Title

River Restoration for a Socially and Ecologically Devastated Border City

Author
Friedman, Noah

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TERM PROJECT

River Restoration for a Socially and Ecologically Devastated Border City

Noah Friedman

LA222

Introduction

The Tijuana River Watershed is one of eight watersheds that encompass the urbanized area of San Diego and Tijuana. The San Diego - Tijuana cross border corridor lies along the 1,951 mile long international border dividing the United States and Mexico, known as the U.S. Mexican Border Region (San Diego Association of Governments). It is currently the fastest growing region in North America (US / Mexico Border Counties Coalition) and accounts for roughly a third of total population growth in the United States and Mexico over the last 15 years (United States Census Burea / Consejo Nacional de Poblacion). The Tijuana River Watershed straddles this international boundary revealing economic inequalities, ecological devastation and social disparities that exist between the two countries. Tijuana has always had a unique role in the region attracting tourism, providing a cheap labor pool and as a staging ground for those trying to pass North through the border to the United States. It also plays a role not unlike the slums and lower income neighborhoods of other U.S. cities; in this case however the poor areas are pushed out to the edge of the urban area and masked behind the screen of the border (Lynch & Appleyard 1974). Could there be a sustainable future for a socially and ecologically devastated border city? How might such a vision come to fruition and what would be the social and ecological impact? At the heart of any solution to the issues raised here is the Tijuana River as it passes through the City of Tijuana.

Tijuana River Watershed

The Tijuana River Watershed is located on the west coast of North America, straddling the border between the United States of America and los Estados Unidos de Mexico. The regional climate is classified as a mid-latitude desert region (Steppe BS, according to the Koppen system of climate classification) and precipitation in the area is extremely variable (National Oceanic and Atmospheric Administration). Precipitation records reveal a pattern of 9 months with little to no flow interrupted by dramatic rainstorms and subsequent high flows in a few winter months (United States Geological Survey).

The drainage area of the Tijuana River Watershed is 1,735 square miles with 30% of the basin in the United States and 70% in Mexico (Tijuana River Watershed: Watershed Overview 00). The Tijuana River Watershed is made up of two main basins; the Alomar river watershed and the Tijuana river watershed, the confluence of the Alomar River and the Tijuana River occurs as these two rivers they enter the City of Tijuana from the east and south, respectively. The Rio Alomar is fed by Cottonwood Creek and Campo Creek, located mostly in the United States, and Tecate Creek, located mostly in Mexico. The Tijuana River is fed by Rio de Las Palmas and Rio Alomar, covering areas only in Mexico. All tributaries drain to the Tijuana River, which then passes through the City of Tijuana north towards the international border and then into the Tijuana Estuary.

There are four damns and reservoirs in place, serving both flood control purposes and providing local water supply (Brown 98). Morena and Barrett Reservoirs were built in 1912 and 1922 respectively and are in the United States and the Rodriguez Damn was built in 1936 and is in Mexico. These three damns cover 78% of the Tijuana River Watershed (Zedler, Nordby, Kus 92). A reservoir, El Carrizo Damn, was built in Mexico to store the City of Tijuana's share of water from the Colorado River (Brown 98).

Urban & Hydrologic Morphology

The City of Tijuana was founded barely over 100 years ago. In response to a new railroad line that was completed at the beginning of the 20th century Tijuana was settled on a large sedimentation deposit at the south west edge of the Tijuana River. In 1916 a major flood occurred in this area that has been anecdotally determined to have been 75,000 cfs, or roughly the equivalent of the 100 year flood event. This flood event left a strong imprint on the landscape as well as the consciousness of the City of Tijuana. With the increase of cross border tourism stimulated by prohibition and the increase in military presence in the United States, the city of Tijuana started to grow. The urban form continued to respect the edges of 1916 flood, encroaching only a few blocks or so into areas that had been inundated.

In the 1920's and 30's three damns were built in the Tijuana River Watershed. Built under the guise of flood protection the new Rodriguez damn in Mexico also provided Tijuana with a new source of water. The city expanded in area and population in the years following this new infrastructural investment. In the late 1960s the United States of America and los Estados Unidos de Mexico agreed to construct a trapezoidal concrete channel to convey Tijuana River waters through the urbanized area of Tijuana, north across the international border and to the Pacific Ocean 5 miles to the west (Brown 98). In 1973 the Mexican portion of this flood channel was completed. A growing environmental awareness in the United States prevented the concrete channel from continuing across the border and led to the creation of the Tijuana National Estuarine Research Reserve.

The Tijuana Estuary now plays a vital role in the local and global ecology, providing habitat for a variety of animal and plant species (Zedler, Nordby & Kus 92). The estuary is also known to the citizens of San Diego as a social amenity that is critical to their identity (Lynch & Appleyard 73). The creation of this protected area and the prevention of a concrete flood control channel is a major victory for environmentalism. However, over thirty years later the Tijuana National Estuarine Research Reserve sits in stark contrast to the concrete channel that lies just south of the border. Since the completion of this massive flood control project the area that once was the flood plain has now been converted incorporated into the urban fabric of the City of Tijuana. This area of the city is known as the Zona del Rio, River Zone, and is characterized by strip malls, open surface parking lots, wasted space and automobiles.

As a backdrop to the dramatic physical changes that both the urban and hydrologic structures of Tijuana and the Tijuana River have experienced is the social disparity that exists in the region. The San Diego-Tijuana urbanized area has undergone extremely disproportionate development over the last century, especially in the last 30 years: the population density of Tijuana is nearly 4 times greater than that of San Diego; the ratio of open space to people is dramatically lower for the City of Tijuana; moderate size areas of Tijuana have limited or no access to running water or sewerage (Cross Border Planning Atlas). The quality of life for the residents of Tijuana is markedly lower than for their neighbors to the north (Lynch & Appleyard 74). Increasing livability and eliminating the negative impacts of human settlement on natural systems will provide a sustainable future for this socially and ecologically devastated border city. There is a growing body of evidence that urban river restorations can perform exactly these functions.

Existing Concrete Channel

The trapezoidal concrete channel that passes through the heart of Downtown Tijuana is designed to convey a flood of 135,000 cfs, or the equivalent of the 200 year event . The greatest peak flow that has passed through since its construction was 33,500 cfs in February 1980 (International Boundary

& Water Commission, TRFCP). This is the greatest peak flow recorded at the Tijuana, Nestor gage, during its 46 years of operation from 1937 to 1982 (United States Geological Survey). Located at the border where the concrete channel transitions through an energy dissipater into the estuary this gage was removed around the same time as the construction of the new International Wastewater Treatment Plant. Any alternative configurations to the existing flood control channel included in a river restoration will be required to demonstrate its response to high flow events and its capacity to protect the surrounding neighborhoods of central Tijuana. There are numerous alternatives to the existing condition of the Tijuana River flood control channel that provide a more livable environment for local residents, more ecological service for the watershed while continuing the critical role of safely conveying flood waters through the urban area.

Precipitation & Streamflow

The Tijuana-Nestor gage records flows produced by 99.6% of the watershed while exiting the existing concrete flood control channel as it crosses the border (Zedler, Nordby & Kus 92). In operation from 1937 until 1982 this gage was installed after the construction of all three damns located in the watershed. Comparing annual precipitation and annual streamflow records from the Tijuana-Nester gage it is evident that very little water is allowed through these damns. With water demand greater than its supply the City of Tijuana attempts to use all the water it can as it passes through the watershed. There have been two years since the construction of the damns that the Tijuana-Nestor gage recorded river flows of over 400,000 cfs. 1941 and 1980 stand out in the annual flow records as compared to most other years. While 1941 was a unique year in terms of precipitation 1980 was not. 1941 had the greatest amount of precipitation recorder in the area, even greater than the 1916 levels which produced flood of 75,000 cfs. However, there are 9 years between 1941 and 1980 with greater levels of precipitation than 1980, yet none produced annual flows of over 150,000 cfs. Both 1941 and 1980 are similar in that they were both preceded by several years of above average rainfall. In 3 out of the 4 years preceding 1941 and 1980 the recorded annual streamflow levels at the Tijuana-Nestor gage are among the top 10 largest recorded flows, most likely filling the existing damns and resulting in limited capacity. During a storm in February 1980 the capacity of the damns must have been limited, adding to the surface flows and spilling excess water and producing the greatest peak recorded by the Tijuana-Nestor gage, 33,500 (International Boundary & Water Commission, TRFCP).

Manning's 'n' vs. Hydraulic Radius

The existing flood control channel is designed to convey flood waters as efficiently as possible and with the least amount of resistance. The channel cross section has a 230 ft. concrete lined base with trapezoidal berms on either side of the channel that are 23 ft. in height with a slope of 2 to 1, horizontal to vertical (International Boundary & Water Commission 76). The cross sectional area is 6,348 ft^2, with a wetted perimeter of 332.83'. When full the concrete channel therefore has a hydraulic radius of 19.07 ft. USGS 7.5 Minute maps of the area show the slope of the concrete channel as .00066 ft/ft with 15,151 feet of run for 10 feet of rise in elevation. Solving Manning's Equation for a full channel, with an estimated roughness coefficient for a trapezoidal concrete channel of .013 (Chow 59) produces a velocity of 21.23 ft/s. This is verified by dividing the discharge (Q) for the design flood of 135,000 cfs by the cross sectional area of the channel (A) of 6,328 ft =VA, I was able to verify that this indeed was the, by dividing the design flow by the cross sectional area of 6,348 ft^2 ft producing the same velocity of 21.23 ft/s.

$$n = \frac{C\,(S^{.5} \times R^{.67})}{V}$$

$$V = \frac{C\,(S^{.5} \times R^{.67})}{n} = \frac{1.49\,(.00066^{.5} \times 19.07^{.67})}{.013} = 21.3 \text{ ft/s}$$

$$Q = VA$$

$$V = \frac{Q}{A} = \frac{135{,}000 \text{ cfs}}{6{,}348 \text{ sf}} = 21.3 \text{ ft/s}$$

Based on previous river restoration projects a roughness coefficient of 0.83 is a reasonable assumption to use for predicting discharge and hydraulic radius for the restored river channel (Butler, Nathaniel L. & Nolan, Lindsey 07). An increase in channel roughness is characteristic of most river restorations and requires an increase in the channel's hydraulic radius to convey the design 200 year flood. By keeping the flow, velocity and slope constant the hydraulic radius needs to be adjust in order to accommodate the increase in roughness associated with the river restoration. The practical effect of this is the need to increase the cross sectional area, allowing the river to expand into areas that have been built up in the historic flood plain over the last 30 years.

A compound channel design that would allow temporary structures, recreation areas and vegetation to be planted within the channel would require that areas adjacent to the existing concrete channel would have to be retrofitted in order to allow flooding during the 200 year event. This can be achieved in a number of different ways ranging from removing all permanent structures from the flood plain to designing buildings and infrastructure that would be able withstand such a flood event.

Conclusion

It is beyond the scope of this term project to predict the cost of retrofitting the existing flood plain and the ecological and social benefits that it may provide. These would none the less be valuable to understand. While I have attempted to show how the existing concrete channel reduces the social livability for the citizens of Tijuana, even more could be done to quantify exactly how this decrease in livability is manifested and exactly what the benefits better access to open space and a greater connection to natural systems a restored river might provide. It is clear that the proposal contained in this term project may be viewed as radical. To remove millions of dollars in infrastructure and valuable development land in order to create public open space and a retrofitted flood plain is almost inconceivable. However, it is not clear which is more radical: the existing trapezoidal flood control channel and the social and ecological devastation that it produces; or a retrofit of that channel and the increase in social livability and ecological service that the Tijuana River could provide.

