Buer

UPPER SACRAMENTO RIVER SPAWNING GRAVEL

APPENDIX A

UPPER SACRAMENTO RIVER SPAWNING GRAVEL STUDY

1980

CREDITS

State of California
The Resources Agency

This atlas was prepared through the efforts of members of the Department of Water Resources, Northern District, under the direction of

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INTRODUCTION

From the City of Red Bluff to Keswick Dam, the Sacramento River shows its long history of erosion, deposition, and flooding. Also visible are the marks of human settlement and the conflict of human development versus the natural environment. Dams, levees, and diversions are parts of this conflict, as are such activities as waste disposal, gravel mining, bank protection, fishing, and recreation.

With the threat of flooding diminished by construction of Shasta Dam in the 1940s, agriculture and urban development moved quickly onto the Sacramento River flood plain, generating the need for bank protection and increased diversion of the river's flows. Urban growth accelerated the builder's need for gravel and produced ever-larger volumes of waste water. Measured releases from Shasta Dam produce riverflows at higher stages for longer periods now, and flows do not peak and subside rapidly, as they once did.

Salmon and steelhead runs have declined, producing poorer fishing in the upper Sacramento River. The cause of the decline cannot be attributed to any single factor. Diversion dams, pollution, hatchery management, flow release schedules, gravel removal, sport and commercial fisheries, and water temperature changes all contribute.

This atlas, in addition to showing the historic channel migration of the Sacramento between the Red Bluff Diversion Dam and Keswick Dam, also provides a baseline description of the physical character of the channel, banks, and adjacent area. It gives a basis for management decisions regarding the conservation, wise use, and enhancement of the upper river and its natural resources.

Historic Channel Migration

The first formal surveying in the North Sacramento Valley was conducted by the Department of Interior's General Land Office between 1852 and 1869. These men surveyed straight-line segments along the bank with transit and chain. Accuracy was to one-quarter degree. To ensure reasonable accuracy in transferring the old channel data to modern base photographs, as many fixed reference points as possible were used -- section lines, stream confluences, and prominent geomorphic features. In some instances, there is no geomorphic evidence of the river having held the surveyed position; in such instances the survey line was adjusted to correspond to the nearest likely geomorphic feature.

The 1938 channel course is derived from aerial photographs taken for the U. S. Army Corps of Engineers (USCE) on April 20 of that year. The line represents water's edge. The reported flow at Kennett for that day was 700 m^3/s (24,700 cfs). Red Bluff reported 900 m^3/s (31,780 cfs).

The 1952 channel course is derived from aerial photographs taken for the U. S. Soil Conservation Service on July 4 and 6 of that year. The reported release from Keswick Dam during the three-day period was about 270 m^3/s (9,500 cfs).

All data are plotted on 1976 aerial photographs originally used in "The Sacramento River Environmental Atlas, 1978", which was prepared for the Upper Sacramento River Task Force by the California Department of Water Resources (DWR). In August, when the photographs were taken, the Keswick release was about 270 m^3/s (9,500 cfs).

In plotting the historic channel courses, it became apparent that for some extended reaches the river has not changed its course since the

surveys of the 1850s and 1860s. Examples are the reaches between Red Bluff and Jelly's Ferry Bridge, Balls Ferry area to the Cow Creek confluence, and from Redding to Keswick Dam. These reaches are entrenched into resistant geologic formations which inhibit lateral channel migration. A thick solid line identifies sections of riverbank that have not changed significantly in historic times.

Other reaches of the river were constant during the 1938 to 1952 period. Because flows were dissimilar in the two sets of photos, it was not readily apparent in some instances which portions of the river had changed significantly and which only appeared to have changed due to the flow differential. Where the difference in water's edge is attributed to the flow differential, the 1938 and 1952 lines are combined to show no significant change for the period. In most instances, this line corresponds with the bank pictured on the 1976 base photograph and thus indicates no significant change during the 1938-1976 period. In places, however, the line diverges from the pictured bank and shows change between 1952 and 1976.

Except for additional bank protection, the breaching of an island near the Stillwater Creek confluence during high flows in the winter of 1979-80 (Sheet 16), and the repositioning of the Cottonwood Creek confluence about 350 m (1,200 ft) south of the pictured confluence (Sheet 13), the channel of the entire study reach has remained virtually unchanged in the 1976 to 1980 period.

Bank Erosion

Bank erosion sites plotted in the atlas were mapped during the summer of 1980 and involved onsite inspection and classification of the grain size of the bank materials. The character of the material being eroded ranges from silty sand in flood plain alluvium to coarse gravel and cobble in stream channel deposits. In addition, portions of the Tehama, Tuscan, and Red Bluff Formations are actively eroding.

Only erosion that was considered significant was identified. Eroding lengths of bank less than three metres long were not mapped, nor were extended reaches of the Tuscan Formation which, though obviously water-sculptured and devoid of vegetation, resist rapid erosion.

Bank Protection and Levees

Bank protection and levees shown in this atlas represent the efforts of individuals, companies, and, in some cases, cities and counties to protect their interests from the erosion and flooding. Most of these works were designed and constructed by the USCE and DWR.

Bank protection usually takes the form of riprap -- boulder-size rocks or pieces of concrete loosely placed on the riverbank. Other methods of bank protection in the study reach use structures similar to retaining walls. About 12 km (7.5 mi) of riverbank are protected along the study reach.

Bank protection limits the river's ability to erode and prevents protected areas from adding to the river's sediment. Adverse effects, such as accelerated bank erosion or channel instability, may occur downstream from the large bank protection projects, and in some cases these may necessitate additional bank protection.

Levees restrict and contain the higher flows. This results in greater mean velocities, soil scour, and channel instability, both upstream

and downstream from the leveed reach. There are about 15 km (9 mi) of levees within the study reach.

The study reach is comprised of about 180 km (110 mi) of riverbank (counting both banks). Of this, less than 7 percent has bank protection, mostly in urban areas, such as Redding and Red Bluff. Levees parallel about 8 percent of the study-reach banks, usually along agricultural areas.

Salmon Spawning Areas

Spawning areas have been reduced or eliminated by increased agricultural and urban use of the river and its tributaries. Historically, considerable runs of salmon spawned above the present site of Keswick Dam. After its construction in 1943, passage to those spawning grounds was blocked. Remaining spawning areas above the Red Bluff Diversion Dam have been damaged by gravel extraction and flow releases from Keswick.

To ensure maximum survival of the salmon eggs and fry, ideal spawning areas contain gravel sizes of 25.4-76.2 mm (1-3 in). In gravel less than 25.4 mm (1 in), siltation may decrease the supply of dissolved oxygen to the redds and suffocate the eggs. Gravels larger from 76.2 mm are difficult for salmon to excavate. When areas of spawning gravel are limited, the salmon may excavate existing redds, destroying eggs already deposited.

In March 1948, an aerial photo reconnaissance of the Sacramento River from Stillwater Creek to Anderson-Cottonwood Irrigation District Dam, at extremely low flow, made clear photographs of redds showing the extent of spawning areas. In 1964, another aerial survey was made from Colusa to Keswick but it was not extensive and showed only general spawning areas ("Sacramento River Environmental Atlas, 1978"). In November 1980, spawning areas were again mapped by ground and air crews during a low-flow period. Each of these mappings, 1948, 1964, and 1980 are plotted in the atlas, and comparisons can be made to determine the reduction of spawning areas.

The most significant change occurred between the City of Anderson and Keswick Dam, where spawning gravel has substantially decreased since 1948. Keswick and Shasta Dams are largely responsible because gravel movement, essential to downstream spawning areas, is blocked by the dams. This loss of gravel, coupled with the high releases from Keswick, results in scouring below the dam. Gravel sizes suitable for spawning are washed away, leaving only large cobbles and boulders. Gravel recruitment from streams below the dams is slight because the tributaries support extensive gravel mining operations. Cottonwood Creek, the major gravel supplier to the river between the Red Bluff Diversion Dam and Keswick, joins the Sacramento River south of Anderson. In this area, the combined bedloads from the upper streams and Cottonwood Creek result in numerous spawning areas extending downstream to the Red Bluff Diversion Dam.

Periodic aerial counts of redds have been made by the California Department of Fish and Game (DFG) through the 1980 spawning season. Little spawning has occurred on the riffles from Anderson upstream to Keswick Dam; most occurs downstream from Anderson. This spawning area is replenished by gravel from the upper streams and Cottonwood Creek.

DFG and U. S. Fish and Wildlife Service personnel maintain accurate records of the number of salmon passing through Red Bluff Diversion

Dam to spawn. Between July 1, 1971 and June 30, 1972, 141,048 chinook salmon were counted. Numbers have declined since then, with 81,750 chinook in 1979-80. The low was 55,363 fish in 1978-79. The dam itself may inhibit spawners from further upstream migration, as the fish ladders on either side of the dam are sometimes inaccessible to the salmon. Those that are able to continue through the ladders, however, find limited suitable spawning areas.

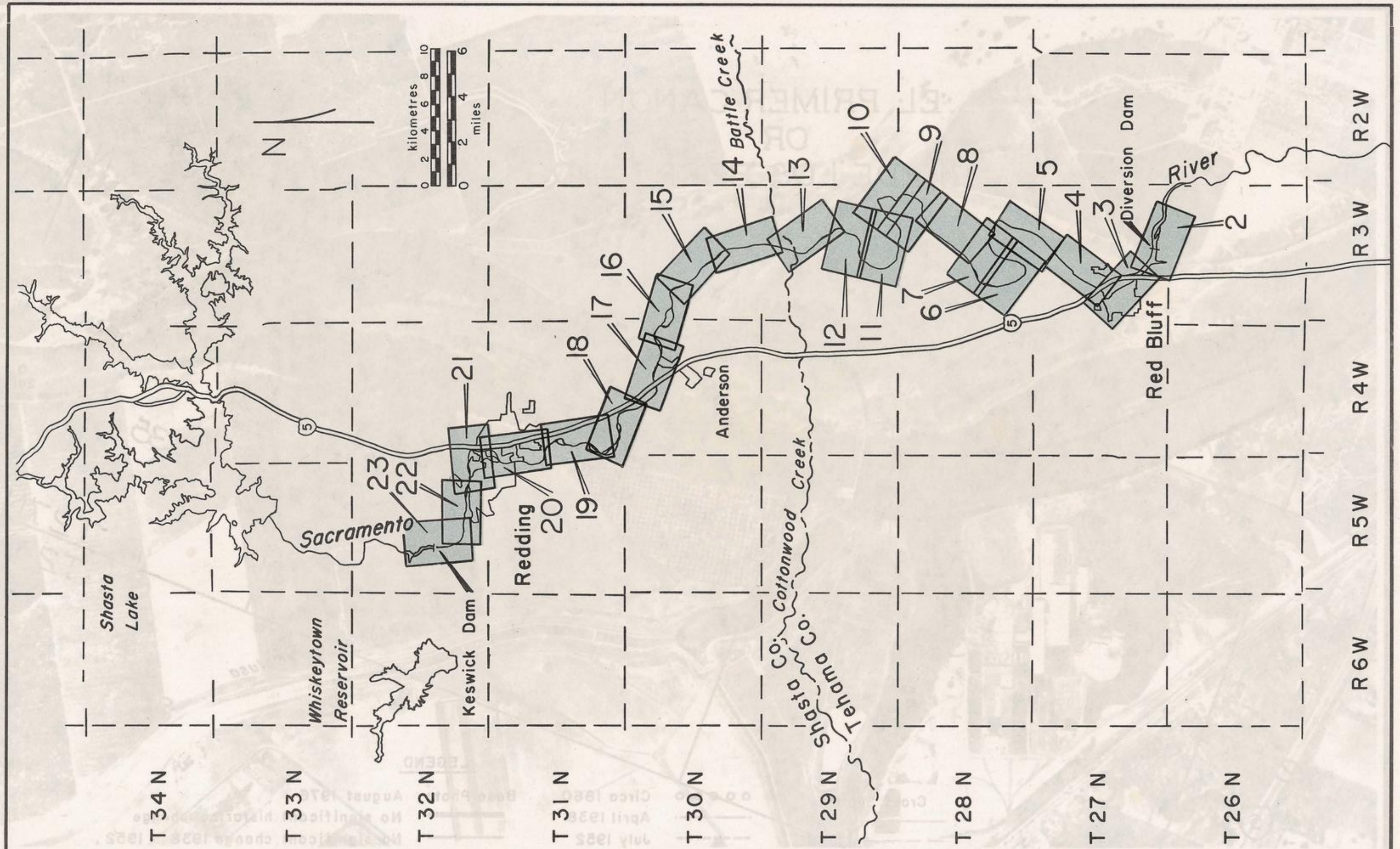
Cross-sections

The feasibility of an enhancement site is a function of flow and velocity characteristics. A potential site may be high and dry during spawning season, or gravels may be scoured out during floods.

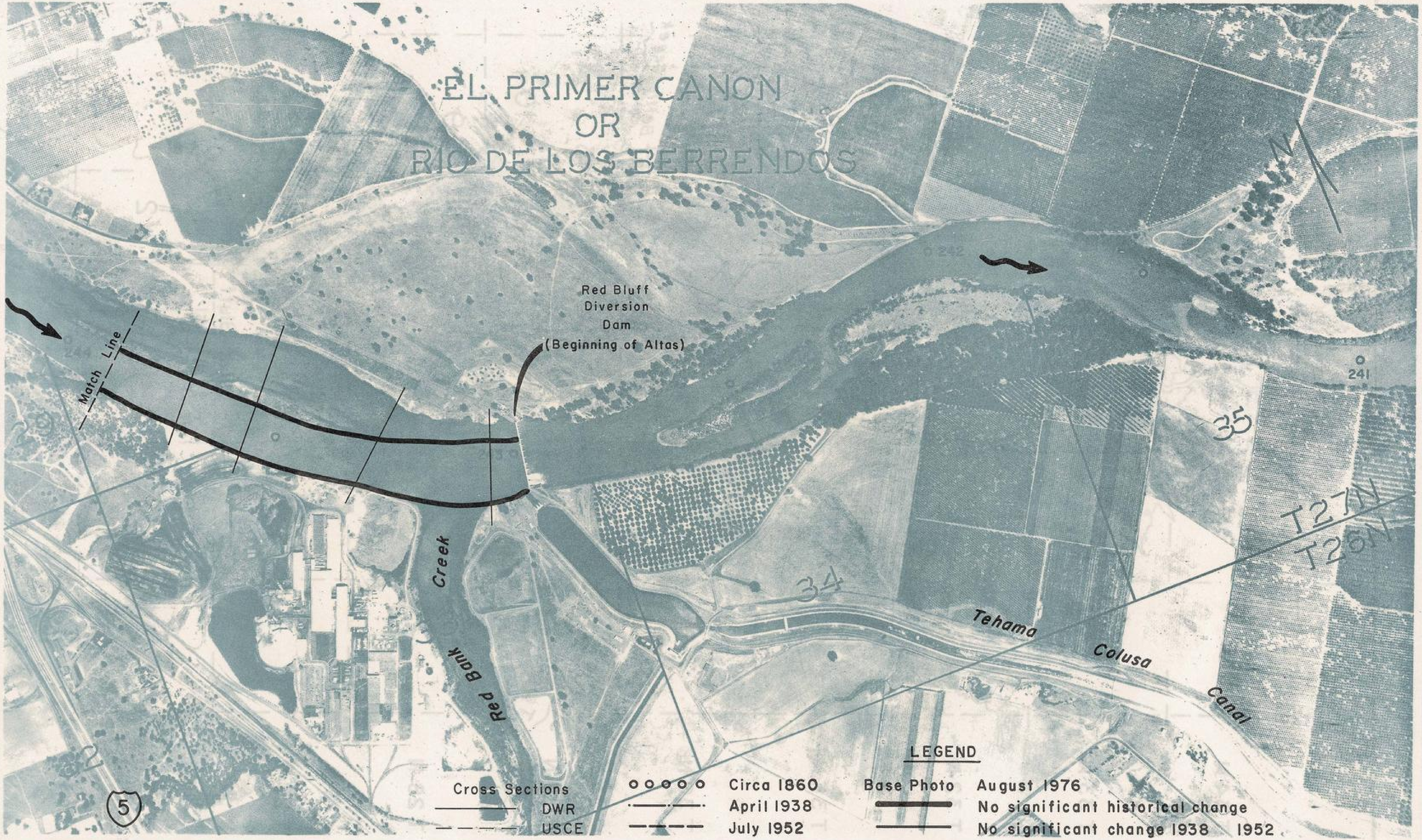
Flood data for the study reach have been developed by DWR and USCE. USCE data cover virtually the entire study reach, while DWR concentrates on populated areas. Thus, for some sections of the river there are two sets of overlapping data.

