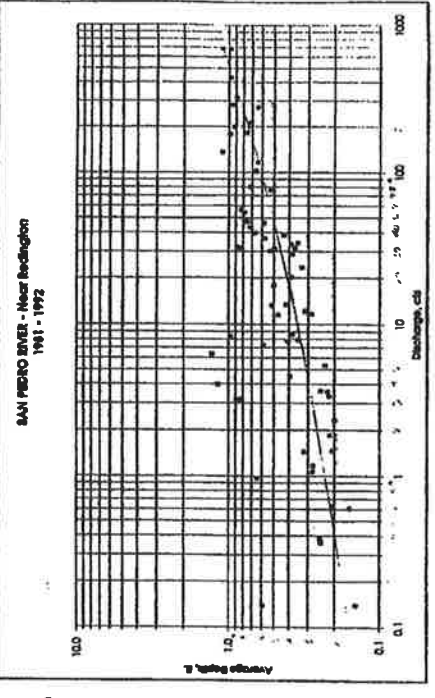
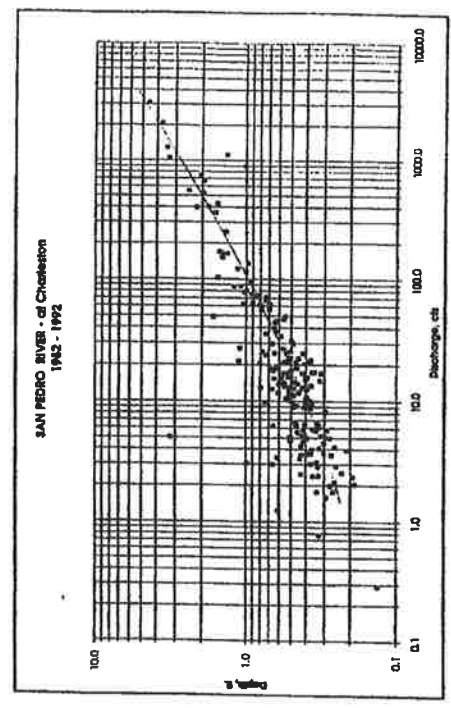
Recent stream gage measurements were available for the Redington (10/81 to 10/92) and Tombstone (9/81 to 10/86) gages. Field measurements of stream width, velocity, topwidth, and velocity were entered into a data base and a rating curve was fit to the data. Hydraulic characteristics for monthly and average annual flow rates were then obtained from the rating curve.

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<sup>4</sup> Manning's equation:  $Q = 1.49 A/n R^{0.67} S^{0.5}$ ; where: Q = Discharge, cfs; A = Flow Area, ft<sup>2</sup>; n = roughness coefficient; R = hydraulic radius, ft.; S = channel slope, ft/ft.



A B



C D

Figure 7-3: Typical Hydraulic Rating Curve for Upper and Lower San Pedro River

Summaries of the data from the rating curves for each station are shown in Tables 7-6 to 7-10. These data are intended to be representative of the following reaches:

- Upper San Pedro River: Charleston (Table 7-6, Historical Data); Charleston (Table 7-7, Recent Data); Fairbank (Table 7-8, Historical Data); Tombstone (Table 7-9, Recent Data)
- Lower San Pedro River: Redington (Table 7-10, Recent Data)

The Tombstone station is located about 5 miles from the historic Near Fairbank station. These data may be compared in a general way to illustrate potential changes in river characteristics from the time of statehood and the present time.