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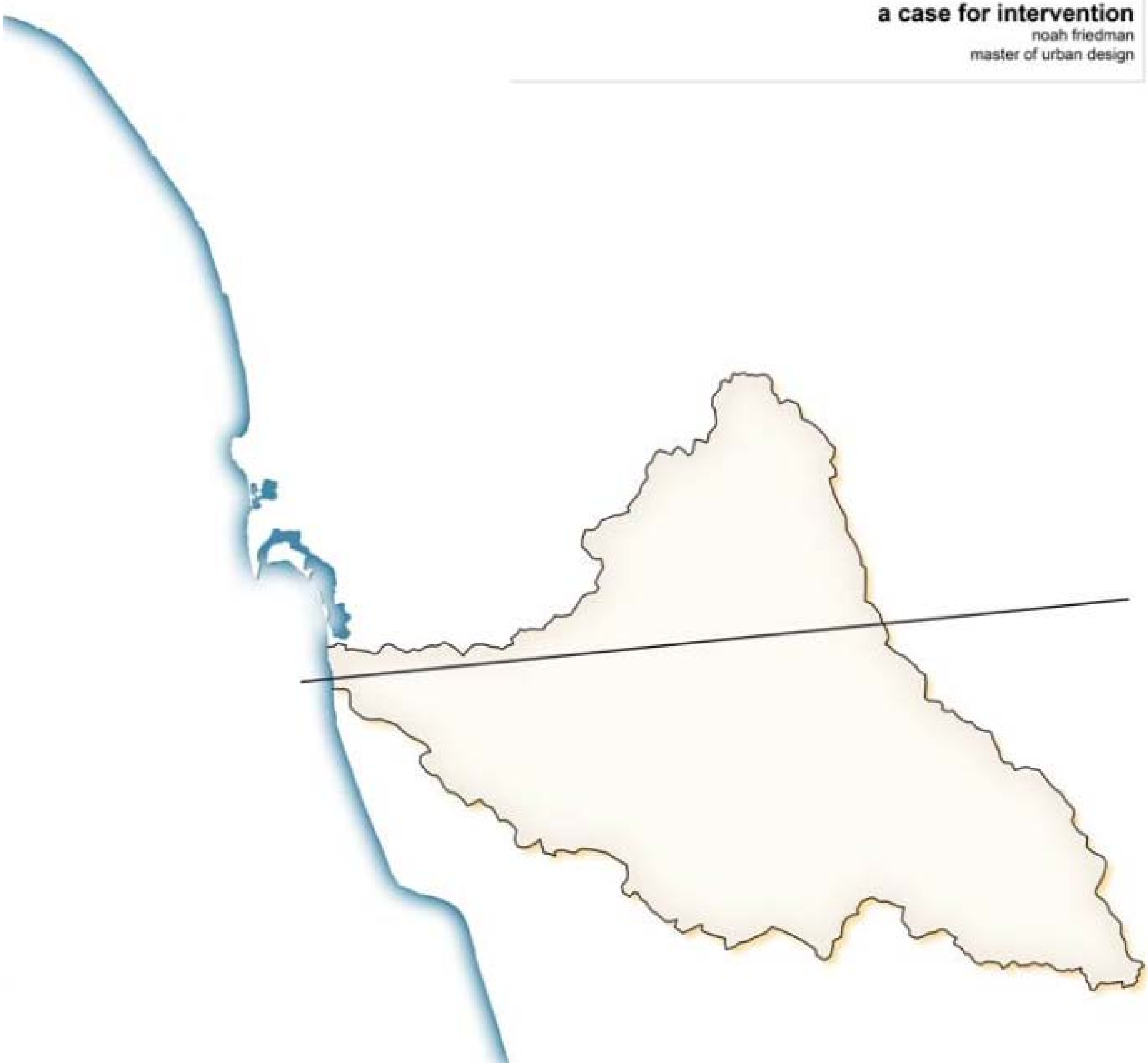
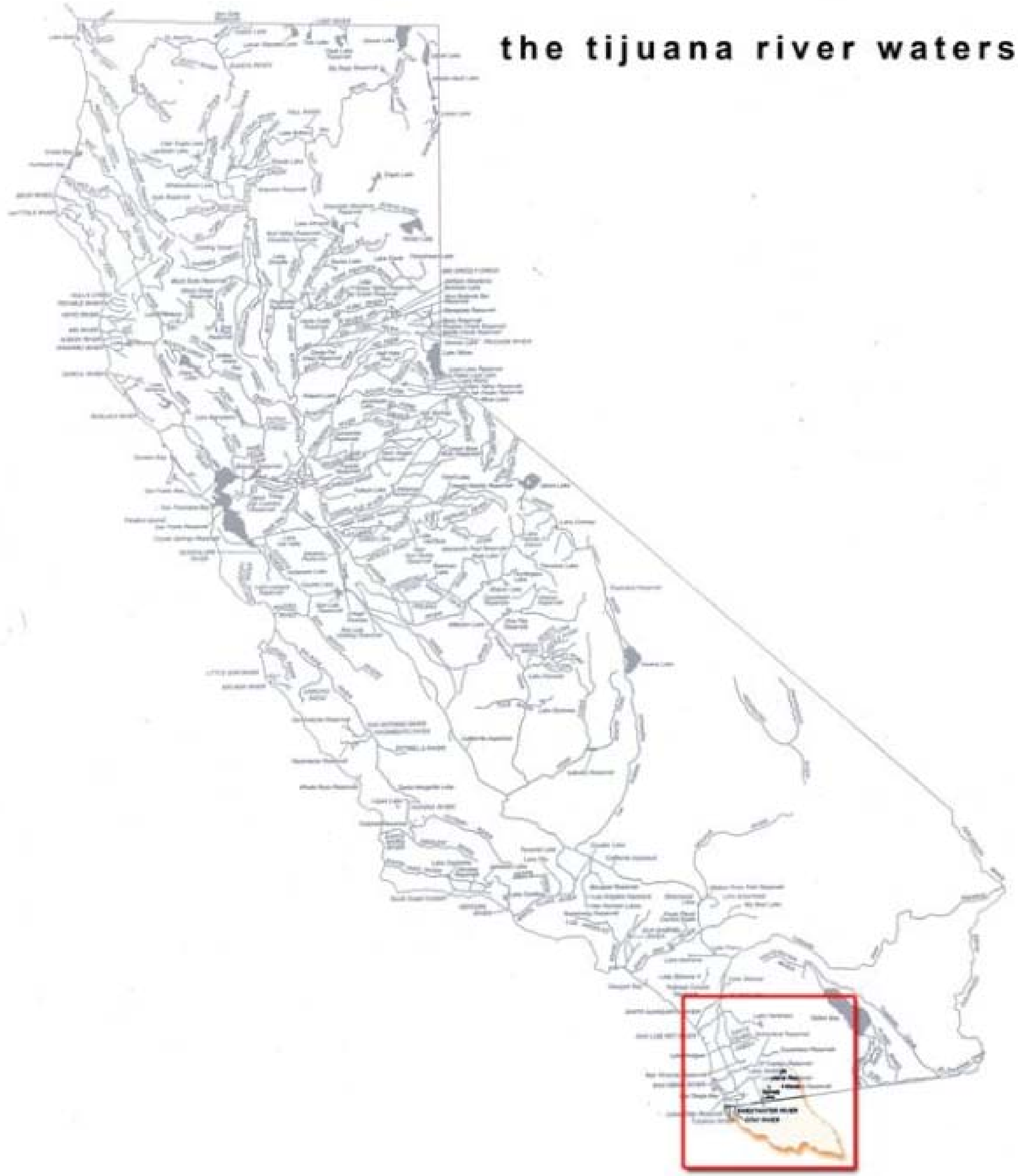
the tijuana river watershed