All DWR cross-sections are plotted in the atlas. USCE cross-sections are plotted only for the sections of river not covered by DWR. However, data for all USCE cross-sections are listed in Appendix C of the "Upper Sacramento River Spawning Gravel" study.

Discharge, velocity and water surface elevation data for the cross-sections plotted in this atlas may be found in Appendix C. This information may be used as a reference in selecting and evaluating enhancement sites.



SCALE 1 : 250,000	PHOTOGRAPHED AUGUST 1976 SYMBOL WR-AFV FOCAL LENGTH 152.66mm	STATE OF CALIFORNIA THE RESOURCES AGENCY DEPARTMENT OF WATER RESOURCES NORTHERN DISTRICT	SACRAMENTO RIVER RED BLUFF DIVERSION DAM TO KESWICK DAM.	INDEX MAP	SHEET 1 OF 23



APPROXIMATE SCALE 1 INCH = 1000 FEET ENLARGED FROM EXPOSURE NUMBER WR-AFV-1-	PHOTOGRAPHED AUGUST 1976 SYMBOL WR-AFV FOCAL LENGTH 152.66mm	STATE OF CALIFORNIA THE RESOURCES AGENCY DEPARTMENT OF WATER RESOURCES NORTHERN DISTRICT	SACRAMENTO RIVER RED BLUFF DIVERSION DAM TO KESWICK DAM.	UPPER SACRAMENTO RIVER SPAWNING GRAVEL STUDY	SHEET 2 OF 23

EL PRIMER CANON
OR
RIO DE LOS BERRENDOS

Red Bluff
Diversion
Dam
(Beginning of Altas)

March Line

F

Diamond
International
Corporation

Red Bank Creek

Tehama Colusa Canal

34

35

T27N
T26N

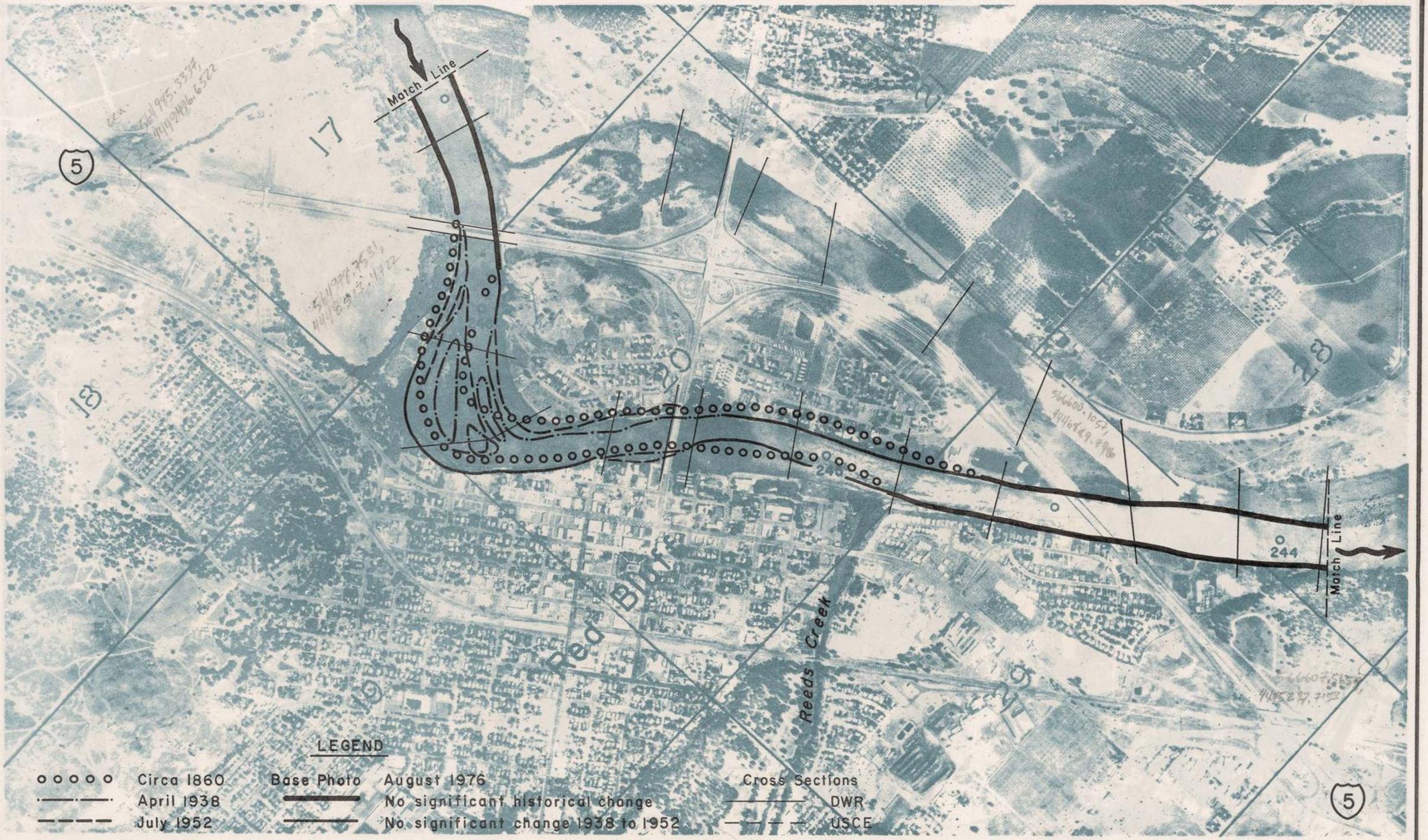
241

5

LEGEND

xxxxxxx	Bank Protection	⊢——⊣	Bank Erosion Site
⊢ – – – ⊣	Levee	C –	Sand and Gravel
	Waste Water Outfall	F –	Predominantly Sand
1964 1980	Spawning Areas	VC –	Cobbles and Gravel

APPROXIMATE SCALE 1 INCH = 1000 FEET ENLARGED FROM EXPOSURE NUMBER WR-AFV-1-	PHOTOGRAPHED AUGUST 1976 SYMBOL WR-AFV FOCAL LENGTH 152.66mm	STATE OF CALIFORNIA THE RESOURCES AGENCY DEPARTMENT OF WATER RESOURCES NORTHERN DISTRICT	SACRAMENTO RIVER RED BLUFF DIVERSION DAM TO KESWICK DAM.	UPPER SACRAMENTO RIVER SPAWNING GRAVEL STUDY	SHEET 2a OF 23



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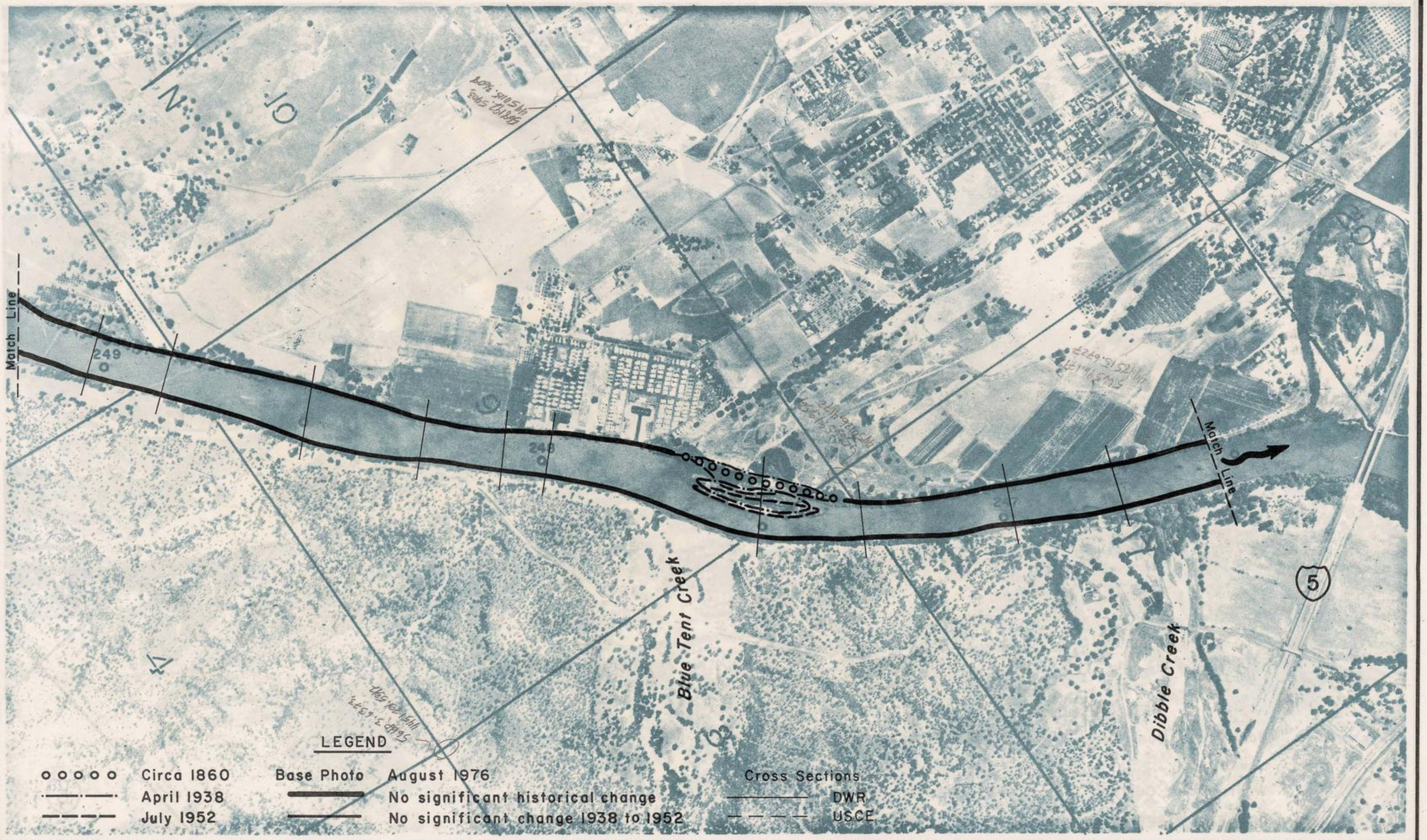

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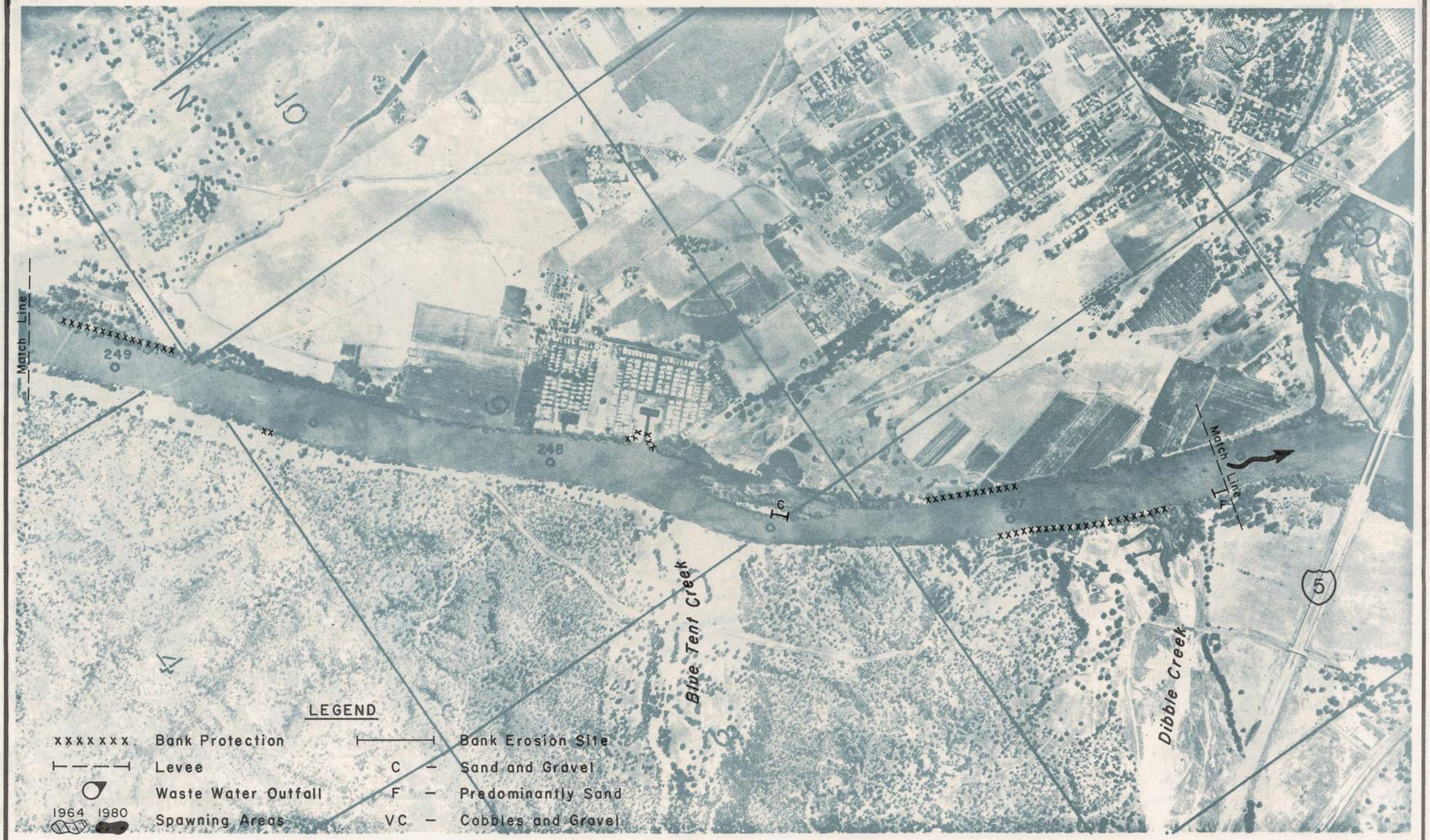

