NAVIGABILITY ALONG THE NATURAL CHANNEL OF THE VERDE RIVER, AZ

Detailed analysis from Sullivan Lake to the USGS gage near Clarkdale. and
General analysis from Clarkdale gage to mouth.

An assessment based on history, Federal GLO surveys, hydrology, hydraulics and morphology

By

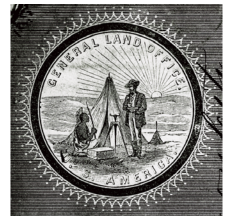
Hjalmar W. Hjalmarson, PE

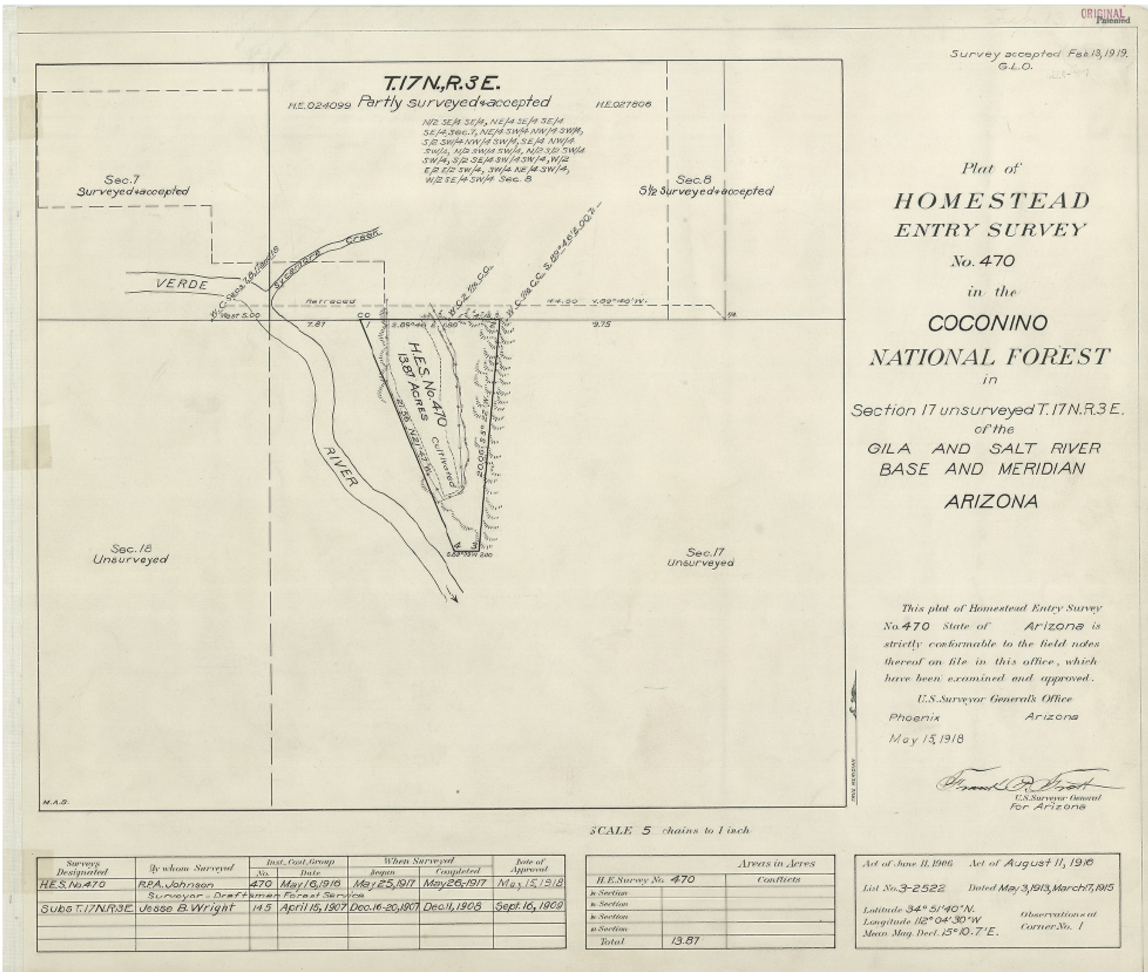
November 14, 2014

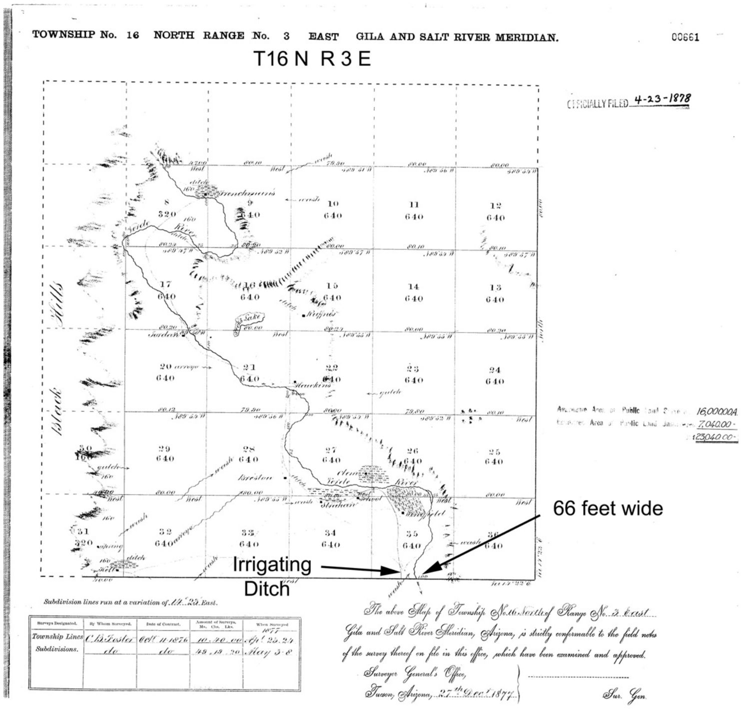
ADDENDUM TO REPORT OF OCTOBER 4, 2014

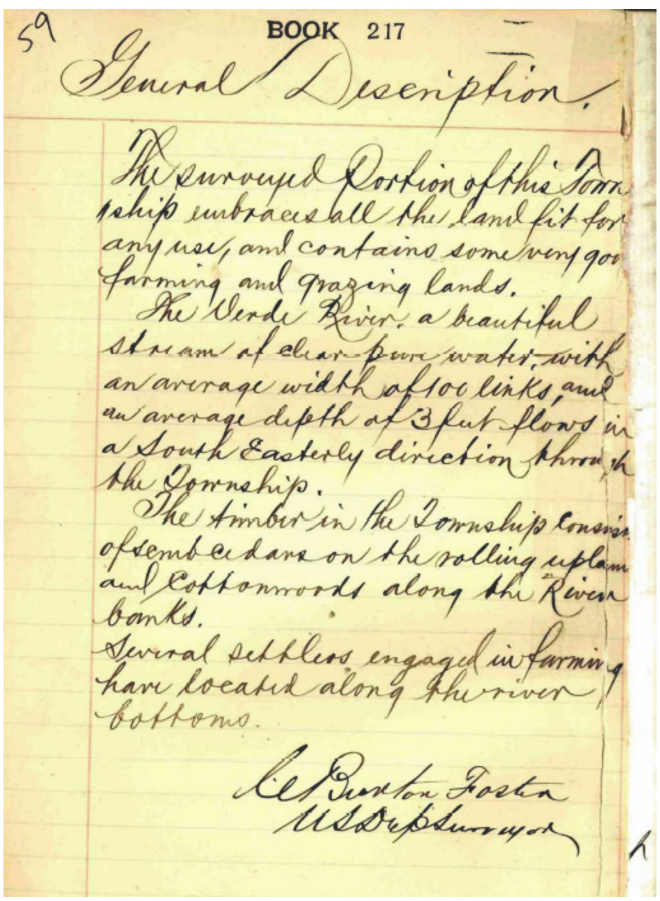
ADDITION 1. Federal land surveys

The following are additional Federal Land Surveys and Homestead Entry Surveys along the Verde River. These plats are additions to the *HYDRAULICS AND CHANNEL GEOMETRY, Section 2.—Federal Land Surveys* of the report.








59 BOOK 217

General Description.

The surveyed Portion of this Township embraces all the land fit for any use, and contains some very goo farming and grazing lands.

The Verde River: a beautiful stream of clear pure water, with an average width of 100 links, and an average depth of 3 feet flows in a South Easterly direction through the Township.

The timber in the Township consis of some cedars on the rolling uplan and Cottonwoods along the River banks.

Several settlers engaged in farming have located along the river bottoms.

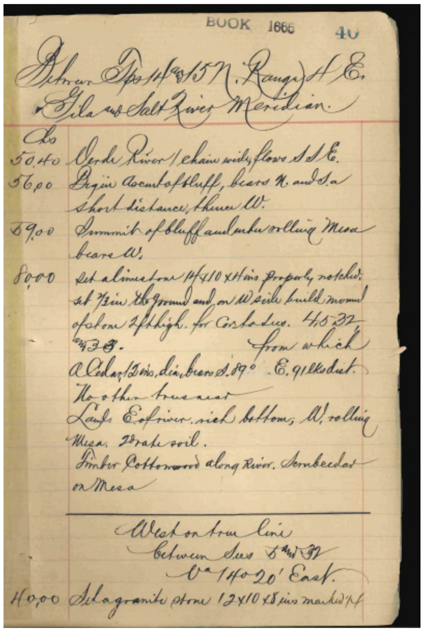
C. Burton Foster
U.S. Dep. Surveyor

General description of T16N R3E is to the left. Survey was by C. B. Foster during April 23-24 and May 3-8, 1877. For this Township the Verde River was described as <u>a beautiful stream with an average width of 66 ft (100 links) and an average depth of 3 ft.</u>

Thus, for roughly 10 miles along the single meandering channel of the Verde River (see map above) the average depth was 3 ft.

Several settlers were engaged in farming in the Township. Note the ditch on above map.

This condition is consistent with the description by *Dr. Pearthree in section G3a.--Geomorphology of Verde River Channel* of Appendix G of this report for ANSAC.



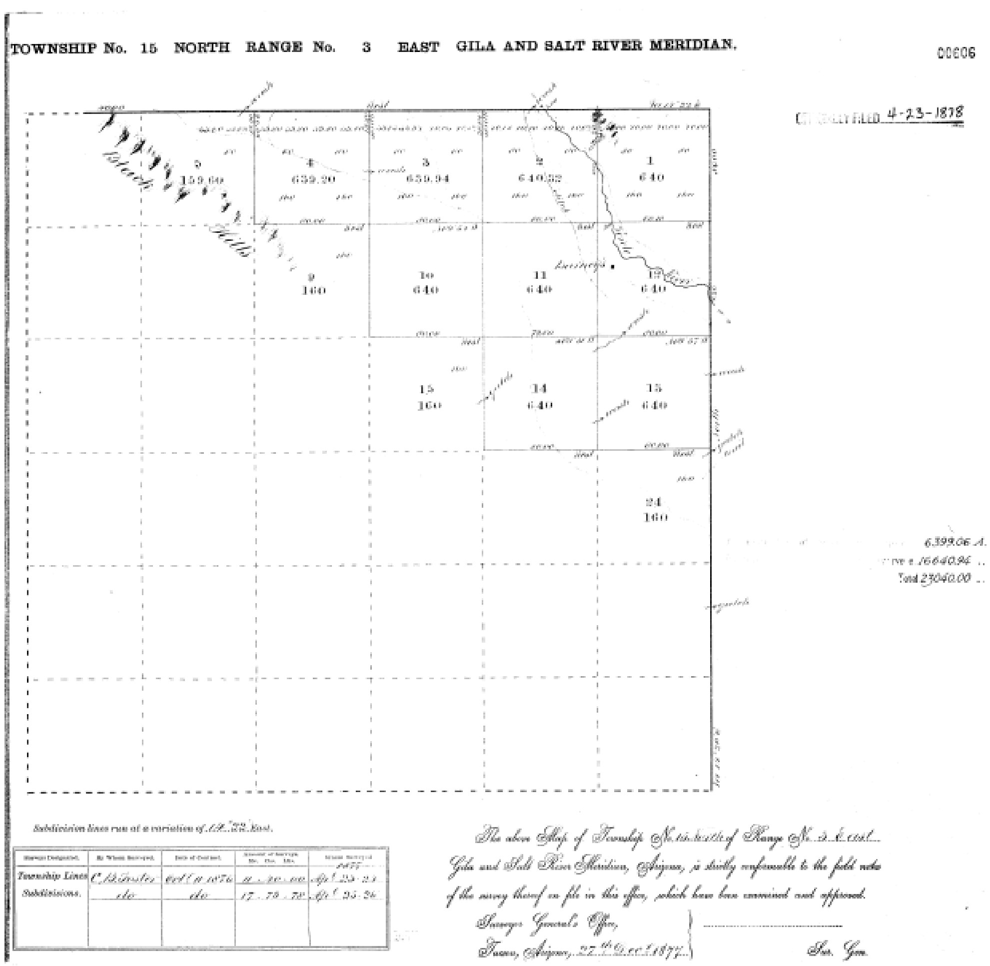
BOOK 1665 40

Between Tps 14 and 15 N. Range 4 E.
Gila and Salt River Meridian

Chs	
50.40	Verde River 1 chain wide, flows S.S.E.
56.00	Begin ascent of bluff, bears N. and S. a short distance, thence W.
59.00	Summit of bluff and enter rolling Mesa bears W.
80.00	Set a limestone 14x10x4 ins properly notched; set 7/3 in the ground and on W side build mound of stone 2 ft high, for Cor to Secs. 4, 5, 32 and 33. from which A Cedar, 12 ins. dia. bears S. 89° E. 91 lks dist. No other trees near
	Land, E of river, rich bottom; W. rolling Mesa. 2d rate soil.
	Timber Cottonwood along River. Scrub cedar on Mesa

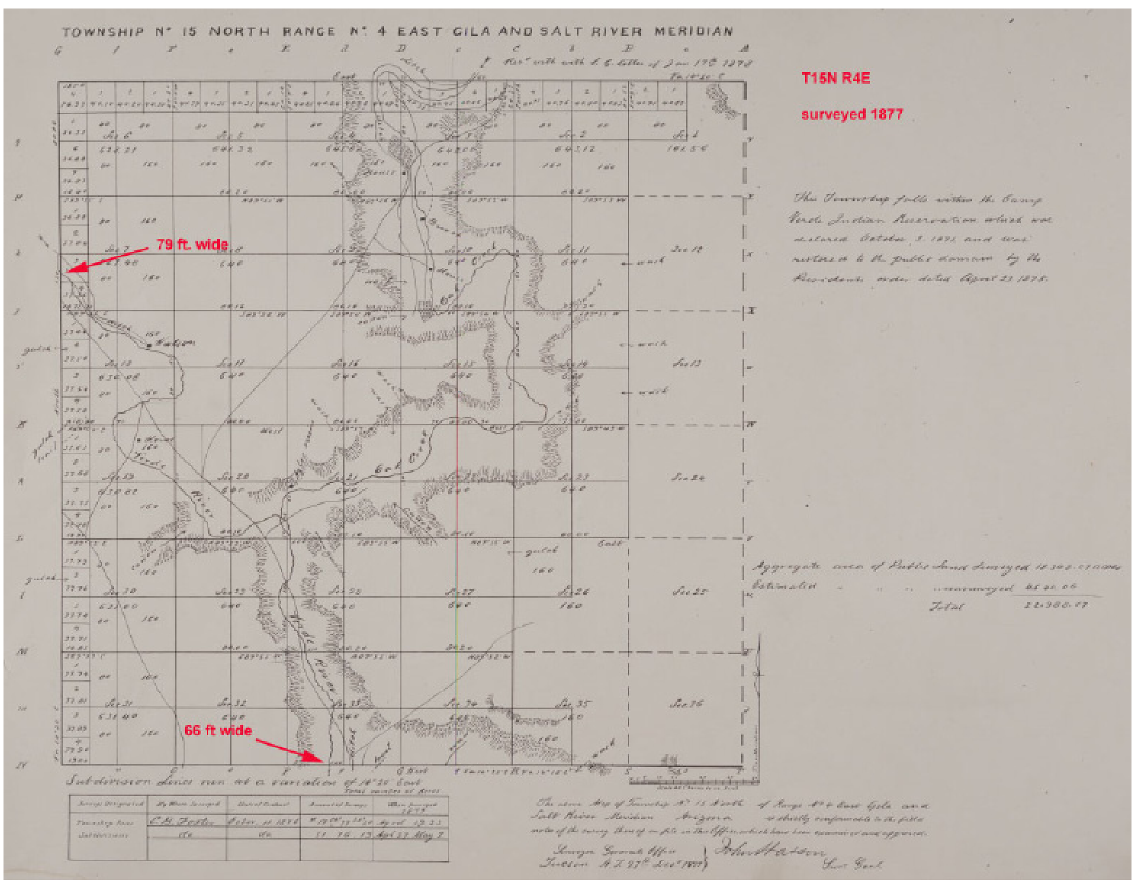
West on true line
Between Secs 5 and 32
Va 14°20' East.

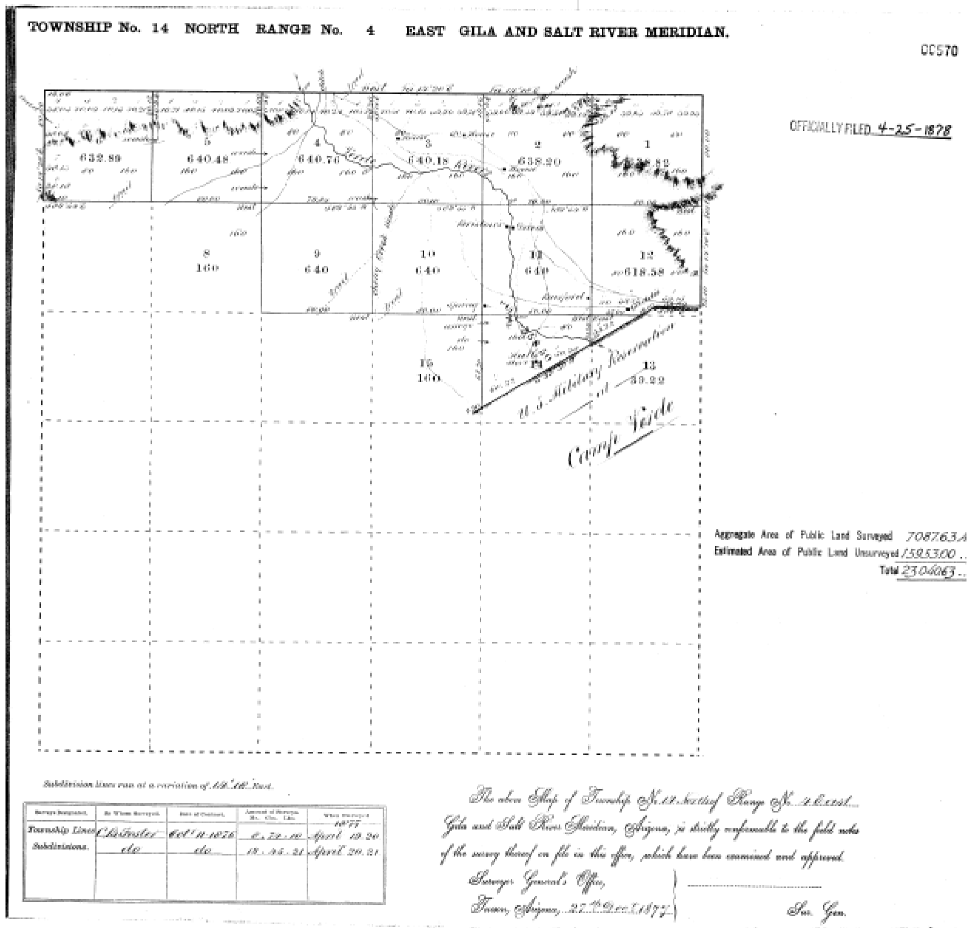
40.00	Set a granite stone 12x10x8 ins marked 1/4

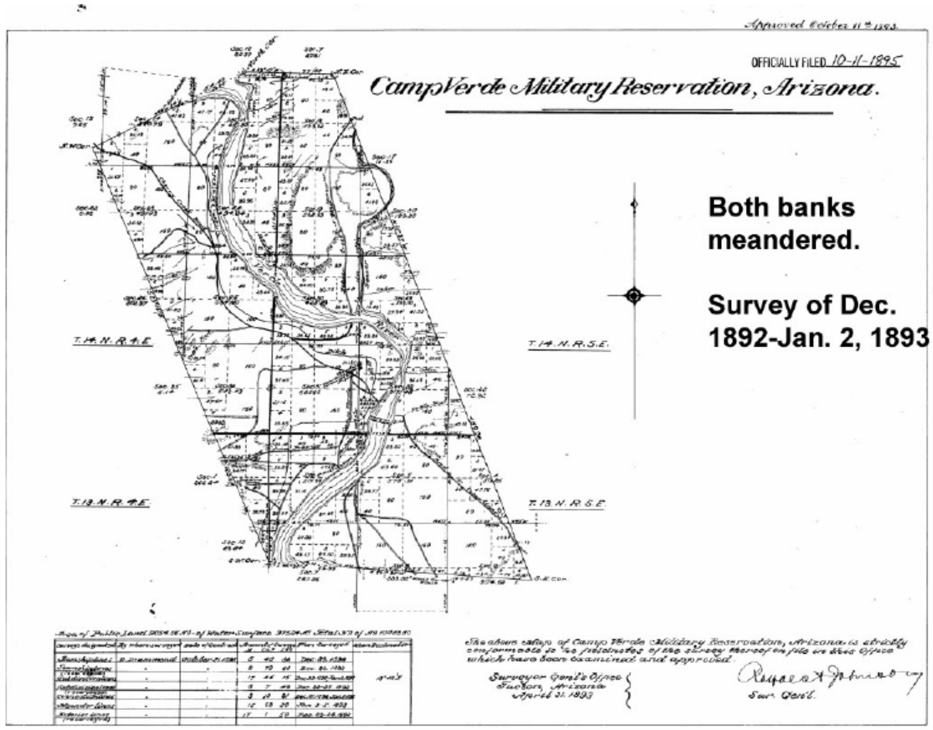


Between Tps 15 & 16 N. Range 4 E.
Gila and Salt River Meridian

Chs	
4.00	Enter level valley, bears N and S
36.90	Verde River 100 lks wide flows S.E.
40.00	Set a granite stone 12x10x6 ins. marked 1/4 S set 2/3
	in the Ground and build mound of stone 2 ft high
	for 1/4 sec Cor. No trees near
41.30	Road bears NNW and SSE and
	Cliff's house bears S. about 8 chs dist.
45.00	Road bears S.E. and N.W.
47.20	Wash 50 lks wide flows S.E.
51.00	Irrigating ditch flows S.
63.40	Road bears S.E. and N.
80.00	Set a post marked and notched 4 ft long, 3 ins square.
	1 ft in the Ground, drive charred Stake, and build mound
	of earth 2 ft high with pits 3x1x1 ft for Cor to Secs
	2.3.34 and 35. No trees near
	Land level. Soil 1st rate.
	No timber or undergrowth

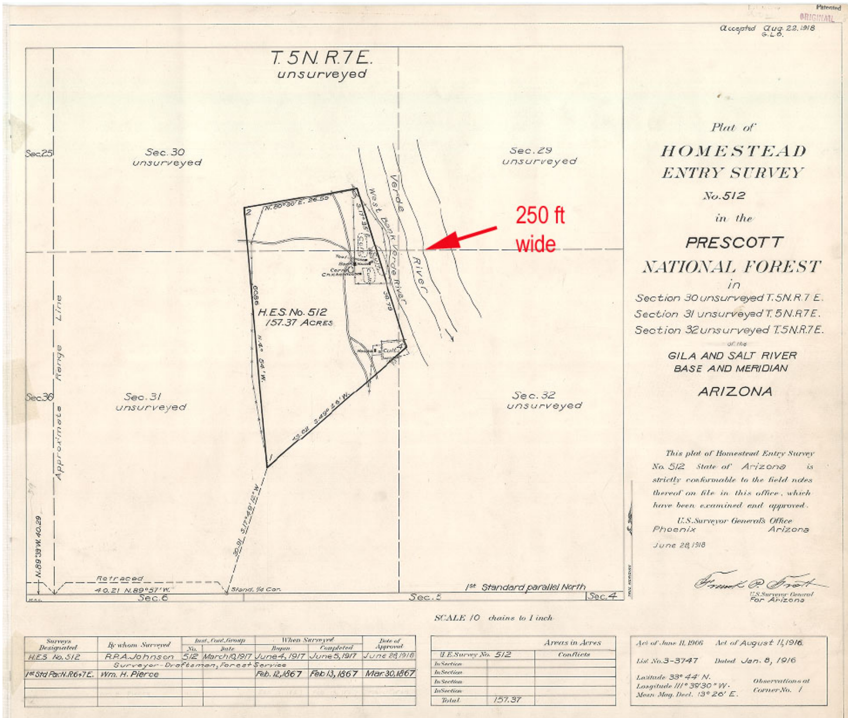


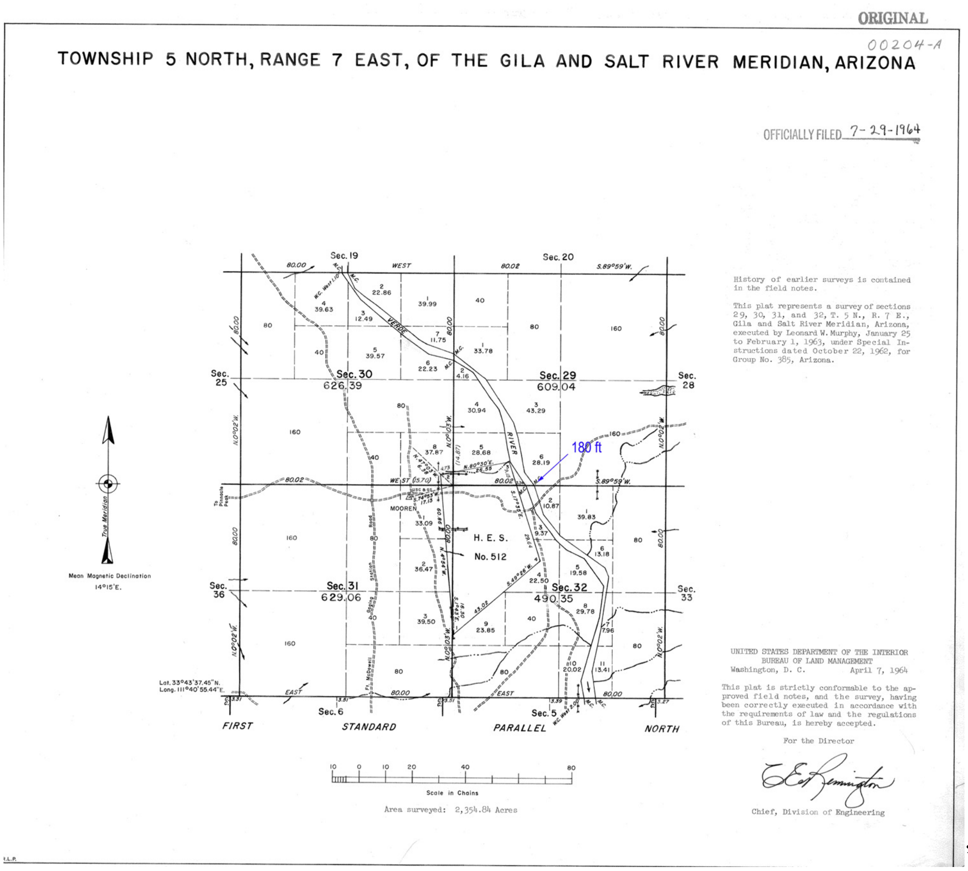




Both banks meandered.