a case for intervention

noah friedman
master of urban design



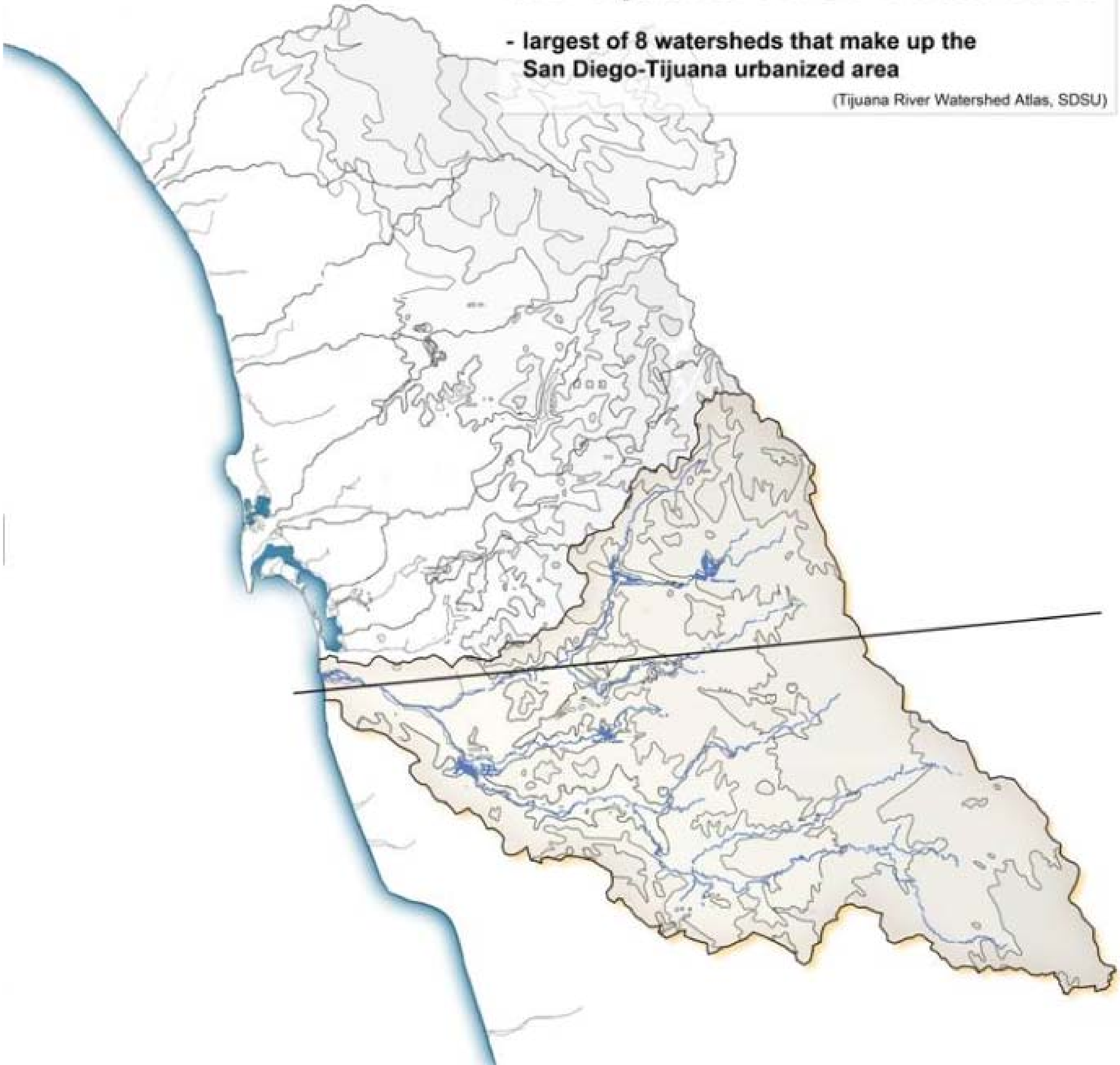
the tijuana river watershed



the tijuana river watershed

- largest of 8 watersheds that make up the San Diego-Tijuana urbanized area

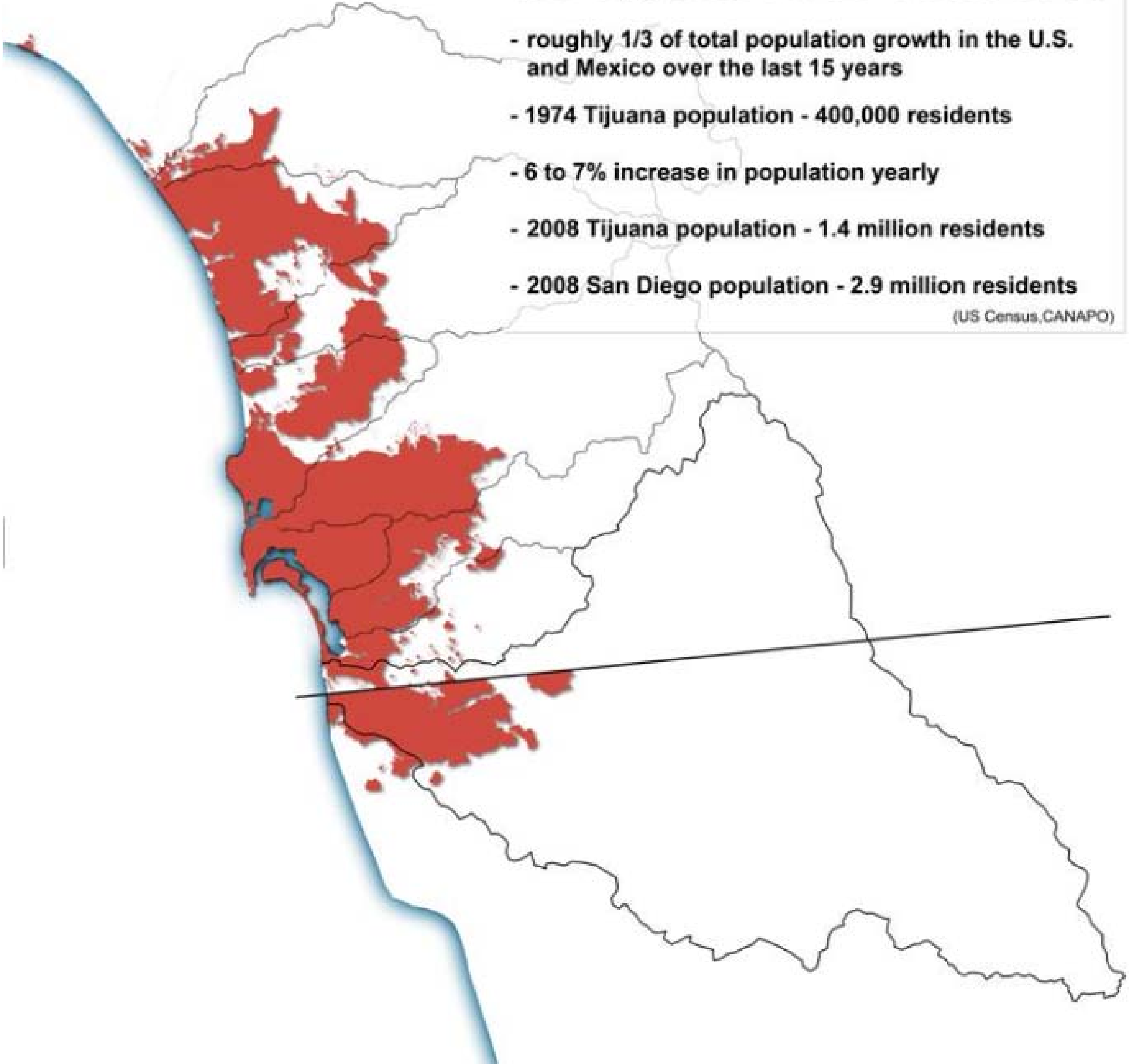
(Tijuana River Watershed Atlas, SDSU)



the tijuana river watershed

- roughly 1/3 of total population growth in the U.S. and Mexico over the last 15 years
- 1974 Tijuana population - 400,000 residents
- 6 to 7% increase in population yearly
- 2008 Tijuana population - 1.4 million residents
- 2008 San Diego population - 2.9 million residents

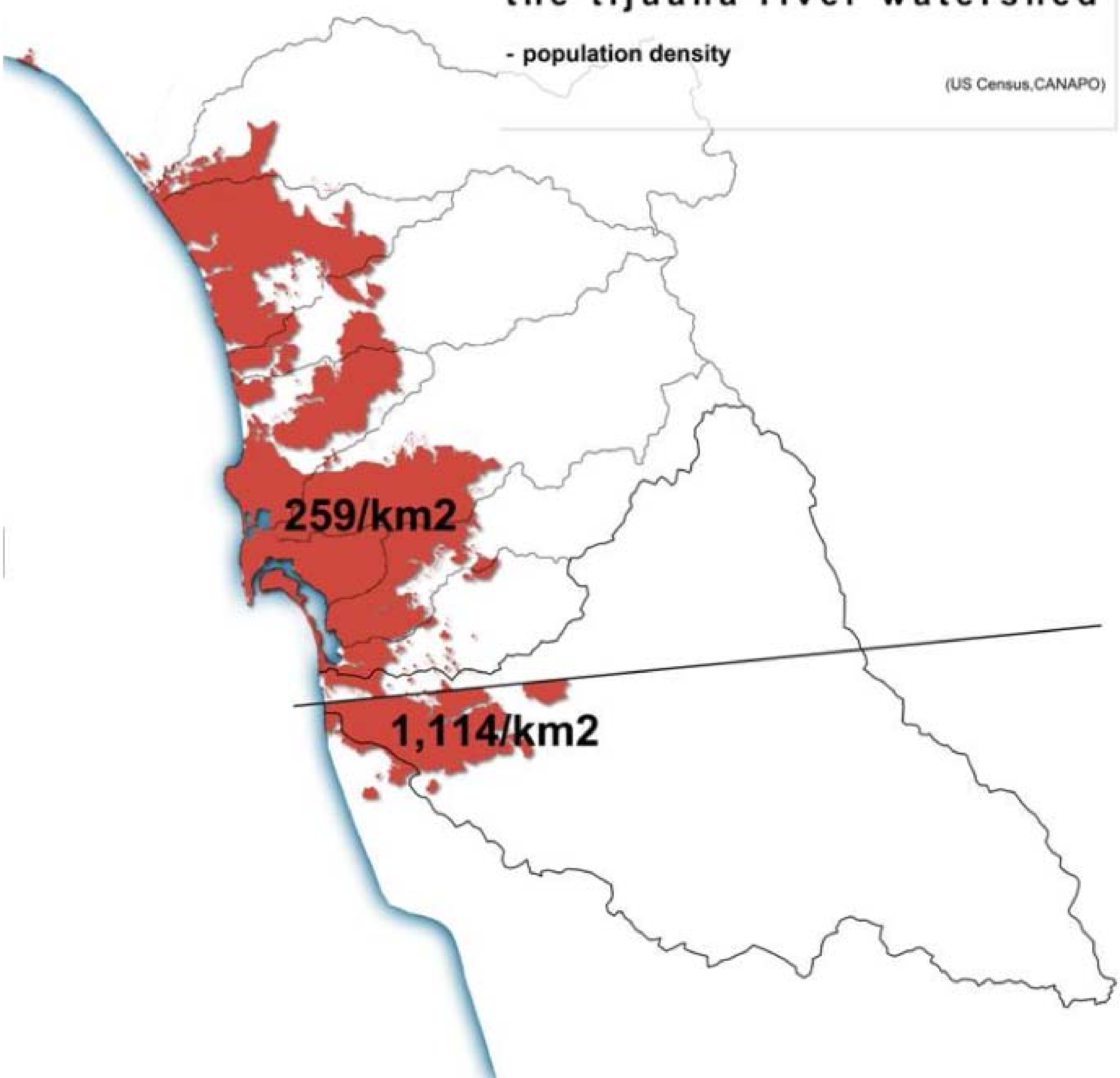
(US Census,CANAPO)



the tijuana river watershed

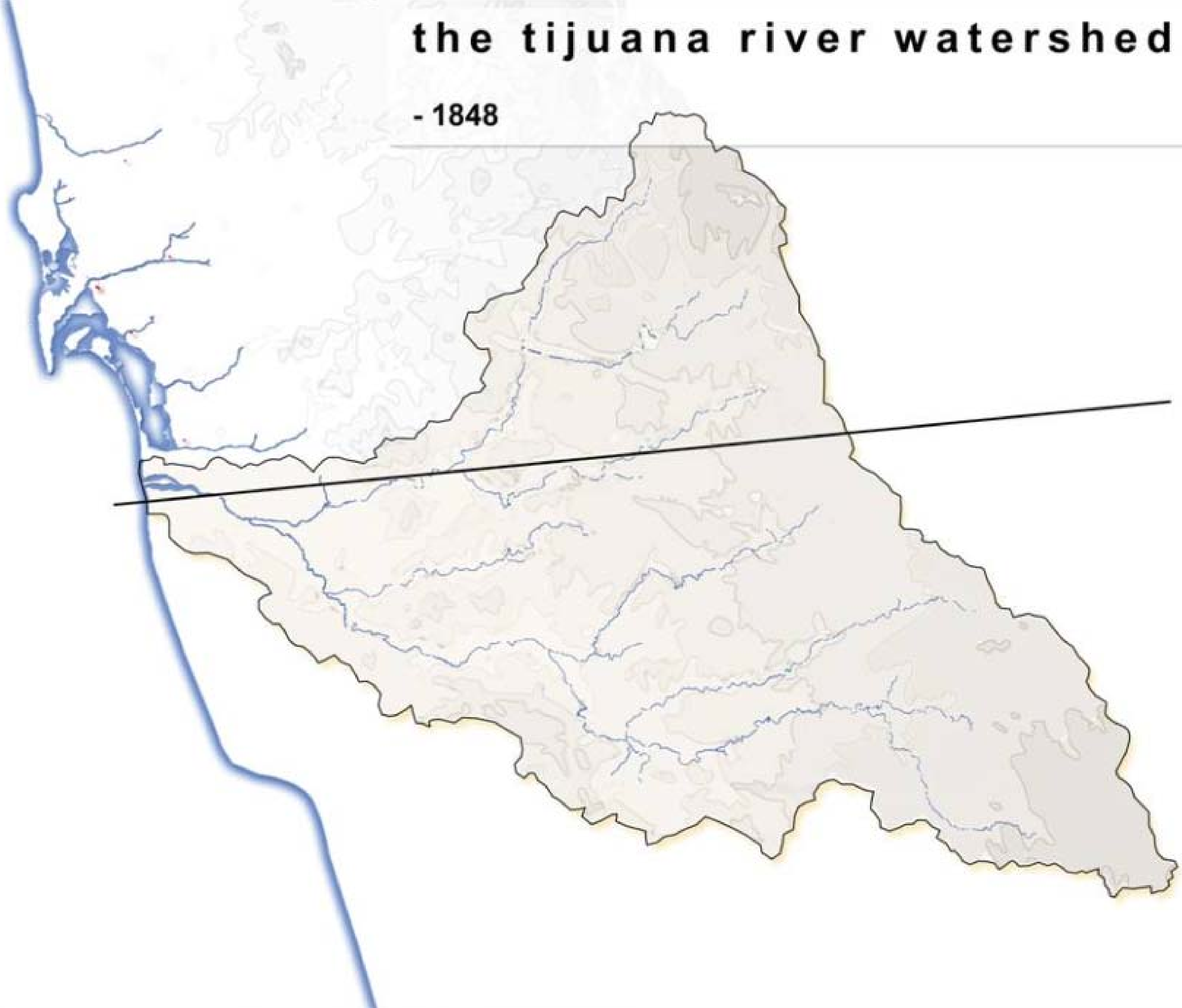
- population density

(US Census,CANAPO)