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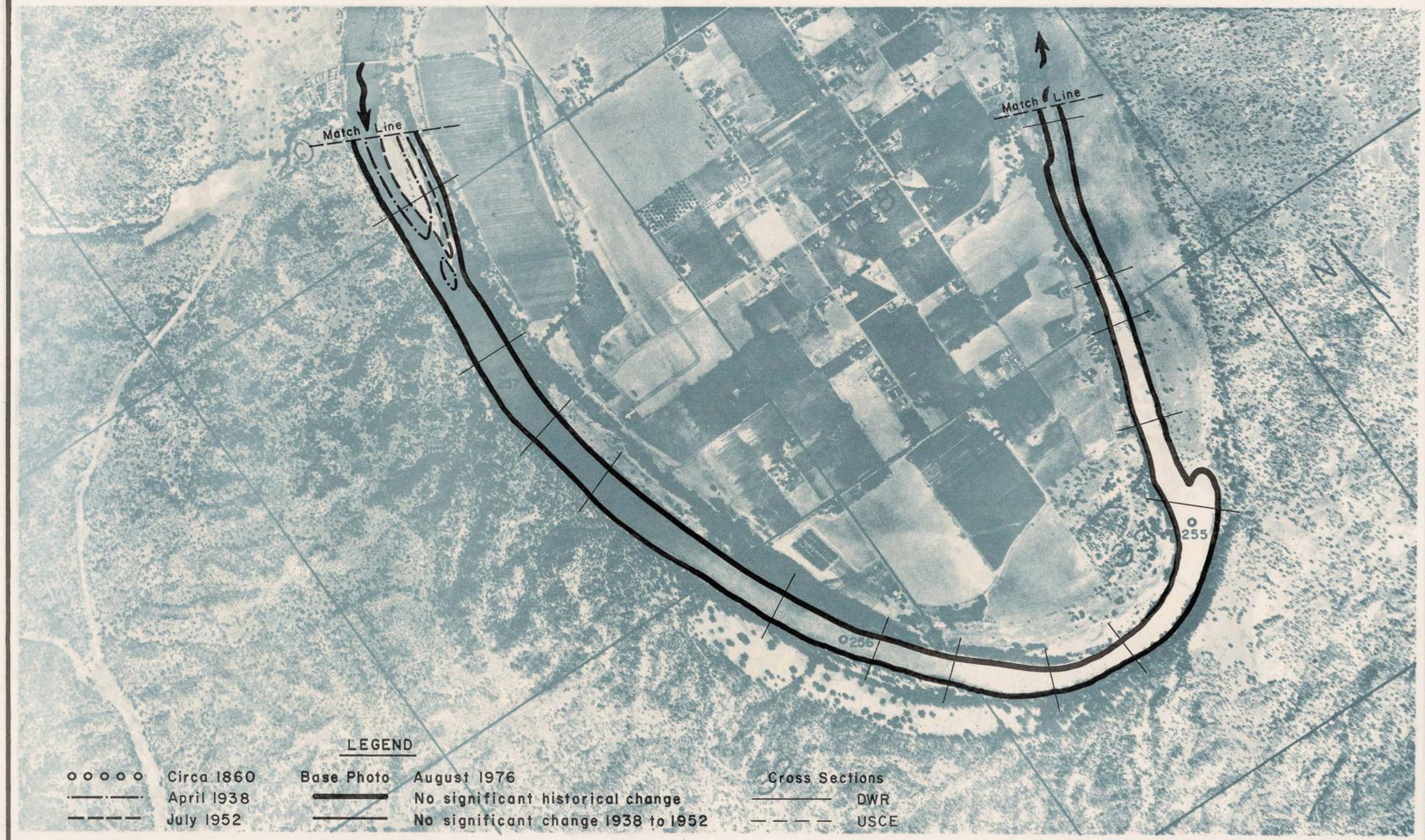

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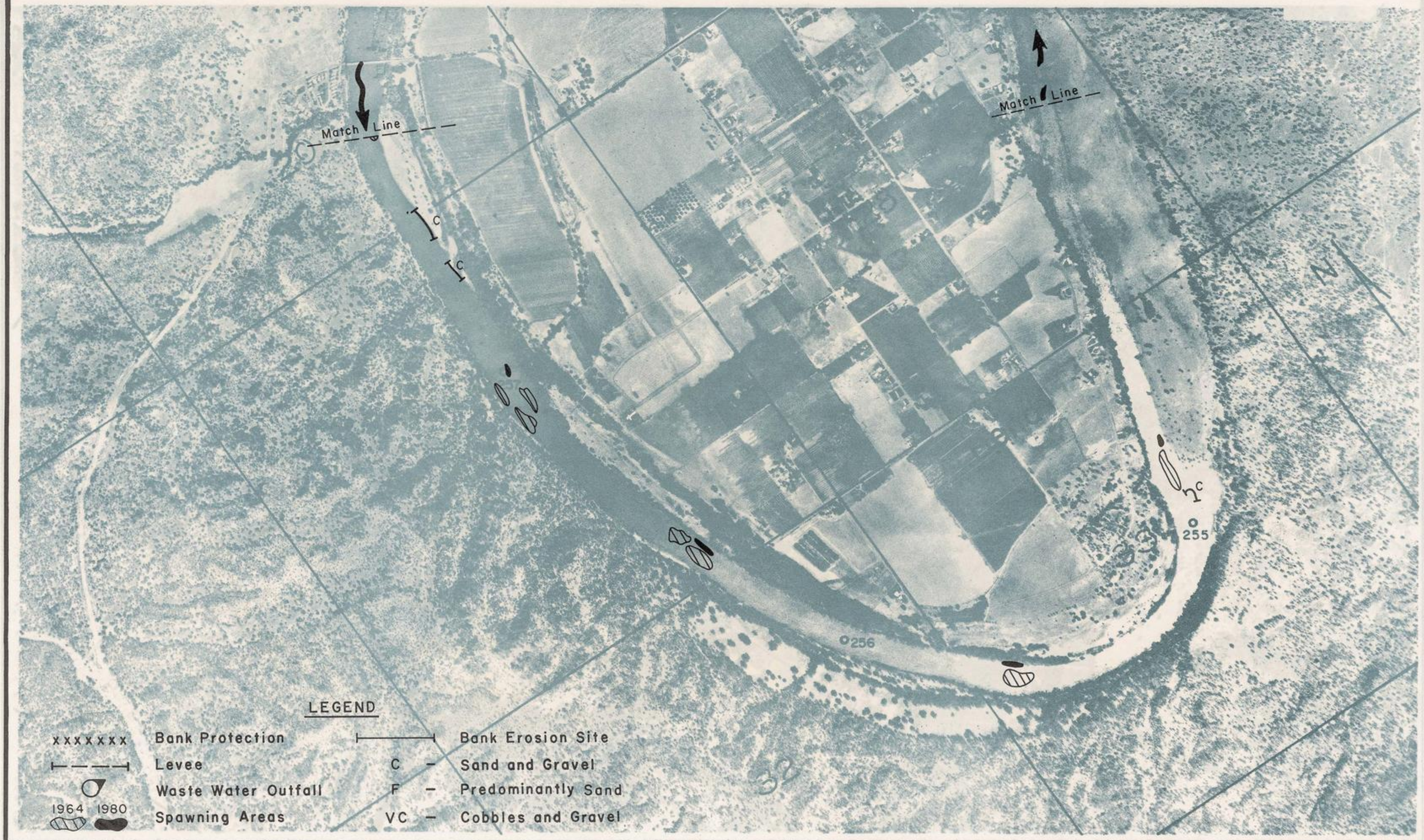

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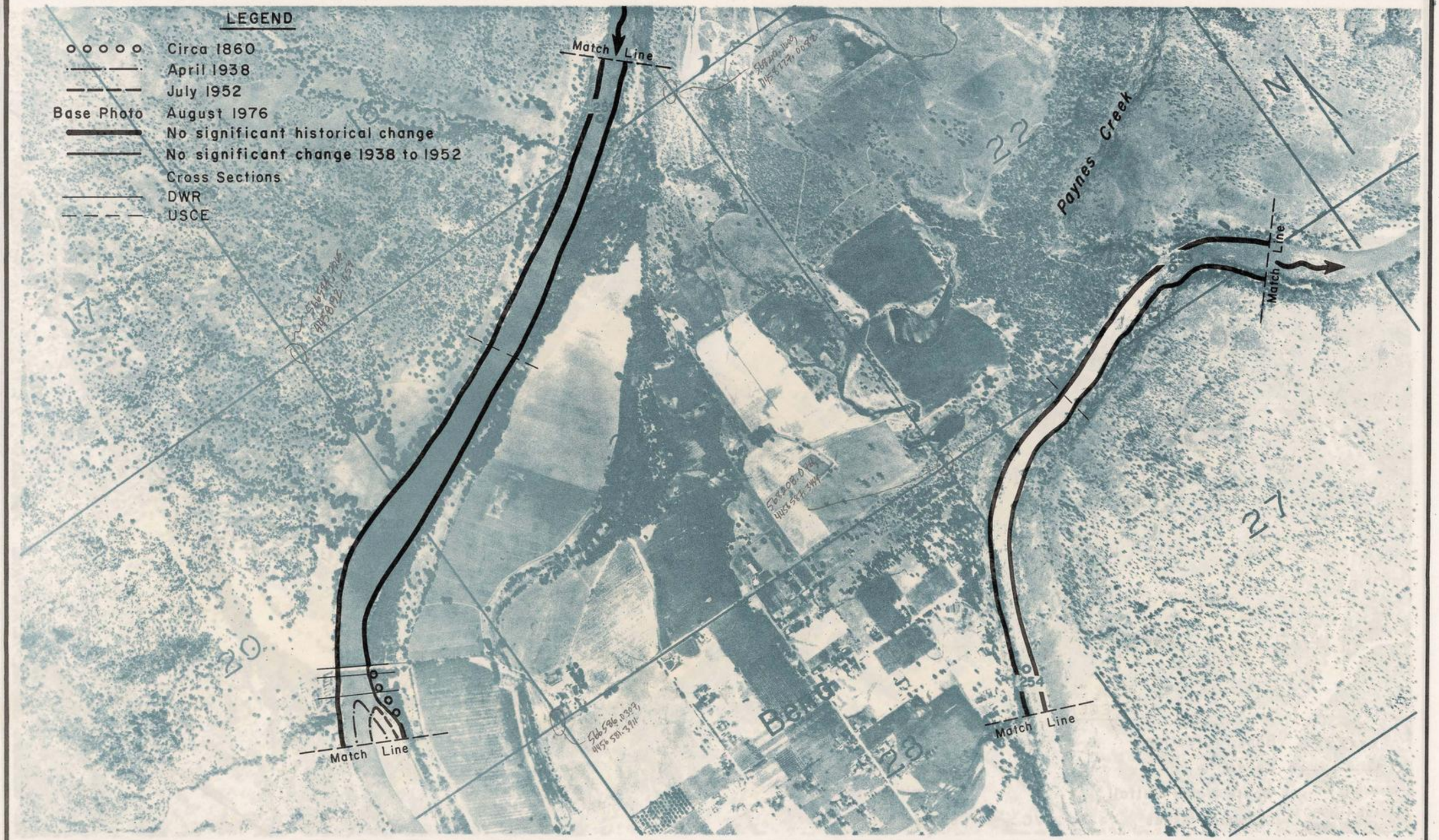

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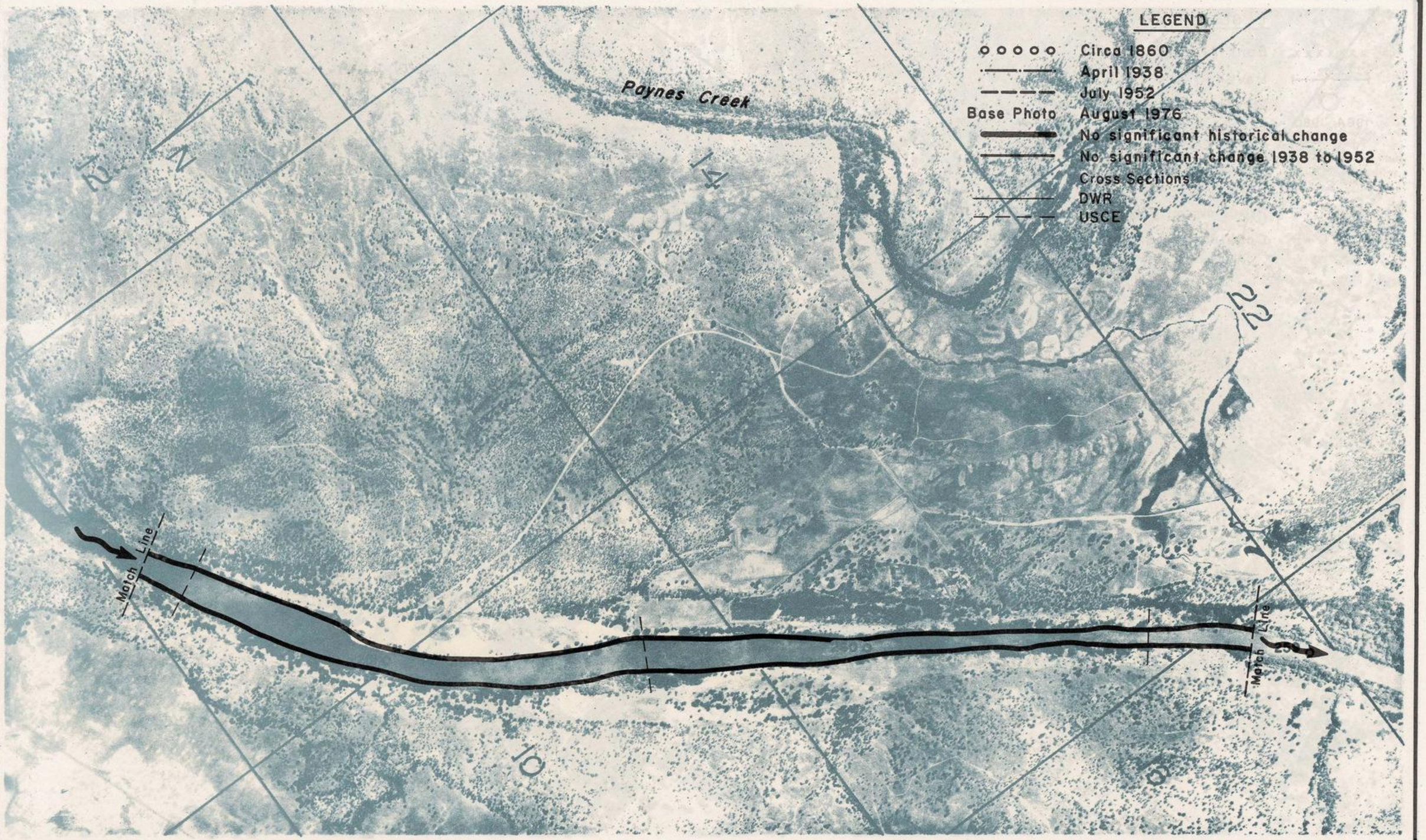