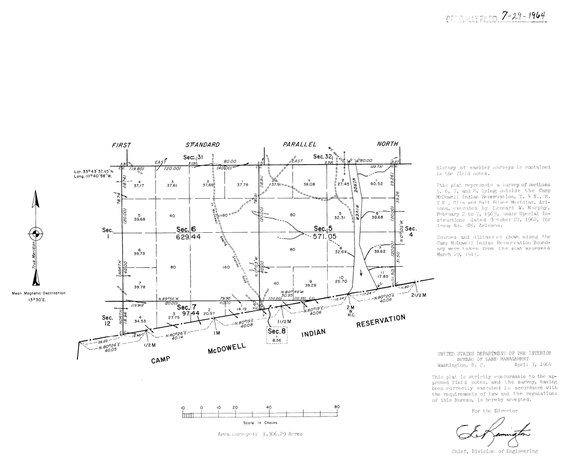
Survey of Dec. 1892-Jan. 2, 1893


T.5N.R.7E.
unsurveyed
Sec. 30
unsurveyed
Sec. 29
unsurveyed
Sec. 31
unsurveyed
Sec. 32
unsurveyed
Verde River
250 ft
wide
H.E.S. No. 512
157.37 Acres
Approximate Range Line
1st Standard parallel North
Sec. 6
Sec. 5
Sec. 4
Plat of
HOMESTEAD
ENTRY SURVEY
No. 512
in the
PRESCOTT
NATIONAL FOREST
in
Section 30 unsurveyed T.5N.R.7E.
Section 31 unsurveyed T.5N.R.7E.
Section 32 unsurveyed T.5N.R.7E.
GILA AND SALT RIVER
BASE AND MERIDIAN
ARIZONA
This plat of Homestead Entry Survey No. 512 State of Arizona is strictly conformable to the field notes thereof on file in this office, which have been examined and approved.
U.S. Surveyor General's Office
Phoenix Arizona
June 28, 1918
SCALE 10 chains to 1 inch


ORIGINAL
00204-A
TOWNSHIP 5 NORTH, RANGE 7 EAST, OF THE GILA AND SALT RIVER MERIDIAN, ARIZONA
OFFICIALLY FILED 7-29-1964
Sec. 19
Sec. 20
Sec. 30
626.39
Sec. 29
609.04
Sec. 31
629.06
Sec. 32
490.35
180 ft
H. E. S.
No. 512
FIRST
STANDARD
PARALLEL
NORTH
Sec. 6
Sec. 5
Mean Magnetic Declination
14°15'E.
History of earlier surveys is contained in the field notes.
This plat represents a survey of sections 29, 30, 31, and 32, T. 5 N., R. 7 E., Gila and Salt River Meridian, Arizona, executed by Leonard W. Murphy, January 25 to February 1, 1963, under Special Instructions dated October 22, 1962, for Group No. 385, Arizona.
UNITED STATES DEPARTMENT OF THE INTERIOR
BUREAU OF LAND MANAGEMENT
Washington, D. C. April 7, 1964
This plat is strictly conformable to the approved field notes, and the survey, having been correctly executed in accordance with the requirements of law and the regulations of this Bureau, is hereby accepted.
For the Director
Chief, Division of Engineering
Scale in Chains
Area surveyed: 2,354.84 Acres

,

TOWNSHIP 4 NORTH, RANGE 7 EAST, OF THE GILA AND SALT RIVER MERIDIAN, ARIZONA

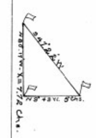


BOOK 2398 112

MxC
Retracement N. bdy. of old Camp McDowell Reservation.

T4N
R7E

Chains	
	M C in E. 2 M P C [illegible] I R W C 1911 in S.
	Land, smooth and sloping to the E. Soil, 2nd rate, gravelly. Timber, palo verde and ironwood. Mesquite brush, greasewood and catclaw. - Feb. 20, 1911.
	February 21, 1911, at 8h., a.m., l.m.t., I set off 33° 42½' on the lat. arc, 10° 46' S. on the decl. arc, and determine a meridian with the solar at 2nd mile cor. on the N. bdy. of old Camp McDowell Reservation.
	Thence I run
	N. 80° 17' E. on a random line
	Along the 3rd mile, W ½.
2.50	Triangulation point on right bank of Verde River.
	To determine the distance across the river I set a flag on line on a sand bar across the channel for triangulation point. Then from the triangulation point on the East side of the Verde River channel, I measure a base N. 9° 43' W., 5.00 chs., from which the flag on West bank of channel bears S. 47° 22' W. Therefore, the distance is the tan. 57° 5' x base or 1.5447 x 5.00 equal 7.72. 2.50 + 7.72 makes
10.22	Triangulation point on East side of channel.
40.08	Fall 3 lks. N. of 2½ mile cor., which is a malpais stone 8x10x20 ins. firmly set, mkd. P L on N. face, Ft McD M R 2½ M on S. face, and witnessed by a mound of stone to the S.
	Returning to the 2nd mile cor., which is also the M. C.,
	Thence I run
	N. 80° 20' E. on a true line
	Along the 3rd mile, W ½.
	Descending left bank of the Verde River, 15 ft. high.
0.20	Point for old M. C. which has been obliterated by erosion.
	Now part of bank.
	Thence through dense arrow weed over sand bar.
2.50	Enter dangerous quicksand of Verde River, course S.
3.00	Channel, about 5 ft. deep, course S.
9.50	Leave channel, course S.

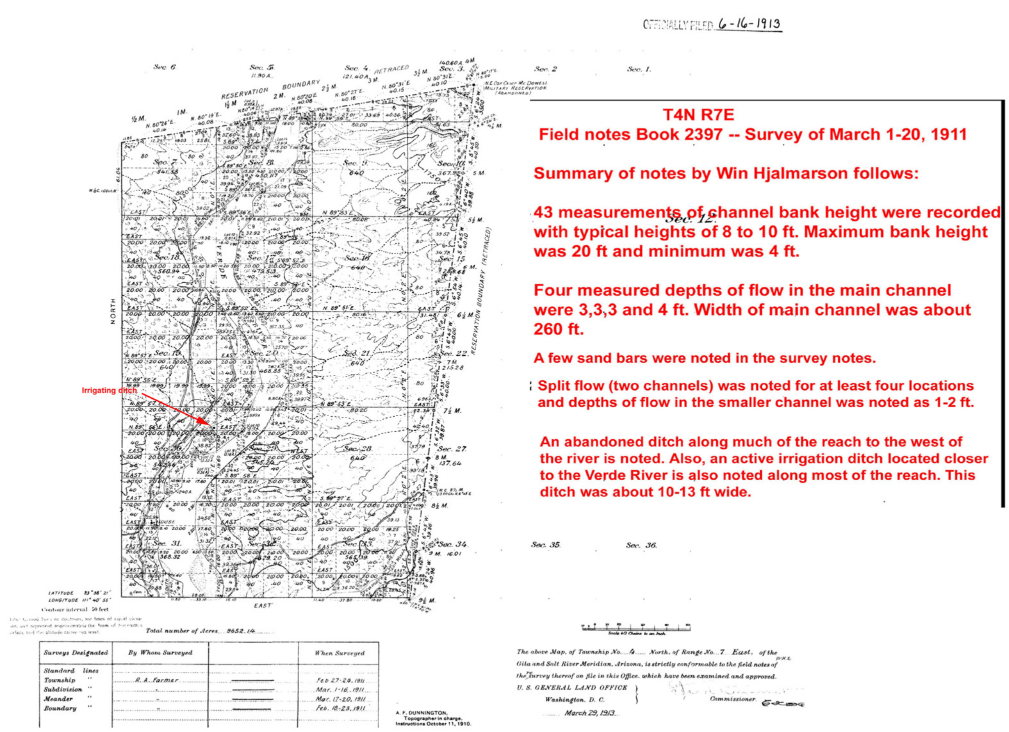


5 feet deep

Resurvey of Township No. 4 North Range No. 7 East of the Gila and Salt River Meridian, Arizona. 800181

SALT RIVER INDIAN RESERVATION

OFFICIALLY FILED 6-16-1913



T4N R7E

Field notes Book 2397 -- Survey of March 1-20, 1911

Summary of notes by Win Hjalmarson follows:

43 measurements of channel bank height were recorded with typical heights of 8 to 10 ft. Maximum bank height was 20 ft and minimum was 4 ft.

Four measured depths of flow in the main channel were 3,3,3 and 4 ft. Width of main channel was about 260 ft.

A few sand bars were noted in the survey notes.

Split flow (two channels) was noted for at least four locations and depths of flow in the smaller channel was noted as 1-2 ft.

An abandoned ditch along much of the reach to the west of the river is noted. Also, an active irrigation ditch located closer to the Verde River is also noted along most of the reach. This ditch was about 10-13 ft wide.

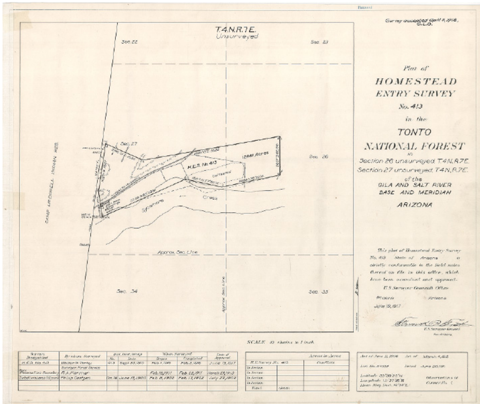
Surveys Designated	By Whom Surveyed		When Surveyed
Standard lines			
Township "	R. A. Farmer		Feb 27-28, 1911
Subdivision "	"		Mar. 1-16, 1911
Meander "	"		Mar. 17-20, 1911
Boundary "	"		Feb. 18-23, 1911

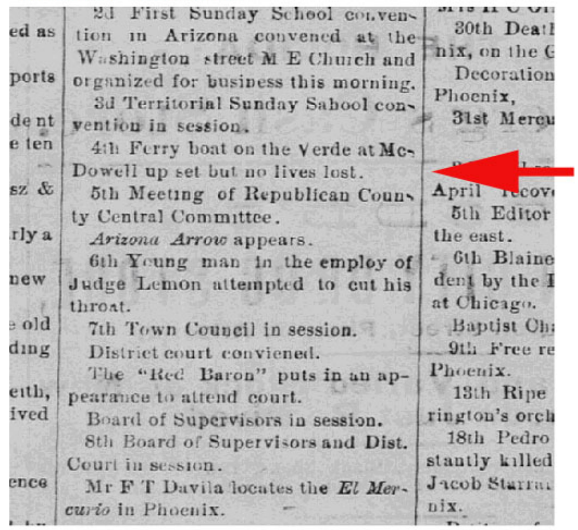
A. F. DUNNINGTON, Topographer in charge, Instructions October 11, 1910.

The above Map of Township No. 4 North, of Range No. 7 East, of the Gila and Salt River Meridian, Arizona, is strictly conformable to the field notes of the survey thereof on file in this Office, which have been examined and approved.

U. S. GENERAL LAND OFFICE
Washington, D. C.
March 29, 1913.

Commissioner.




11/9/2014 Chronicling America - The Library of Congress

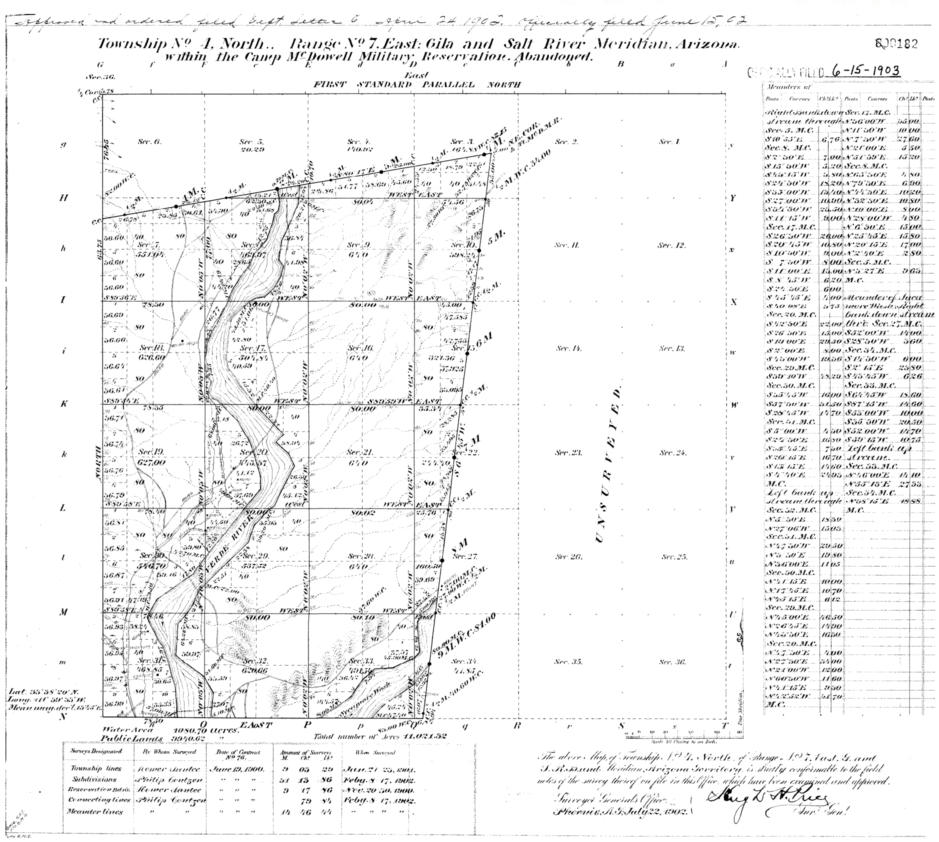
Weekly Phoenix herald. (Phoenix, Maricopa County, Ariz. Territory [Ariz.]) 1882-1896, January 01, 1885, Image 2

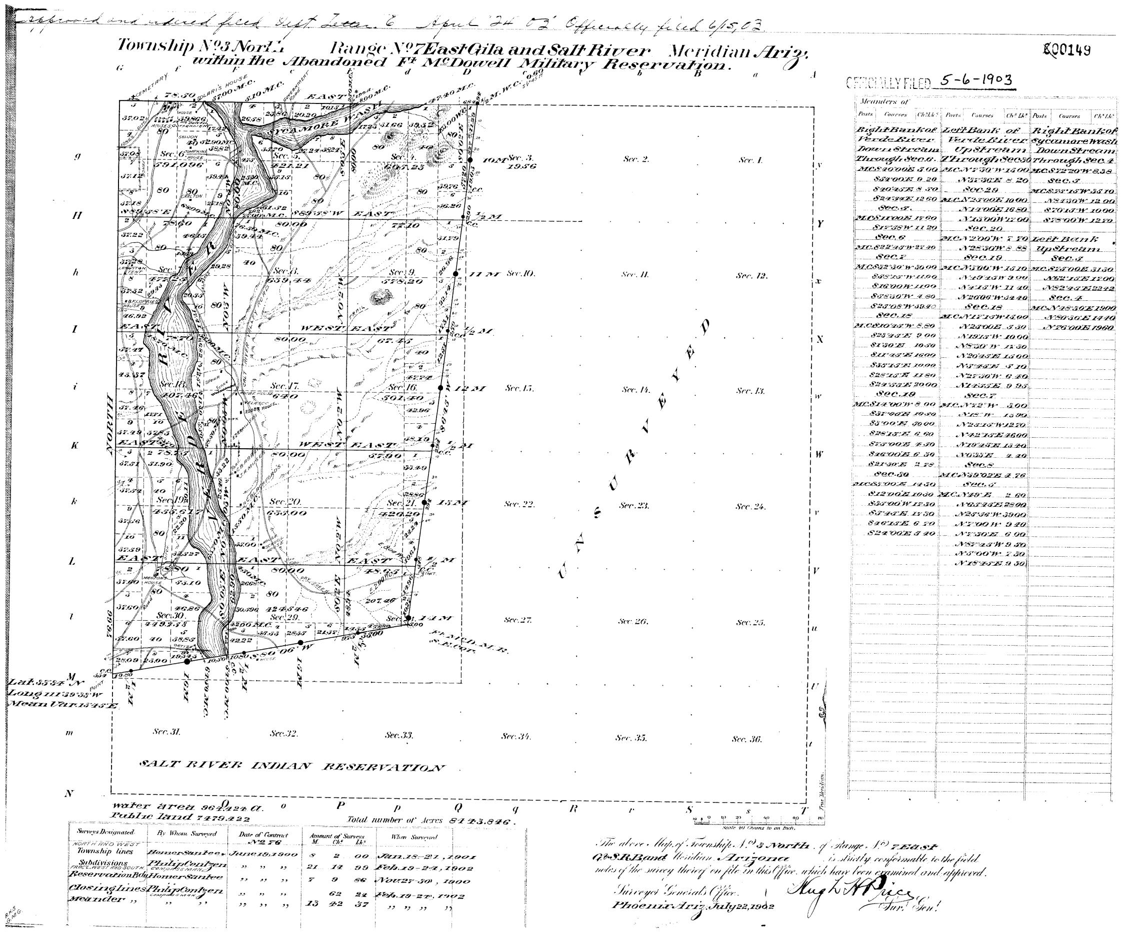
Image provided by Arizona State Library, Archives and Public Records; Phoenix, AZ
Persistent link: http://chroniclingamerica.loc.gov/lccn/sn83025459/1885-01-01/ed-1/seq-2/

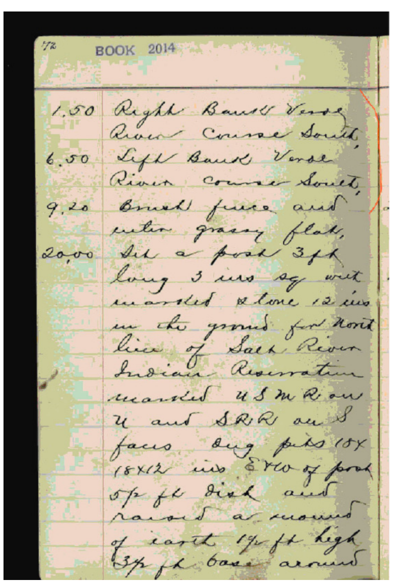
Print this image | Download this image

2d First Sunday School convention in Arizona convened at the Washington street M E Church and organized for business this morning.
3d Territorial Sunday Sabool convention in session.
4th Ferry boat on the Verde at McDowell up set but no lives lost.
5th Meeting of Republican County Central Committee.
Arizona Arrow appears.
6th Young man in the employ of Judge Lemon attempted to cut his throat.
7th Town Council in session.
District court convienel.
The "Red Baron" puts in an appearance to attend court.
Board of Supervisors in session.
8th Board of Supervisors and Dist. Court in session.
Mr F T Davila locates the *El Mercurio* in Phoenix.

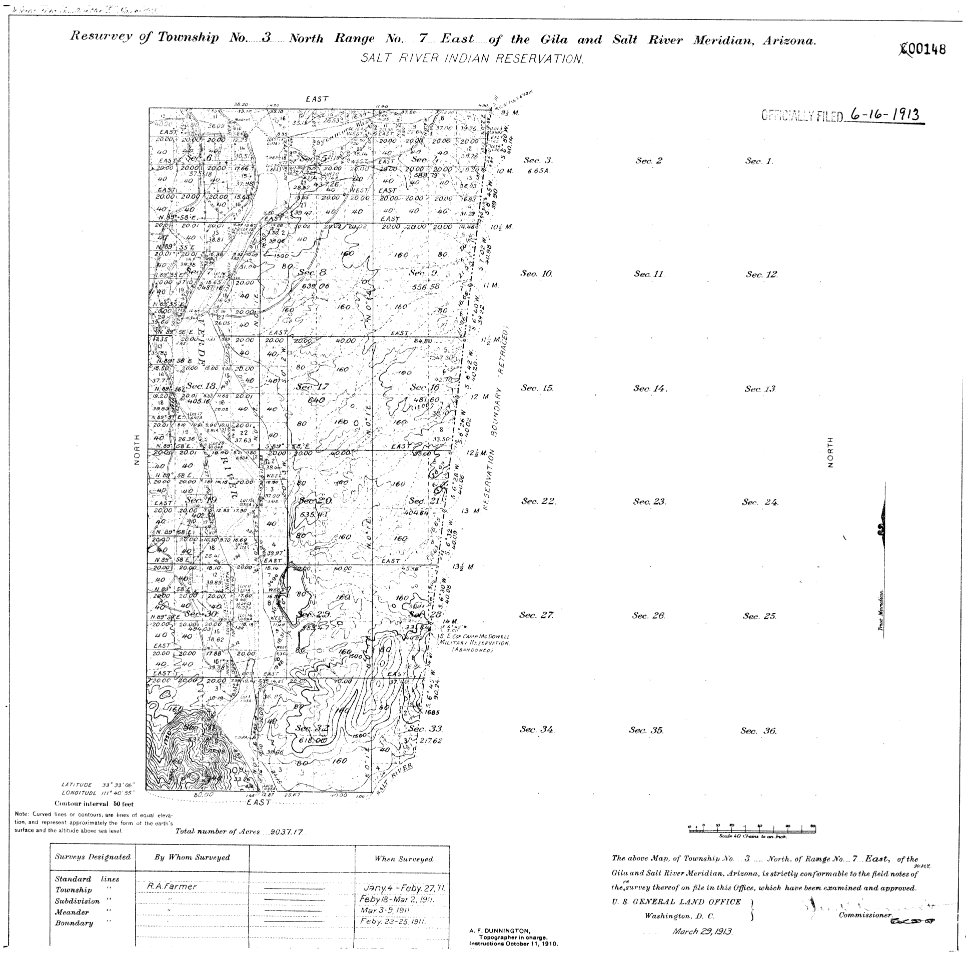
http://chroniclingamerica.loc.gov/lccn/sn83025459/1885-01-01/ed-1/seq-2/print/image_681x647_from_1531%2C5728_to_2507%2C6656/ 1/1







Federal Land Survey (on left) along northern boundary of the Salt River Indian Reservation (see above plat) show width of Verde River of 330 ft. (5 chains). Correcting for skew, width is about 250 ft.



GENERAL DESCRIPTION.

The portion of T. 3 N., R. 7 E., which is within the Salt River Indian Reservation, contains two kinds of land, rolling and rocky, 4th rate, and flat and sandy along river, 2nd rate.

Verde River runs Southerly through secs. 5,6,7,8,18,19, 20,29,30,31,32. At the time of survey it was very low, being from 2½ to 4 ft. deep.

Sycamore Wash runs Westerly through secs. 4 and 5, into Verde River. At time of survey, it was dry.

There is very little land East of the Verde River fit for cultivation, but almost all of the land West of the river, except sec. 31 and the S. ½ of sec. 30, can be cultivated when cleared.

There are groups of Indian huts all along the West side of the river, but none on the East side.

The quarters of the Indian Superintendent are in the North ½ of sec. 6. An artesian well and windmill are in the NE. ¼ of sec. 6.

There is a fringe of cottonwood trees along the West bank of the river, but on the East side the mesquite extends to edge of the bank.

Robert A. Farmer,
Topographer and U. S. Surveyor.

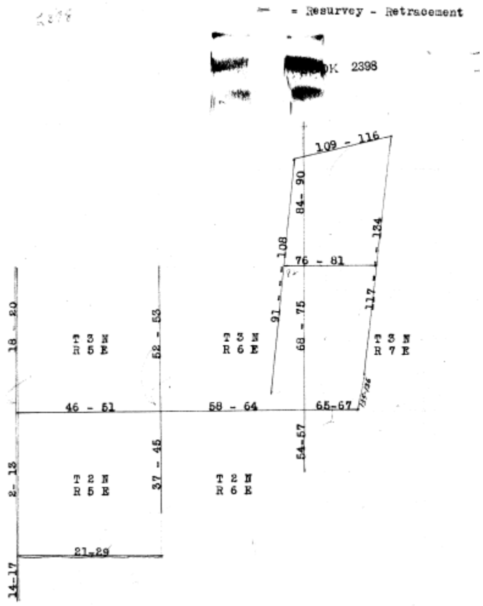
Book 2396 3N 7E Feb. 18 to Mar. 9, 1911 Surveyor Farmer

Row	Width in chains	Width, in feet	Average Depth, in feet
1	4	264	3.0
2	6	396	3.0
3	4	264	2.5
4	4	264	2.5
5	4	264	3.0
6	4	264	2.5
7	5	330	3.0
8	4	264	4.0
9	4	264	3.0
10	5	330	3.0
11	7	462	2.5
12	6	396	2.5
13	5	330	3.0
14	3	198	2.5

Mean of Average Depth, in feet

Mean of Average Depth, in feet = 2.9

Note: Widths and average depths correspond to a portion of the total width that was considered the main channel that was at least 250 ft wide. My estimate of the mean of the **maximum depths is 4 ft.** for the 250 + ft wide main channel.



BOOK 2398

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BOOK 2398

MxC
Retracement N. bdy. of old Camp McDowell Reservation.

Chains

M C in E.
2 M P C [illegible] I R W C 1911 in S.

Land, smooth and sloping to the E.
Soil, 2nd rate, gravelly.
Timber, palo verde and ironwood.
Mesquite brush, greasewood and catclaw.
\- Feb. 20, 1911.

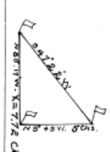
February 21, 1911, at 8h., a.m., l.m.t., I set off 33° 42½' on the lat. arc, 10° 46' S. on the decl. arc, and determine a meridian with the solar at 2nd mile cor. on the N. bdy. of old Camp McDowell Reservation.

Thence I run

N. 80° 17' E. on a random line

Along the 3rd mile, W ½.

2.50 Triangulation point on right bank of Verde River.



To determine the distance across the river I set a flag on line on a sand bar across the channel for triangulation point. Then from the triangulation point on the East side of the Verde River channel, I measure a base N. 9° 43' W., 5.00 chs., from which the flag on West bank of channel bears S. 47° 22' W. Therefore, the distance is the tan. 57° 5' x base or 1.5447 x 5.00 equal 7.72. 2.50 + 7.72 makes

10.22 Triangulation point on East side of channel.

40.08 Fall 3 lks. N. of 2½ mile cor., which is a malpais stone 8x10x20 ins. firmly set, mkd. P L on N. face, Ft McD M R 2½ M on S. face, and witnessed by a mound of stone to the S.

Returning to the 2nd mile cor., which is also the M. C.,

Thence I run

N. 80° 20' E. on a true line

Along the 3rd mile, W ½.

Descending left bank of the Verde River, 15 ft. high.

0.20 Point for old M. C. which has been obliterated by erosion.

Now part of bank.

Thence through dense arrow weed over sand bar.

2.50 Enter dangerous quicksand of Verde River, course S.

3.00 Channel, about 5 ft. deep, course S.

9.50 Leave channel, course S.

A 5 ft. depth of flow was noted for a survey on Feb. 20, 1911 in T4N R7E by Farmer, RA., 1911(page on left); General Land Office Survey Notes, Book 2398.

The location is shown on the above map of the boundaries surveyed with the corresponding page numbers of the survey notes.

A description of the Verde River along the boundary line between T3N R7E and T2N R7E
is shown on the following page.