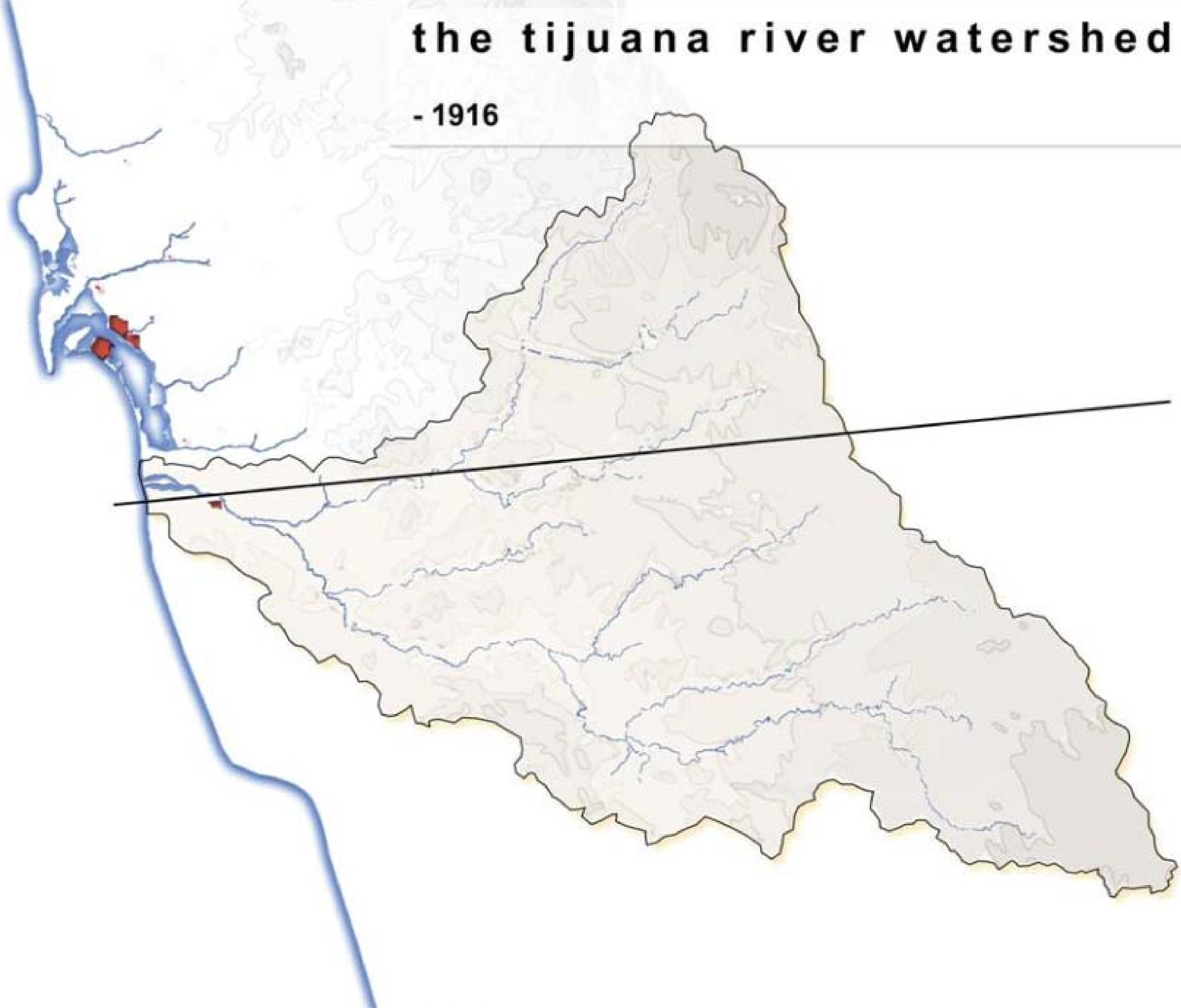
the tijuana river watershed

- 1848



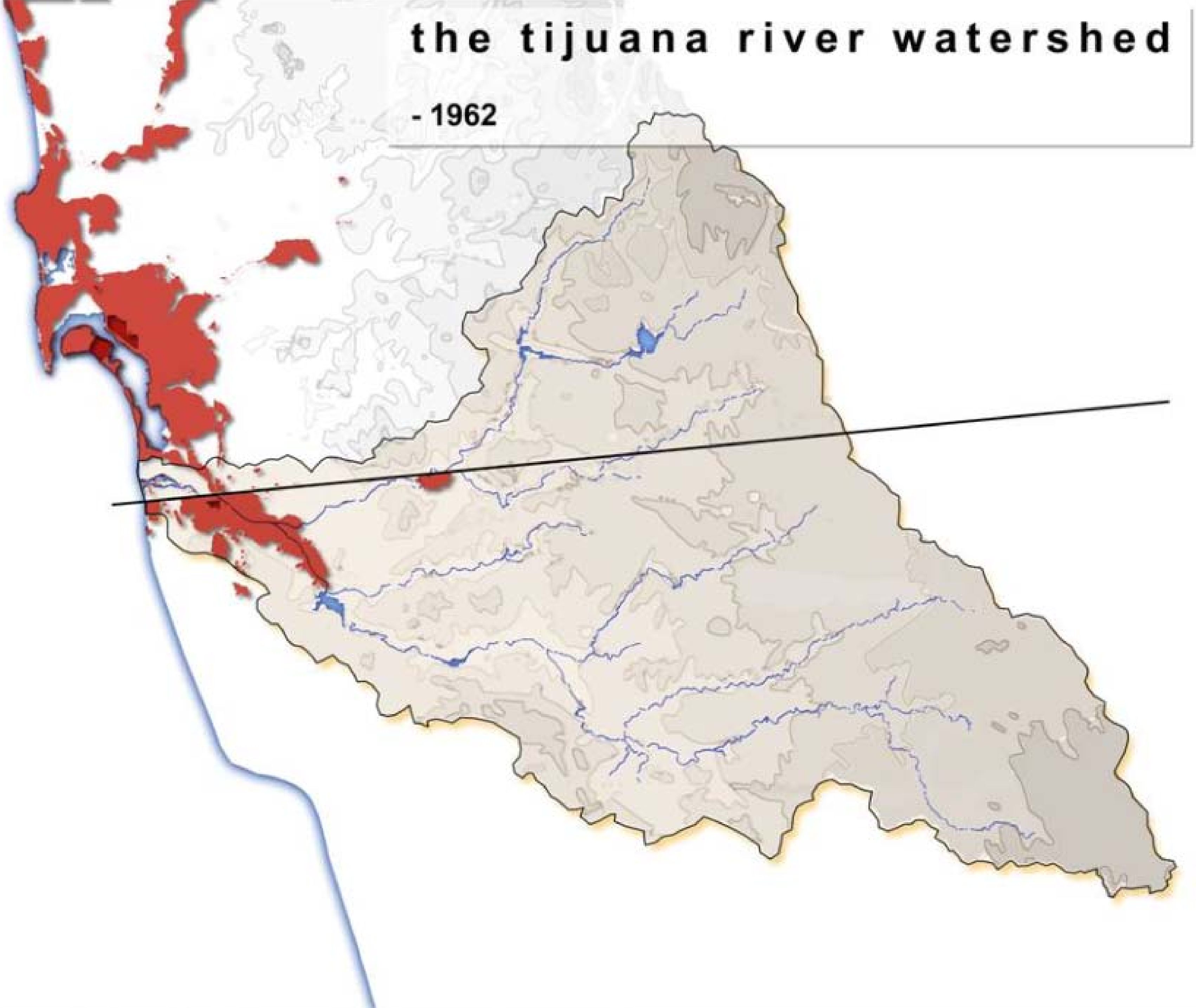
the tijuana river watershed

- 1916



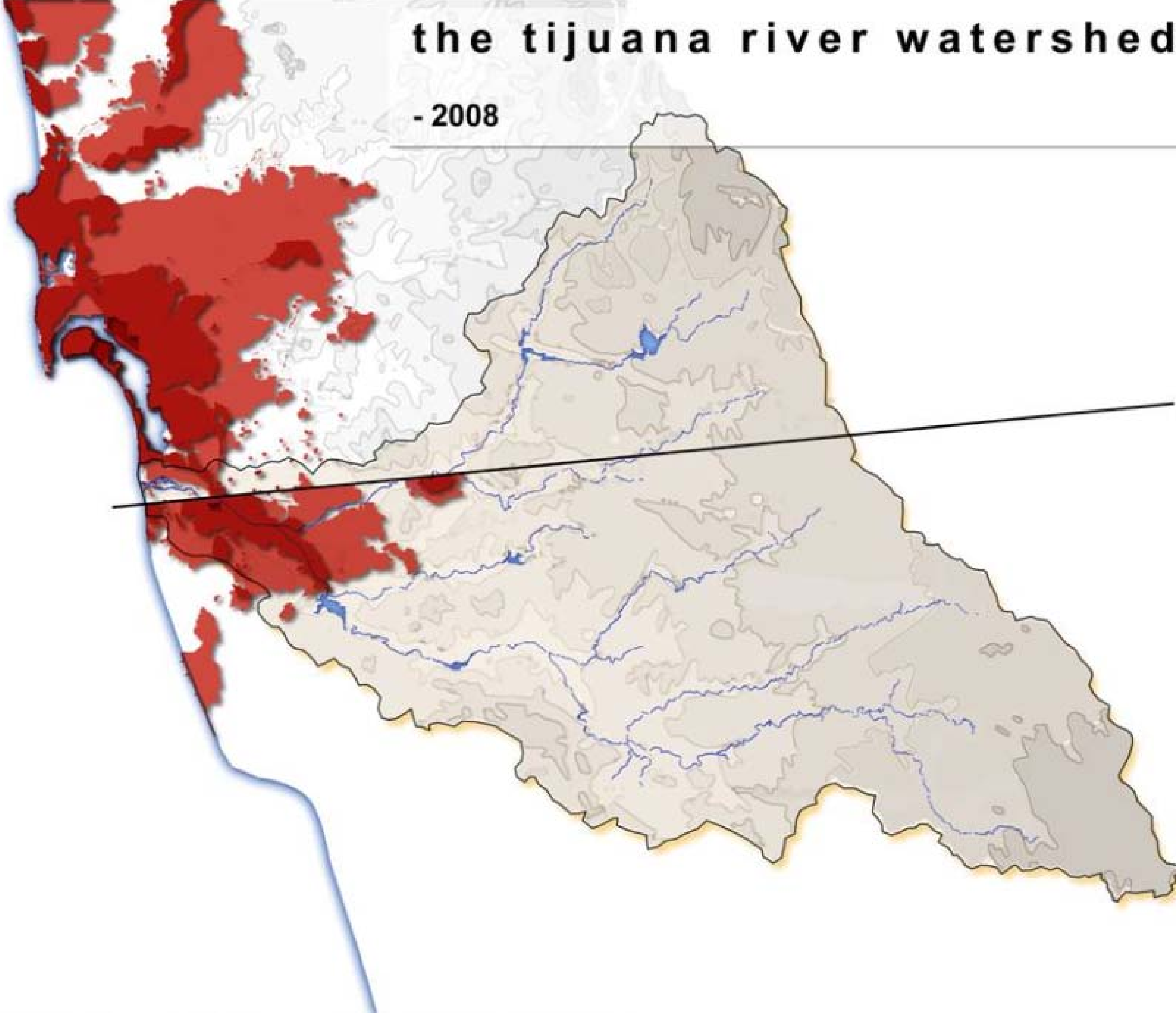
the tijuana river watershed

- 1962