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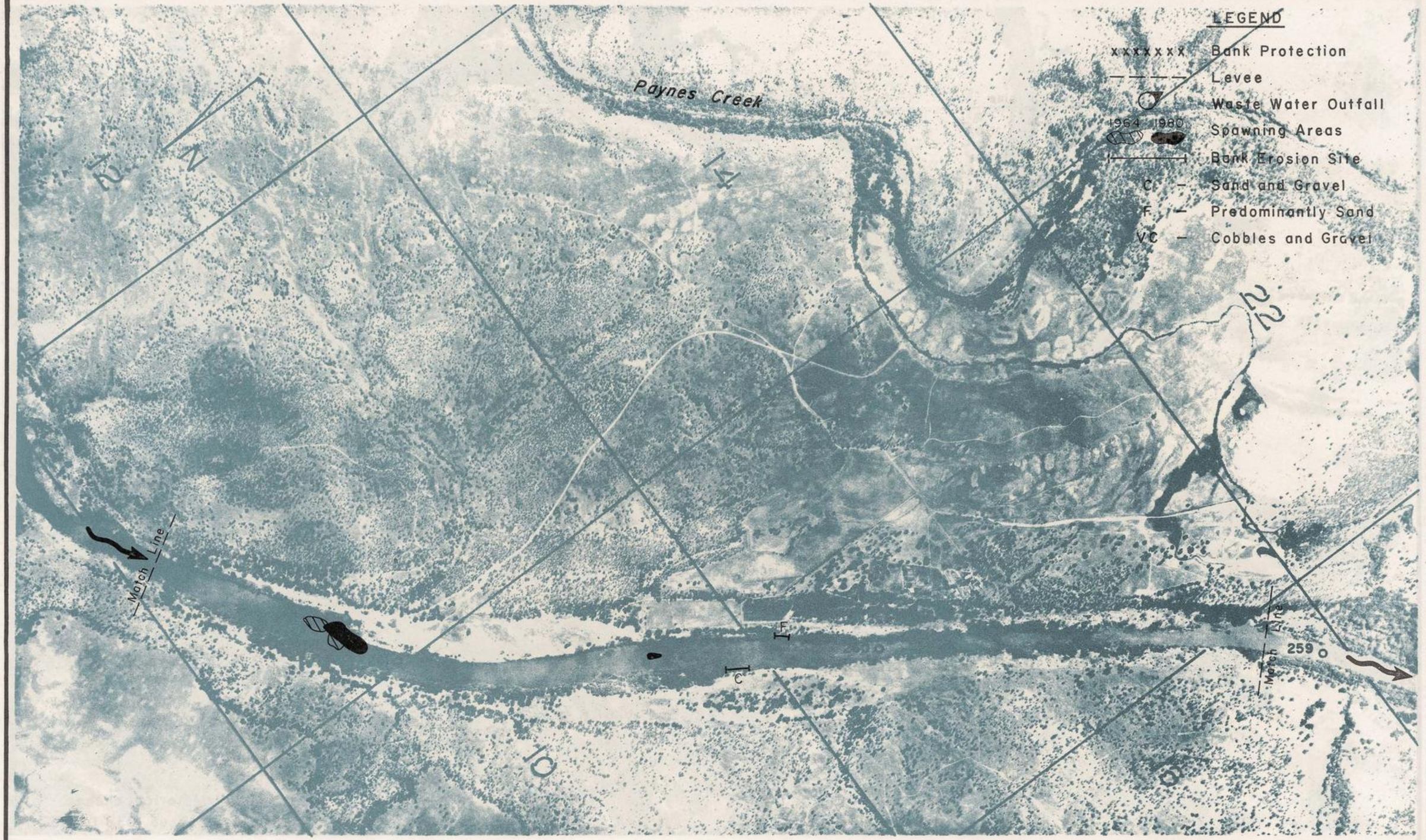

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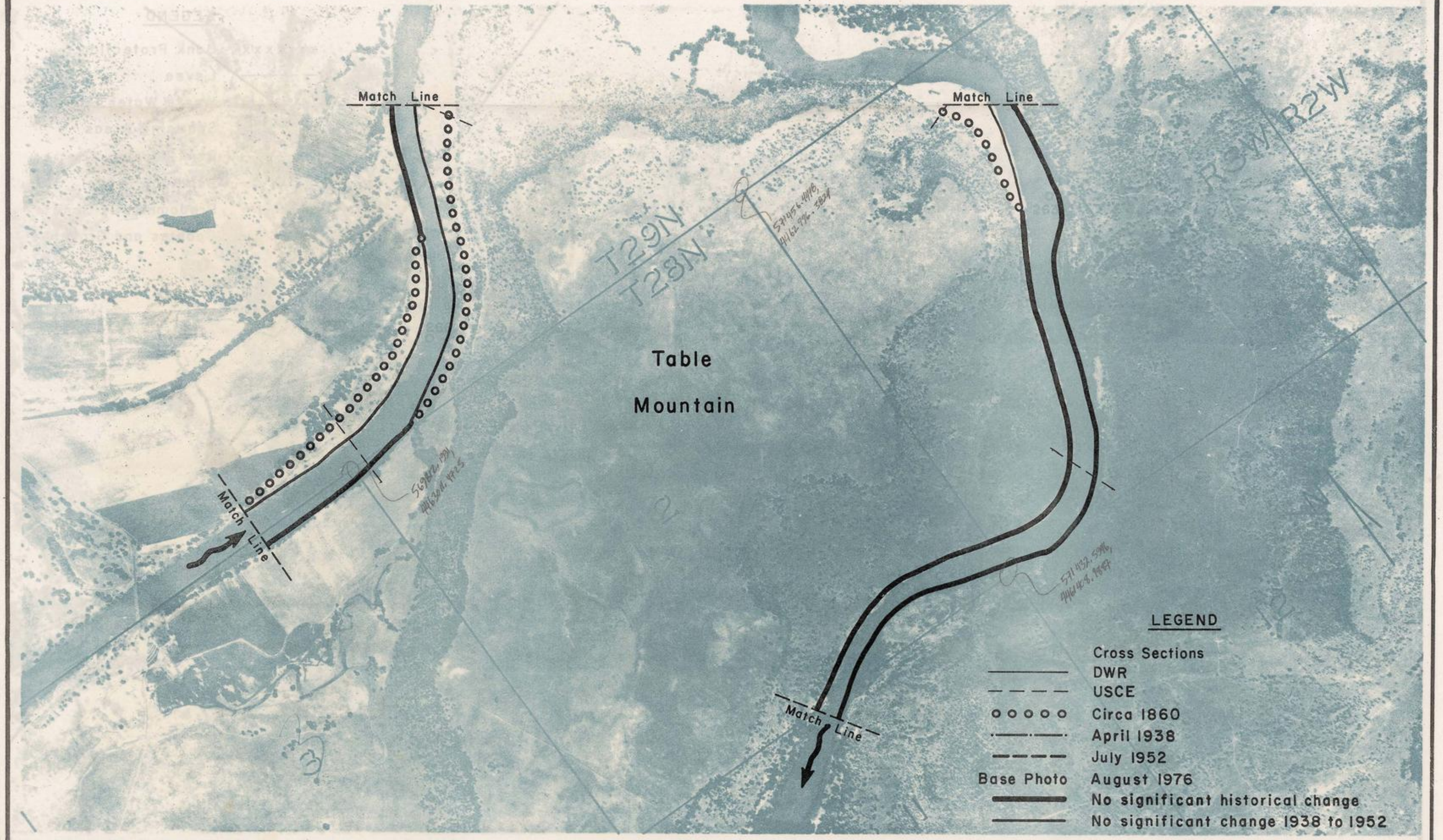

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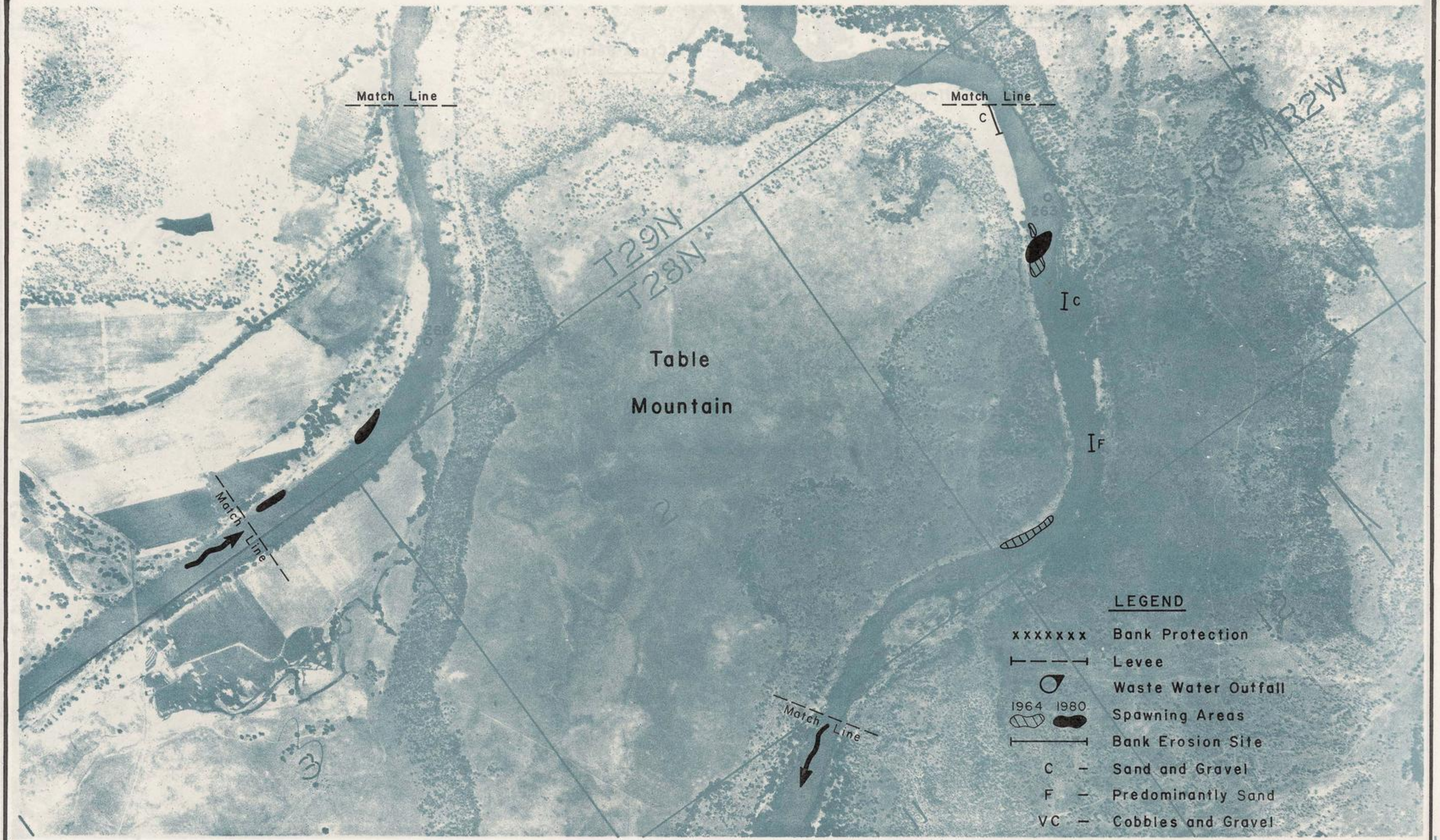

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LEGEND

ooooo Circa 1860
·—·—· April 1938
— — — July 1952

Base Photo August 1976
No significant historical change
No significant change 1938 to 1952

Cross Sections
DWR
USCE

N

R3W

R2W

T29N

T28N

Match Line

Match Line

APPROXIMATE SCALE 1 INCH = 1000 FEET ENLARGED FROM EXPOSURE NUMBER WR-AFV-1-	PHOTOGRAPHED AUGUST 1976 SYMBOL WR-AFV FOCAL LENGTH 152.66mm	STATE OF CALIFORNIA THE RESOURCES AGENCY DEPARTMENT OF WATER RESOURCES NORTHERN DISTRICT	SACRAMENTO RIVER RED BLUFF DIVERSION DAM TO KESWICK DAM.	UPPER SACRAMENTO RIVER SPAWNING GRAVEL STUDY	SHEET 10 OF 23

LEGEND

xxxxxxx Bank Protection

Levee

Waste Water Outfall

1964 1980 Spawning Areas

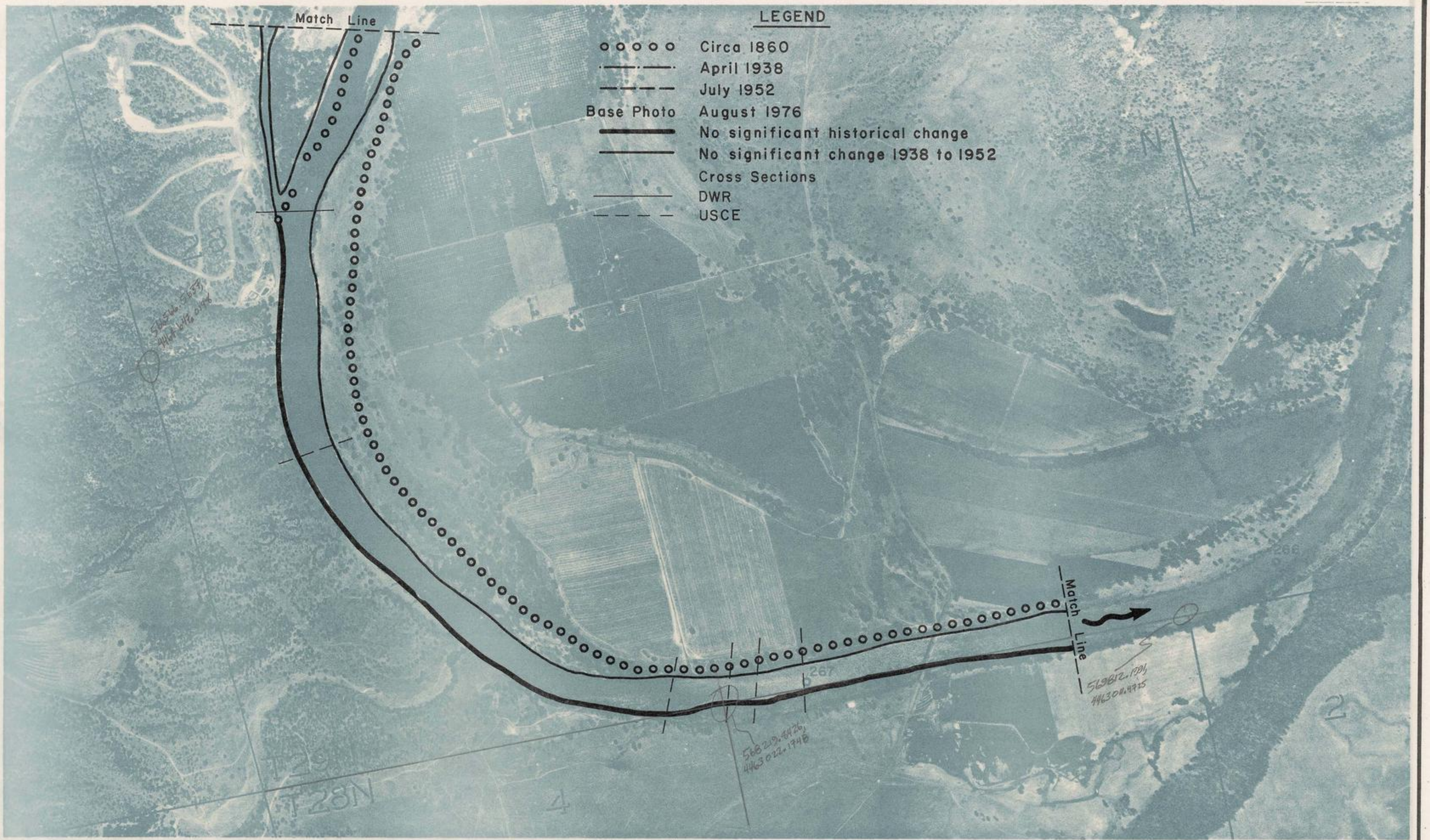
Bank Erosion Site

C – Sand and Gravel

F – Predominantly Sand

VC – Cobbles and Gravel

APPROXIMATE SCALE 1 INCH = 1000 FEET ENLARGED FROM EXPOSURE NUMBER WR-AFV-1-	PHOTOGRAPHED AUGUST 1976 SYMBOL WR-AFV FOCAL LENGTH 152.66mm	STATE OF CALIFORNIA THE RESOURCES AGENCY DEPARTMENT OF WATER RESOURCES NORTHERN DISTRICT	SACRAMENTO RIVER RED BLUFF DIVERSION DAM TO KESWICK DAM.	UPPER SACRAMENTO RIVER SPAWNING GRAVEL STUDY	SHEET 10a OF 23