65

BOOK 2395

North Boundary T. 2 N., R. 7 E.

Chains

January 4, 1911. -

From the cor. of Tps. 2 and 3 N., Rgs. 6 and 7 E., I run East on a true line along the N. bdy. of T. 2 N., R. 7 E., bet. secs. 6 and 31

Over rough, rocky land, descending,

Through brush.

6.00 Foot of descent, brs. N. and S. Begin ascent.

30.00 Top of ascent; begin descent of E. slope of mountain about 900 ft. high.

40.00 Set an iron post for ¼ sec. cor. bet. secs. 6 and 31, with brass cap stamped

¼ S 31 in N. half
S 6 1911 " S. "

Raise mound of stone 2 ft. base, 1½ ft. high, N. of cor.

78.00 Leave rocky mountain land; enter flat land.

80.00 Set an iron post for cor. of secs. 5, 6, 31 and 32, with brass cap stamped

T 3 N S 32 in NE. quadrant
R 7 E S 5 " SE. "
T 2 N S 6 " SW. "
S 31 " NW. "
1911 " S.
1-notch on the W. and 5 on the E. edge.

From which -

Palo verde, 6 ins. in diam., brs. N. 29° E., 92 lks. dist., mkd. T 3 N R 7 E S 32 B T
Mesquite, 8 ins. in diam., brs. N. 28½° W., 59 lks. dist., mkd. T 3 N R 7 E S 31 B T

No other tree available as B. T.

Raise mound of stone 2 ft. base, 1½ ft. high, W. of cor.

Land, rough, rocky mountain.
Soil, 4th rate.
Scattered palo verde and mesquite timber.
Greasewood brush near end of mile.

East on a true line bet. secs. 5 and 32

Over level land,

Through mesquite brush and timber.

1.46 Right bank of Verde River.

Set an iron post for M. C. bet. secs. 5 and 32, with brass cap stamped

66

BOOK 2395

North Boundary T. 2 N., R. 7 E.

Chains

M C in E.
1911 in S.
T 3 N R 7 E S 32 in NW. quadrant
T 2 N S 5 " SW. "
6 notches on the N. and 6 on the S. edge.

From which -

Mesquite, 8 ins. in diam., brs. N. 62½° W., 40 lks. dist., mkd. T 3 N R 7 E S 32 M C B T
Mesquite, 8 ins. in diam., brs. S. 22½° E., 41 lks. dist., mkd. T 2 N R 7 E S 5 M C B T

1.96 Bed of river; thence over sand bar.

9.00 West edge of main channel of river, course S.

13.00 E. edge of main channel.

14.33 Left bank of Verde River.

Set an iron post for M. C. bet. secs. 5 and 32, with brass cap stamped

M C in W.
1911 in S.
T 3 N R 7 E S 32 in NE. quadrant
T 2 N R 7 E S 5 " SE. "
6 notches on the N. and 6 on the S. edge.

From which -

Palo verde, 8 ins. in diam., brs. N. 3½° W., 40 lks. dist., mkd. T 3 N R 7 E S 32 M C B T

No other tree available as B. T.

Raise mound of stone 2 ft. base, 1½ ft. high, E. of cor.

40.00 Set an iron post for ¼ sec. cor. bet. secs. 5 and 32, with brass cap stamped

¼ S 32 in N. half
S 5 1911 " S. "

Dig pits 18x18x12 ins. E. and W. of post 3 ft. dist.; and raise mound of earth 3½ ft. base, 1½ ft. high, N. of cor.

80.00 Set an iron post for cor. of secs. 4, 5, 32 and 33, with brass cap stamped

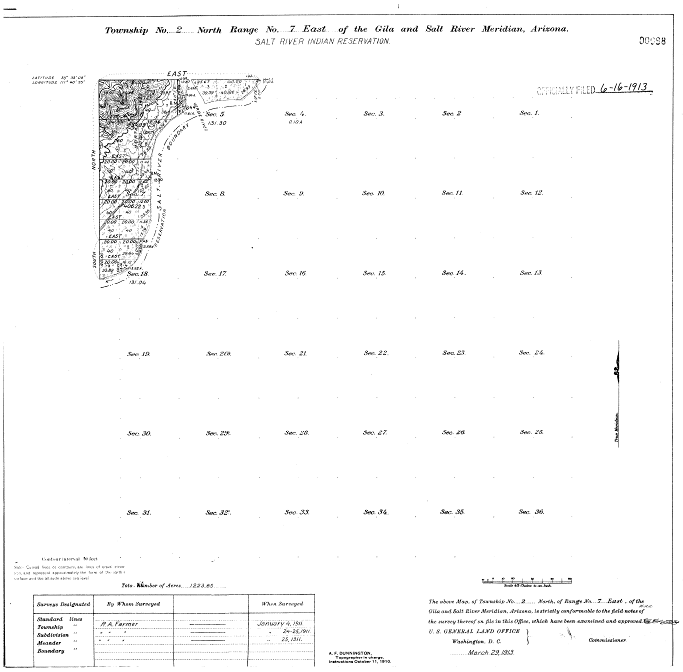
T 3 N S 33 in NE. quadrant
R 7 E S 4 " SE. "
T 2 N S 5 " SW. "
S 32 " NW. "
1911 " S.
2 notches on the W. and 4 on the E. edge.

From which -

Mesquite, 18 ins. in diam., brs. S. 80° W., 25 lks. dist., mkd. T 2 N R 7 E S 5 B T

No other tree available as B. T.

Raise mound of stone 2 ft. base, 1½ ft. high, W. of cor.



The total width of the Verde River along the boundary line between T3N R7E and T2N R7E was about 850 ft. (66 x (14.33-1.46)) with a main channel of 264 ft. wide. A sand bar is noted on the west side of the main channel. This condition is consistent with the description by *Dr. Pearthree in section G3a.--Geomorphology of Verde River Channel* of Appendix G of this report for ANSAC.

ADDITION 2. Riparian trees need soil and water to exist—a comment.

Sediments along the Verde River have different textures, depending on factors such as how quickly the stream moves laterally, the presence of upstream dams such as Bartlett Dam and the presence of slack water or wide overflow areas. Fast-moving water, especially in the absence of a supply of sediment, leaves gravel, rocks, and sand that hardly qualify as a soil. Slow-moving water leaves fine textured material (clay and silt) when sediments in the water settle out. Soils typically are classed by texture that is determined by the percent of clay, silt and sand. Thus, to be a typical soil, clay, silt and sand is needed while gravel, cobbles and boulders have little to do with being a soil.

The fact is trees grow in soil along stream channels where water is available for seed germination and plant growth. Reservoirs behind dams such as stock tanks, Watson Lake Dam and Bartlett Dam store sediments that once were available for downstream soil development along the Verde River and other Arizona rivers. It stands to reason that with less soil there are fewer trees that afford protection from bank erosion during floods.

Obviously there is little bank protection where trees will not grow without water that has been stored behind dams, diverted in canals to fields and/or lowered below the root zone by ground water withdrawal.

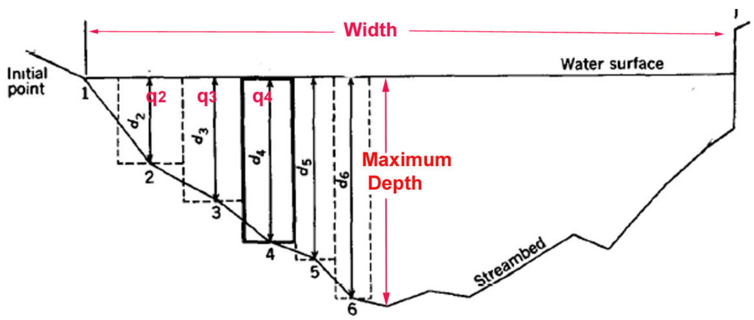
"Human activities that have led to the negative alteration of riparian areas began with the intentions of benefiting society. Still, these alterations have had significant impacts in the degradation of riparian areas. In Arizona, these alterations are even more important since there are fewer riparian areas."

Zaimes, G. (2007). *Understanding Arizona's Riparian Areas.* Tucson, AZ: University of Arizona Cooperative Extension, 109p.

ADDITION 3. Channel depth as measure for navigability—three examples.

The following information on channel depth along the Verde River is from USGS data and is related to *Item B of the SUMMARY AND CONCLUSION* of the report. About 95% of the pool and riffle sequence in the Verde River is in the form of pools. Because measurements of stream discharge, historically current-meter measurements, typically are made near the ends of pools where depths can be waded (less than about 3.3 ft) and flow velocities are greater than the USGS recommended minimum velocity of 0.5 ft/sec., a small adjustment was made to the measured depths and a minimum depth of 3 ft was used for the entire river. This condition is also discussed in the first paragraph of the Navigability section of the report and in *section G4c.- Verde River Channel of Appendix G.*

A brief word about measurements of stream discharge: A current-meter measurement is the summation of the products of the subsection areas of the stream cross section and their respective average velocities. The cross section is defined by depths at verticals 1,2,3,4, . . . n. Etc.... These depths, measured by the USGS, are used for the assessment of navigability.



Measurements of discharge are made by wading, using boats and from cableways. Wading and cableway measurements are shown in the USGS photographs below. The man wading the stream is using a wading rod to measure depth and an acoustic velocity meter to measure velocity. A tape is across the stream to measure location and width perpendicular to the direction of flow. Wading is limited to depths of about 3 ft depending mostly on velocity of flow and condition of the channel bottom.

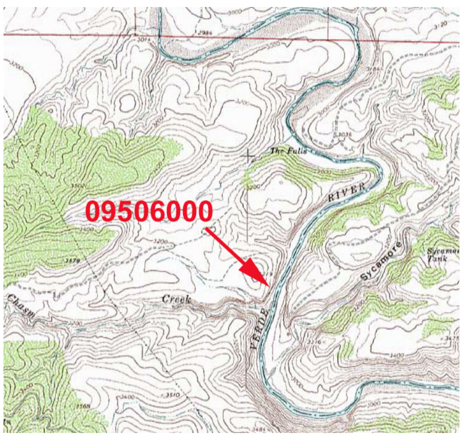
For greater depths the measurement is from a cableway. An Acoustic Doppler Current Profiler (ADCP) is used in the scene to the left. The ADCP measures velocity magnitude and direction using the Doppler shift of acoustic energy reflected by material suspended in the water column, providing essentially a complete vertical profile of velocity (and also the depth of water).

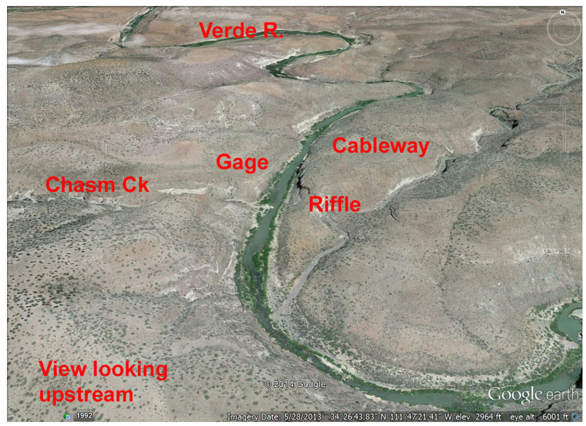
Channel conditions that are related to navigability at two USGS gages are briefly examined. The gages are:

09506000 Verde River near Camp Verde, AZ
09508000 Verde R. below E. Verde River near Childs, AZ
09504000 Verde R. near Clarkdale, AZ

A. USGS gage 09506000

An example of the difference of depth for a riffle and the depth for corresponding upstream pool. Measurement data are from USGS website for station 09506000.



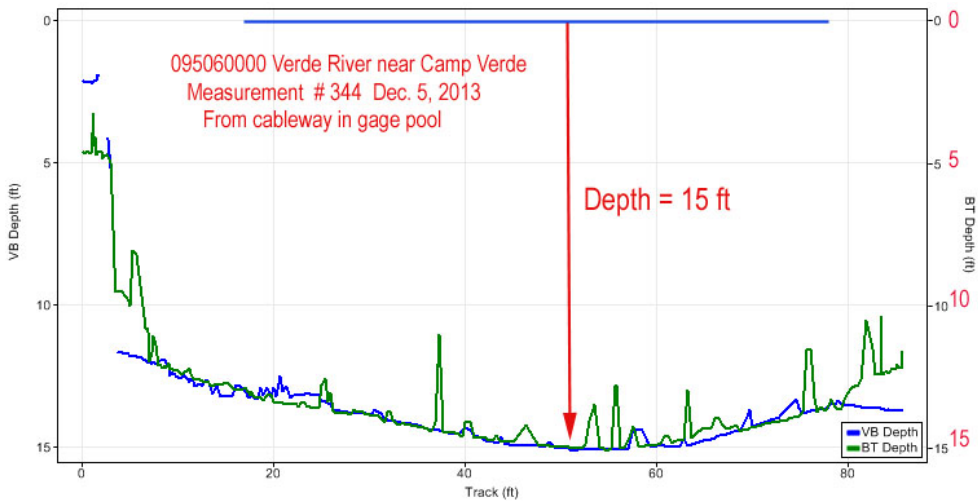


Site is the USGS gage 09506000 Verde River near Camp Verde, AZ. Low flow measurements normally are made at the riffle 800 ft downstream near the mouth of Chasm Creek. On December 5, 2013 a measurement of low flow (No. 344) was made at the cableway located in the pool about 1000 ft upstream of the gage. Nearly the same discharge (210 cfs versus 205 cfs) was measured (No. 345) at the riffle 13 days later on December 18, 2013.

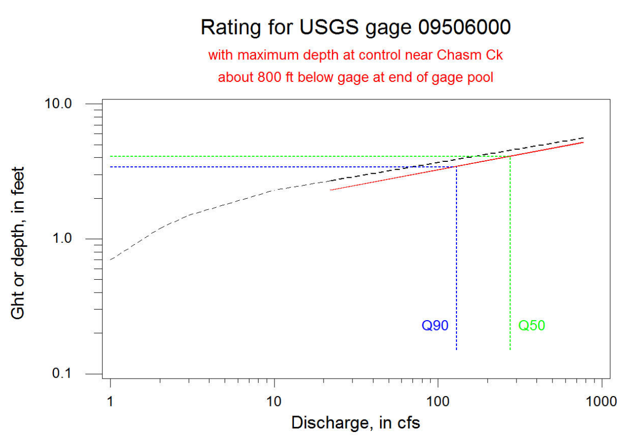
The mean depth of flow at the riffle and cableway was 1.56 ft and 12.9 ft., respectively.

Meas No.	Date	Q cfs	Ght ft	Site	Mean depth ft	Max. depth ft.
346	2014-06-11	43.6	3.18	Chasm Ck (riffle)	1.82	
345	**2013-12-18**	**210**	**4.41**	**Chasm Ck (riffle)**	**1.56**	**3.70**
344	**2013-12-05**	**205**	**4.44**	**Cable (pool)**	**12.90**	**15.00**
343	2013-09-12	1010	6.98	Cable (pool)	15.90	

The measured cross section in the pool for USGS measurement 344 was determined by the USGS using an Acoustic Doppler Current Profiler (See below). The BT graph is what the USGS considers the real depth. The VB graph can have some spurious results from the effect of the beam reflecting off of some type of debris in the water (algae mat, clump of floating grass, etc.). The **maximum measured depth of flow in the pool at USGS gage 09506000 was 15 ft** during a base discharge of 205 cfs on Dec. 5, 2013.



The rating for USGS gage 09506000 that reflects hydraulic conditions at the riffle (a constriction formed by deposited sediment at mouth of Chasm Ck.) control about 800 ft downstream of the gage is shown below. The maximum depth of flow (red line) is also shown. **A maximum flow depth of about 3.7 ft. at the riffle area corresponds to a discharge of 205 cfs on Dec. 5, 2013** for USGS measurement 344. Obviously, the depth in the pool of 15 ft. is considerably greater than the depth of 3.7 ft. at the control (condition defined by the rating curve) for the gage.



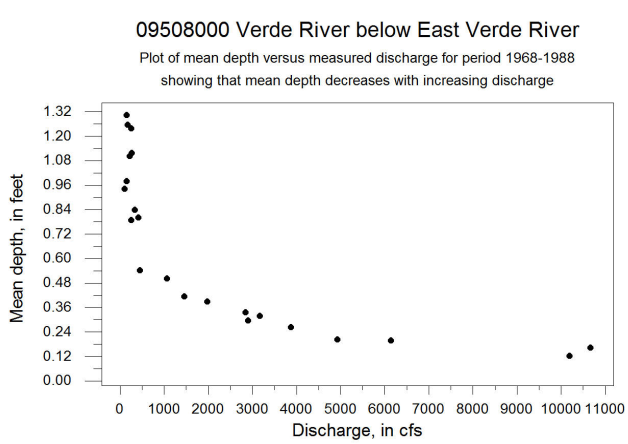
Note: The measurements of discharge at the numerous miscellaneous sites used for this assessment of navigability typically were made in riffle areas where the river could be waded. Most of the pools that comprise about 95% of the river are deeper than 3 ft and thus could not be waded using conventional methods. The deep pool in the preceding example at gage 09506000 is not necessarily the deepest pool along the Verde River. It simply is a deep pool where the depth was measured and is a good example of the differences in flow depth at pools and riffles. Clearly the typical depth of base flow along the Verde River is greater than the depth suggested by current meter measurements made while wading.

By the way: In the Verde Valley upstream from this site -- “The main Verde River channel may be considered as a fairly deep drain extending down the approximate center of a narrow basin 40 miles long and from 1/4-mile to a mile wide.....” (Hayden, 1940, p.12).

Hayden, T. S., 1940, Irrigation on upper Verde River watershed from surface waters: unpublished report of SRP, 329 pages.

B. USGS gage 09508000

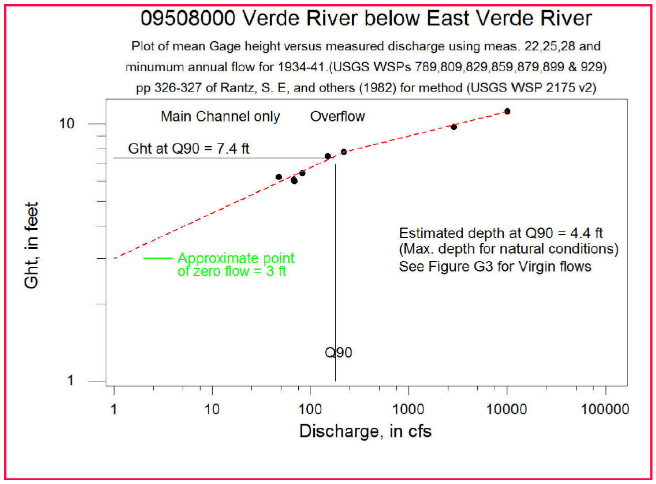
A plot of mean depth of flow for measurements of discharge at USGS gage 09508000 is shown below. The relation of decreasing mean depth as discharge increases clearly shows how worthless the use of mean depth for a channel can be for the assessment of navigability. Obviously, both the maximum and mean depth in the main channel, where potential navigation would occur, increases with increasing discharge.



I (Win Hjalmarson) personally made one of the measurements of discharge shown on the plot and can assure ANSAC that mean depth, especially when the computation includes an overflow area, is a meaningless measure of navigability at this and nearly all locations. Also, the low water control for the gage is very unstable. The gage has been operated by the USGS to define high flow conditions.

For further discussion on this subject of mean depth across the entire channel, that includes the main channel and overflow areas, versus maximum depth, that represents the depth for small watercraft, see Item 3 of Appendix D in Hjalmarson, 2014, NAVIGABILITY ALONG THE NATURAL CHANNEL OF THE SANTA CRUZ RIVER (From the Mexican border to the mouth at the Gila River near Buckeye, Arizona), An assessment based on history, hydrology, hydraulics and morphology.

The stage versus discharge relation for 09508000 is to the right. This relation uses low flow data (discharge and corresponding gage height) for annual minimum daily discharge for the 1930s. Corresponding measurements of higher flows, available on the USGS web site, that represent similar control conditions are also plotted. USGS rating methods are used and the estimated maximum depth for the main channel below the gage is about 4.4 ft. Care was taken to identify where overflow on the flood plain first occurs to avoid confounding the estimate of channel depth.

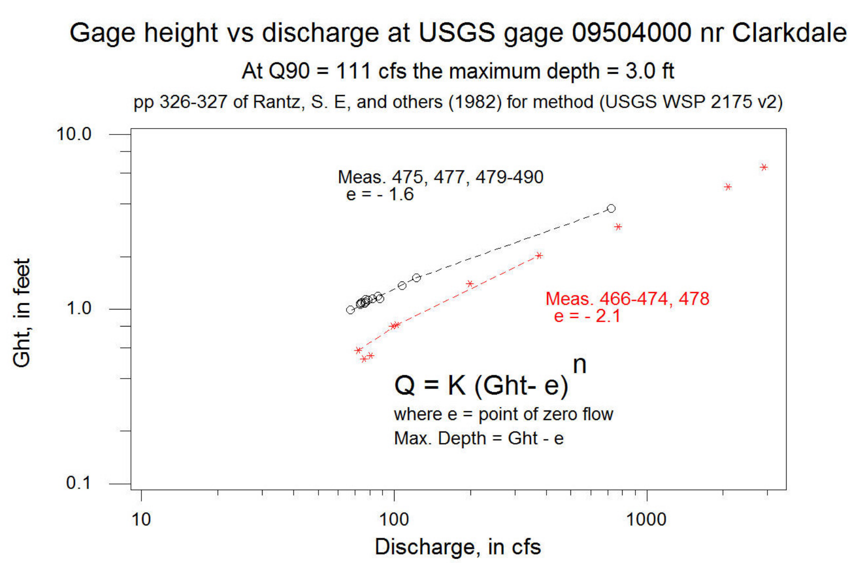


C. <u>USGS gage 09504000</u>

Two low-water segments of ratings for the gage where the control is a riffle approximately 50-100 ft. below the gage are shown below. The rating segments represent a channel filling in the riffle area of about 0.5 ft resulting from a small flood. The control for the gage and another rating for this site at the cableway are shown on page 79 of the report.

The gage is located on a bend to the right where the gravel, cobble and boulder riffle remains on the left side of the channel. The water surface slope changes from a stepped water-surface profile to a rather uniform profile with increasing flow rates (figures on p. 79 of report). As stage increases at the gage the control changes from what is know as a section control to a channel control.

The estimate on the right of maximum channel depth at the riffle control for the gage incorporates classic analytical methods used by the USGS.



ADDITION 4. Channel and vegetation downstream from Bartlett Dam—unpublished USGS aerial photos.

The following unpublished areal photographs are from Anderson, T.W., 1976, Evapotranspiration losses from flood-plain areas in central Arizona: U.S. Geological Survey Open-File Report 76–864, 91 p. When the single channel is compared to the channel shown in the 1904 USGS Fort McDowell Quadrangle in the next section (and also in Appendix K) it appears very similar except at the mouth of Sycamore Creek. The single channel at Sycamore Creek is further to the west in the 1973 aerial photo. Channel movement where tributary debris, especially at the mouths of large tributaries, is dumped (typically during floods) into the Verde River is expected.

The channel depicted in the following 1973 aerial photos clearly is not a wide-braided channel with a braided pattern and unstable low-flow channels as described by Mussetter on p. 3 of his recent declaration *Navigability of the Verde River.*

Obviously the flow depicted in the following photos is human impacted and highly regulated at Bartlett Dam.

Following from Anderson, 1976:

Mapping of Vegetation Types and Densities

Aerial photographs were used to map the areal extent, areal density, and general type of vegetation. The photographs were taken between May 30 and June 18, 1973, using black and white modified infrared film. The film enabled easy identification and distinction of certain types of riparian vegetation because of the different infrared-reflectance characteristics of the different vegetation types. The vegetation was in full foliage at the time the aerial photographs were taken. The scale of the photographs is about 1:13, 000 or 1 in (25 mm) equals about 1, 100 ft (330 m).