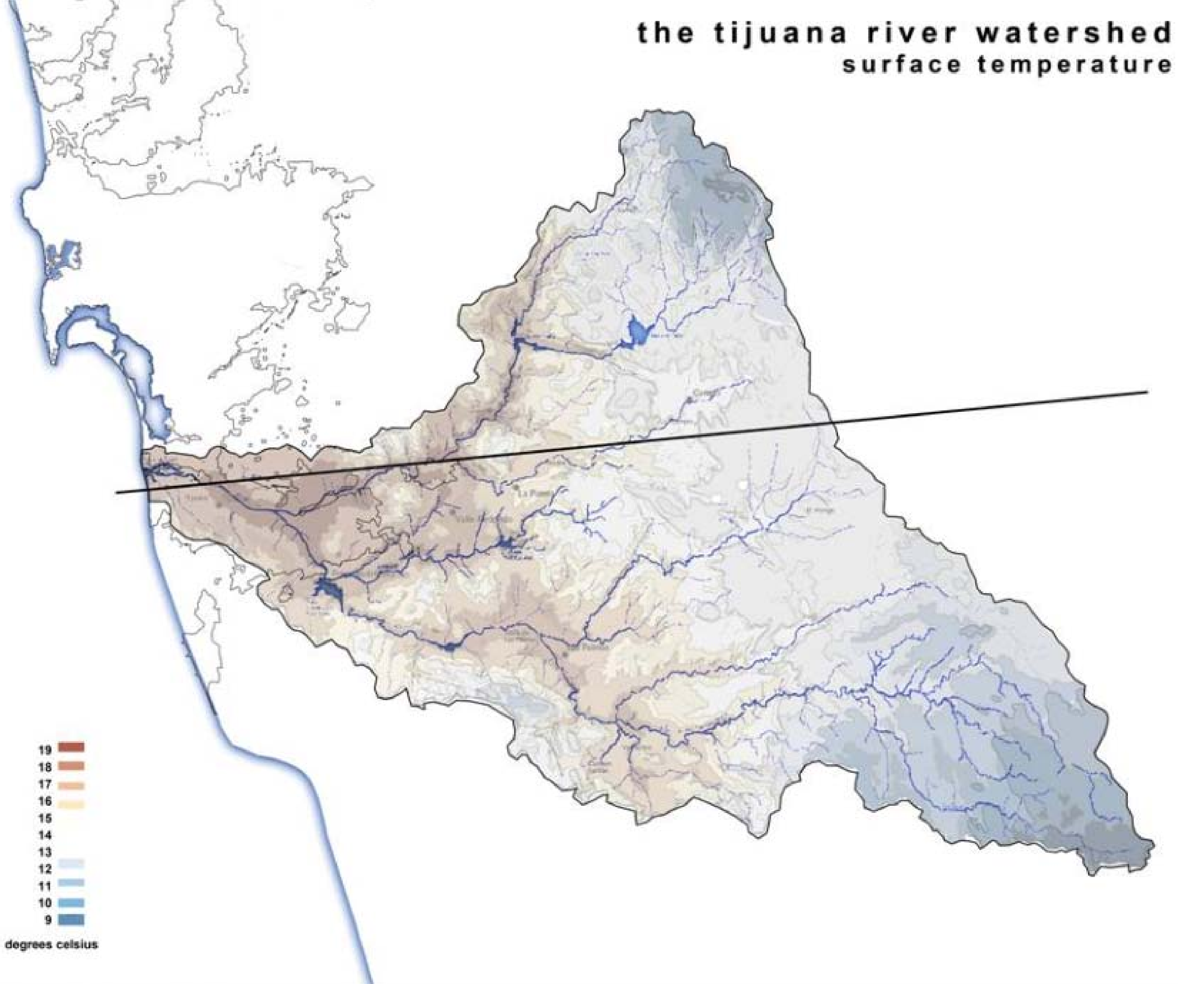


the tijuana river watershed

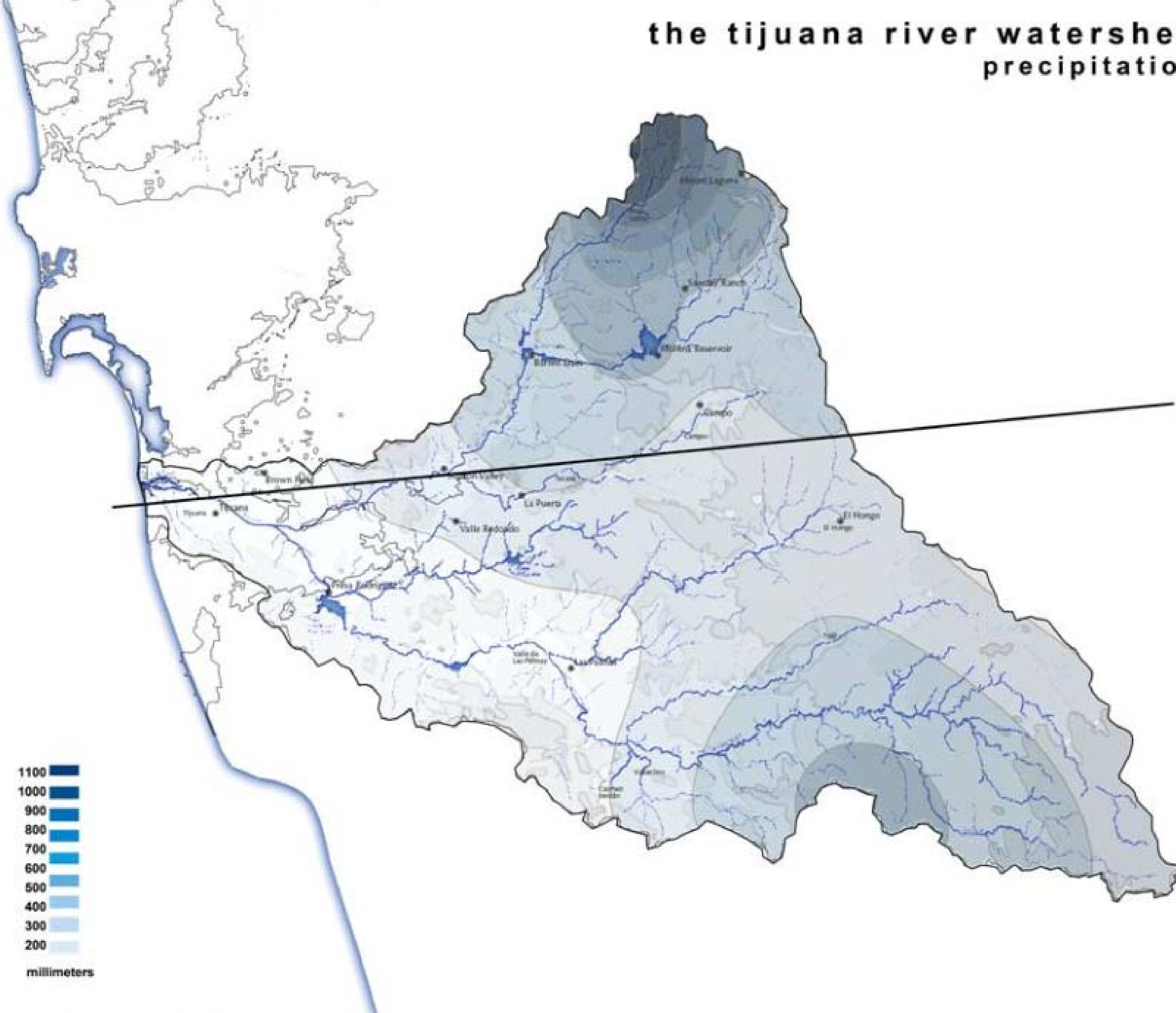
- 2008



the tijuana river watershed
surface temperature



the tijuana river watershed
precipitation