<b>Table 7-6a</b>				
<b>San Pedro River at Charleston, 1904 to 1906</b>				
<b>Average Hydraulic Characteristics</b>				
<b>Month</b>	<b>Flow Rate (cfs)</b>	<b>Average Depth (ft)</b>	<b>Velocity (ft/sec)</b>	<b>Topwidth (ft)</b>
January	38	1.1	3.9	8
February	28	1.0	3.7	7
March	24	1.0	3.6	7
April	13	0.5	3.0	5
May	9	0.4	2.8	4
June	3	0.2	2.5	3
July	148	1.7	5.1	17
August	233	1.9	5.6	19
September	91	1.5	4.6	13
October	40	1.2	4.0	8
November	18	0.7	3.3	5
December	50	1.3	4.2	10
Annual	59	1.3	4.3	10
NOTE: Discharges from entire gage record: 1904-1991				

**Table 7-6b**  
**San Pedro River at Charleston, 1904 to 1906**  
**Flow Duration Hydraulic Characteristics**

<b>Flow Period</b>	<b>Flow Rate (cfs)</b>	<b>Average Depth (ft)</b>	<b>Velocity (ft/sec)</b>	<b>Topwidth (ft)</b>
Average Annual Flow	59	1.3	4.3	10
90% Flow	77	1.4	4.4	12
50% Flow	14	0.5	3.0	5
10% Flow	4	0.2	2.5	3

**Table 7-7a**  
**San Pedro River at Charleston Gage #09471000**  
**Average Hydraulic Characteristics**

<b>Month</b>	<b>Flow Rate (cfs)</b>	<b>Average Depth (ft)</b>	<b>Velocity (ft/sec)</b>	<b>Topwidth (ft)</b>
January	38	0.7	1.7	37
February	28	0.6	1.5	33
March	24	0.5	1.4	31
April	13	0.4	1.2	23
May	9	0.4	1.1	19
June	3	0.3	0.9	10
July	148	1.2	2.3	60
August	233	1.4	2.7	69
September	91	0.9	2.1	50
October	40	0.7	1.7	38
November	18	0.5	1.3	28
December	50	0.7	1.8	41
Annual	59	0.8	1.9	43

NOTE: Discharges from entire gage record: 1904-1991

**Table 7-7b**  
**San Pedro River at Charleston, Gage #09471000**  
**Flow Duration Hydraulic Characteristics**

<b>Flow Period</b>	<b>Flow Rate (cfs)</b>	<b>Average Depth (ft)</b>	<b>Velocity (ft/sec)</b>	<b>Topwidth (ft)</b>
Average Annual Flow	59	0.8	1.9	43
90% Flow	77	0.9	2.0	48
50% Flow	14	0.4	1.3	24
10% Flow	4	0.3	1.0	12

**Table 7-8a**  
**San Pedro River at Fairbank, 1915 to 1924**  
**Average Hydraulic Characteristics**

<b>Month</b>	<b>Flow Rate (cfs)</b>	<b>Average Depth (ft)</b>	<b>Velocity (ft/sec)</b>	<b>Topwidth (ft)</b>
January	56	0.9	3.0	20
February	45	0.9	2.9	17
March	37	0.9	2.8	15
April	15	0.7	2.4	9
May	8	0.5	2.2	6
June	4	0.5	2.0	5
July	104	1.1	3.3	29
August	160	1.3	3.7	34
September	58	0.9	3.0	20
October	95	1.0	3.2	28
November	16	0.7	2.4	9
December	63	1.0	3.0	22
Annual	56	0.9	3.0	20

NOTE: Discharges derived from San Pedro near Tombstone gage.

**Table 7-8b  
San Pedro River near Fairbanks, 1915 to 1924  
Flow Duration Hydraulic Characteristics**

<b>Flow Period</b>	<b>Flow Rate (cfs)</b>	<b>Average Depth (ft)</b>	<b>Velocity (ft/sec)</b>	<b>Topwidth (ft)</b>
Average Annual Flow	56	0.9	3.0	20
90% Flow	82	1.0	3.2	25
50% Flow	13	0.7	2.4	9
10% Flow	0	0	0	0