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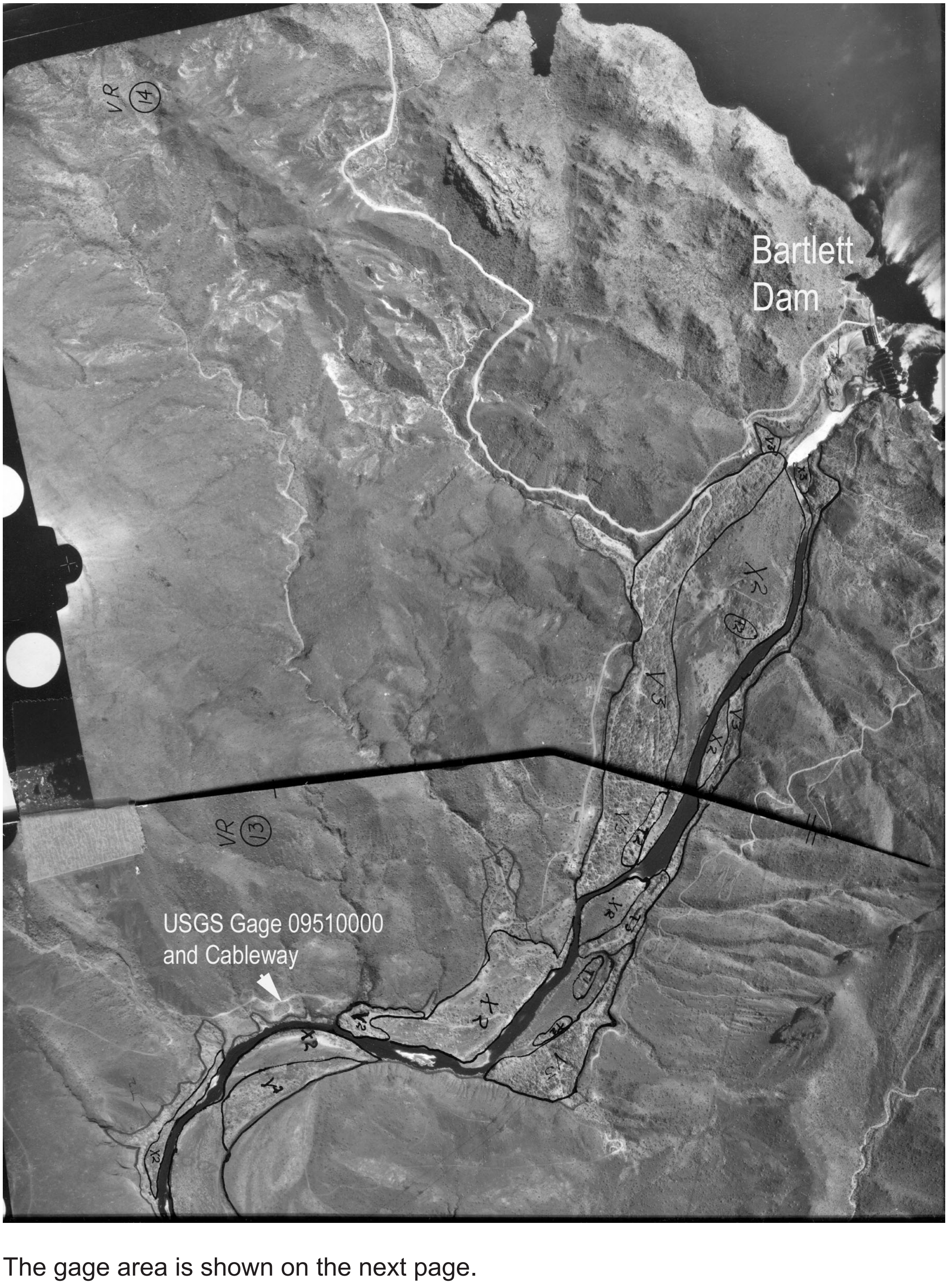
EXPLANATION

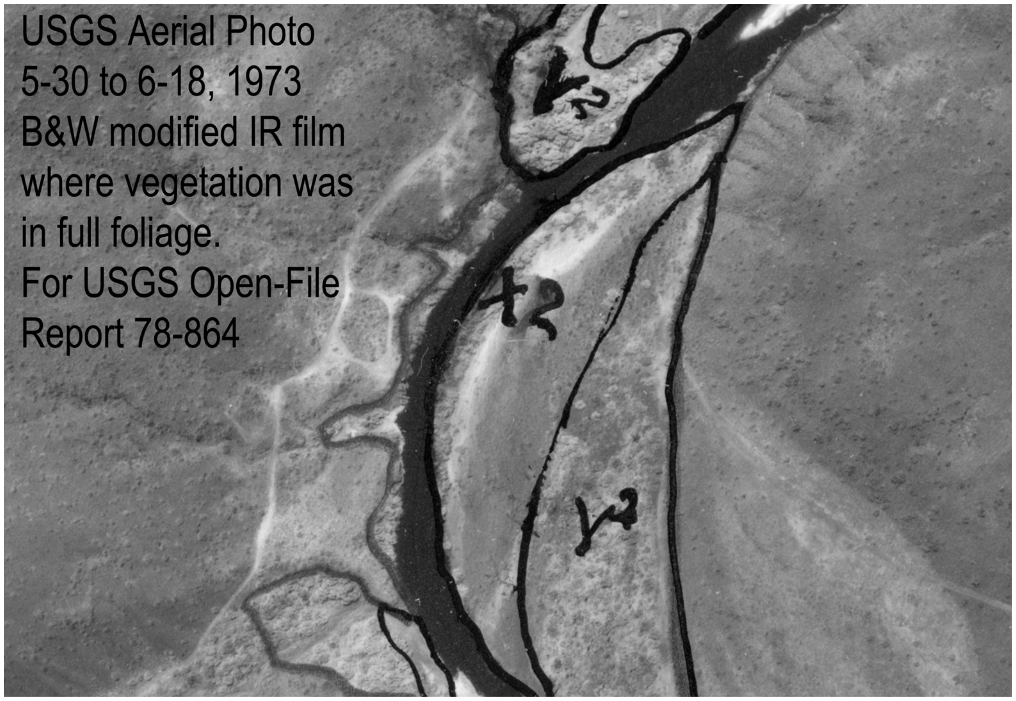
DESIGNATION OF VEGETATION TYPE AND DENSITY, 1

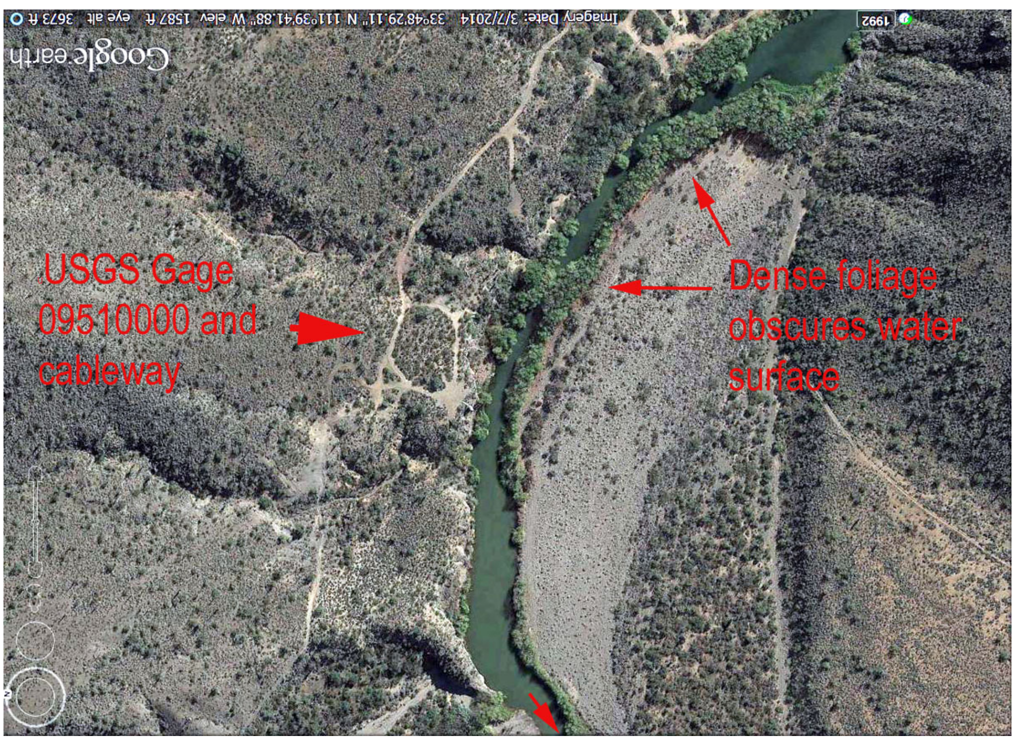
T	Cottonwood-willow
V	Mesquite
X	Riparian scrub
1	Light density
2	Medium density
3	Heavy density

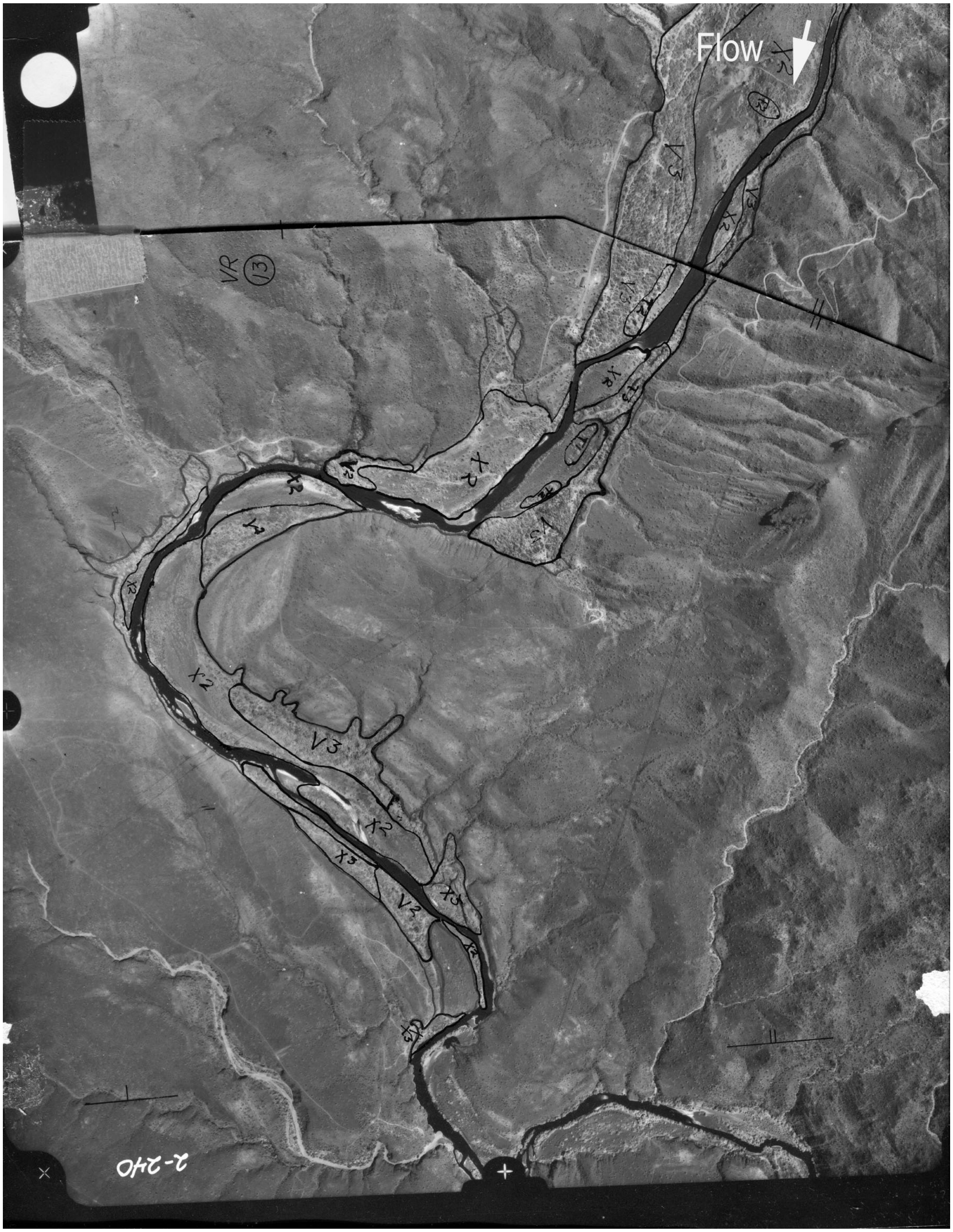


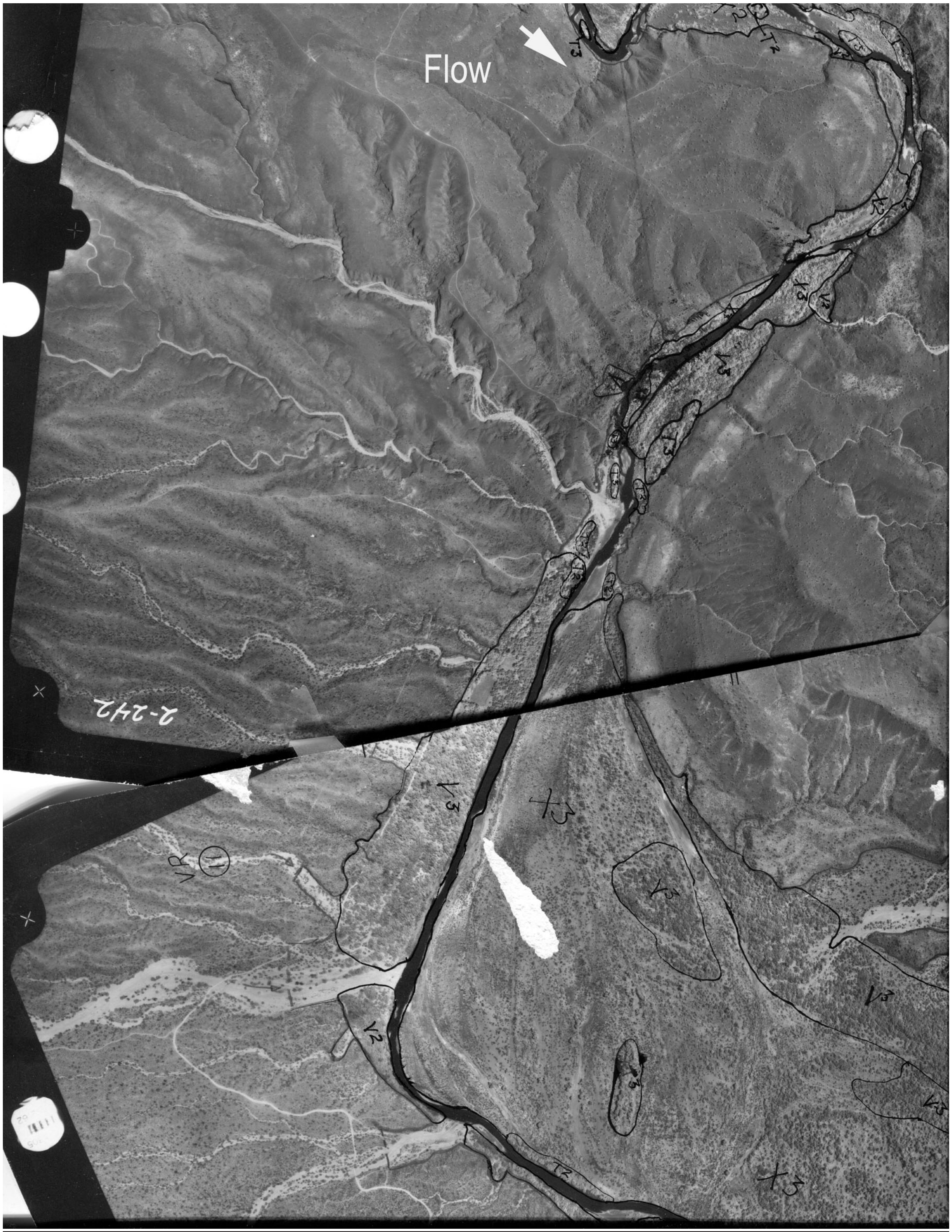
The gage area is shown on the next page.

The number and size of trees along the channel of the Verde River in 2014 is considerably different than in 1973 as shown in the two photos below.