the tijuana river watershed
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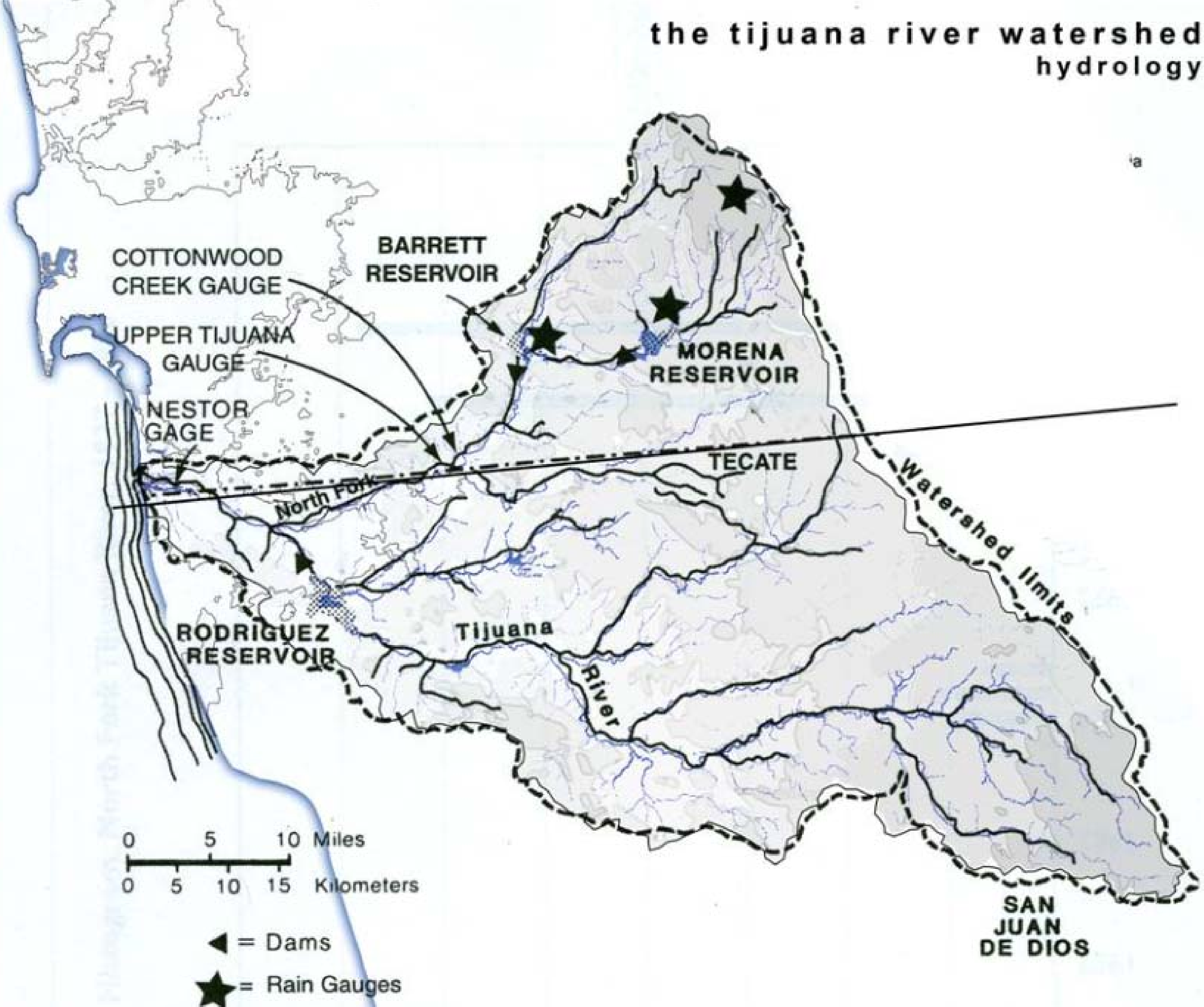
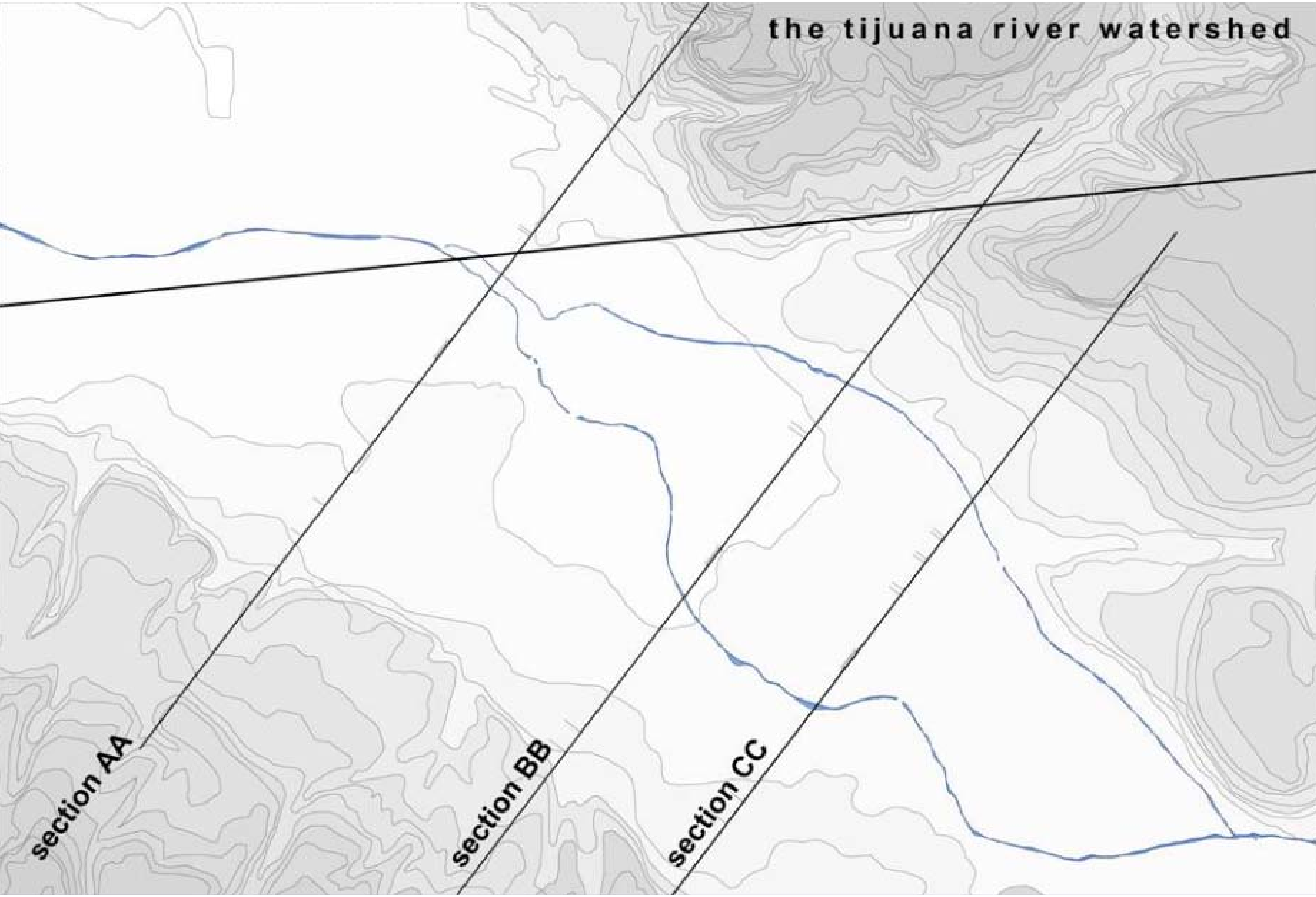
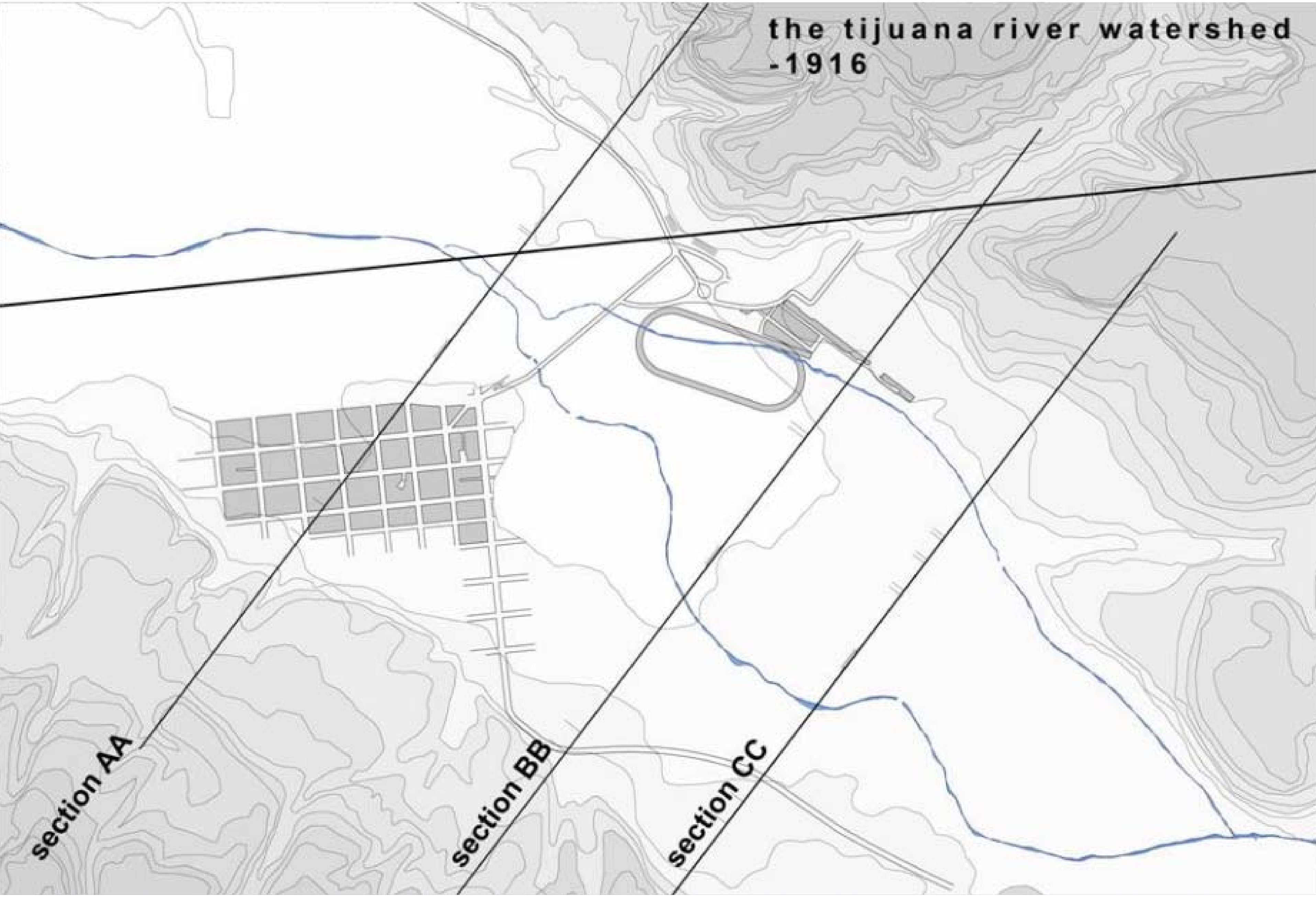
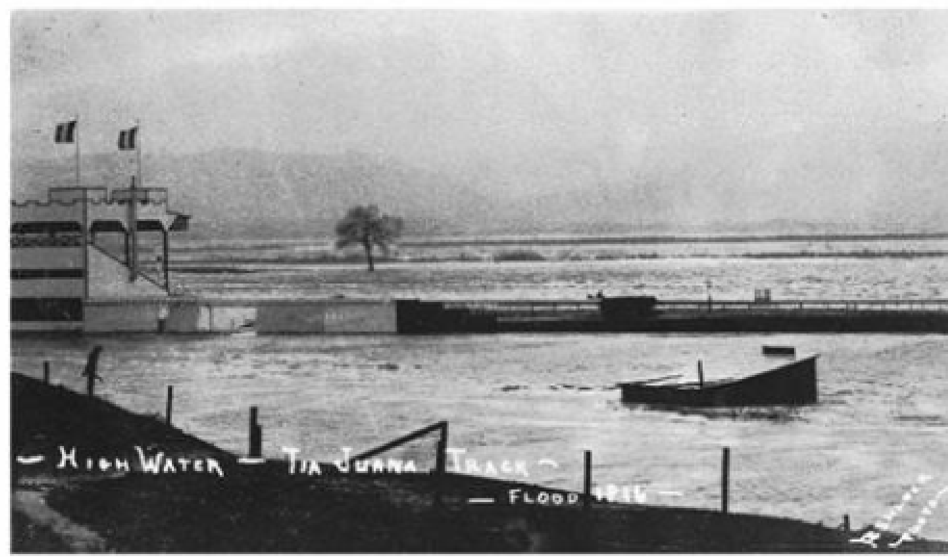