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LEGEND

ooooo	Circa 1860	Base Photo	August 1976
—·—·—	April 1938	▬▬	No significant historical change
— — —	July 1952	——	No significant change 1938 to 1952
	Cross Sections		
——	DWR		
— — —	USCE		

Match Line

22

21

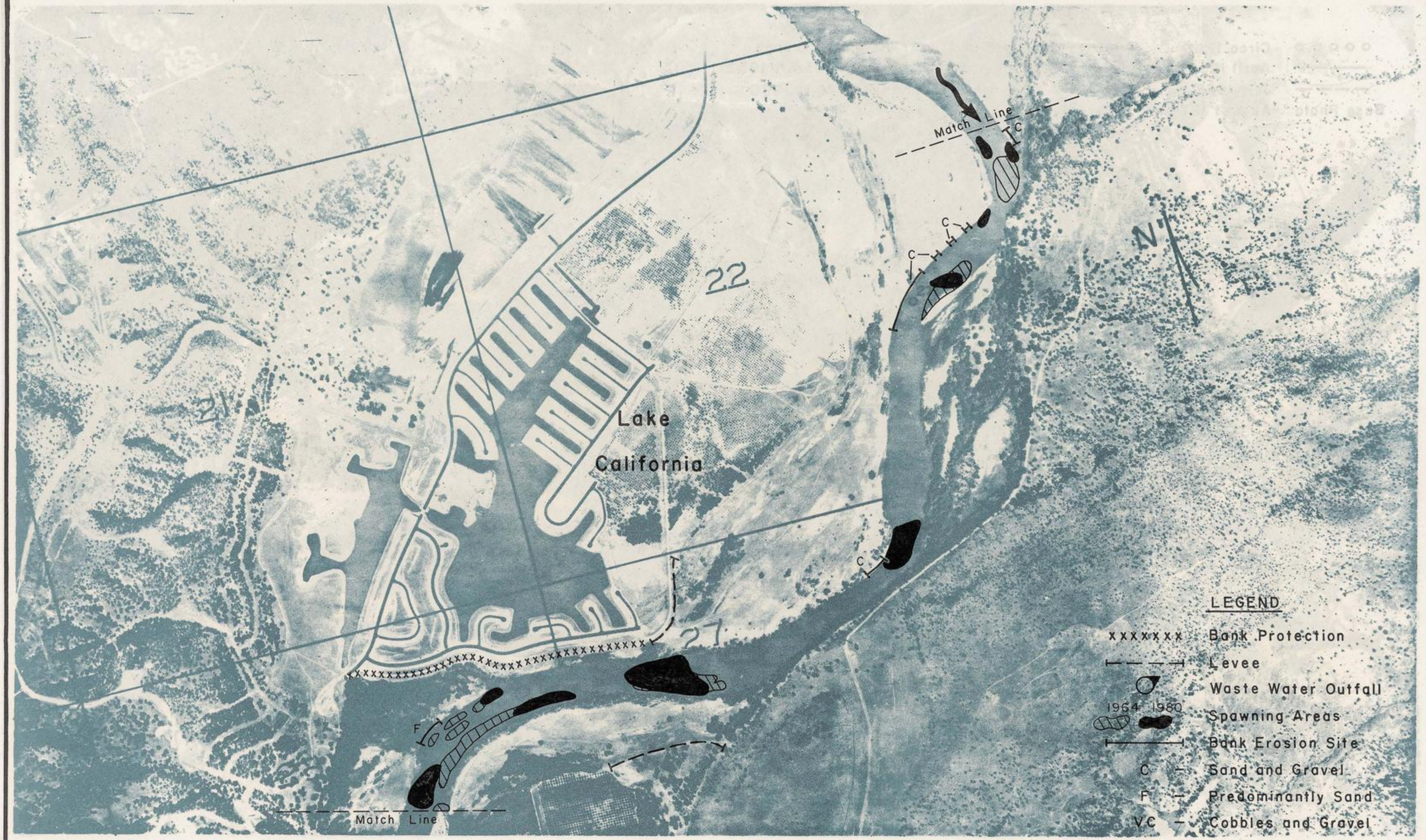
Lake

California

Match Line

N

APPROXIMATE SCALE 1 INCH = 1000 FEET ENLARGED FROM EXPOSURE NUMBER WR-AFV-1-	PHOTOGRAPHED AUGUST 1976 SYMBOL WR-AFV FOCAL LENGTH 152.66mm	STATE OF CALIFORNIA THE RESOURCES AGENCY DEPARTMENT OF WATER RESOURCES NORTHERN DISTRICT	SACRAMENTO RIVER RED BLUFF DIVERSION DAM TO KESWICK DAM.	UPPER SACRAMENTO RIVER SPAWNING GRAVEL STUDY	SHEET 12 OF 23



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LEGEND

Circa 1860
April 1938
July 1952
Base Photo August 1976

No significant historical change
No significant change 1938 to 1952
Significant change 1976 to 1980
Cross Sections
DWR
USCE

Match Line

Battle Creek

Bloody Island

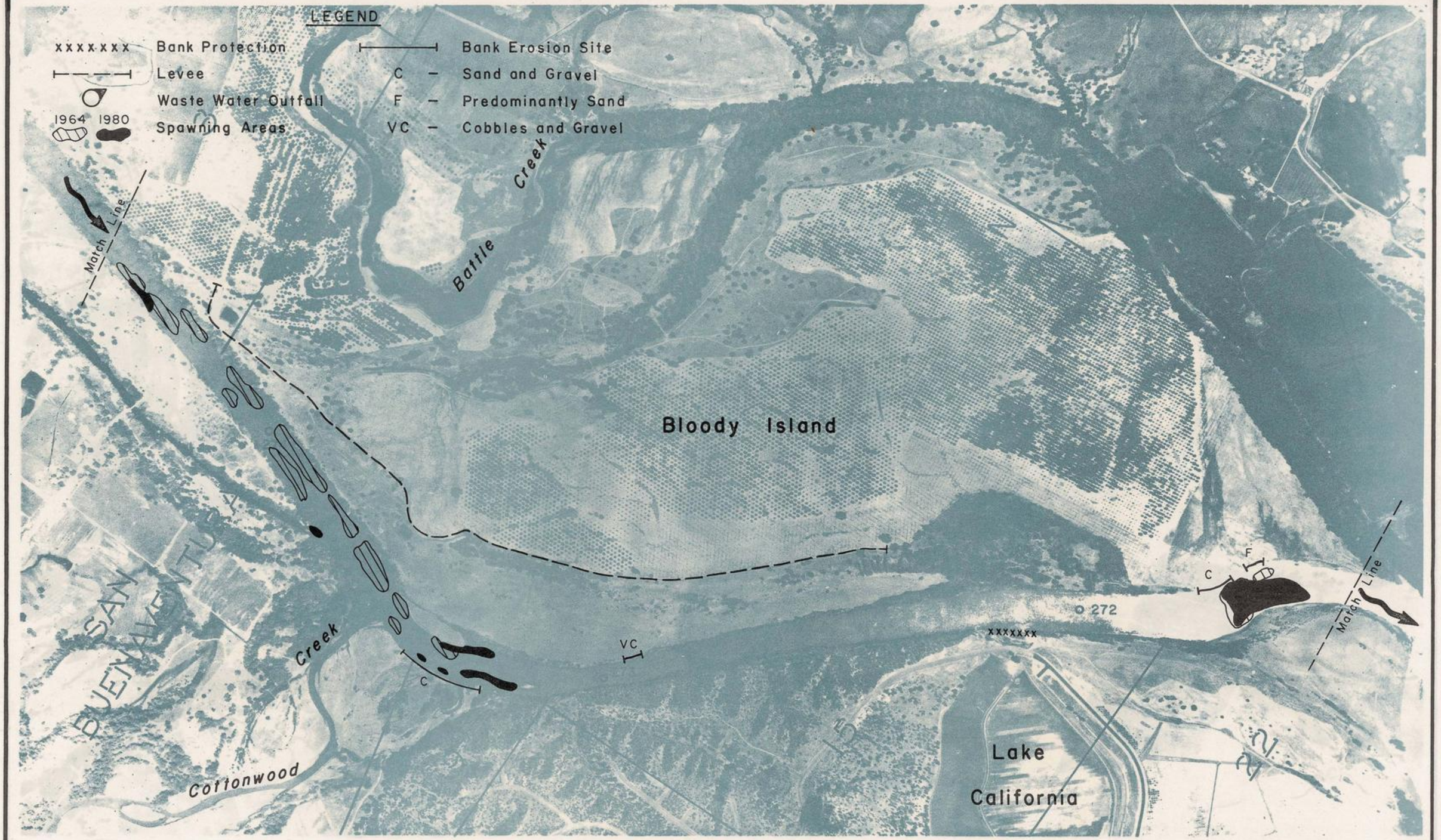
Lake California

Cottonwood Creek

272

Match Line

APPROXIMATE SCALE 1 INCH = 1000 FEET ENLARGED FROM EXPOSURE NUMBER WR-AFV-1-	PHOTOGRAPHED AUGUST 1976 SYMBOL WR-AFV FOCAL LENGTH 152.66mm	STATE OF CALIFORNIA THE RESOURCES AGENCY DEPARTMENT OF WATER RESOURCES NORTHERN DISTRICT	SACRAMENTO RIVER RED BLUFF DIVERSION DAM TO KESWICK DAM.	UPPER SACRAMENTO RIVER SPAWNING GRAVEL STUDY	SHEET 13 OF 23



APPROXIMATE SCALE 1 INCH = 1000 FEET ENLARGED FROM EXPOSURE NUMBER WR-AFV-1-	PHOTOGRAPHED AUGUST 1976 SYMBOL WR-AFV FOCAL LENGTH 152.66mm	STATE OF CALIFORNIA THE RESOURCES AGENCY DEPARTMENT OF WATER RESOURCES NORTHERN DISTRICT	SACRAMENTO RIVER RED BLUFF DIVERSION DAM TO KESWICK DAM.	UPPER SACRAMENTO RIVER SPAWNING GRAVEL STUDY	SHEET 13a OF 23

LEGEND

Circa 1860
April 1938
July 1952

Base Photo August 1976
No significant historical change
No significant change 1938 to 1952