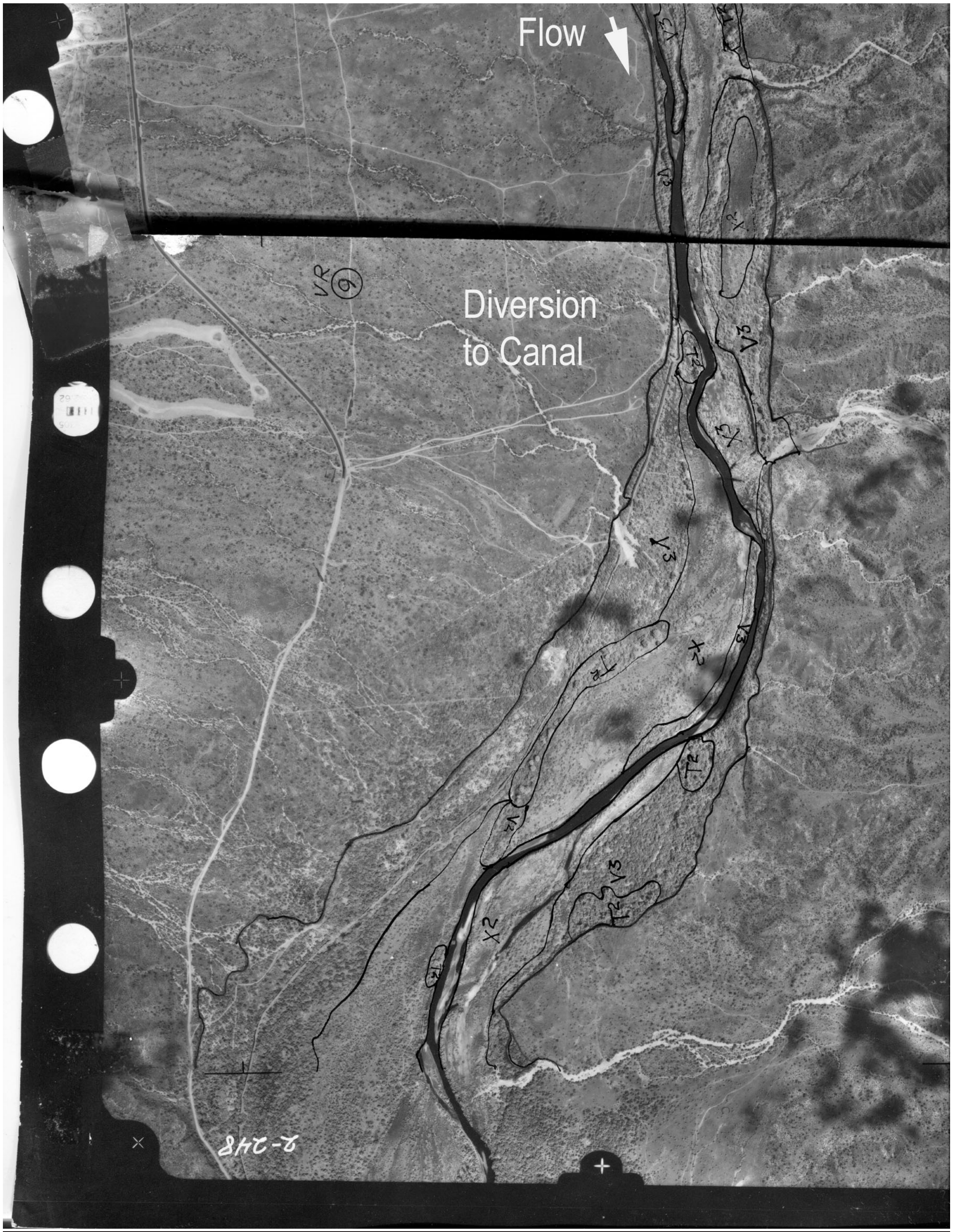


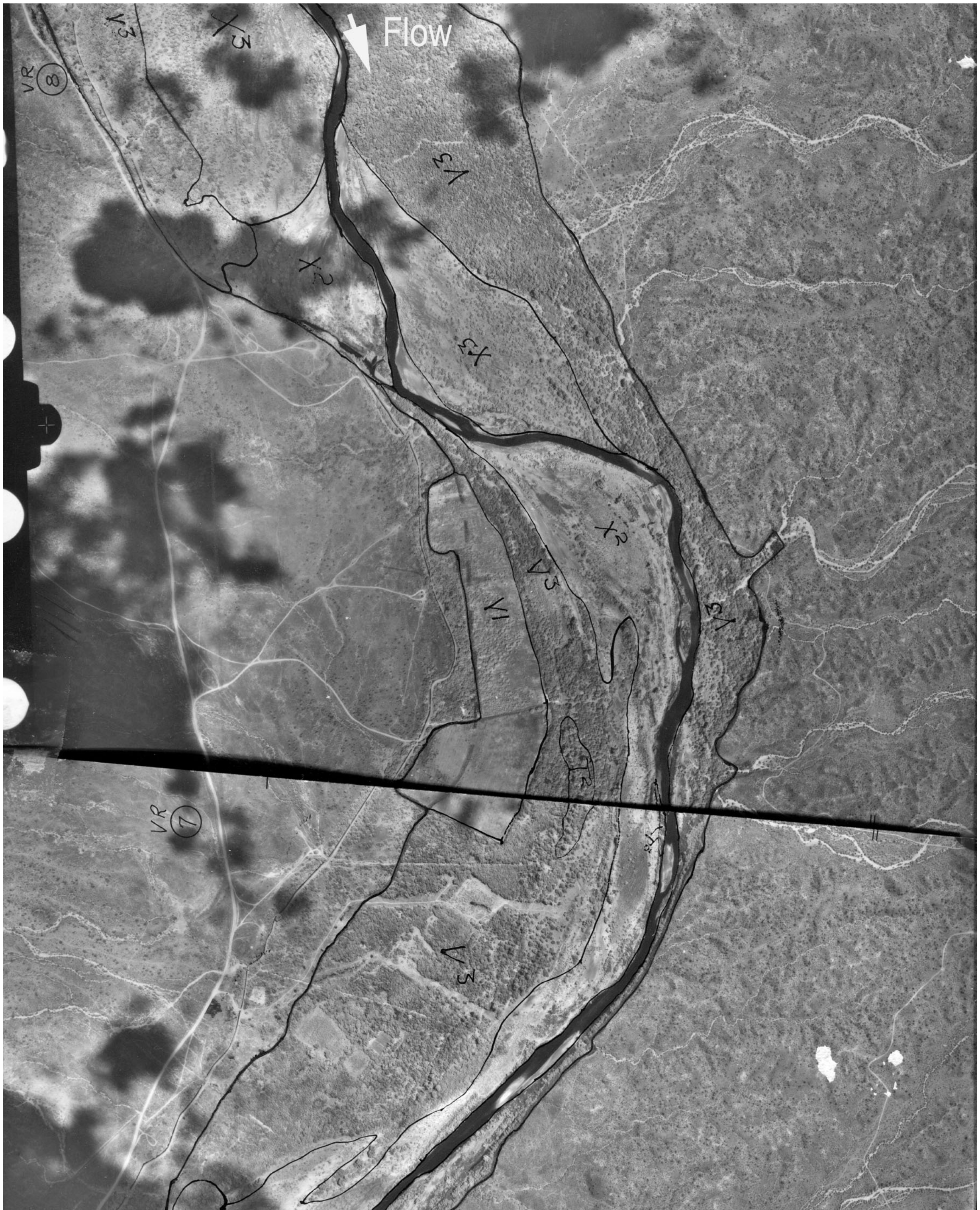


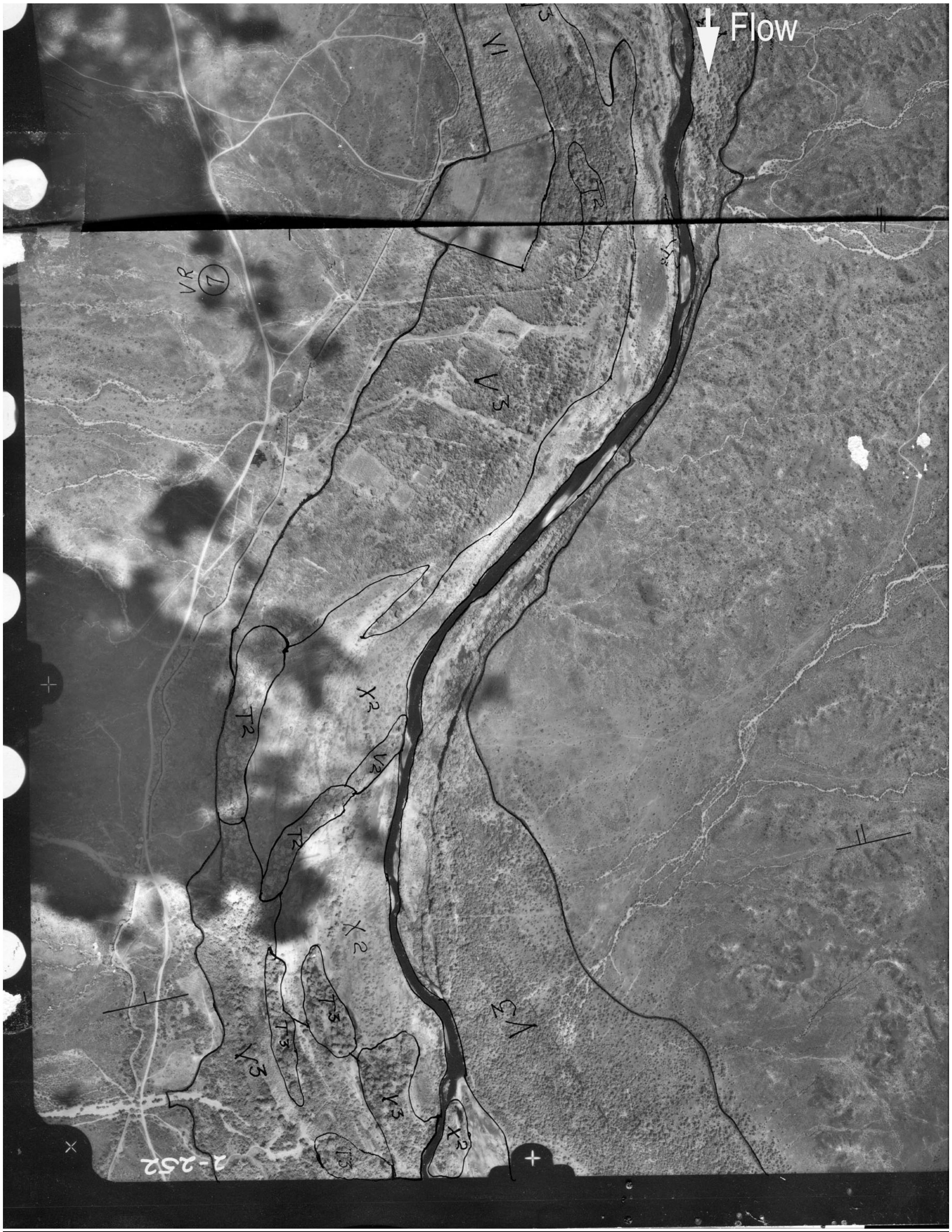

Flow
VR 13
V3
XR
X2
V2
2-240

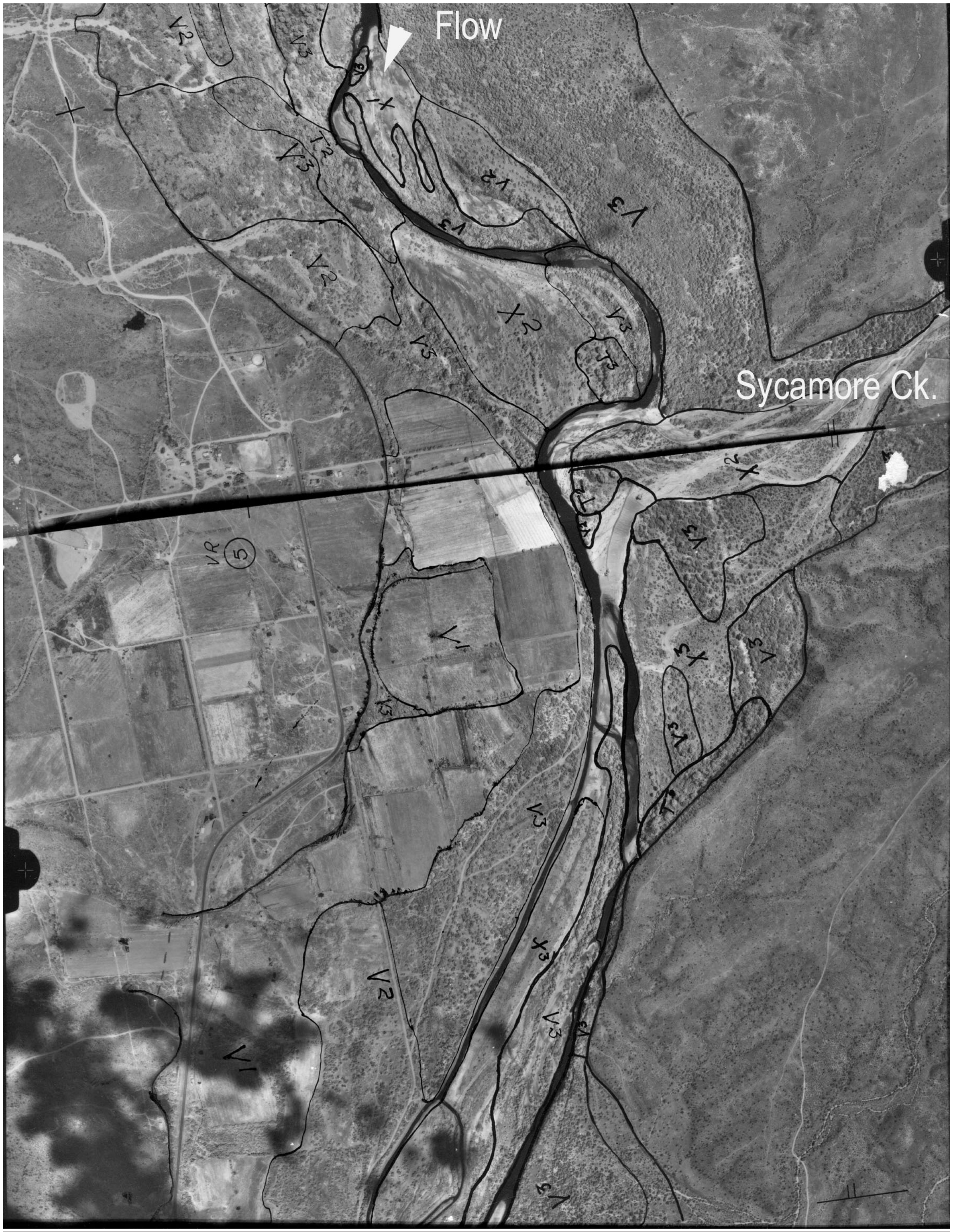

Flow

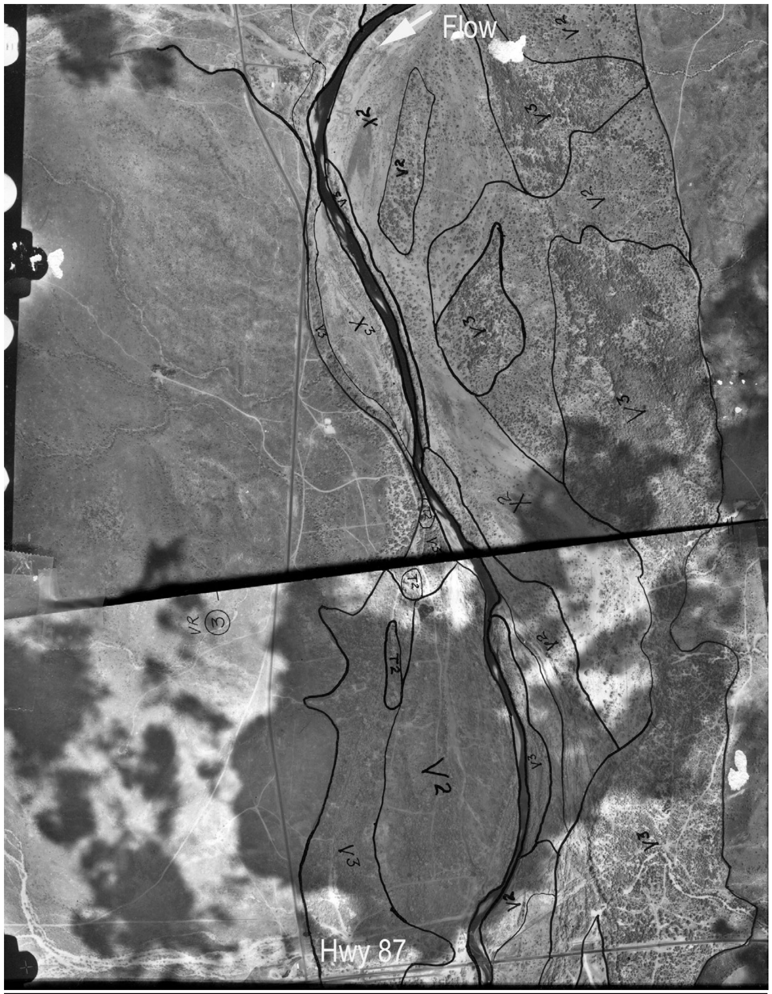

Flow


Flow
Diversion
to Canal

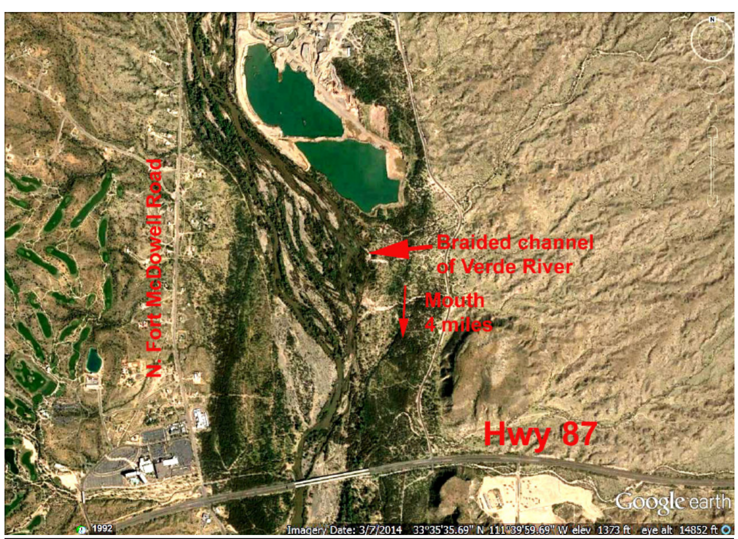

Flow

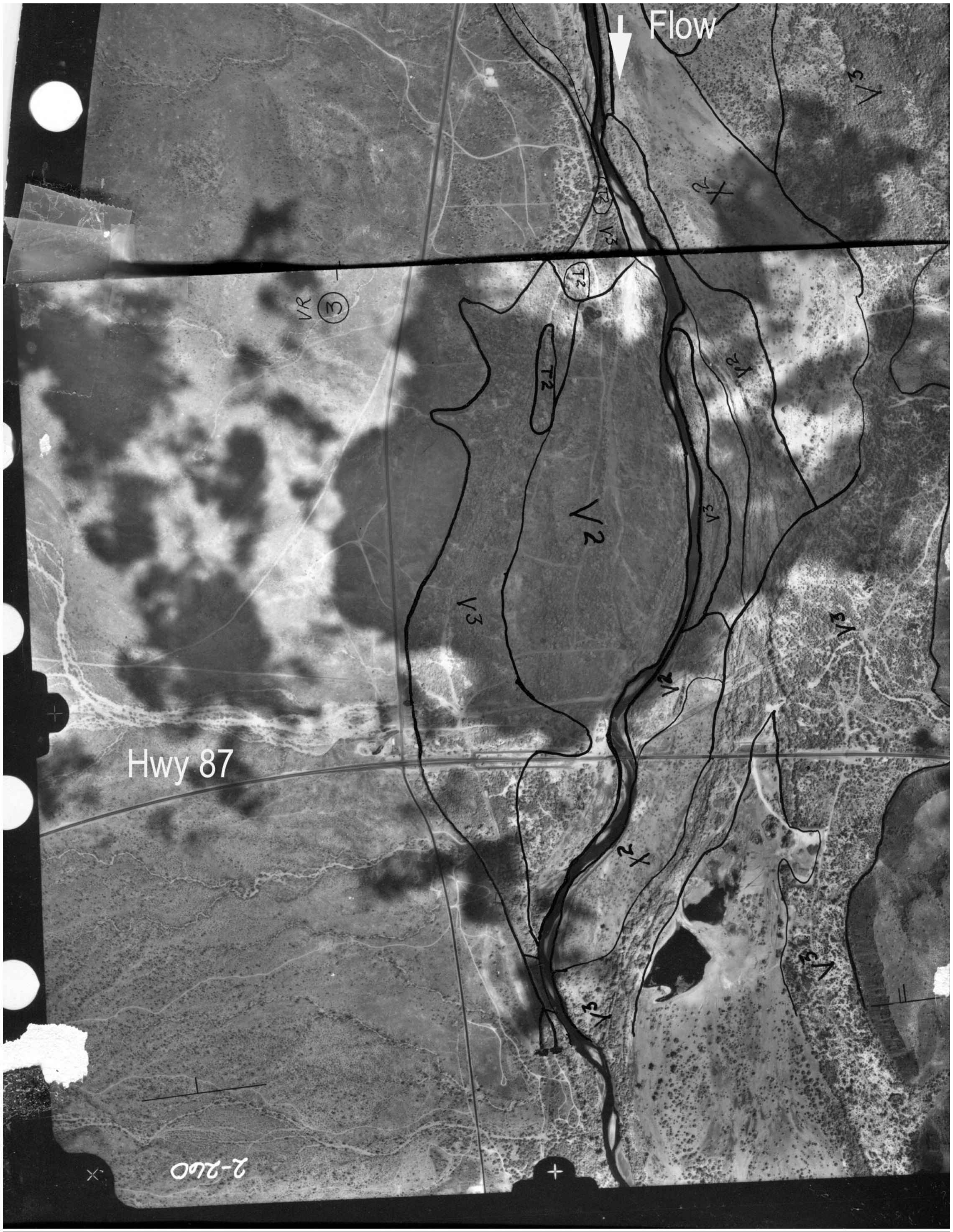

Flow


Flow
Sycamore Ck.



Note the recent (post 1973) braiding upstream of Highway 87 shown below.




Flow
Hwy 87
V2
V3
X2
T2
VR
3
2-260

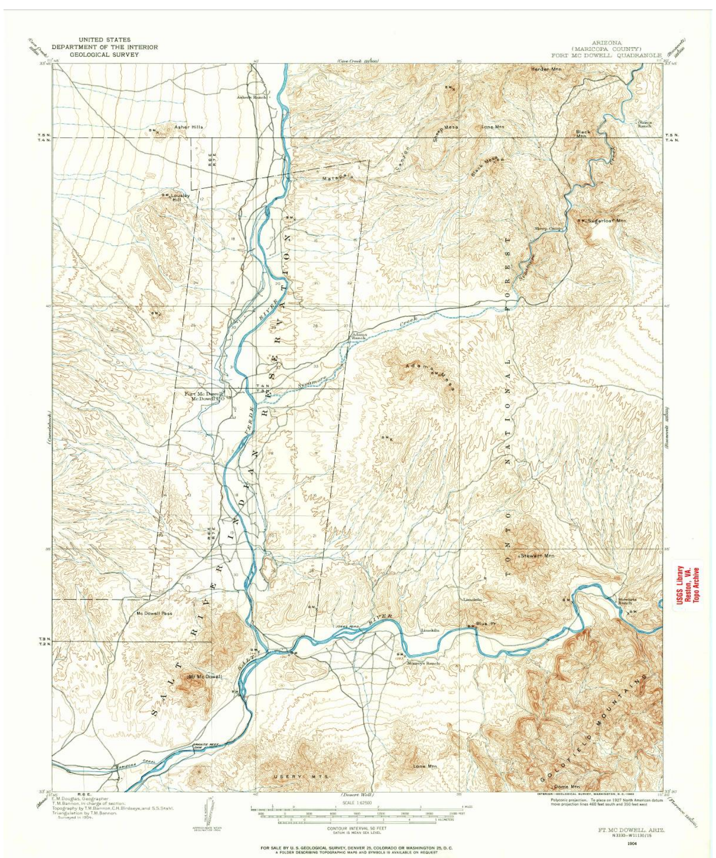

Flow
Salt River
VR 2
VR 1

ADDITION 5. Channel for lower 18 mile reach located upstream of the mouth at the Salt River --three items to consider

On p. 3 of his declaration *Navigability of the Verde River,* Dr. Mussetter states the following:

2. The downstream approximately 18 miles of the reach flows through a wider valley where the river is bounded by modern, more erodible alluvium in most locations. Under present conditions, the reach has an island-braided character, with multiple channels in many locations that are stabilized by riparian vegetation that remains relatively stable due to the upstream flow regulation. Under natural conditions prior to significant upstream flow-regulation, this reach responded to periodic high flow events such as those that occurred in the late-19th and early 20th centuries by developing a wide, braided pattern with multiple, unstable low-flow channels that would have precluded reliable navigation using the watercraft that were in customary use at and prior to Arizona's statehood.

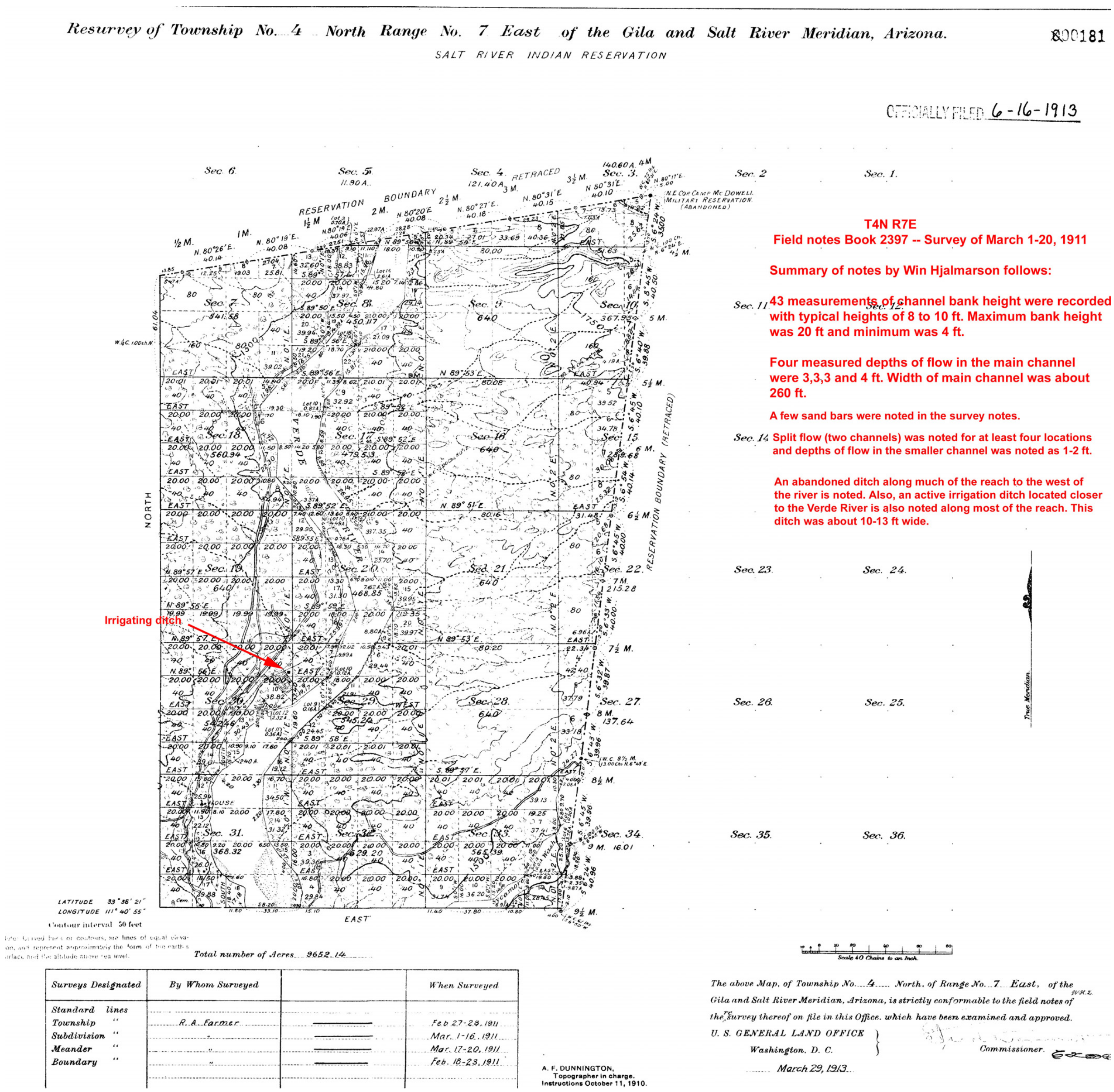
Item 1.-- The 1904 USGS map below shows a single channel for the same reach that Dr. Mussetter says was a wide-braided channel with a braided pattern and unstable low-flow channels. Also, the 1913 (survey of 1911) Federal Land Survey map on the following page shows a single channel. Other plats presented previously (Addition 1) also show a single channel.



Note the diversion canal on the west side of the Verde River.

From Appendix K.

From p. 67 of Appendix G.



Item 2.— On page 28 of his declaration *Navigability of the Verde River* Dr. Mussetter presents an aerial photograph (Figure 22) of the mouth of the Verde River. He alleges the photo was taken in 1934 and he appears to assume the recent sand and silt deposit is representative of the lower Verde River. Perhaps this photo is the basis for his “braided pattern and unstable low-flow channels.” The deposited sand in the photo appears to me to be recent and temporary based mostly on the damming effect along the right-bank side of the Salt River.

The City of Phoenix had an early history of deposited silt sealing its infiltration gallery and wells along the west side of the Verde River near the mouth. In fact, the USGS wrote a report on the issue that stated “Sediments deposited by the river are highly effective in sealing up the gravels that supply the city's wells, the amount of sealing depending on the silt content of the water and the discharge of the river at the well fields.”(McDonald, Harris B. and Padgett , Harold D., Jr., 1945, Geology and ground-water resources of the Verde River Valley near Fort McDowell, Arizona, USGS Open-File Report 45-109, 119p., page 82 and others).

A photograph from this report follows:

Plate 5. View of the Verde River channel near the upper well field of the City of Phoenix, showing silt deposits near the banks of the stream.

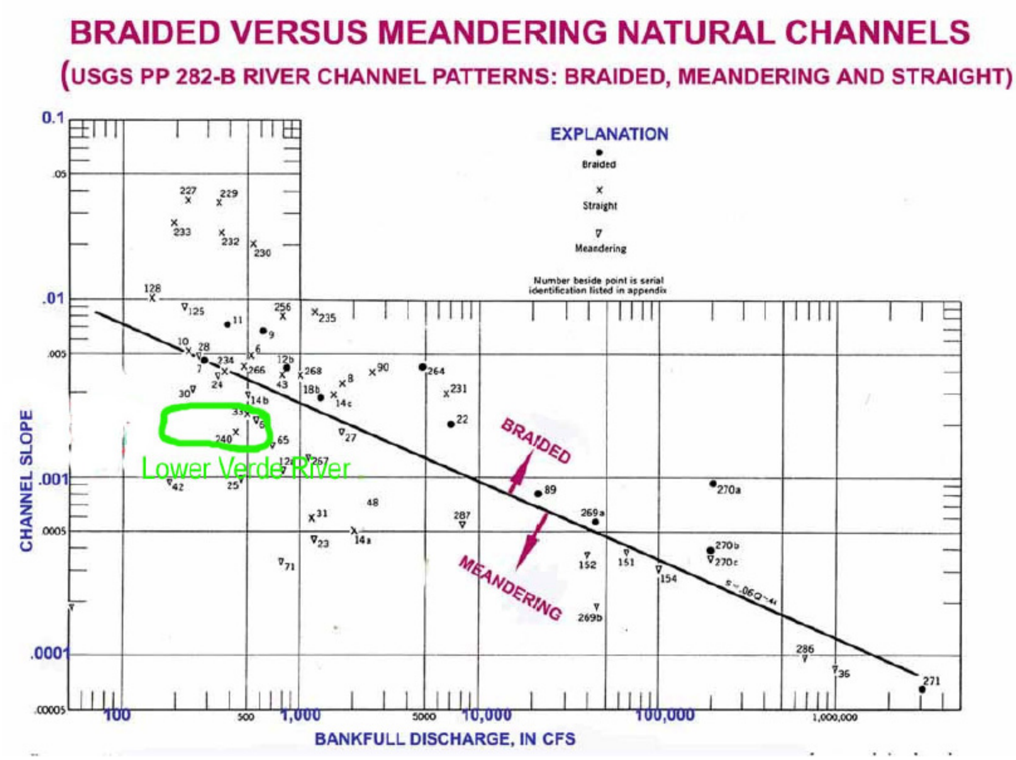
In their abstract McDonald and Padgett (1945) state:

> *The Verde River is a perennial stream that rises about 20 miles north of Prescott, Arizona, and flows southeast and then south to its junction with the Salt River about 20 miles northeast of Phoenix, Arizona. The area considered in this report is the lower part of the Verde Valley, below Bartlett Dam. In this area the Verde Valley is cut in valley-fill deposits that occupy a basin formed by down faulting in ancient crystalline rocks.*

On pages 16-18 McDonald and Padget (1945) describe the geomorphology of the reach below Bartlett Dam to the mouth at the Salt River. The following is part of their description that is related to navigability:

> *The valley-fill sediments at one time covered the hard rocks at the edges of the valley to a higher elevation than they do now. The drainage system was developed on the unconsolidated sedimentary material, and as down cutting of the main valley progressed the tributary streams held their previously established courses across hard rock barriers that normally would have resisted erosion. This may be seen in several of the washes that enter the Verde River from the east.*
>
> *The present flood plain of the Verde River below Bartlett Dam ranges in width from one- to three- quarters of a mile* ***and the relatively narrow stream channel swings from one side to the other.*** *At the surface in the flood plain is fine material, largely silt, which overlies gravels and sands laid down in former channels of the river. The river has not showed much tendency to cut into and destroy the areas of the flood plain lying outside the present channel; consequently these areas have been developed for human use. Much of the farming is done in these areas and the entire water supply for the City of Phoenix has been developed in them. (emphasis added)*

Item 3.--For the same discharge, rivers like the Verde River with low slopes tend to have meandering channels (Leopold, L.B., Wolman, M.G., and Miller, J.P, 1964, Fluvial processes in geomorphology: New York, Dover Books on Earth Sciences, 503 p.). The plot below is the result of a scientific study where characteristics of many natural river channels were examined. The USGS scientists found a distinction between meandering and braided channels based on slope. This distinction shown below has withstood the test of time. Thus, why would Dr. Mussetter expect braiding? Surely Dr. Mussetter isn't basing his opinion on a single aerial photo in 1934 of local flood debris at the mouth of the Verde River.



Summary of Addition 5.-- Based of the Verde River that is shown in both the 1904 USGS Ft McDowell Quadrangle map and the Federal Land Surveys (for example of 1911 for T4N R7E), information in the USGS report by McDonald and Padget (1945) and the science based distinction between meandering and braided of Leopold, Wolman and Miller (1964), the natural single channel of the Verde River was meandering. Also, the 1973 channel shown in the USGS aerial photos of the preceding section (Addition 4) was meandering.

I'm left to wonder if Dr. Mussetter is showing a temporary condition where sand and silt that had collected in pools along the river channel (see for example Appendix G section G3b) was remobilized (flushed) during direct runoff and carried downstream as suspended and bed load to be re-deposited downstream. Another possibility is that tributary sand and silt was simply temporarily deposited along the lower Verde River by a small flood and subsequently removed when the flow of the river was increased sufficiently (or for a sufficiently long time) to produce scouring action in the channel.

Clearly, except possibly for a temporary condition, Dr. Mussetter's idea that the natural channel was braided for base flow conditions is simply not supported by the evidence. The natural typically single channel was meandering.

ADDITION 6. Dr. Musseter's three sites, Dr. Schumm's report and what is natural and ordinary—some thoughts and facts.

On p. 3 of his declaration *Navigability of the Verde River* Dr. Mussetter states the following:

> Based on my review of Dr. Schumm's report and background material, independent review of other background material, my knowledge of the climatic, hydrologic and geomorphic conditions along the Verde River, results from a study of three typical sites that was conducted under my supervision in 2003, observations during an aerial overflight of the portion of the reach from the Salt River confluence to the Beasley Flat area about 5 miles south of Camp Verde, and my knowledge of processes in arid stream channels, I agree with the opinions that were expressed by Dr. Schumm in his report and testimony, and offer the following clarifications and additional opinions for ANSAC's consideration in this matter:

Item 1.—First, Dr. Mussetter neglects the fact that the navigability issue is being revisited because the rules used by ANSAC for the first assessment did not meet Federal Standards. For example, Dr. Schumm's opinions that Dr. Mussetter agrees with were based on a different set of rules that do not pertain to the natural and ordinary condition now being used. My understanding is that the present purpose is to determine if the Verde River was susceptible to navigation at the time of Arizona statehood (February 14, 1912) in its ordinary and natural condition. (See for example p. 5 of my report). When human impacts are understood and applied with the proper hydrologic context, we can begin to see what the natural Verde River once was.

A rather recent report by the Salt River Project (SRP) discusses human activities that alter the quality or flow of water, particularly flood control and irrigation, along the Verde River. For example, according to the environment assessment report (SRP, 2007, pages 91-92) human factors and the riparian vegetation along the Verde River are as follows:

a) Historical Vegetation

For the purposes of this discussion of pre-dam vegetation, "historical" refers to the period of time prior to dam construction on the Verde River. Most information for historical vegetation was derived from aerial photography taken in January and February of 1934, photos taken during construction of Bartlett Dam (1936 to 1939), and photos taken during construction of Horseshoe Dam (1941 to 1945).

The Verde River experiences periods of drought interspersed with extreme flood events. Historically, flood events scoured the floodplain—removing most vegetation—and redistributed sediment and raised the water table, allowing establishment of tall woody vegetation. This natural cycle favors establishment of woody vegetation along the main river channel and in backwater areas where shallow water tables persist and provide supportive hydrology.

Prior to the construction of Horseshoe and Bartlett dams, the major human factors that influenced riparian vegetation included grazing and irrigation. Ranchers along the Verde River grazed livestock in the watershed and along the riverbanks, and diverted water from the stream for irrigation purposes. Livestock can have many impacts on natural riparian systems including: increasing erosion by trampling river banks; trampling or consuming stabilizing vegetation; and preventing or reducing establishment of woody vegetation by consuming or trampling seedlings, saplings, and young trees (FWS 2002a, Appendix G). Historically, other human activities, such as vehicle travel within the floodplain, likely had low effects on riparian vegetation because recreation and other use of the area were limited.

(1) Horseshoe

Before completion of Horseshoe Dam in 1945, tall woody vegetation was present in limited amounts along the channel of the Verde River within the reservoir area (Figure III-21; 1934 photos on file at SRP). Based on review of historical photographs, topography and hydrology, this tall woody vegetation was concentrated in relatively small areas and narrow bands along the Verde River channel. Overstory riparian species included Fremont cottonwood–Goodding willow galleries and tamarisk or salt cedar stands near the river at low elevations, and mesquite stands on higher benches. The largest areas of vegetation historically occurred at the north end of the reservoir at the mouth of several small, unnamed washes including drainages through Ister Flat and

Figure III-21. Horseshoe dam site in 1944, looking upstream from the east dam abutment.

Hell's Canyon. Other large inlets near the southern end of the present reservoir (including unnamed drainages, Mullen Wash, Deadman Creek, and Lime Creek) were mostly bare historically, consisting of sand and cobble washes. Livestock grazing on USFS grazing allotments predate Horseshoe, and historically may have limited the establishment of new stands of woody vegetation (FWS 2002a; Appendix G).

Salt River Project, 2007, Draft Habitat Conservation Plan Horseshoe and Bartlett Reservoirs, SUBMITTED PURSUANT TO SECTION 10(A)(1)(B) OF THE ENDANGERED SPECIES ACT; 403p

By the way, there is an interesting description with human impacts in the same SRP report (2007, pages 171-172) of the riparian area along the Verde River in the Verde Valley:

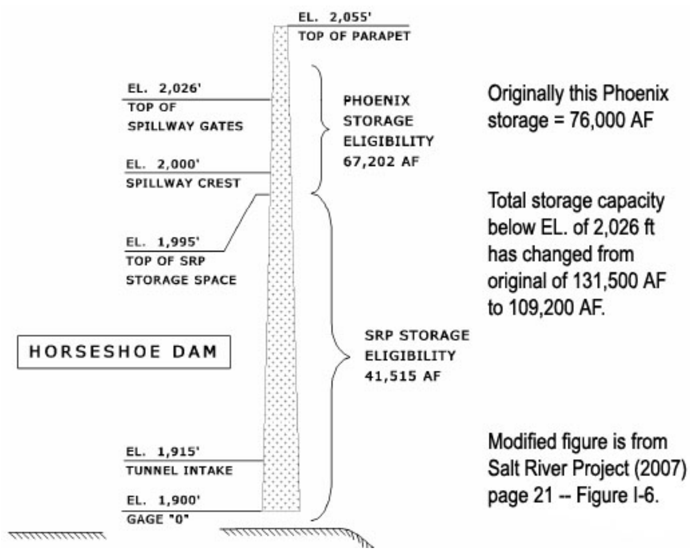
Description of Riparian Habitat in the Verde Valley. The Verde River runs for approximately 140 miles from its headwaters at Sullivan Lake Dam near Paulden in Yavapai County eastward to Perkinsville, and then southeastward to its confluence with Fossil Creek where it continues southward until it joins with the Salt River. In general, the upper Verde above the town of Clarkdale tends to be confined to a narrow canyon

CHAPTER V. ACTIONS TO MINIMIZE, MITIGATE, MONITOR AND MANAGE THE IMPACTS
HORSESHOE AND BARTLETT HABITAT CONSERVATION PLAN

that is scoured by floods periodically. From just upstream of the town of Clarkdale, the floodplain widens, and the river meanders through the Verde Valley for approximately 43 miles until it re-enters a confined canyon about 10 miles below the town of Camp Verde (Fichtel and Marshall 1999). Habitat fragmentation, water diversion, trampling due to adverse recreational and livestock use of the river, and development pressures impact the biological integrity of the river (Id.).