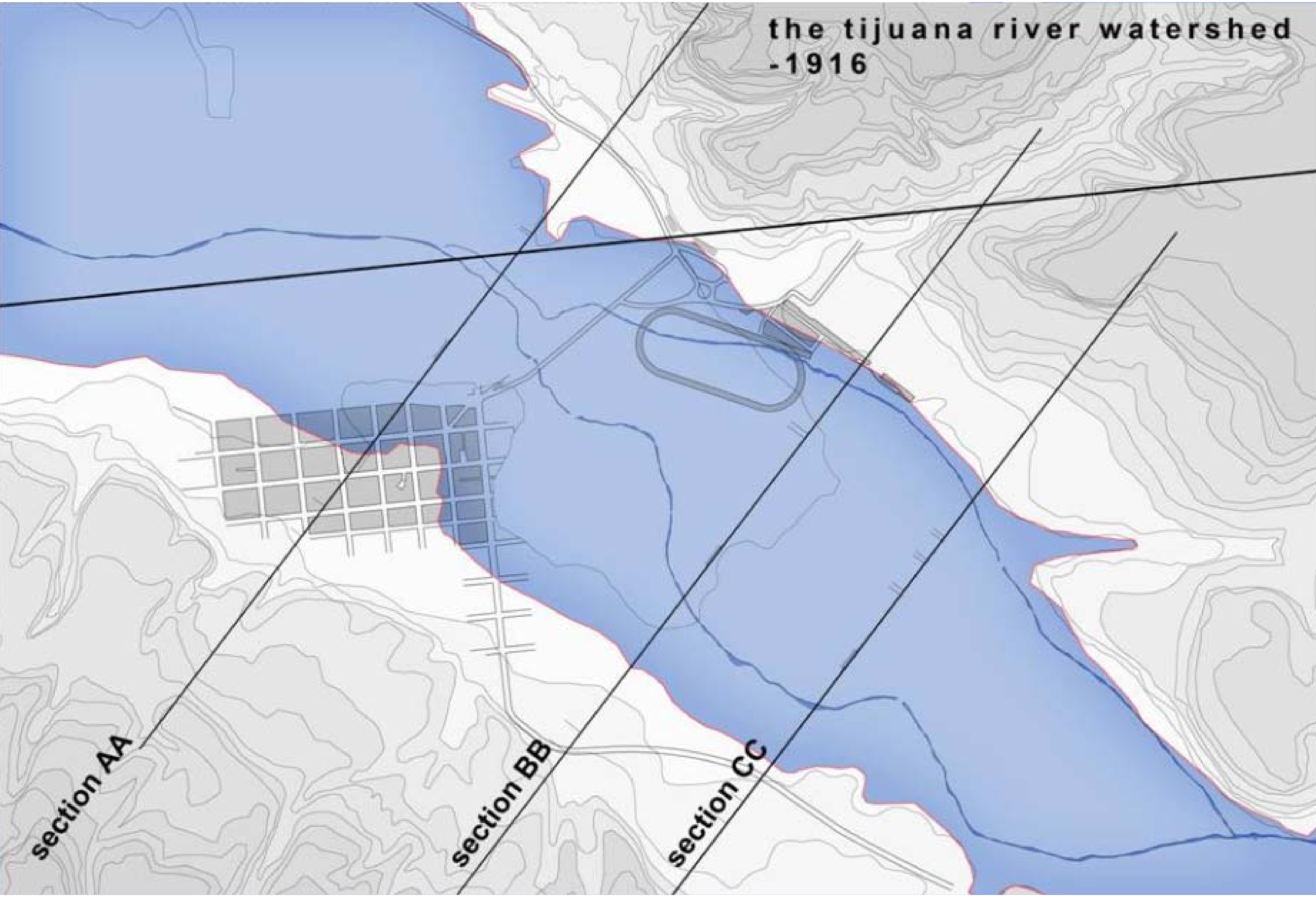


the tijuana river watershed
section AA
section BB
section CC


the tijuana river watershed
-1916
section AA
section BB
section CC

1916 flood - Tijuana




the tijuana river watershed
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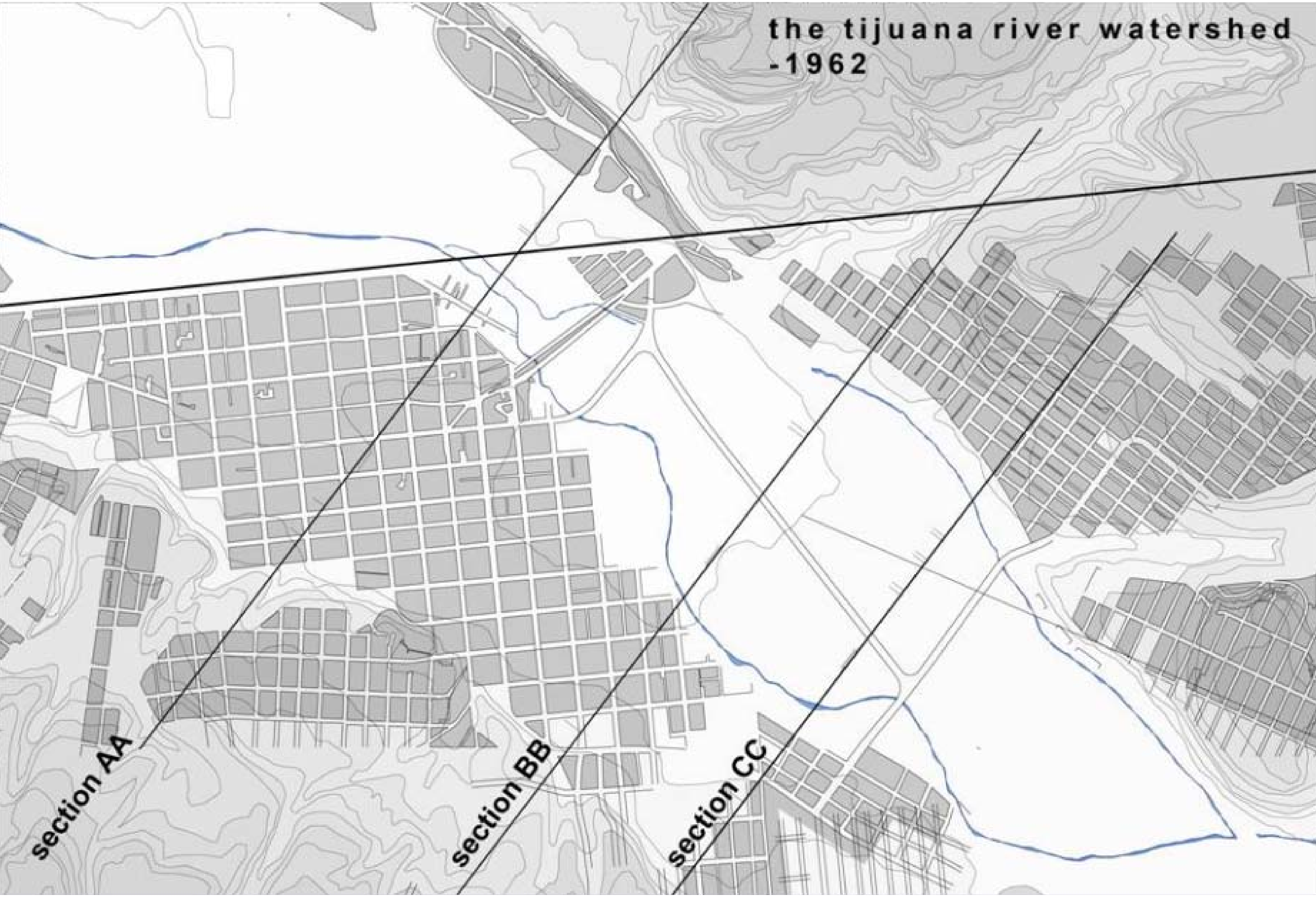
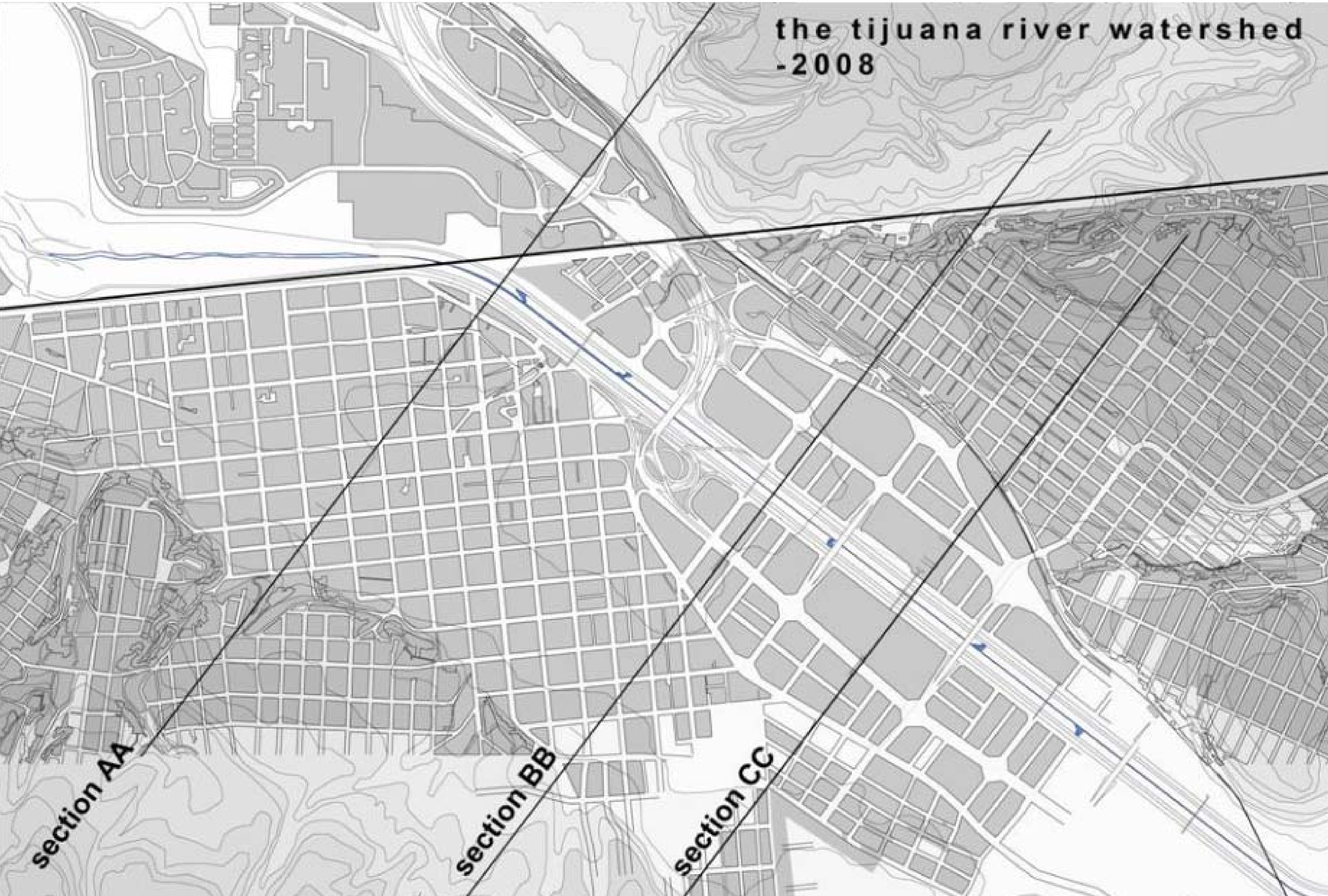
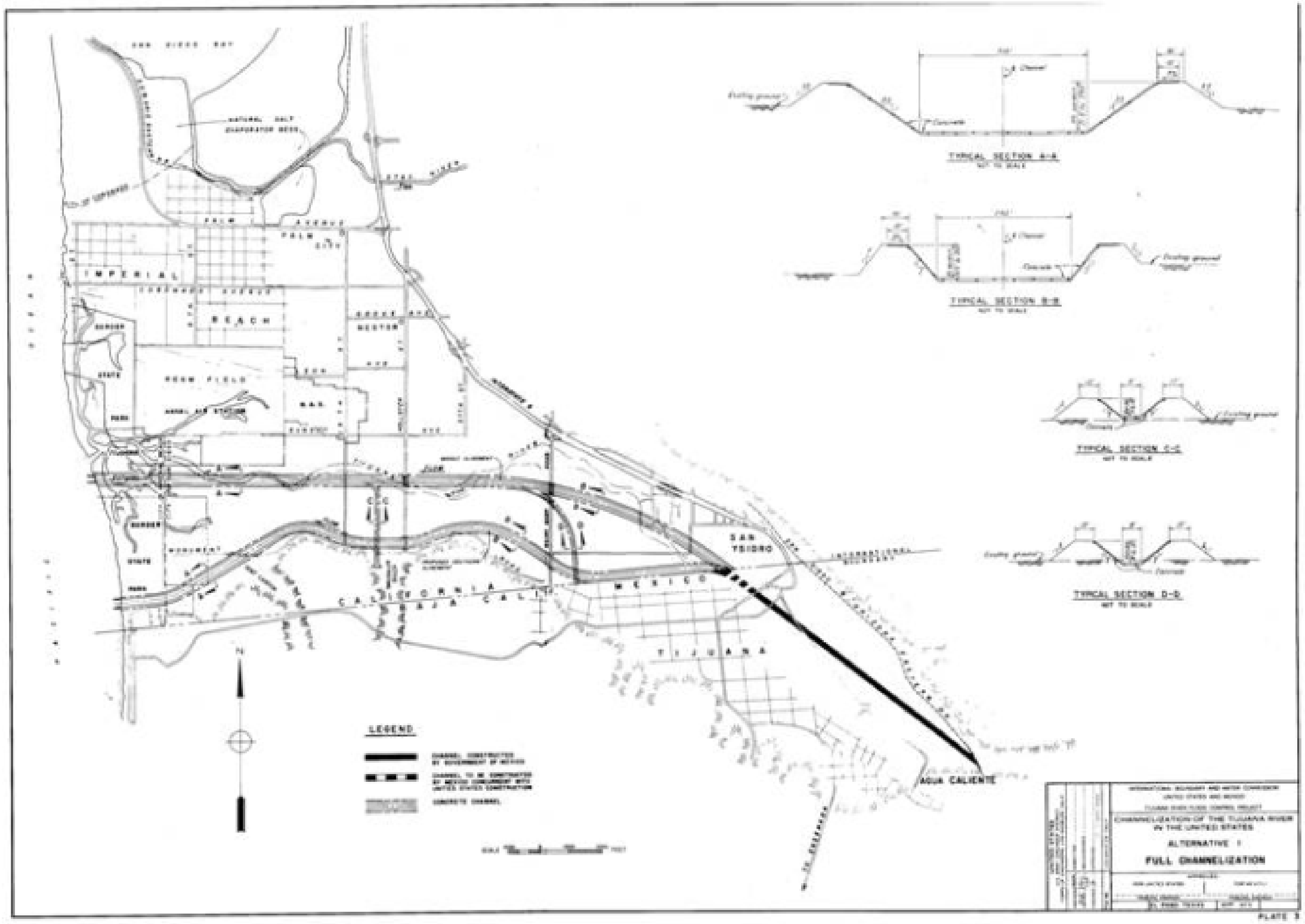
section AA
section BB
section CC