**Table 7-9a  
San Pedro River: Near Tombstone, Gage 09471550  
Average Hydraulic Characteristics**

<b>Month</b>	<b>Flow Rate (cfs)</b>	<b>Average Depth (ft)</b>	<b>Velocity (ft/sec)</b>	<b>Topwidth (ft)</b>
January	56	0.5	1.9	58
February	45	0.5	1.8	53
March	37	0.5	1.7	48
April	15	0.4	1.4	28
May	8	0.3	1.3	16
June	4	0.3	1.2	9
July	104	0.6	2.1	72
August	160	0.8	2.4	84
September	58	0.5	1.9	59
October	95	0.6	2.1	70
November	16	0.4	1.5	29
December	63	0.5	1.9	61
Annual	56	0.5	1.9	58

<b>Table 7-9b</b> <b>San Pedro River: Near Tombstone, Gage 09471550</b> <b>Flow Duration Hydraulic Characteristics</b>				
<b>Flow Period</b>	<b>Flow Rate (cfs)</b>	<b>Average Depth (ft)</b>	<b>Velocity (ft/sec)</b>	<b>Topwidth (ft)</b>
Average Annual Flow	56	0.5	1.9	58
90% Flow	82	0.6	2.0	66
50% Flow	13	0.4	1.4	24
10% Flow	0	0	0	0

<b>Table 7-10a</b> <b>San Pedro River: Near Redington, Gage 09472000</b> <b>Average Hydraulic Characteristics</b>				
<b>Month</b>	<b>Flow Rate (cfs)</b>	<b>Average Depth (ft)</b>	<b>Velocity (ft/sec)</b>	<b>Topwidth (ft)</b>
January	33	0.5	2.2	27
February	22	0.4	1.9	21
March	16	0.4	1.7	18
April	4	0.3	1.1	8.5
May	1	0.3	0.8	5.7
June	2	0.3	0.9	6.0
July	103	0.6	3.1	50
August	215	0.8	3.6	74
September	50	0.5	2.6	33
October	51	0.5	2.6	33
November	4	0.3	1.1	8
December	36	0.5	2.3	28
Annual	45	0.5	2.5	31



<b>Flow Period</b>	<b>Flow Rate (cfs)</b>	<b>Average Depth (ft)</b>	<b>Velocity (ft/sec)</b>	<b>Topwidth (ft)</b>
Average Annual Flow	45	0.5	2.5	31
90% Flow	55	0.5	2.6	35
50% Flow	0.6	0.2	0.6	4
10% Flow	0	0	0	0

Rating curves of depth vs. discharge for high flow conditions have been developed by the BLM (1987) for seven locations between Hereford and St. David. BLM rating curves are based application of Manning's equation to surveyed cross section information. These rating curves probably have little applicability to navigability on "ordinary and natural" conditions, since flows in excess of 1,000 cfs occur less than one percent of the time, according to flow duration statistics, and because no flow velocities are given. In general, the BLM curves agree with the low flow rating curve data summarized in Tables 7-6 to 7-10, in that low flows are about two feet deep or less. The BLM cross section data also predict flow depths of 5 to 10 feet for the 2-year flood. BLM cross section plots are attached in Appendix E.

*Summary.* Hydraulic rating curves are shown for five stations on the San Pedro River. These data indicate that flow depths are generally less than one foot and flow velocities are generally about two to four feet per second. Historical rating curves indicate somewhat greater flow depths and higher velocities than comparable rating curves for nearby stations developed from recent field measurements of flow conditions.

## Floods

Flood frequency data are available from Flood Insurance Studies (FEMA, 1989; 1990) and from USGS gage records (1991). Large flood occurred in the year prior to statehood, as well, reported causing channel erosion and channelization of most of the San Pedro River.

*Flood Recurrence Intervals.* Flood discharge rates at various key concentration points are listed in Table 7-11. Flow rates obtained from Flood Insurance Studies (FIS, 1989; 1990) are based on rainfall runoff modeling and are significantly different from flow rates determined by the USGS (1991) using streamflow records.