Item 2.— A brief look at Dr. Mussetter's sites 1-3 (see map on next page that is from his report). Sites 1-3 are significantly impacted by humans and are not natural.

Photograph from: www.usbr.gov/projects/PrintFacilityAttributes.jsp?fac_Name=Horseshoe Dam



The normal water surface elevation is 2026 ft. The original corresponding water storage of 131,500 ac-ft has been reduced to 109,200 ac-ft (2007 SRP report p. 14, and 2003 survey of reservoir area) by sediment deposition in the reservoir area. As of 2003, deposited sediment had reduced the water storage capacity behind Horseshoe Dam by about 22,300 ac-ft.

Another excerpt from the SRP environment assessment report (Salt River Project (SRP) (2007) pages 94) discusses the riparian vegetation along the Verde River and human impacts:

(4) Downstream of Bartlett

Immediately below Bartlett, the floodplain is narrow and was frequently scoured (Figure III-22). About 6 miles downstream of Bartlett, below Needle Rock near Box Bar Ranch (Figure III-23), the Verde Valley changes character from a relatively high-gradient, bedrock-restricted, steep-sided channel with a narrow floodplain to a lower gradient, more braided channel with a broader floodplain. Topographically, there is more opportunity for riparian vegetation to establish and develop from this point to the mouth of the river. Historically, the river floodplain in this reach was periodically scoured bare, and did not support extensive stands of woody riparian vegetation. From 1934 aerial photographs, it appears that most areas of woody vegetation were relatively sparse (less than 50 percent vegetation cover). Human impacts, such as livestock grazing and irrigation diversions, pre-date the dam and likely impacted vegetation cover and establishment in some areas.

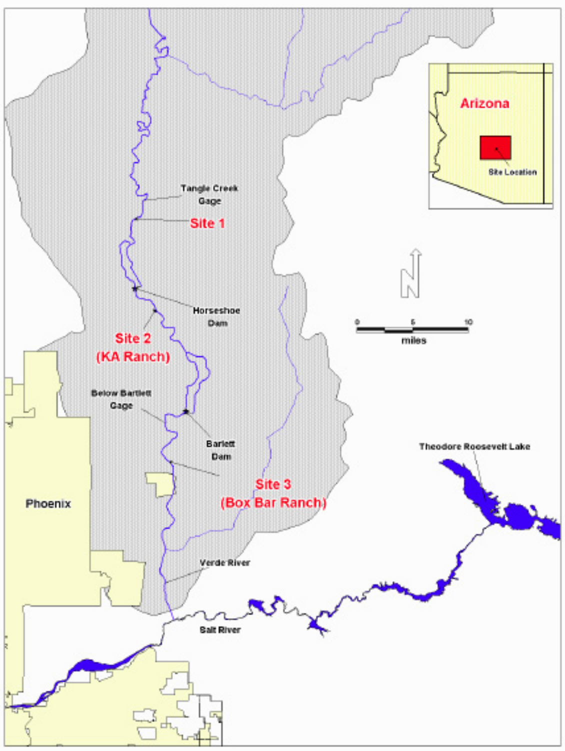
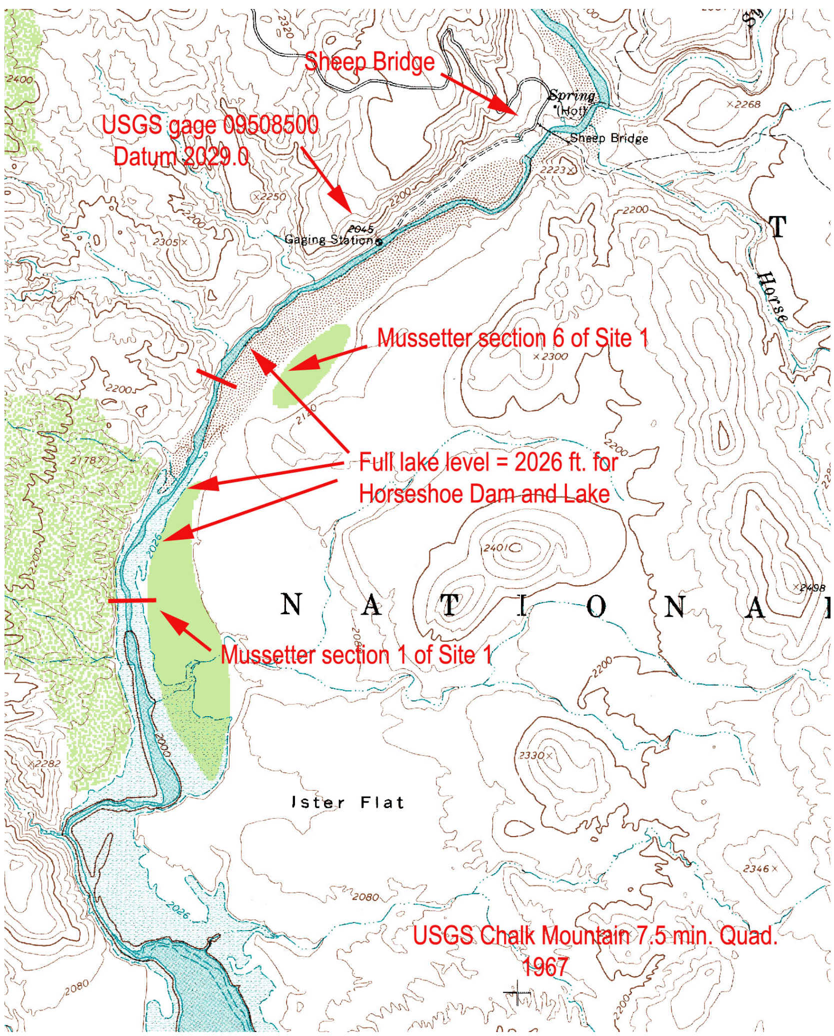


Figure 1.1. Location map.

1.2 Mussetter Engineering, Inc.

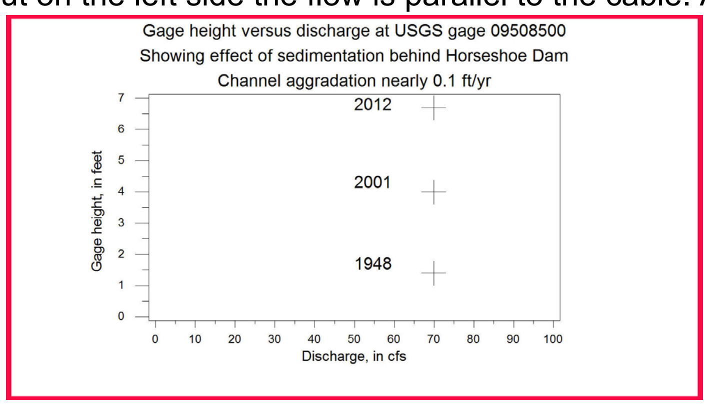
Sites 2 and 3 obviously are impacted by regulated flow below Horseshoe and Bartlett Dams. Impacts include altered streamflow and sediment discharge that are discussed in my report. Dr. Mussetter neglects to show that the hydrologic and hydraulic conditions at sites 2 and 3 do not represent natural and ordinary conditions. The simple fact is sites 2-3 are affected by humans.

Site 1 is interesting because Dr. Mussetter neglects to mention that it lies within the normal water surface elevation of Horseshoe Reservoir (see map below) and has been inundated a few times by water stored behind Horseshoe Dam. Also, site 1 has been subjected to backwater and associated deposition of river transported sediment during large floods especially when storage in Horseshoe Reservoir was large. The amount of reduction in reservoir storage by deposited sediment captured by Horseshoe Dam is on the order of 620 AF per year (SRP 2007, p. 90). The relatively recent (historically speaking) deposited sediment along the Verde River in and along Site 1 is easily scoured, especially during storm runoff, and is quite variable in amount and location because of the influence of fluctuations in lake levels. Site 1 is located in one of the most unstable areas along the human impacted Verde River.

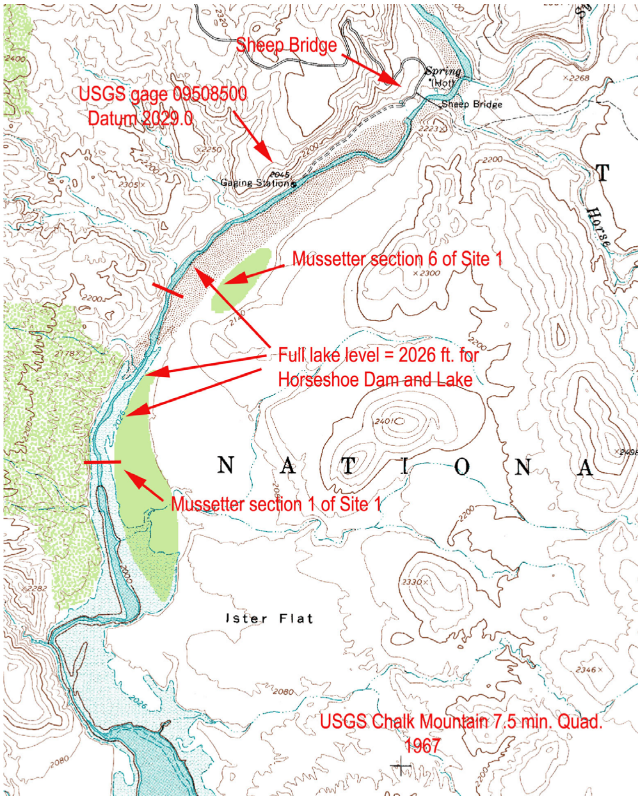


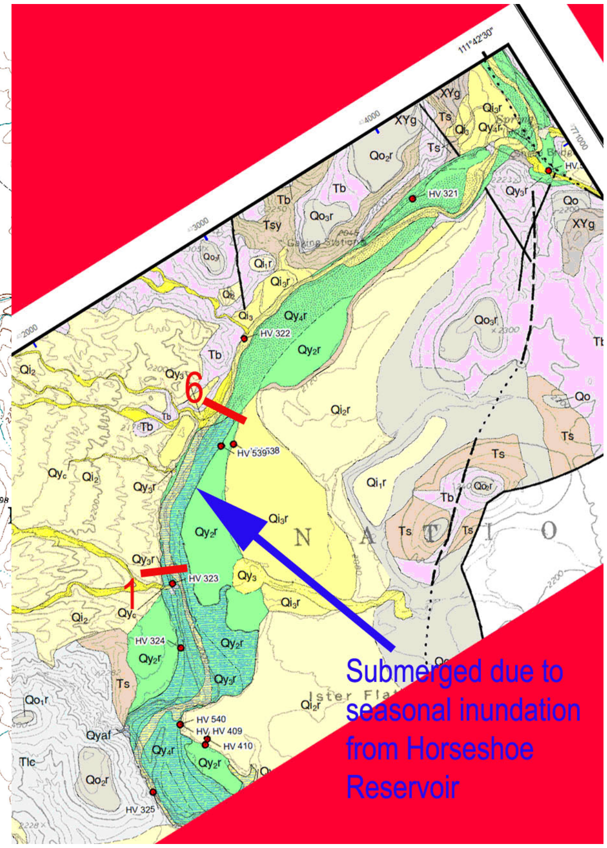
The Chalk Mountain USGS topographic map is on the next page. The full lake level is also known as the active conservation pool.

The relation below shows the effect of the aggrading channel of the Verde River at gage 09508500 where a delta like environment has been created by backwater and associated sediment deposition at the USGS gage and cableway above Horseshoe Dam and reservoir. On the right side of the cableway the flow is perpendicular to the cable but on the left side the flow is parallel to the cable. A small small human caused delta has formed at the cableway. The channel geometry is ever changing in this human caused unstable environment. Site 1 is downstream of the USGS gage, (see map on previous page)



The surficial geologic map of the upper end of Horseshoe Reservoir is shown on the next page.





Above to the right is the surficial geologic map of the upper end of Horseshoe Reservior that corresponds to the USGS map on the left. Site 1 of Mussetter's report clearly is seasonally submerged.

SURFICIAL GEOLOGIC MAP OF THE VERDE RIVER CORRIDOR, CENTRAL ARIZONA

by

Cook, J.P., Bigio, E.R., Youberg, A., Pearthree, P.A., and House, P.K.

July 2010

Arizona Geological Survey

Digital Map DM-RM-2H

version 1.1

Funding for this project was provided by the Arizona Department of Water Resources

USGS 24k quadrangle series topographic base maps. North American Datum of 1983. Projection and 1000-meter grid ticks (blue): Universal Transverse Mercator, zone 12.

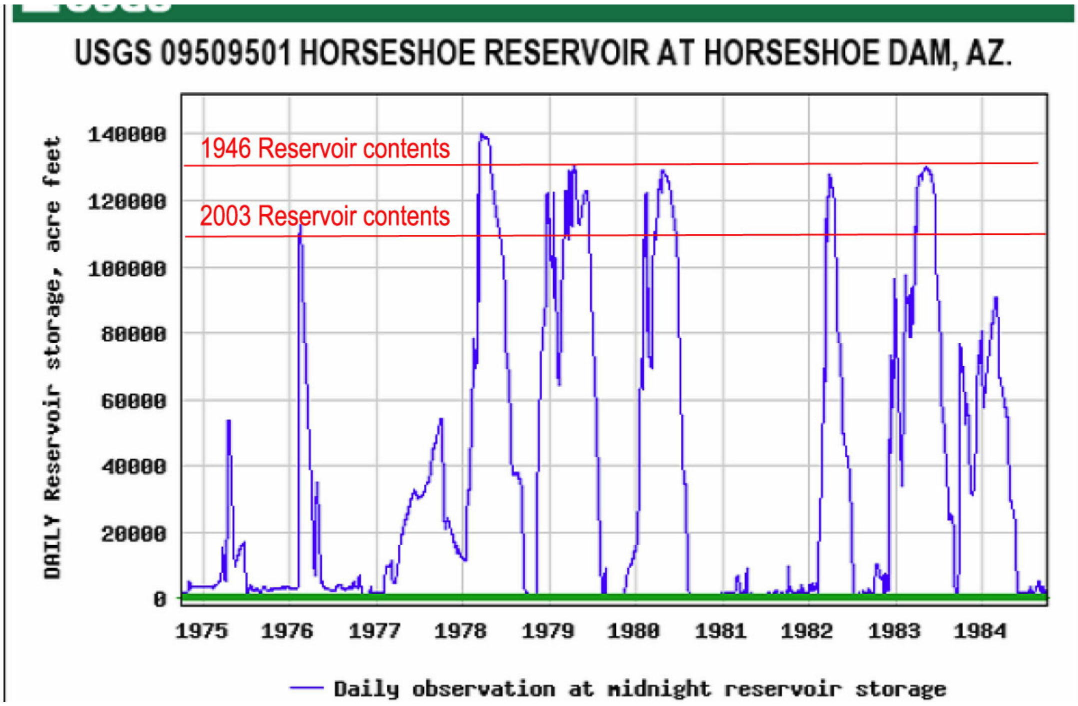
Other Units

- W — **Water** - Underlying geology obscured by standing water (Pecks Lake, Horseshoe and Bartlett Reservoirs)
- **Submerged** - underlying unit submerged due to seasonal inundation in Bartlett and Horseshoe Reservoirs
- Qyl — **Modern lake and marsh sediments** - Underlying geology obscured by lake sediments (Pecks Lake, Horseshoe and Bartlett Reservoirs)
- Qtc — **Quaternary hillslope talus and colluvium** - unconsolidated to weakly consolidated, very poorly sorted angular rock debris deposited at the base of bedrock slopes

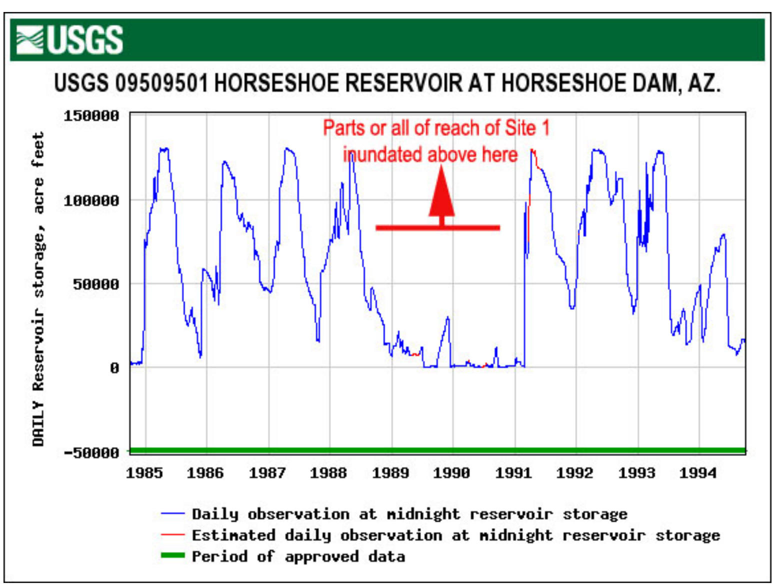
River Alluvium

- Qy₅r — **Active river channel deposits** - unconsolidated, very poorly sorted sandy to cobbly beds in active river channels
- Qy₄r — **Flood channel and low terrace deposits** - unconsolidated sand, gravel and silt deposits on bars, low terraces and flood channels
- Qy₃r — **Historical river terrace deposits** - unconsolidated sand, gravel and silt deposits on low terraces inset below the abandoned early historical floodplain
- Qy₂r — **Late Holocene to historical river terrace deposits** - silt, clay, sand and minor gravel deposits underlying the early historical floodplain
- Qy₁r — **Late to early Holocene river terrace deposits** - silt, clay, sand and minor gravel terrace deposits slightly above the early historical floodplain
- Qi₃r — **Late Pleistocene river terrace deposits** - gravelly, sandy river terrace deposits up to 25 m above the active river channel

Samples of when reservoir storage was large enough to impact Site 1 are shown on the following page. Site 1 has been inundated by the reservoir and by backwater associated with the reservoir a few times since Horseshoe Dam first stored water on Nov. 15, 1945.



Because of reduced storage from deposited sediment since Horseshoe Dam was constructed, Site 1 was inundated more frequently and at greater depth in recent times. This changing inundation of Site 1 is depicted in the above USGS figure.



Probable backwater during high flows starts a few feet above reservoir elevation of 2000 ft. (sill of spillway) at 67,000 ac-ft capacity. Capacity is from p. 103 of Giordano (2010).

Giordano, Gerard, 2010, The Verde River, Bartlett and Horseshoe Dams, Images of America, Arcadia Pub. Charleston SC, 127p.

Below are cross sections 1 and 6 for Dr. Musseter's site 1 that is located within the active conservation pool according to the USBR. Clearly the channel condition is impacted by the reservoir where there would be backwater effects during high flows when storage in the reservoir was great. An obvious impact would be sediment deposition in and even upstream of the reach of site 1.

MEI (Mussetter Engineering, Inc.). 2004. Inundation and substrate stability study to support Verde River vegetation analysis. Prepared for Salt River Project. Unpublished. Available at <http://www.fws.gov/southwest/es/arizona/HCPs.htm>.

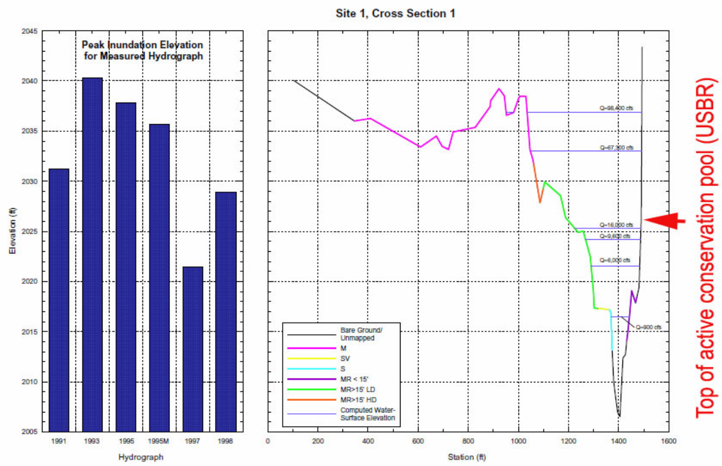
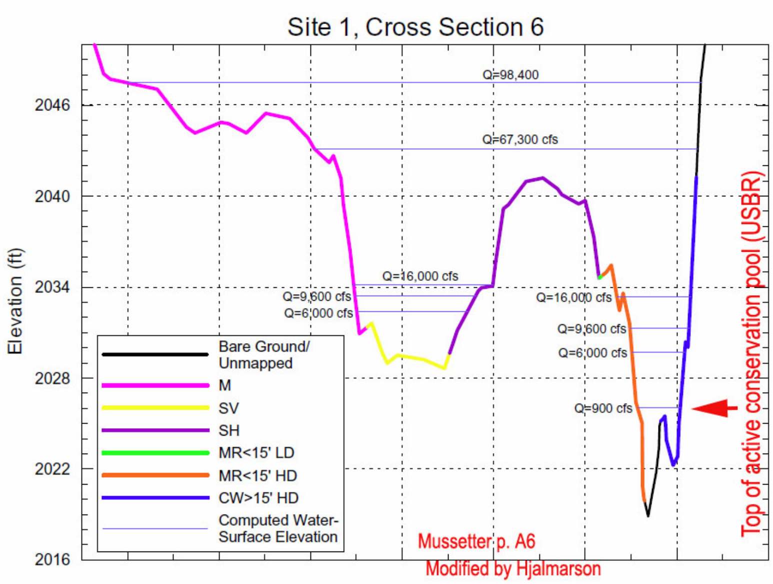


Figure 5.4. Peak discharge elevations for the 1991, 1993, 1995, 1995M, 1997 and 1998 floods plotted with the cross section profile for Cross Section 1 at Site 1. The cross section is color coded to show the distribution of the various types of vegetation at the site (refer to Table 5.1 for full descriptions of the vegetation codes).

Modified by Hjalmarson.

5.12 Mussetter Engineering, Inc.



In the evaluation of the navigability of the Verde River, the greatest challenge to me is the fact that by 1912, the river had been so altered by human activities that it is difficult to assess its condition in its "natural and ordinary" state. In this regard I find it unconvincing that SRP (2007) down plays the impact of Horseshoe and Bartlett Dams on Verde River morphology and the riparian habitat. Conversely, SRP (2007) blames ranchers and cattle and irrigation diversion for negative impacts to the riparian vegetation and wildlife. Surely the trapping of 22,300 ac-ft of sediment behind Horseshoe Dam impacts channel morphology and/or plant growth. For example it's obvious to me that the fluctuating lake levels, stream flows, sediment deposition, scouring of fresh sediment deposits by floods and growth and removal of woody riparian vegetation along the Verde River where it enters Horseshoe in the Site 1 area is the result of human impacts.

USGS
science for a changing world

Water-Data Report 2013

09509500 RESERVOIR SYSTEM ON VERDE RIVER AT AND BELOW HORSESHOE DAM, AZ

Verde Basin
Lower Verde Subbasin

LOCATION.--Lat 33°49′05″, long 111°37′52″ referenced to North American Datum of 1927, Maricopa County, AZ, Hydrologic Unit 15060203, This system comprises two storage reservoirs created by Horseshoe and Bartlett Dams on Verde River, Maricopa and Yavapai Counties,. Gages on Horseshoe Reservoir, formed by Horseshoe Dam, lat 33°59′05″, long 111°42′35″, in sec.2, T.7 N., R.6 E. (unsurveyed); and Bartlett Reservoir, formed by Bartlett Dam, lat 33°49′05″,long111°37′52″, in sec.34, T.6 N., R.7 E. (unsurveyed)

DRAINAGE AREA.--6,157 mi², at Bartlett Dam, of which 365 mi² is non-contributing, including 357 mi² in Aubrey Valley Playa, a closed basin.

SURFACE-WATER RECORDS

PERIOD OF RECORD.--July 1939 to current year. Prior to 1946 published as "Bartlett Reservoir at Bartlett Dam."

REVISED RECORDS.--WDR AZ-89-1: Drainage area.

GAGE.--Water-stage recorders on dam structures. Datum of gage on Horseshoe Reservoir is 1,900.00 ft and on Bartlett Reservoir 1,599.46 ft above sea level. Prior to Oct. 14, 1964, Bartlett Reservoir gage datum was 10.00 ft higher.

COOPERATION.--Capacity tables furnished by Salt River Valley Water Users' Association.

REMARKS.--Horseshoe Reservoir is formed by earthfill and rockfill dam; dam completed and storage began Nov. 15, 1945. Bartlett Reservoir is formed by concrete multiple-arch dam; dam completed May 1939 and storage began Feb. 5, 1939. Total capacity of the two reservoirs is 287,400 acre-ft divided as follows: Horseshoe Reservoir, 109,200 acre-ft between elevations 1,915.00 ft (sill of outlet gate) and 2,026.00 ft (top of spillway gates) based on capacity table derived from survey in April, 2002; Bartlett Reservoir, 178,200 acre-ft between elevations 1,619.46 ft (10 ft above sill of outlet gates) and 1,797.46 ft (top of spillway gates) based on capacity table dated 1978, based on survey in 1977-78. No dead storage. Records given herein represent usable contents. Water is used for irrigation of Salt River Valley and for municipal supply.

EXTREMES FOR PERIOD OF RECORD.--Maximum contents of system, 318,000 acre-ft May 9, 1973; no storage at times when natural flow of river was passed through reservoir system.

EXTREMES FOR CURRENT YEAR.--Maximum contents of system: 231,500 acre-feet; March 21. minimum contents of system: 89,560 acre-feet; October 8.

Horseshoe Dam

Overview

Horseshoe Dam, on the Verde River 58 miles northeast of Phoenix, is an earthfill structure 202 feet high, with a reservoir capacity of 131,500 acre-feet. Horseshoe Dam was built from 1944-1946 by the Phelps-Dodge Copper Products Corp. for the Salt River Valley Water Users' Association under a water exchange agreement. Spillway gates were added to the dam in 1949 by the city of Phoenix to increase the domestic water supply. In 1952 the dam was raised 4 feet to elevation 2044.

Horseshoe Dam was also modified by Reclamation in 1993 to address concerns about its safety in the event of a Probable Maximum Flood or Maximum Credible Earthquake. Modifications included construction of a fuse plug auxiliary spillway with an erodible embankment and a concrete foundation 2,000 feet west of the existing spillway. In addition, a 148,000 cubic-yard stability berm was constructed at the downstream toe of the dam to help stabilize it in the event of an earthquake, and the dam was raised eight feet to enable the spillway to pass the Probable Maximum Flood. To prevent overtopping of the structure from wave action, an additional 4-foot parapet was built on the dam's crest. Other work included modifying the service spillway gates, and construction of an auxiliary spillway, closure dike and training dike. The dam tender facilities were also relocated and the road to the boat ramp upgraded.