Cross Sections
DWR
USCE

Match Line

Match Line

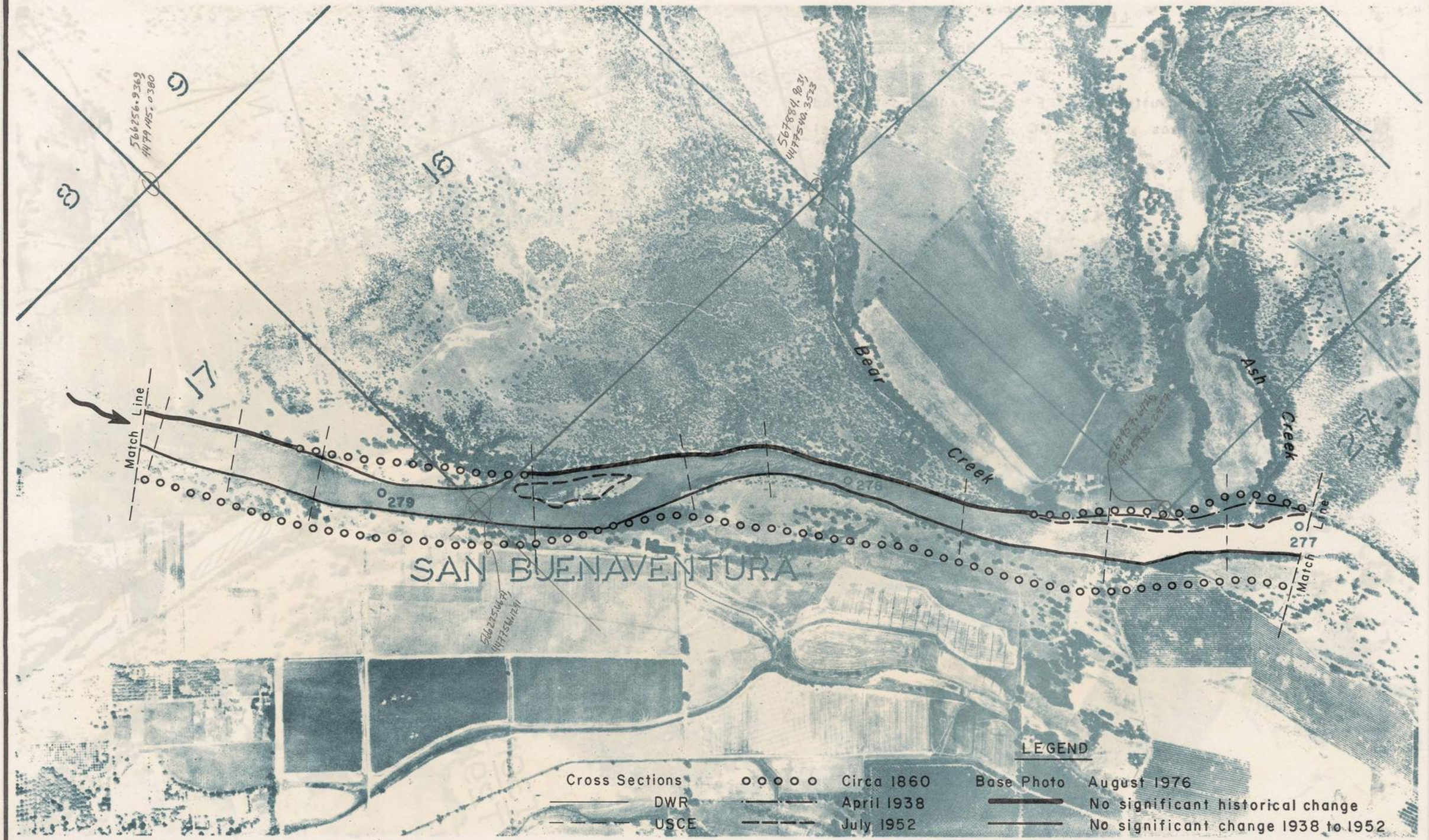
SAN BUENAVENTURA

Anderson Creek

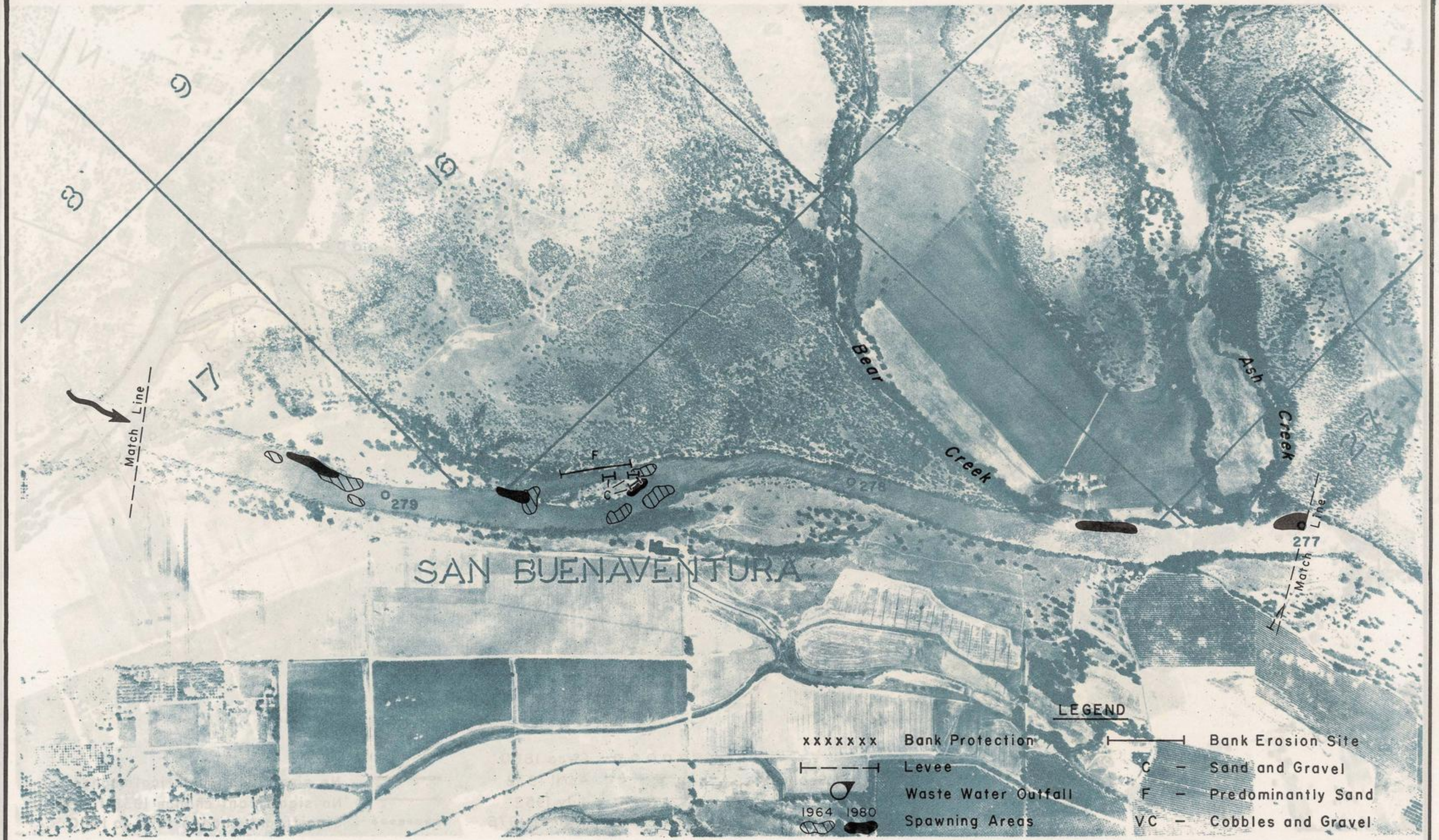
T30N
T29N

APPROXIMATE SCALE 1 INCH = 1000 FEET ENLARGED FROM EXPOSURE NUMBER WR-AFV-1-	PHOTOGRAPHED AUGUST 1976 SYMBOL WR-AFV FOCAL LENGTH 152.66mm	STATE OF CALIFORNIA THE RESOURCES AGENCY DEPARTMENT OF WATER RESOURCES NORTHERN DISTRICT	SACRAMENTO RIVER RED BLUFF DIVERSION DAM TO KESWICK DAM.	UPPER SACRAMENTO RIVER SPAWNING GRAVEL STUDY	SHEET 14 OF 23

APPROXIMATE SCALE 1 INCH = 1000 FEET ENLARGED FROM EXPOSURE NUMBER WR-AFV-1-	PHOTOGRAPHED AUGUST 1976 SYMBOL WR-AFV FOCAL LENGTH 152.66mm	STATE OF CALIFORNIA THE RESOURCES AGENCY DEPARTMENT OF WATER RESOURCES NORTHERN DISTRICT	SACRAMENTO RIVER RED BLUFF DIVERSION DAM TO KESWICK DAM.	UPPER SACRAMENTO RIVER SPAWNING GRAVEL STUDY	SHEET 14a OF 23



APPROXIMATE SCALE 1 INCH = 1000 FEET ENLARGED FROM EXPOSURE NUMBER WR-AFV-1-	PHOTOGRAPHED AUGUST 1976 SYMBOL WR-AFV FOCAL LENGTH 152.66mm	STATE OF CALIFORNIA THE RESOURCES AGENCY DEPARTMENT OF WATER RESOURCES NORTHERN DISTRICT	SACRAMENTO RIVER RED BLUFF DIVERSION DAM TO KESWICK DAM.	UPPER SACRAMENTO RIVER SPAWNING GRAVEL STUDY	SHEET 15 OF 23



APPROXIMATE SCALE 1 INCH = 1000 FEET ENLARGED FROM EXPOSURE NUMBER WR-AFV-1-	PHOTOGRAPHED AUGUST 1976 SYMBOL WR-AFV FOCAL LENGTH 152.66mm	STATE OF CALIFORNIA THE RESOURCES AGENCY DEPARTMENT OF WATER RESOURCES NORTHERN DISTRICT	SACRAMENTO RIVER RED BLUFF DIVERSION DAM TO KESWICK DAM.	UPPER SACRAMENTO RIVER SPAWNING GRAVEL STUDY	SHEET 15a OF 23

APPROXIMATE SCALE 1 INCH = 1000 FEET ENLARGED FROM EXPOSURE NUMBER WR-AFV-1-	PHOTOGRAPHED AUGUST 1976 SYMBOL WR-AFV FOCAL LENGTH 152.66mm	STATE OF CALIFORNIA THE RESOURCES AGENCY DEPARTMENT OF WATER RESOURCES NORTHERN DISTRICT	SACRAMENTO RIVER RED BLUFF DIVERSION DAM TO KESWICK DAM.	UPPER SACRAMENTO RIVER SPAWNING GRAVEL STUDY	SHEET 16 OF 23

Stillwater Creek

Cow Creek

City of Anderson

Stillwater Bypass Enhancement Site

Simpson Paper Company

Match Line

Match Line

SAN JUAN RAMIREZ

LEGEND

xxxxxxx	Bank Protection	⊢——⊣	Bank Erosion Site
⊢— — —⊣	Levee	C –	Sand and Gravel
	Waste Water Outfall	F –	Predominantly Sand
1948 1964 1980	Spawning Areas	VC –	Cobbles and Gravel

APPROXIMATE SCALE 1 INCH = 1000 FEET ENLARGED FROM EXPOSURE NUMBER WR-AFV-1-	PHOTOGRAPHED AUGUST 1976 SYMBOL WR-AFV FOCAL LENGTH 152.66mm	STATE OF CALIFORNIA THE RESOURCES AGENCY DEPARTMENT OF WATER RESOURCES NORTHERN DISTRICT	SACRAMENTO RIVER RED BLUFF DIVERSION DAM TO KESWICK DAM.	UPPER SACRAMENTO RIVER SPAWNING GRAVEL STUDY	SHEET 16a OF 23

LEGEND

Circa 1860
April 1938
July 1952

Base Photo August 1976
No significant historical change
No significant change 1938 to 1952