General

Region	Facilities in Lower Colorado | Lower Colorado Home Page
State	Arizona
County	Maricopa
Project	Salt River
Dam Type	Zoned Rockfill Embankment
Reservoir	Horseshoe
Watercourse	Verde River
Location	58 miles northeast of Phoenix, AZ
Latitude	33.9834
Longitude	-111.708939
Original Construction	1944-1946
Modified Construction	1949, 1952, 1993
National ID Number	AZ10310
Hydrologic Unit Code	

Dimensions

Structural Height	202.0 ft
Hydraulic Height (Normal Operating Depth at Dam)	157.0 ft
Top Parapet (Elevation)	2055.0 ft
Spillway Crest Elevation	2000.0 ft
Crest Elevation	2052.0 ft
Crest Length	1652.0 ft (with spillways 1994 ft)
Crest Width	16.0 ft
Base Width	619 ft
Volume of Dam Construction Materials	1,595,780 cu-yds
Streambed at Dam Axis	1894.9 ft
Top of Exclusive Flood Control Pool (Elevation)	
Top of Joint Use Pool (Elevation)	
Top of Active Conservation Pool (Elevation)	2026.0 ft
Top of Inactive Conservation Pool (Elevation)	
Top of Dead Storage Pool (Elevation)	1915.0 ft (Tunnel intake elevation)

Hydraulics & Hydrology

Total Water Storage at Elevation	131,500 af at 2026.0 ft
Maximum Water Surface Elevation	2051.9 ft
Normal Water Surface Elevation	2026 ft
Spillway Type	Gate concrete ogee crest
Service Spillway Capacity at	318,000 cfs at 2051.5 ft

Storage as of 2007 was 109,217 af. The change was bcause of sediment being deposited behind the dam. Source: Salt River Project, 2007, Draft Habitat Conservation Plan Horseshoe and Bartlett Reservoirs, Attachment 1, 403p. (See for example page 14--Chapter 1).

Modified by Hjalmarson.

Elevation	
Auxiliary Spillway	Yes
Auxiliary Spillway Capacity at Elevation	240,000 cfs at 2051.5 ft
Uncontrolled Spillway Capacity at Elevation	558,000 cfs at 2051.5 ft
Outlet Works Capacity at Elevation	2200.0 cfs at 2026.0 ft
Diversion Capacity at Elevation	
Drainage Area	5630 sq mi
Hydrometeorological Report (HMR)	HMR 49
Probable Maximum Flood (PMF) Report	

Contact Information

Owner	Title	Area Office Manager
	Organization	Phoenix Area Office
	Address	6150 West Thunderbird Road
	City	Glendale, AZ 85306-6200
	Phone (Fax)	623 773-6480
	Phone (Office)	623 773-6200
Operator	Organization	Area Office Manager
	Address	Phoenix Area Office
	City	Phoenix, AZ 85306-6200
	Phone (Office)	623 773-6200

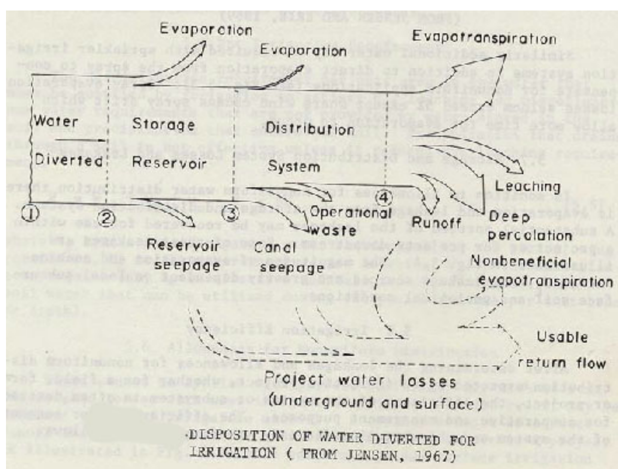
Last updated: Jun 29, 2009

ADDITION 7. Hydrology, consumptive use of water by crops, and estimated base runoff – comments related to my general approach

Method 1.—As discussed on p. 21 of the Report, this method uses records of cultivated land by early settlers as defined mostly on the original Federal Land Survey plats. Water consumption by crops was estimated using an irrigation water use factor of 3.15 ac-ft/year. The annual amount of water consumed by crops in the headwater area of the Verde River is simply the product of the acres of irrigated land and the water use factor (See page 26 of report). At the Clarkdale gage (09504000) the water use was equated to a base flow of 36 cfs, that was adjusted for transmission loss along stream channels, to evapotranspiration (ET) of 5 cfs to yield an addition of 31 cfs to the gaged median discharge of 86 cfs. The resulting estimated natural median discharge is 117 cfs (See p. 26 of report). This budgeting method obviously uses average annual amounts of water but we know, for example, that water consumption by crops is seasonal where losses to ET are much greater in the summer than in the winter.

Let's examine Method 1 a little closer. The general disposition of the water along Big Chino Creek (Appendix F), for example, can be represented using a flow diagram by the American Society of Civil Engineers (Jensen, 1973) (See diagram below). A large percentage of the water diverted to crops may return to the Big Chino Creek (See the usable return flow arrow at bottom right). Thus, the crops (See the large evapotranspiration arrow on the right of the diagram) may use a relatively small portion of the water. The remaining losses of water diverted, as shown below, include evapotranspiration along the distribution system, runoff and non beneficial evapotranspiration.

Method 1 does not require precise definition of these losses that can remain undefined for this analysis. Method 1 simply uses the estimated annual evapotranspiration by crops and makes a small adjustment for average annual project water losses.

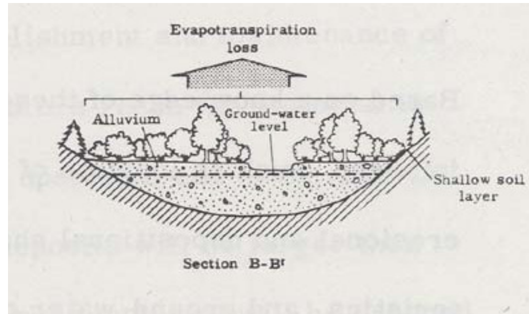


DISPOSITION OF WATER DIVERTED FOR IRRIGATION (FROM JENSEN, 1967)

M. E. Jensen, 1973, Consumptive use of water and irrigation water requirements, by American Society of Civil Engineers, 215 pages

Method 1 continued.-- water use by plants changes throughout the year.

The evapotranspiration by the riparian vegetation along the flood plain of the Verde River and tributary streams is shown in the simple cross section to the right.



The same type of diagram could be shown for the crops such as corn.

Anderson, T. W., 1976, Evapotranspiration losses from flood-plain areas in Central Arizona, USGS Open-File Report 76-864

The monthly water use by plants (transpiration), in percent of the annual water use, is shown to the right. Nearly all of the water use is during the growing season of May through September. There is very little water use during the months of November through March.

The daily and weekly water use by plants varies more than the mean monthly values shown to the right.

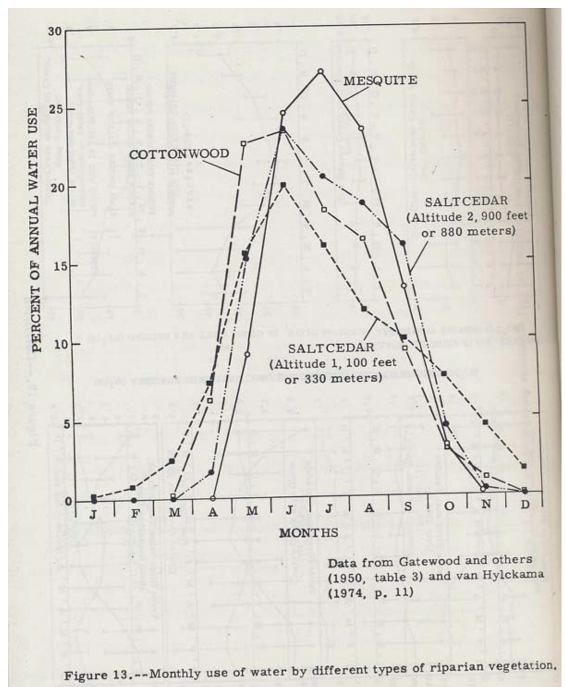
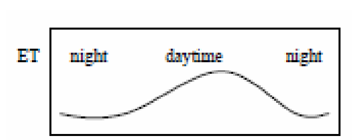


Figure 13.--Monthly use of water by different types of riparian vegetation.

A sketch of the daily change in water use by plants is shown to the right. Nearly all of the water use (ET) is during the daylight hours. Water use also varies from day to day because of cloud cover, rainfall, temperature and wind.



A few samples of the within-year distribution of water consumed by crops are shown below. These samples are simply to give the reader an idea of how water use varies by crop type and throughout the year. Source: Erie, L. J. and others, May 1982, Consumptive use of water by major crops in the southwestern United States, U.S. Dept. of Agriculture, Conservation Research Report No. 29, 41p.

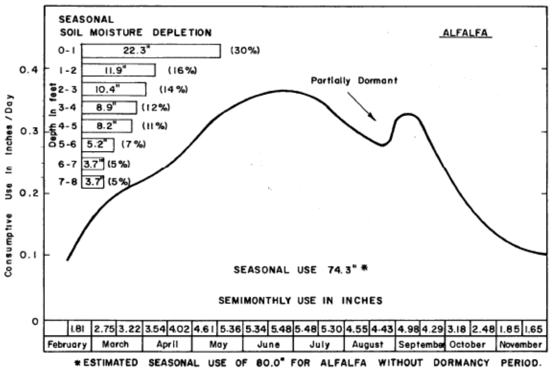


Figure 7.—Mean consumptive use for alfalfa at Mesa and Tempe, Ariz., 1946, 1950, 1962-63.

Appendix I: Consumptive-Use Curves for Various Crops

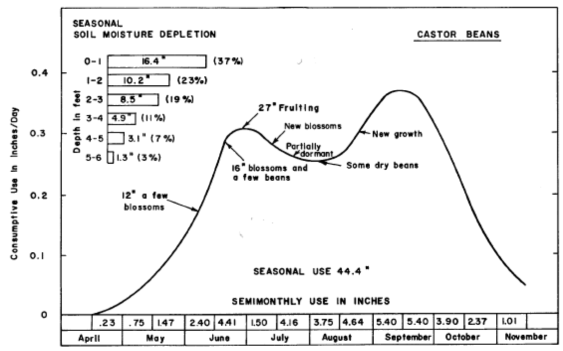


Figure 1.—Mean consumptive use for castor beans at Mesa, Ariz., 1958.

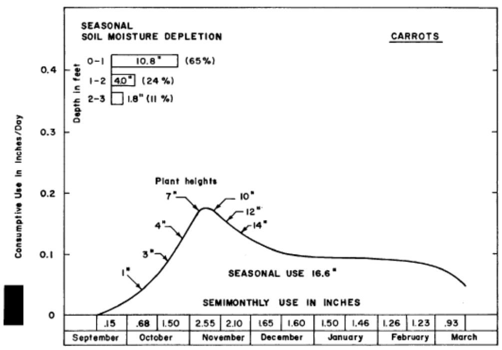


Figure 24.—Mean consumptive use for carrots at Mesa, Ariz., 1960-62.

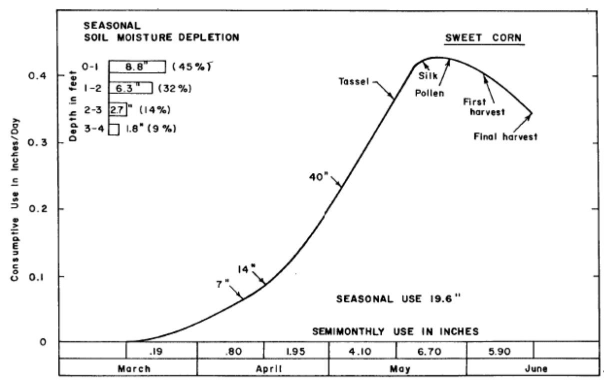


Figure 30.—Mean consumptive use for sweet corn at Mesa, Ariz., 1959, 1961-62.

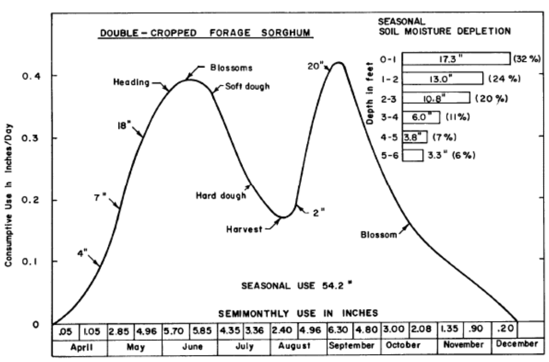
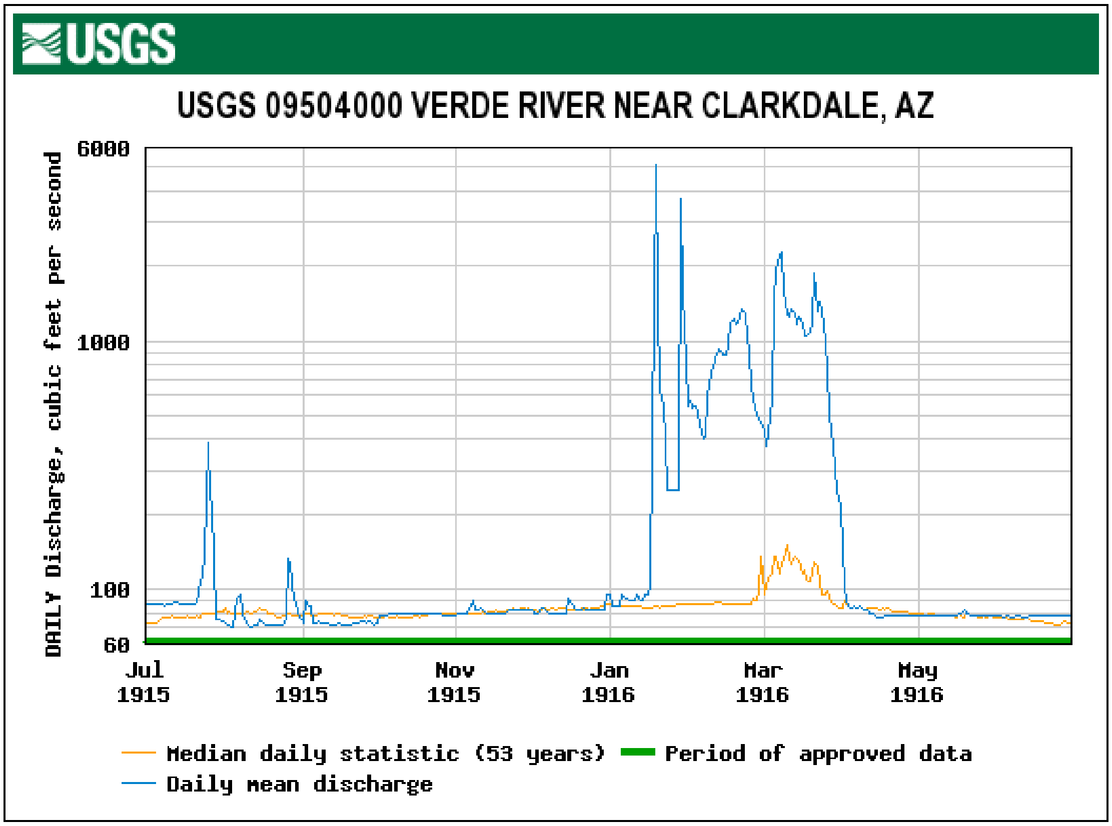


Figure 13.—Mean consumptive use for double-cropped forage sorghum at Mesa, Ariz., 1962.

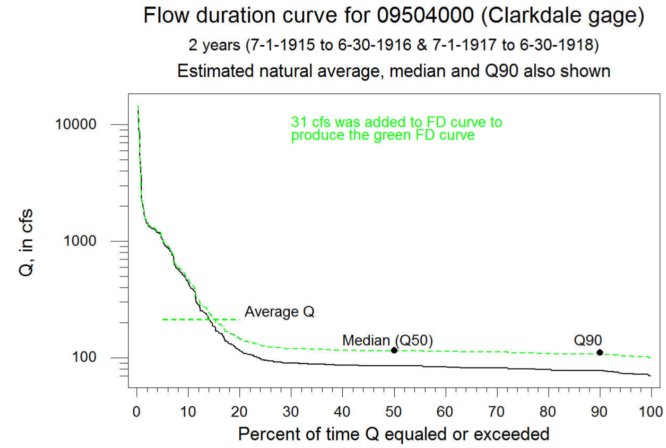
Method 1 continued.—significance of changing water use by crops

Because of the somewhat erratic flows of tributary streams and the lack of regulatory storage, settlers typically applied surface water to the fields during the growing season. There was little water diverted from streams during the non-growing season. Thus, diversions and associated consumptive use by crops was seasonal and occurred typically during warmer periods when losses of water to ET were high and base runoff was low. For example, the decrease of base discharge in Aug. and Sept. 1915 shown below appears to be the result of upstream diversion for crops.

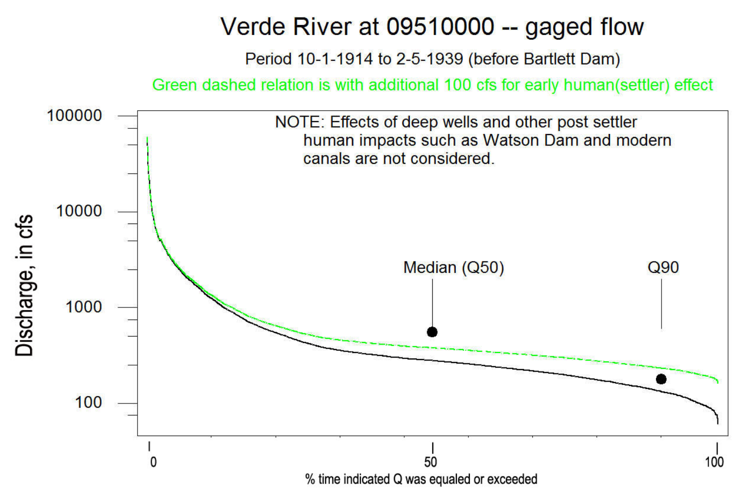


For this assessment for ANSAC an annual average amount of consumptive use by crops was used (See, for example, the annual water budgets on pages 26-28 of the report). This simple method obviously ignores the impact of seasonal consumptive use by crops that produced a seasonal effect on the base flow of the Verde River. Because there was considerably less loss of base flow in the winter than during the summer and spring when natural flow was/is rather low, this simple method computes (estimates) a conservatively lesser amount of natural base discharge.

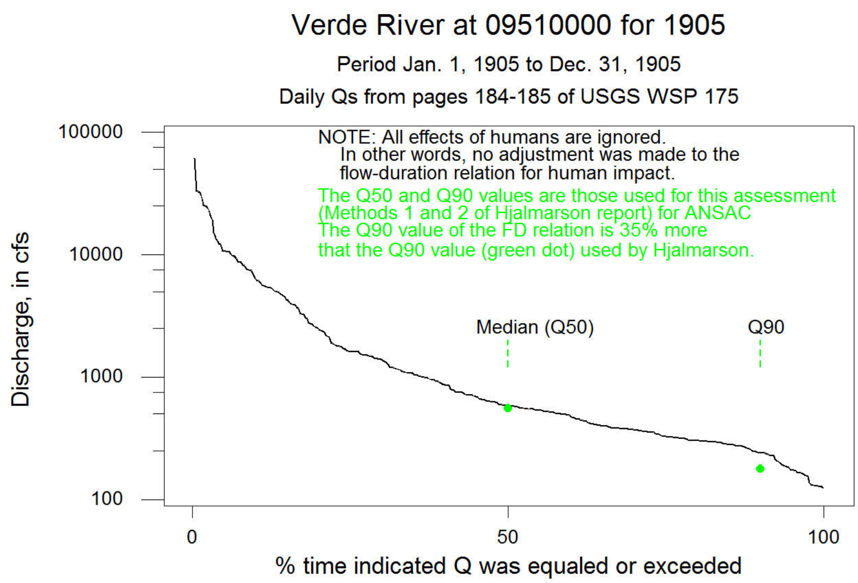
Methods 1 and 2.--Below is a simple example (a flow-duration relation) of the annual water budget method that simply adds an average value (31 cfs) for consumptive use by crops to the human impacted river flow.



Another simple example of using the average annual consumptive use by crops method is shown below. This example is related to Method 2 (pages 28-30 of the report and pages 52-53 of Appendix G). In Figure G3 is stated: *Graphs are smoothed in places but show sufficient detail for assessment of navigability.* Detail is needed to define lower flows that potentially limit navigability but less detail is needed for high flow. Of particular importance for the assessment is the lower flow (Q90) as discussed in item B on p. 106 of the report and also in section G4d of Appendix G. The conservative nature of this method of analysis can be seen using the flow-duration relation below where the Q90 value for this assessment is below the green relation that doesn't even account for much of the human effects. This method produced a conservative assessment of navigability.



A third simple example that is also related to Method 2 as discussed in the previous example uses supplemental evidence Item No. X023, 10/15/14, FMI-Sean Hood, Freeport X002 (USGS Water Supply and Irrigation Paper 175). As with the previous example, the conservative nature of this assessment of navigability is further demonstrated in the following flow-duration for the lower Verde River.



Hydrology and navigability.—Is hydrology necessary? Brief thoughts.

While going to great lengths with considerable time and effort to estimate the natural hydrology of the Verde River watershed—especially the upper watershed above the USGS gage near Clarkdale (09504000), I sometimes wondered if such effort was warranted for the ANSAC issue. Rather than make causal claims the natural river was navigable (or not navigable) it seemed important to add substance to such claim of navigability. However, it's been said that the hydrology is not needed because the entire Verde River presently (past 25 years) is navigated by small watercraft. Also, under present channel conditions we know that most of the pool-riffle river is pools that typically are more than 3 ft deep. There also are the original Federal Land Surveys that show a much wider (and therefore larger because of more base flow) river than the present river channel above gage 09504000. The Federal Land Surveys also show average depths of flow of 3 ft of more at many locations downstream of gage 09504000 (keeping in mind that some of this reach is unsurveyed). Also, over much of the river, the present channel geometry is similar to past geometry because the incised channel is constrained by bedrock and other erosion resistant rock. Thus, even the U. S. Fish and Wildlife Service Method shows much of the river condition of the Verde River is (was) optimal for navigability without using natural hydrology for the assessment. However, as a curious river engineer, I felt a need to know more about the natural flow of the entire Verde River.

As part of examining the natural hydrology and associated subsequent human effects I dusted off the Hayden report (in my library) and refreshed my memory of cultivated lands in the Verde River headwaters along areas such as Granite Creek, Williamson Valley Creek, Big Chino Creek and Walnut Creek (see for example page 21 of my report). The Hayden report (Hayden, 1940) contains exhibit E by C. A. Turney (1901) and exhibit F by H. L. Hancock (1914) that purportedly show irrigated lands of the Verde River watershed. However, these reports do not show irrigated lands and water use in much of the upper watershed above the USGS gage near Paulden (09503700). For example, neither report shows irrigated lands for Williamson and Big Chino Valleys and also along Walnut Creek. Mr. Turney said (p. 9) that the upper Verde watershed was not visited and Mr. Hancock appeared to follow his lead. There were many farms of early settlers in the upper Verde watershed (For example, see last page of this addition). However, Mr. Hancock examined at least part of the Granite Creek area but he neglected the remainder of the upper Verde River watershed. Therefore, the Hayden report with exhibits was of little (very limited) value for my assessment.

I've learned to be cautious of the Hayden report and present an example of why. Seems the idea of pumping Montezuma Well, a unit of Montezuma Castle National Monument, was considered plausible by Phoenix area water users as discussed on page 19 as follows:

NEW DEVELOPMENT

The idea has been suggested by Mr. Lee L. Smart, who now lives in Phoenix but formerly owned the old Packard ranch at the mouth of Sycamore Creek, that relief for the time being from acute water shortage in dry seasons in Salt River Valley might be obtained by development work, pumps, etc., to increase the flow of Montezuma Well and other large springs on the Upper Verde. This idea is sufficiently plausible to warrant consider-ation and in July the writer made a trip over the entire upper Verde area

Montezuma Well is a tourist attraction and important to the local economy let alone the fact that the well has served as an oasis for humans and wildlife for thousands of years.

The Hayden report was used for Method 2 as described on p. 28 of my report.

A note in regard to my Method 2 and the use of the virgin flow at the mouth of the Verde River (751 cfs on page 20 of my report, based on the 1952 USBR report). A recent study financed by the U. S. Department of the Interior (USGS) examined the 1946 USBR estimate of virgin flow at the mouth of the Gila (Lukas and all, 2012). This recent study suggested that the 1946 estimate might be "... improved, or at least confirmed with modern hydrologic modeling." (Note: The estimates of virgin flow in the 1946 and 1952 USBR reports are nearly identical at the USGS gage at Gila River at Gillespie Dam) It's difficult to speculate how a confirmation or a change of the virgin flow at the mouth of the Gila River (USGS gage at Dome) would translate to the virgin flow at the mouth of the Verde River. A large part of the uncertainty is related to the large estimated losses of Gila River flow to evapotransporation (ET) downstream of Phoenix (mostly below the USGS gage at Gillespie Dam). Thus, if improvement of the USBR estimate of virgin flow at the mouth of the Gila is found (assuming there was a study), the associated change in virgin flow may translate to improving the estimate of ET and not translate to the virgin flow of the Verde River or other rivers. In any event, aside from this pure speculation, there is no known substantiated reason to not use the USBR (1952) virgin flow for the Verde River. Also, information in the 1952 USBR report has been used by several parties for other rivers that are part of this ANSAC issue. Thus, a virgin flow of 751 cfs was used for the mouth of the Verde River.

Lukas, J. J., Wade, Lisa and Balaji, R, Oct. 2012, Paleohydrology of the Lower Colorado River Basin and Implications of Water Supply Availability, Colorado Water Institute, Colorado State University, Completion Report No. 223, financed by USGS, 34p.

USBR, March 1946, The Colorado River: A comprehensive report of the development of the water resources of the Colorado River Basin for irrigation, power production, and other beneficial uses in Arizona, California, Nevada, New Mexico, Utah, and Wyoming. Bureau of Reclamation, United States Department of Interior, Washington: Government Printing Office, 300p.

Finally: An obvious challenge of ANSAC is to *naturalize* (a term related to present national politics) human-affected hydrologic and hydraulic conditions in the post diction process. For example, the human-affected observed streamflow records should be *naturalized* to remove the effects of human depletions, diversions, reservoir operations, and the like. Methods used to accomplish *naturalization*, with a minimum of error, are described in my report. Every reasonable effort was made to substantiate the *naturalization.* Some error is unavoidable in post diction of natural conditions. For example, human effects on hydrology are not necessarily recorded by the tree rings and their presence in streamflow records introduces error into the *naturalization* and post diction.

Relating Methods 1 and 2 to recent conditions. – A different perspective.

Consider the study by the USGS (Blasch and others, 2006, page 2 and Table 21) that presents rather recent water use for the Verde Valley and upper watershed as follows:

> Average water use in the Big Chino, Little Chino, and Verde Valley subbasins was about 12,000, 13,000, and 47,000 acre-feet per year, respectively, for 1990–2003. Agricultural and residential water use exceeds other water uses; however, agricultural use within the Chino subbasins has decreased since the 1960s and 1970s.