Cross Sections
DWR
USCE

Churn Creek

Match Line

Match Line

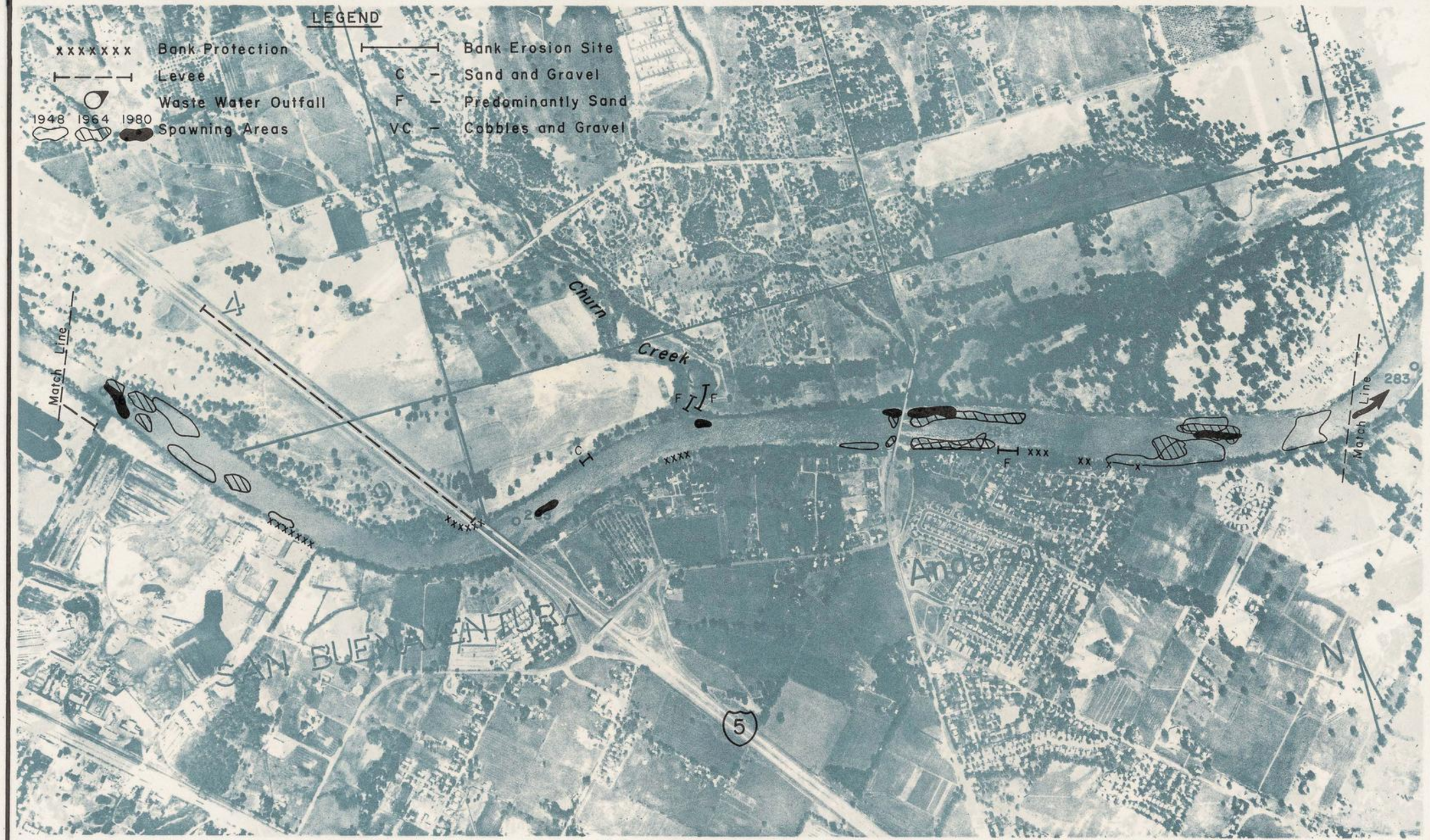
SAN BUENAVENTURA

Ander

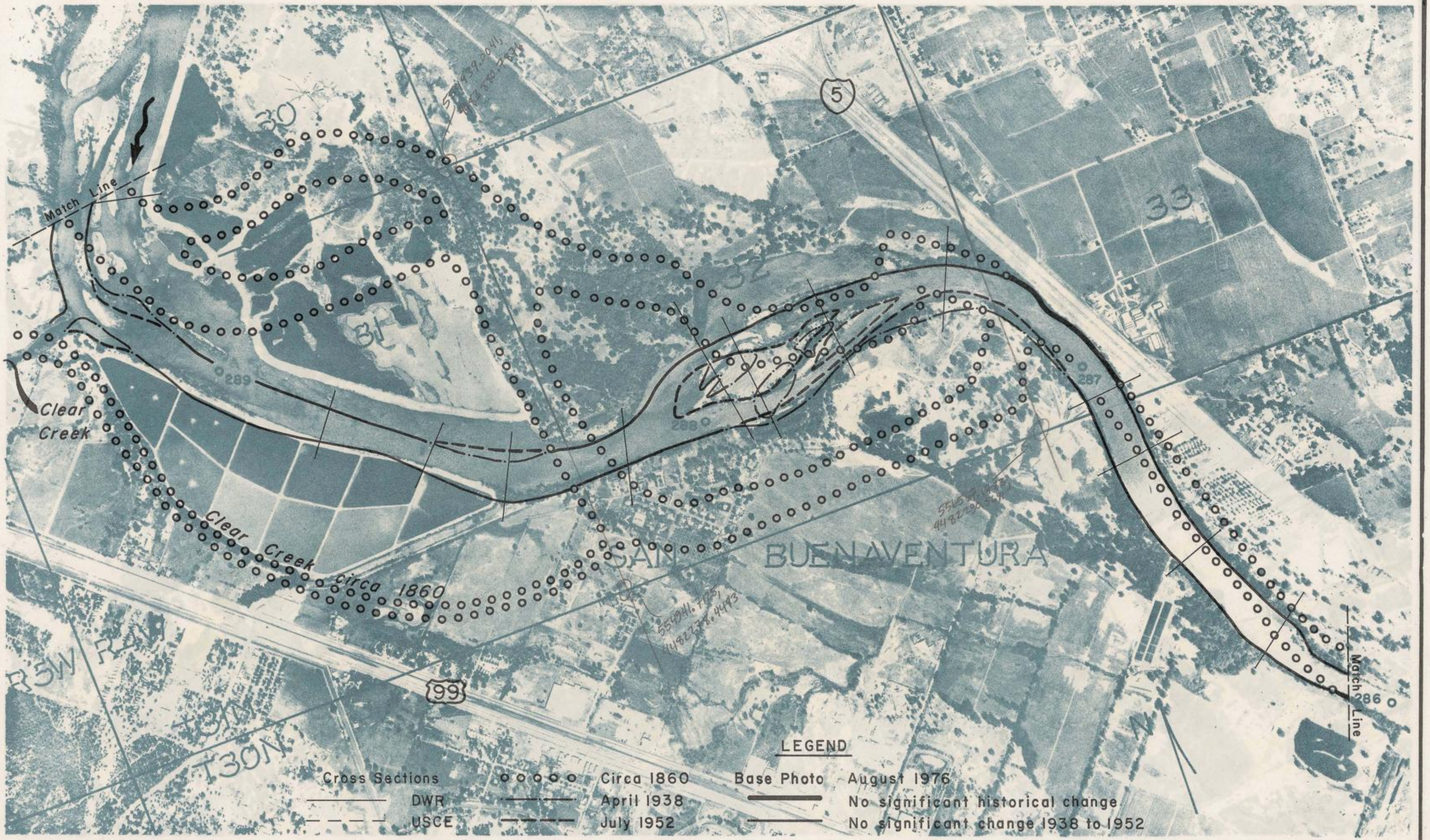
5

N

APPROXIMATE SCALE 1 INCH = 1000 FEET ENLARGED FROM EXPOSURE NUMBER WR-AFV-1-	PHOTOGRAPHED AUGUST 1976 SYMBOL WR-AFV FOCAL LENGTH 152.66mm	STATE OF CALIFORNIA THE RESOURCES AGENCY DEPARTMENT OF WATER RESOURCES NORTHERN DISTRICT	SACRAMENTO RIVER RED BLUFF DIVERSION DAM TO KESWICK DAM.	UPPER SACRAMENTO RIVER SPAWNING GRAVEL STUDY	SHEET 17 OF 23



APPROXIMATE SCALE 1 INCH = 1000 FEET ENLARGED FROM EXPOSURE NUMBER WR-AFV-1-	PHOTOGRAPHED AUGUST 1976 SYMBOL WR-AFV FOCAL LENGTH 152.66mm	STATE OF CALIFORNIA THE RESOURCES AGENCY DEPARTMENT OF WATER RESOURCES NORTHERN DISTRICT	SACRAMENTO RIVER RED BLUFF DIVERSION DAM TO KESWICK DAM.	UPPER SACRAMENTO RIVER SPAWNING GRAVEL STUDY	SHEET 17a OF 23



APPROXIMATE SCALE 1 INCH = 1000 FEET ENLARGED FROM EXPOSURE NUMBER WR-AFV-1-	PHOTOGRAPHED AUGUST 1976 SYMBOL WR-AFV FOCAL LENGTH 152.66mm	STATE OF CALIFORNIA THE RESOURCES AGENCY DEPARTMENT OF WATER RESOURCES NORTHERN DISTRICT	SACRAMENTO RIVER RED BLUFF DIVERSION DAM TO KESWICK DAM.	UPPER SACRAMENTO RIVER SPAWNING GRAVEL STUDY	SHEET 18 OF 23

APPROXIMATE SCALE 1 INCH = 1000 FEET ENLARGED FROM EXPOSURE NUMBER WR-AFV-1-	PHOTOGRAPHED AUGUST 1976 SYMBOL WR-AFV FOCAL LENGTH 152.66mm	STATE OF CALIFORNIA THE RESOURCES AGENCY DEPARTMENT OF WATER RESOURCES NORTHERN DISTRICT	SACRAMENTO RIVER RED BLUFF DIVERSION DAM TO KESWICK DAM.	UPPER SACRAMENTO RIVER SPAWNING GRAVEL STUDY	SHEET 18a OF 23

17
18
20
21
29
5
N
292
291
289
Match Line
Match Line
SAN BUENAVENTURA
Clear Creek
99

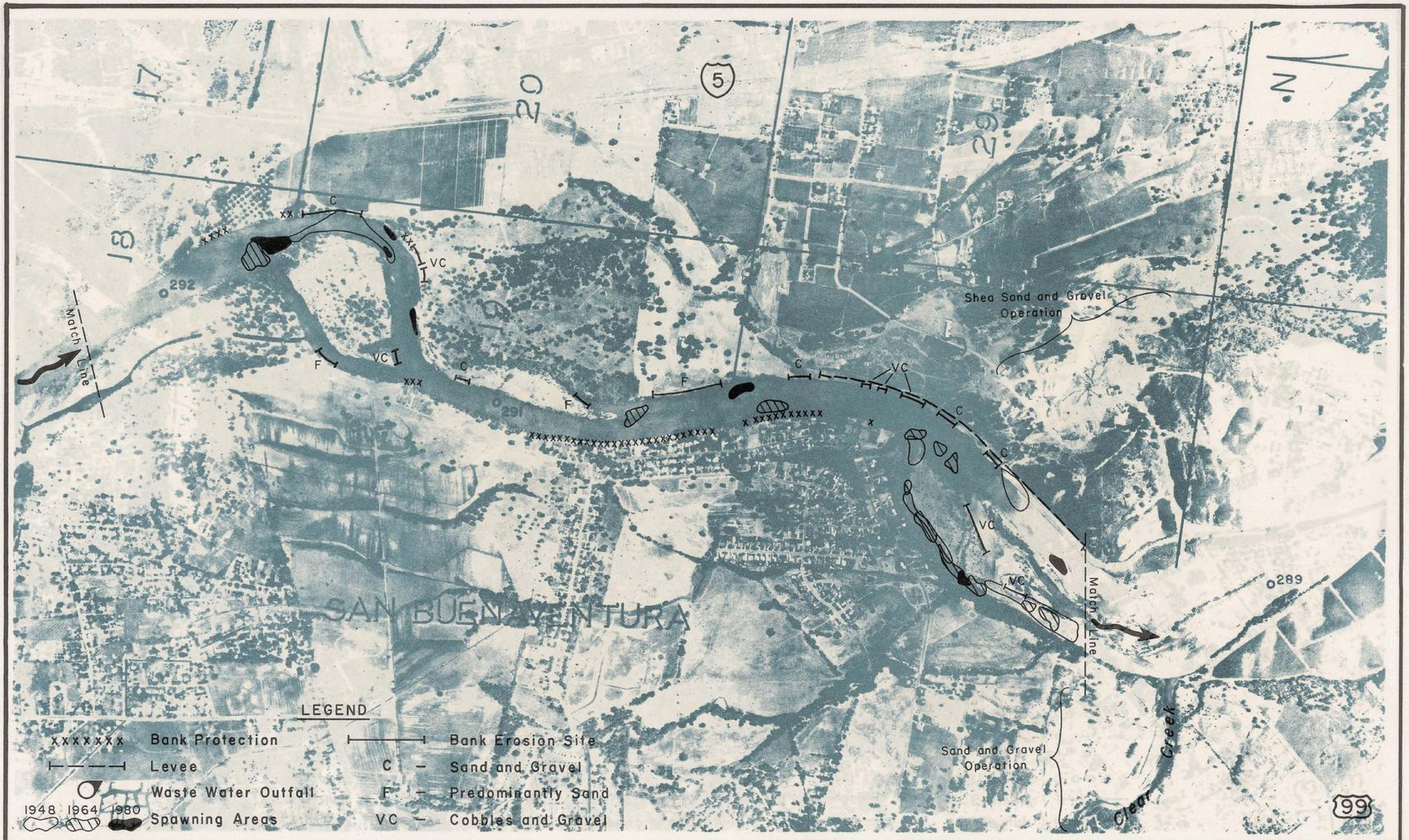
LEGEND

Circa 1860
April 1938
July 1952

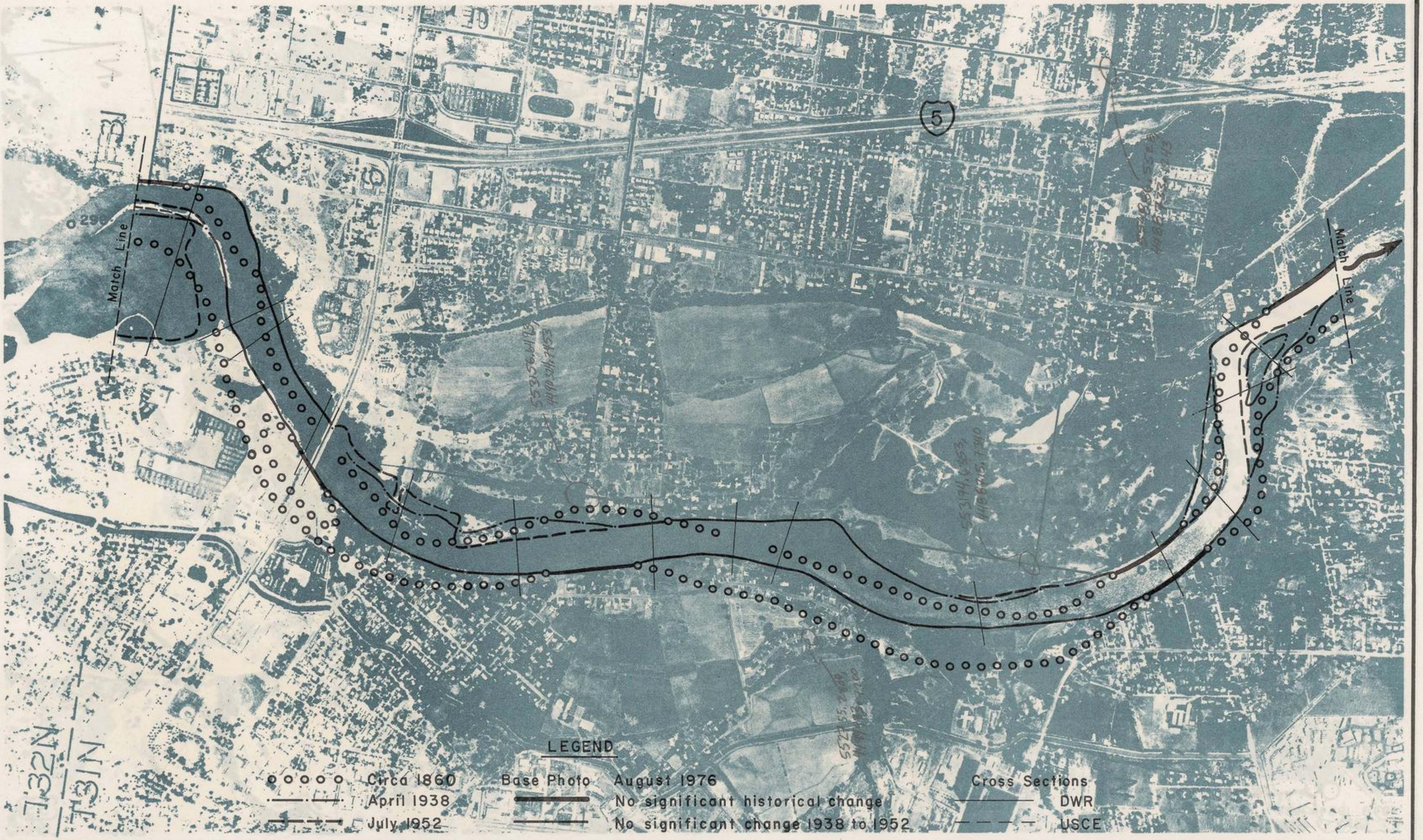
Base Photo August 1976
No significant historical change
No significant change 1938 to 1952

Cross Sections
DWR
USCE

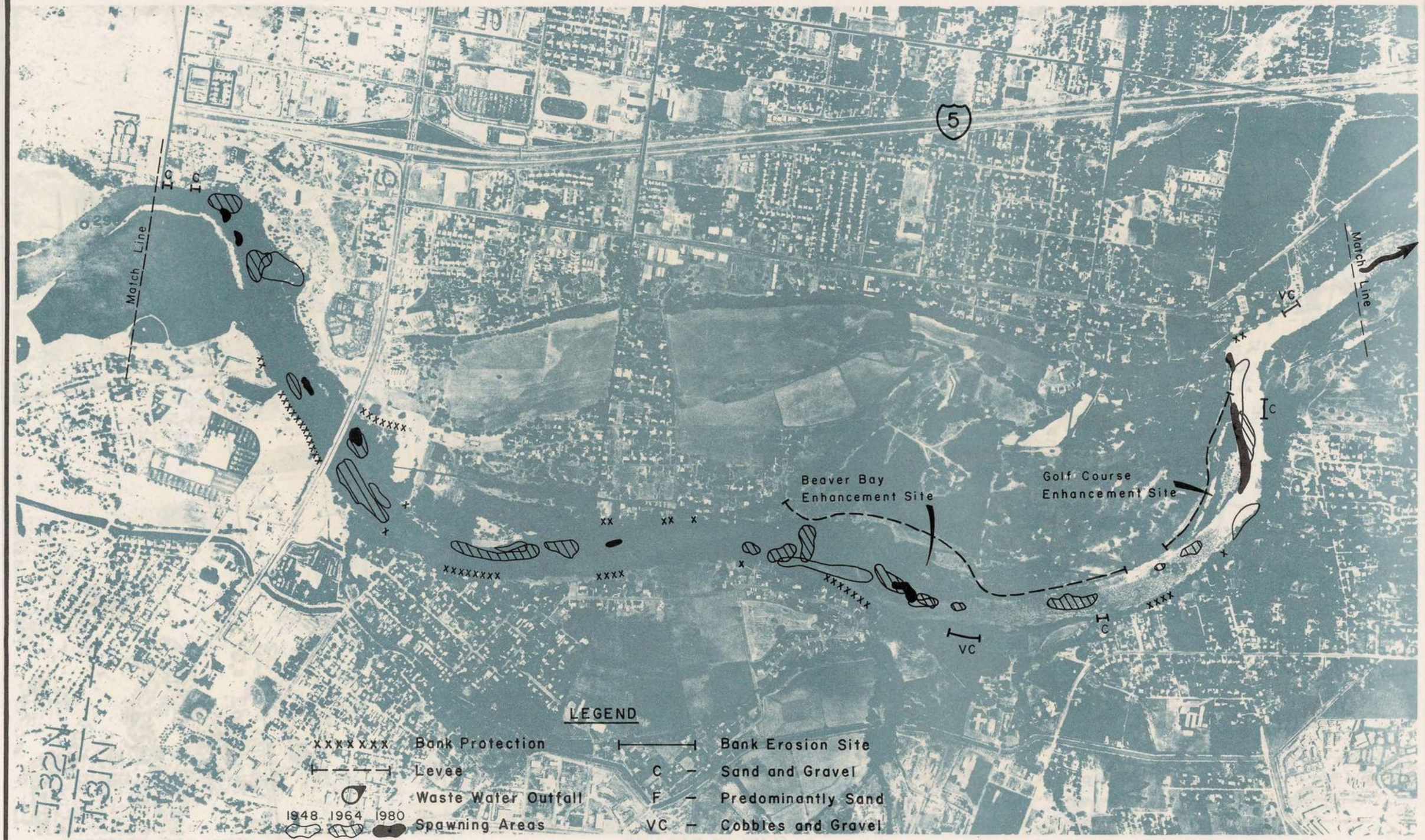
APPROXIMATE SCALE 1 INCH = 1000 FEET ENLARGED FROM EXPOSURE NUMBER WR-AFV-1-	PHOTOGRAPHED AUGUST 1976 SYMBOL WR-AFV FOCAL LENGTH 152.66mm	STATE OF CALIFORNIA THE RESOURCES AGENCY DEPARTMENT OF WATER RESOURCES NORTHERN DISTRICT	SACRAMENTO RIVER RED BLUFF DIVERSION DAM TO KESWICK DAM.	UPPER SACRAMENTO RIVER SPAWNING GRAVEL STUDY	SHEET 19 OF 23



APPROXIMATE SCALE 1 INCH = 1000 FEET ENLARGED FROM EXPOSURE NUMBER WR-AFV-1-	PHOTOGRAPHED AUGUST 1976 SYMBOL WR-AFV FOCAL LENGTH 152.66mm	STATE OF CALIFORNIA THE RESOURCES AGENCY DEPARTMENT OF WATER RESOURCES NORTHERN DISTRICT	SACRAMENTO RIVER RED BLUFF DIVERSION DAM TO KESWICK DAM.	UPPER SACRAMENTO RIVER SPAWNING GRAVEL STUDY	SHEET 19a OF 23



APPROXIMATE SCALE 1 INCH = 1000 FEET ENLARGED FROM EXPOSURE NUMBER WR-AFV-1-	PHOTOGRAPHED AUGUST 1976 SYMBOL WR-AFV FOCAL LENGTH 152.66mm	STATE OF CALIFORNIA THE RESOURCES AGENCY DEPARTMENT OF WATER RESOURCES NORTHERN DISTRICT	SACRAMENTO RIVER RED BLUFF DIVERSION DAM TO KESWICK DAM.	UPPER SACRAMENTO RIVER SPAWNING GRAVEL STUDY	SHEET 20 OF 23



APPROXIMATE SCALE 1 INCH = 1000 FEET ENLARGED FROM EXPOSURE NUMBER WR-AFV-1-	PHOTOGRAPHED AUGUST 1976 SYMBOL WR-AFV FOCAL LENGTH 152.66mm	STATE OF CALIFORNIA THE RESOURCES AGENCY DEPARTMENT OF WATER RESOURCES NORTHERN DISTRICT	SACRAMENTO RIVER RED BLUFF DIVERSION DAM TO KESWICK DAM.	UPPER SACRAMENTO RIVER SPAWNING GRAVEL STUDY	SHEET 20a OF 23

28

25

30

5

N

Match Line

553076.6866
4493576.2127

554800.4080
4493597.2387

298

296

299

Redding

32

T32N

T31N

LEGEND

Cross Sections
DWR
USCE

Circa 1860
April 1938
July 1952

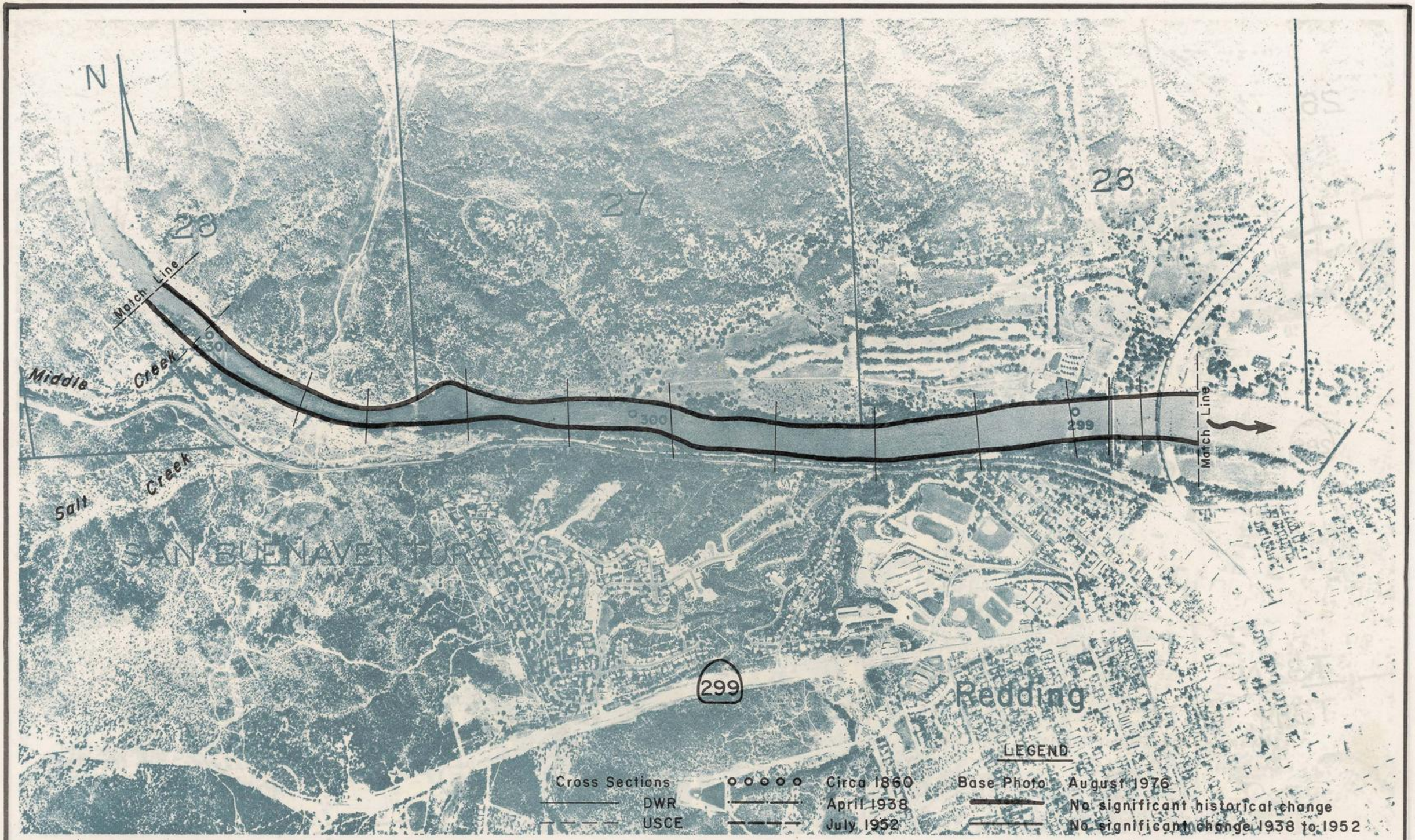
Base Photo August 1976
No significant historical change
No significant change 1938 to 1952

552966.1000, 4491962.6100

554870.3786, 4491978.3869

APPROXIMATE SCALE 1 INCH = 1000 FEET ENLARGED FROM EXPOSURE NUMBER WR-AFV-1-	PHOTOGRAPHED AUGUST 1976 SYMBOL WR-AFV FOCAL LENGTH 152.66mm	STATE OF CALIFORNIA THE RESOURCES AGENCY DEPARTMENT OF WATER RESOURCES NORTHERN DISTRICT	SACRAMENTO RIVER RED BLUFF DIVERSION DAM TO KESWICK DAM.	UPPER SACRAMENTO RIVER SPAWNING GRAVEL STUDY	SHEET 21 OF 23

APPROXIMATE SCALE 1 INCH = 1000 FEET ENLARGED FROM EXPOSURE NUMBER WR-AFV-1-	PHOTOGRAPHED AUGUST 1976 SYMBOL WR-AFV FOCAL LENGTH 152.66mm	STATE OF CALIFORNIA THE RESOURCES AGENCY DEPARTMENT OF WATER RESOURCES NORTHERN DISTRICT	SACRAMENTO RIVER RED BLUFF DIVERSION DAM TO KESWICK DAM.	UPPER SACRAMENTO RIVER SPAWNING GRAVEL STUDY	SHEET 21a OF 23



APPROXIMATE SCALE 1 INCH = 1000 FEET ENLARGED FROM EXPOSURE NUMBER WR-AFV-1-	PHOTOGRAPHED AUGUST 1976 SYMBOL WR-AFV FOCAL LENGTH 152.66mm	STATE OF CALIFORNIA THE RESOURCES AGENCY DEPARTMENT OF WATER RESOURCES NORTHERN DISTRICT	SACRAMENTO RIVER RED BLUFF DIVERSION DAM TO KESWICK DAM.	UPPER SACRAMENTO RIVER SPAWNING GRAVEL STUDY	SHEET 22 OF 23

N

28

27

26

Match Line

Middle Creek

Salt Creek

SAN BUENAVENTURA

299

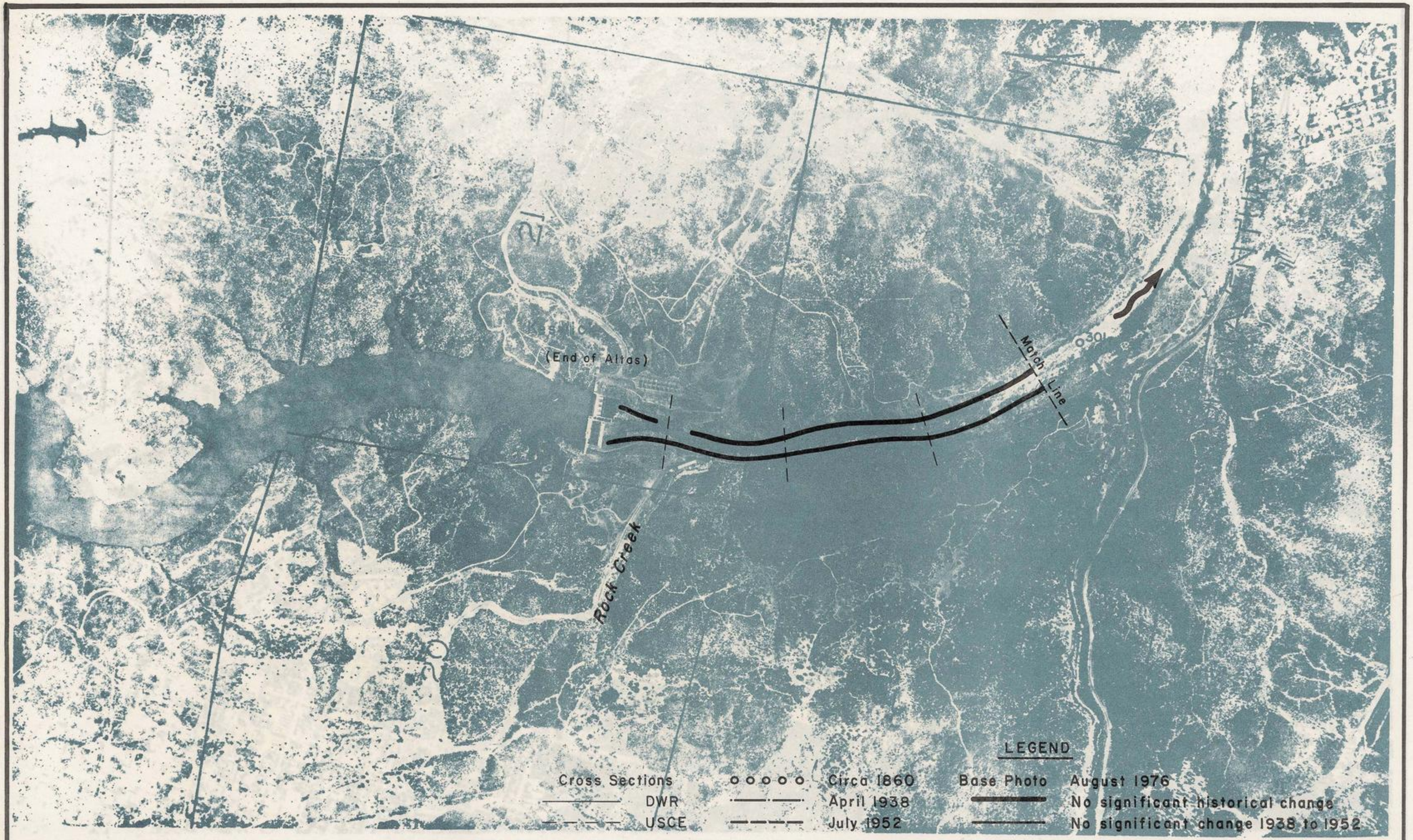
Redding

Match Line

LEGEND

xxxxxxx	Bank Protection		Bank Erosion Site
	Levee	C –	Sand and Gravel
	Waste Water Outfall	F –	Predominantly Sand
1964 1980	Spawning Areas	VC –	Cobbles and Gravel

APPROXIMATE SCALE 1 INCH = 1000 FEET ENLARGED FROM EXPOSURE NUMBER WR-AFV-1-	PHOTOGRAPHED AUGUST 1976 SYMBOL WR-AFV FOCAL LENGTH 152.66mm	STATE OF CALIFORNIA THE RESOURCES AGENCY DEPARTMENT OF WATER RESOURCES NORTHERN DISTRICT	SACRAMENTO RIVER RED BLUFF DIVERSION DAM TO KESWICK DAM.	UPPER SACRAMENTO RIVER SPAWNING GRAVEL STUDY	SHEET 22a OF 23



APPROXIMATE SCALE 1 INCH = 1000 FEET ENLARGED FROM EXPOSURE NUMBER WR-AFV-1-	PHOTOGRAPHED AUGUST 1976 SYMBOL WR-AFV FOCAL LENGTH 152.66mm	STATE OF CALIFORNIA THE RESOURCES AGENCY DEPARTMENT OF WATER RESOURCES NORTHERN DISTRICT	SACRAMENTO RIVER RED BLUFF DIVERSION DAM TO KESWICK DAM.	UPPER SACRAMENTO RIVER SPAWNING GRAVEL STUDY	SHEET 23 OF 23

APPROXIMATE SCALE 1 INCH = 1000 FEET ENLARGED FROM EXPOSURE NUMBER WR-AFV-1-	PHOTOGRAPHED AUGUST 1976 SYMBOL WR-AFV FOCAL LENGTH 152.66mm	STATE OF CALIFORNIA THE RESOURCES AGENCY DEPARTMENT OF WATER RESOURCES NORTHERN DISTRICT	SACRAMENTO RIVER RED BLUFF DIVERSION DAM TO KESWICK DAM.	UPPER SACRAMENTO RIVER SPAWNING GRAVEL STUDY	SHEET 23a OF 23