Blasch, K.W., Hoffmann, J.P., Graser, L.F., Bryson, J.R., and Flint, A.L., 2006, Hydrogeology of the upper and middle Verde River watersheds, central Arizona: U.S. Geological Survey Scientific Investigations Report 2005–5198,101 p., 3 plates.

On pages 26 and 27 of my report I discuss Method 1 and show the impact of human depletions mostly for agriculture equal to about 31 cfs for the watershed above the Clarkdale gage 09504000. This is equivalent to 22,500 ac-ft per year. Considering the losses to ET along the stream channels (5 cfs) the human depletion at the fields (cultivated land) is 36 cfs or 26,100 ac-ft per year. These amounts of human water use compare very closely with the rather recent water loss of 25,000 acre-feet per year shown above (Blasch and others, 2006, page 2). While agricultural conditions including deep well pumping started during the comparative period, the close agreement supports Method 1.

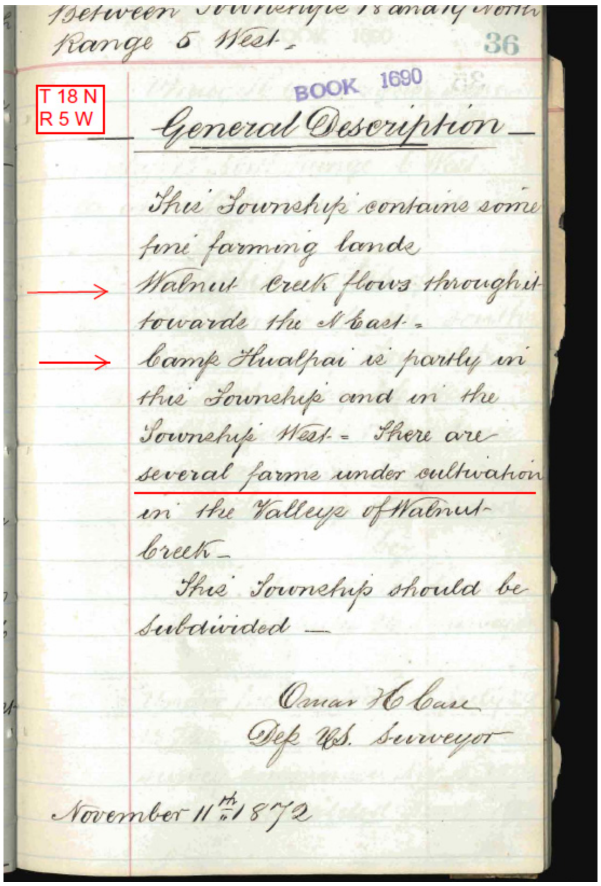
Also, because the results of Methods 1 and 2 closely agree, this comparison with the close agreement is considered support of both Methods 1 and 2 of my study.'

It's also interesting that the recent water use of 72,000 ac-ft per year (100 cfs) for the watershed (Blasch and others, 2006, page 2) is the same amount of loss I computed for naturalization using the Virgin flow (USBR 1952) at the mouth of the Verde River as shown on pages 20 and 28 of my report.

Again, because the average annual water use of 100 cfs for my methods is the same as the average annual water use for the USGS study (Blasch and others, 2006, page 2), all methods (Blasch and others (2006), USBR (1952) and my methods for this ANSAC study) are considered supported.

This is an example of the many settler farms in the upper Verde River watershed. Exhibit E by C. A. Turney (1901) and exhibit F by H. L. Hancock (1914) of the Hayden report (Hayden, 1940) did not include irrigated lands like the farms to the left for much of the upper Verde River watershed.

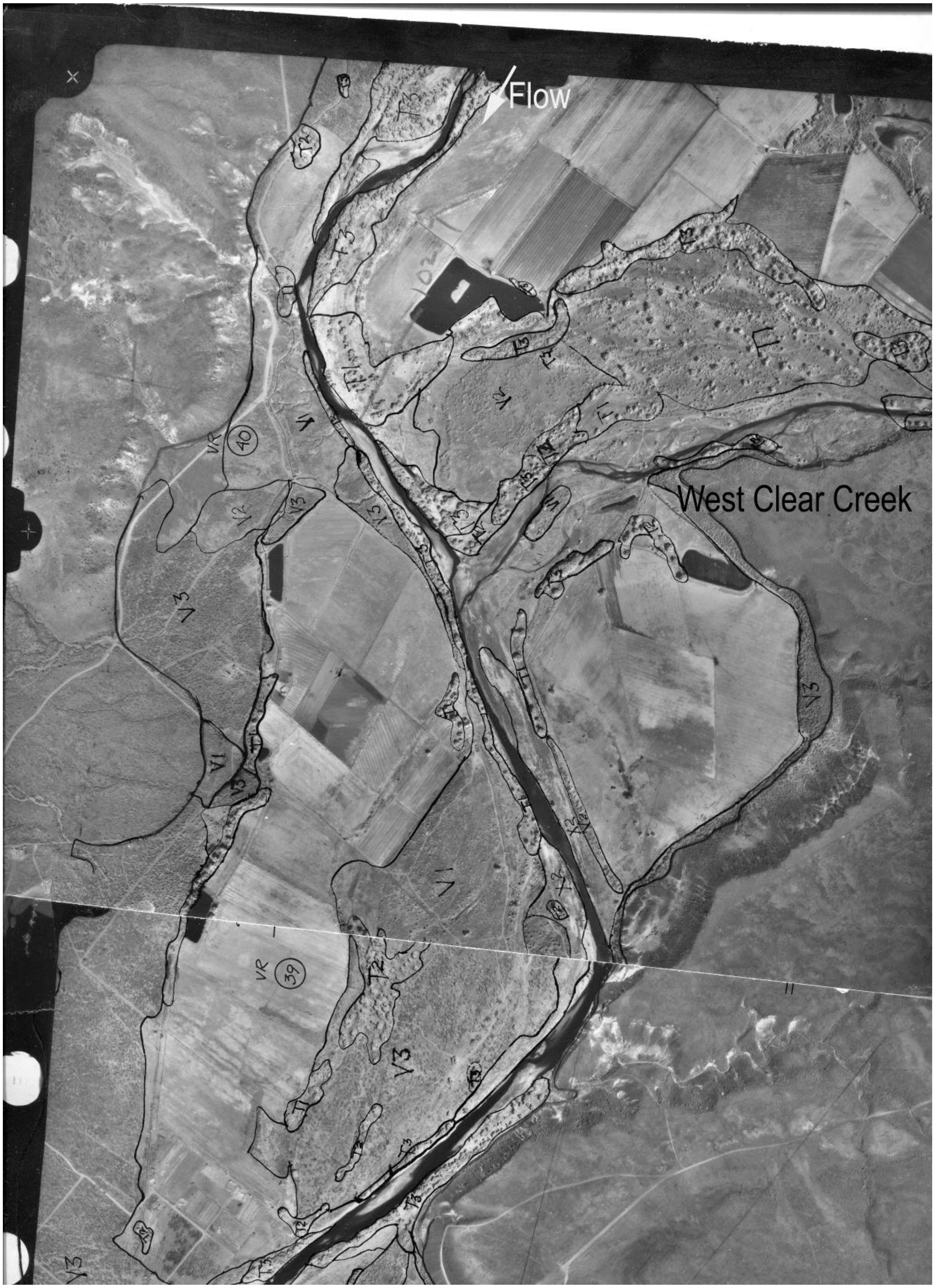
Irrigated lands in the upper Verde River watershed are documented in Appendices C, D, E and F of this report.

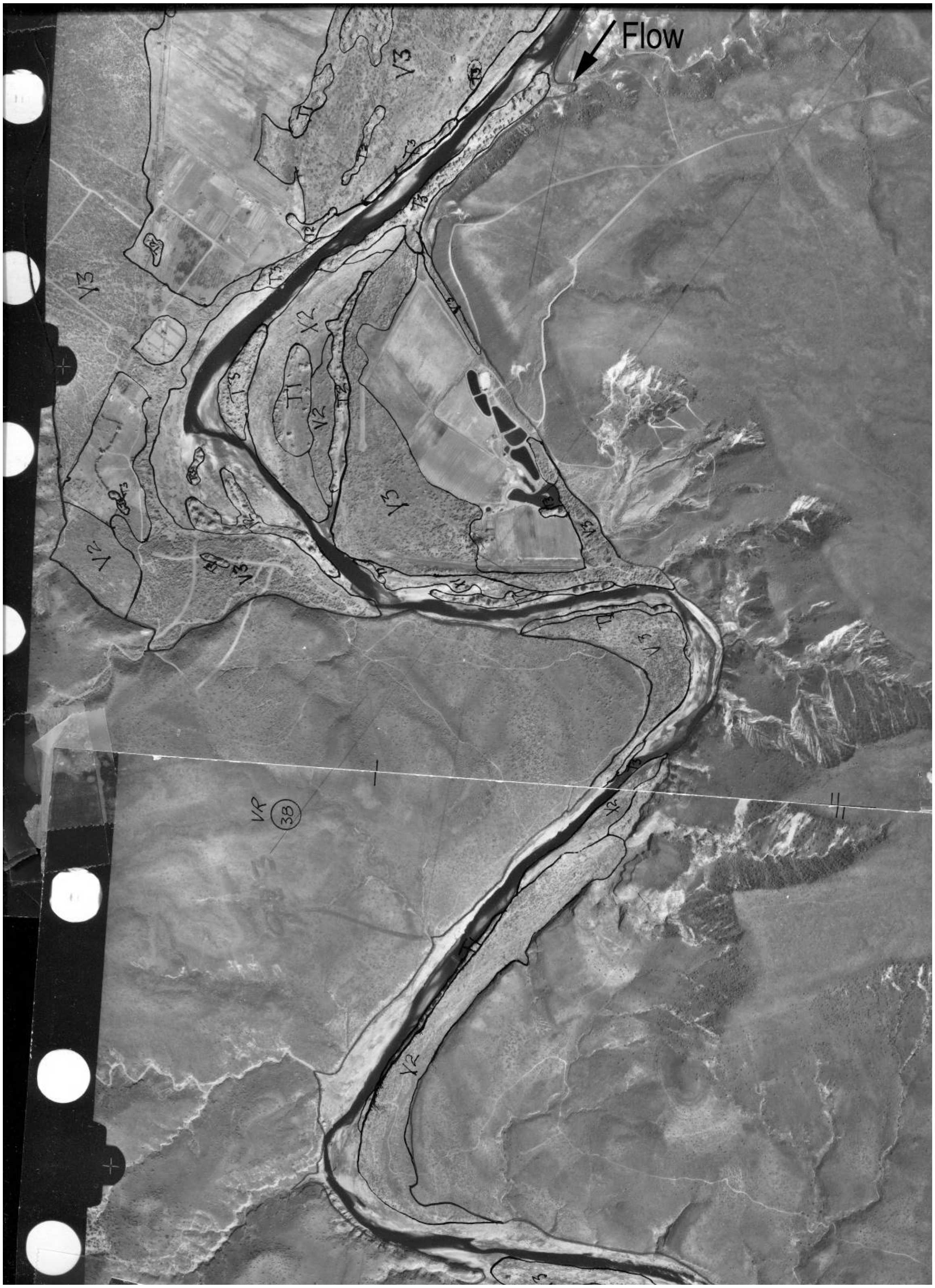

Between
Range 5 West.
36
T 18 N
R 5 W
BOOK 1690
General Description
This Township contains some fine farming lands
Walnut Creek flows through it towards the N East.
Camp Hualpai is partly in this Township and in the Township West. There are several farms under cultivation in the Valleys of Walnut Creek.
This Township should be subdivided.
Omar H Case
Dep U.S. Surveyor
November 11th 1872

ADDITION 8. Channel and vegetation downstream from West Clear Creek downstream to Sheep Crossing--unpublished USGS aerial photos.

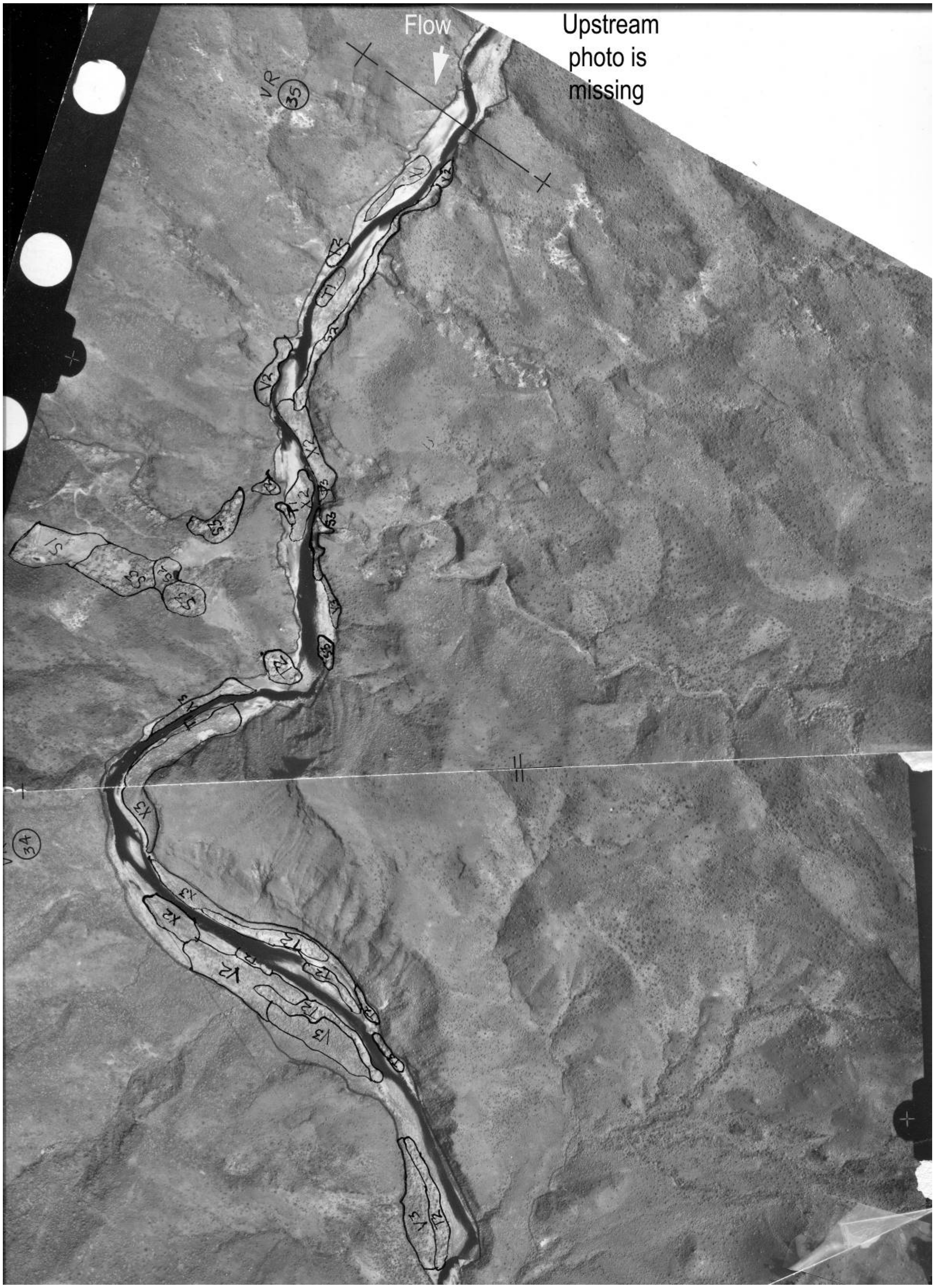
The channel depicted in the following unpublished 1973 aerial photos clearly is a pool-riffle meandering channel. Much of this area was not surveyed by GLO surveyors. The explanation for the mapped vegetation is given in Addition 4.

Following from Anderson, 1976:


Flow
West Clear Creek

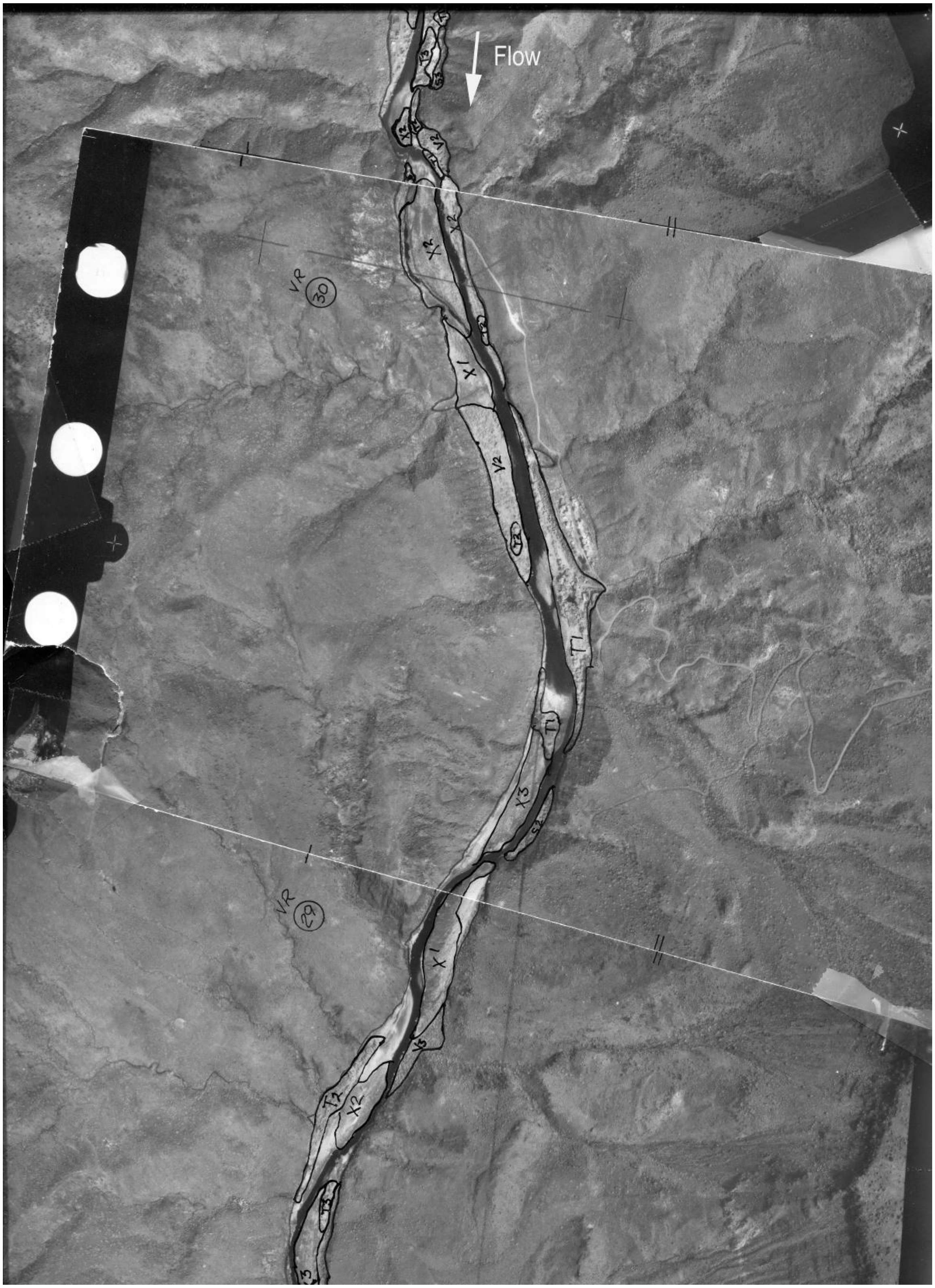

Flow
V3
V2
T1
T2
V3
VR
38


Flow
VR 3B
VR 3T
Chasm Creek
09506000


Flow
Upstream
photo is
missing

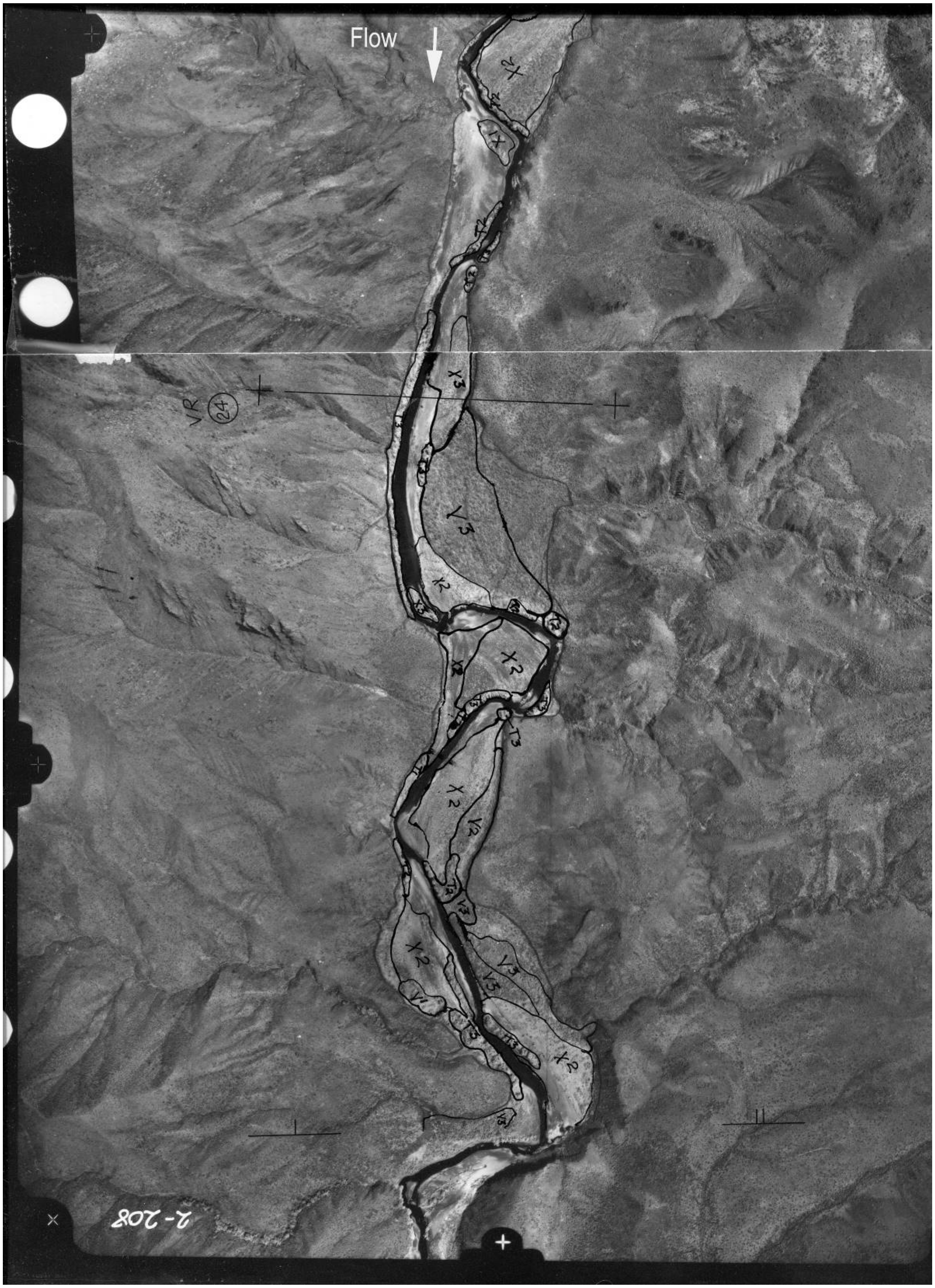

Flow


Flow
VR
32
VR
31

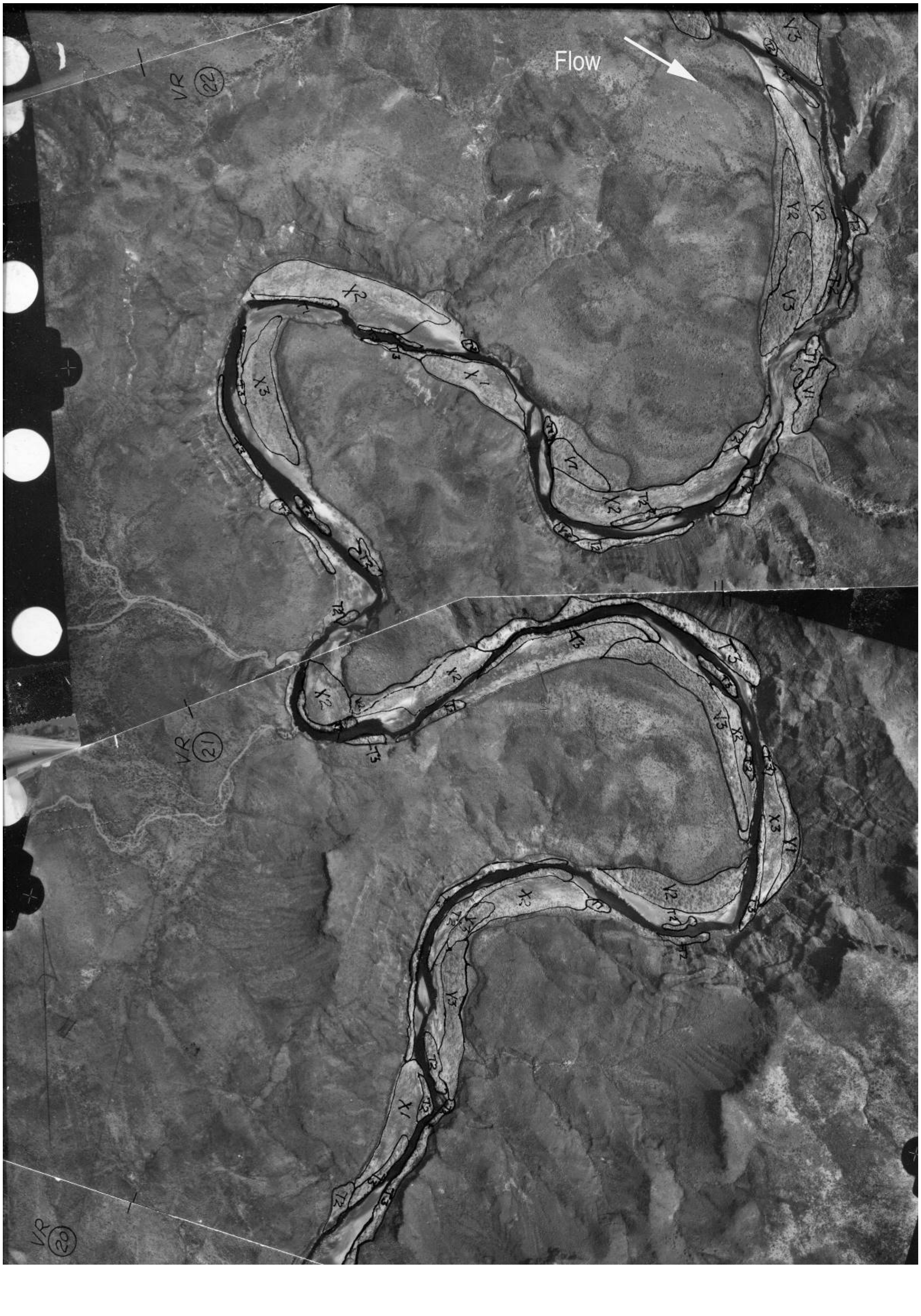

Flow
VR 30
X1
V2
T1
X3
VR 29
X1
X2


Flow
Fossil Creek


Flow
East Verde
River


Flow


VR 23
Flow
X2
VR 22
V3
X3


Flow
VR 22
VR 21
VR 20


Flow
Sheep Bridge
USGS gage 09508500