the tijuana river watershed
-1962
section AA
section BB
section CC


the tijuana river watershed
-2008
section AA
section BB
section CC

the tijuana river watershed
unbuilt proposal



the tijuana river watershed
Tijuana National Estuarine Research Reserve, San Diego

the tijuana river watershed
zona del rio, tijuana

Tijuana River Watershed

Date	CFS	Rank	Recurrence Interval	Probability
2/7/1937	17,700	2	23.5	4.26
3/3/1938	6,760	5	9.4	10.64
2/4/1939	1,730	12	3.916666667	25.53
2/4/1940	109	26	1.807692308	55.32
2/22/1941	13,800	3	15.66666667	6.38
3/17/1942	2,770	7	6.714285714	14.89
1/27/1943	1,060	14	3.357142857	29.79
2/24/1944	11,100	4	11.75	8.51
3/5/1945	442	20	2.35	42.55
12/23/1945	2,100	10	4.7	21.28
11/14/1946	35	30	1.566666667	63.83
12/5/1947	510	18	2.611111111	38.30
1/13/1949	2,600	8	5.875	17.02
2/7/1950	11	36	1.305555556	76.60
1/1/1951	0	41	1.146341463	87.23
3/16/1952	2,460	9	5.222222222	19.15
1/1/1953	0	42	1.119047619	89.36
3/23/1954	580	16	2.9375	34.04
1/1/1955	0	43	1.093023256	91.49
1/1/1956	0	44	1.068181818	93.62
1/29/1957	60	28	1.678571429	59.57
4/8/1958	471	19	2.473684211	40.43
2/21/1959	124	24	1.958333333	51.06
1/14/1960	111	25	1.88	53.19
1/1/1961	0	45	1.044444444	95.74
1/21/1962	75	27	1.740740741	57.45
3/17/1963	8	38	1.236842105	80.85
1/1/1964	0	46	1.02173913	97.87
4/10/1965	3	40	1.175	85.11
11/23/1965	267	21	2.238095238	44.68
12/7/1966	2,020	11	4.272727273	23.40
12/18/1967	150	23	2.043478261	48.94
2/26/1969	553	17	2.764705882	36.17
3/5/1970	20	34	1.382352941	72.34
12/21/1970	9	37	1.27027027	78.72
1/6/1972	56	29	1.620689655	61.70
2/13/1973	34	31	1.516129032	65.96
1/8/1974	32	32	1.46875	68.09
4/9/1975	20	35	1.342857143	74.47
2/9/1976	168	22	2.136363636	46.81
1/7/1977	26	33	1.424242424	70.21
3/1/1978	6,370	6	7.833333333	12.77
3/29/1979	1,610	13	3.615384615	27.66
2/21/1980	33,500	1	47	2.13
3/1/1981	690	15	3.133333333	31.91
11/28/1981	4	39	1.205128205	82.98

Table 2_Flood Chronology

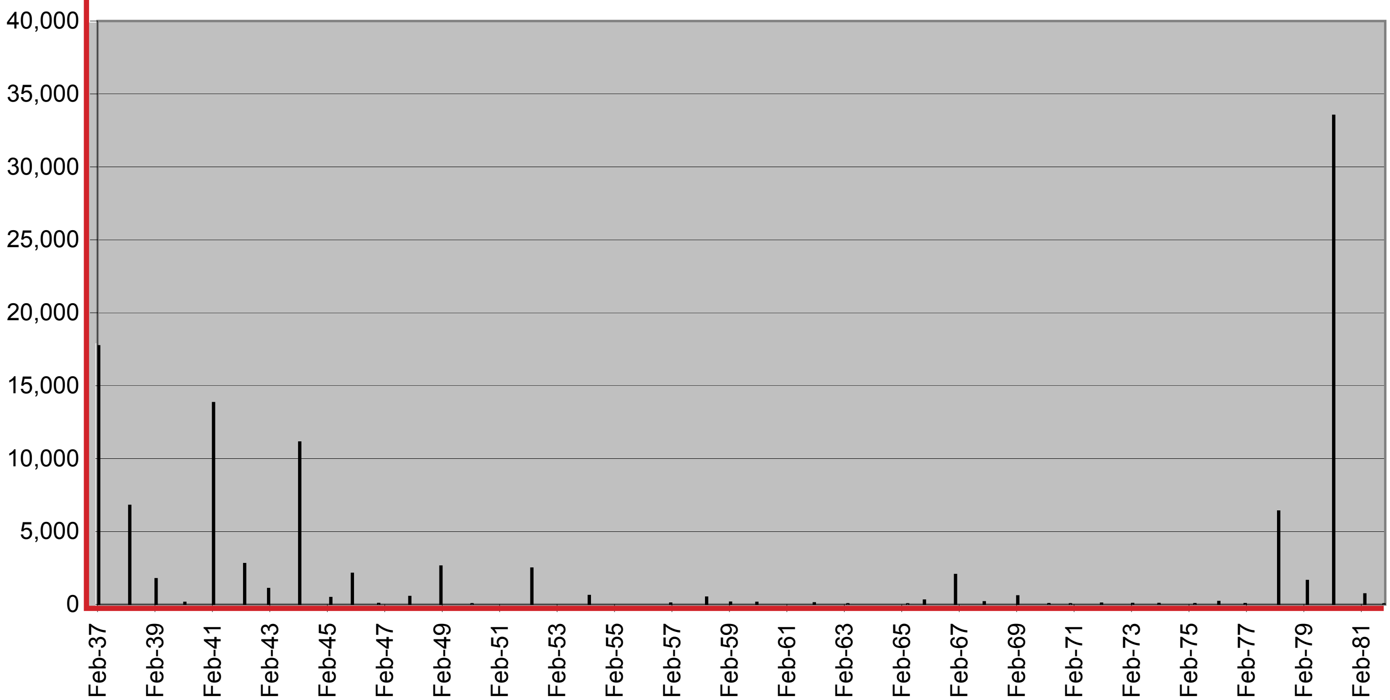


Figure 3_Flood Histogram

Flood Chronology & Histogram

Date	CFS	Rank	Recurrence Interval	Probability
2/21/1980	33,500	1	47	2.13
2/7/1937	17,700	2	23.5	4.26
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2/4/1939	1,730	12	3.916666667	25.53
3/29/1979	1,610	13	3.615384615	27.66
1/27/1943	1,060	14	3.357142857	29.79
3/1/1981	690	15	3.133333333	31.91
3/23/1954	580	16	2.9375	34.04
2/26/1969	553	17	2.764705882	36.17
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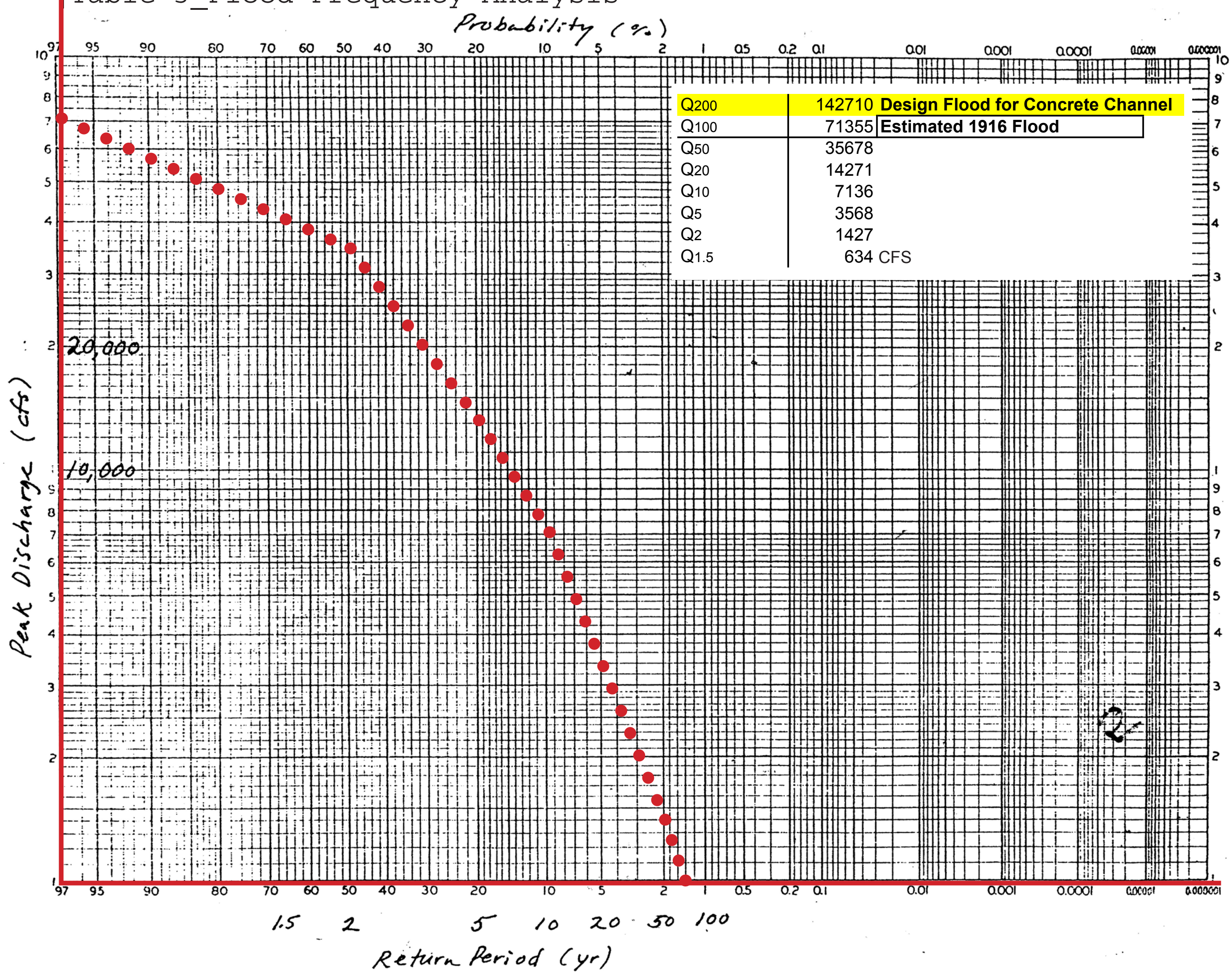
1/21/1962	75	27	1.740740741	57.45
1/29/1957	60	28	1.678571429	59.57
1/6/1972	56	29	1.620689655	61.70
11/14/1946	35	30	1.566666667	63.83
2/13/1973	34	31	1.516129032	65.96
1/8/1974	32	32	1.46875	68.09
1/7/1977	26	33	1.424242424	70.21
3/5/1970	20	34	1.382352941	72.34
4/9/1975	20	35	1.342857143	74.47
2/7/1950	11	36	1.305555556	76.60
12/21/1970	9	37	1.27027027	78.72
3/17/1963	8	38	1.236842105	80.85
11/28/1981	4	39	1.205128205	82.98
4/10/1965	3	40	1.175	85.11
1/1/1951	0	41	1.146341463	87.23
1/1/1953	0	42	1.119047619	89.36
1/1/1955	0	43	1.093023256	91.49
1/1/1956	0	44	1.068181818	93.62
1/1/1961	0	45	1.044444444	95.74
1/1/1964	0	46	1.02173913	97.87

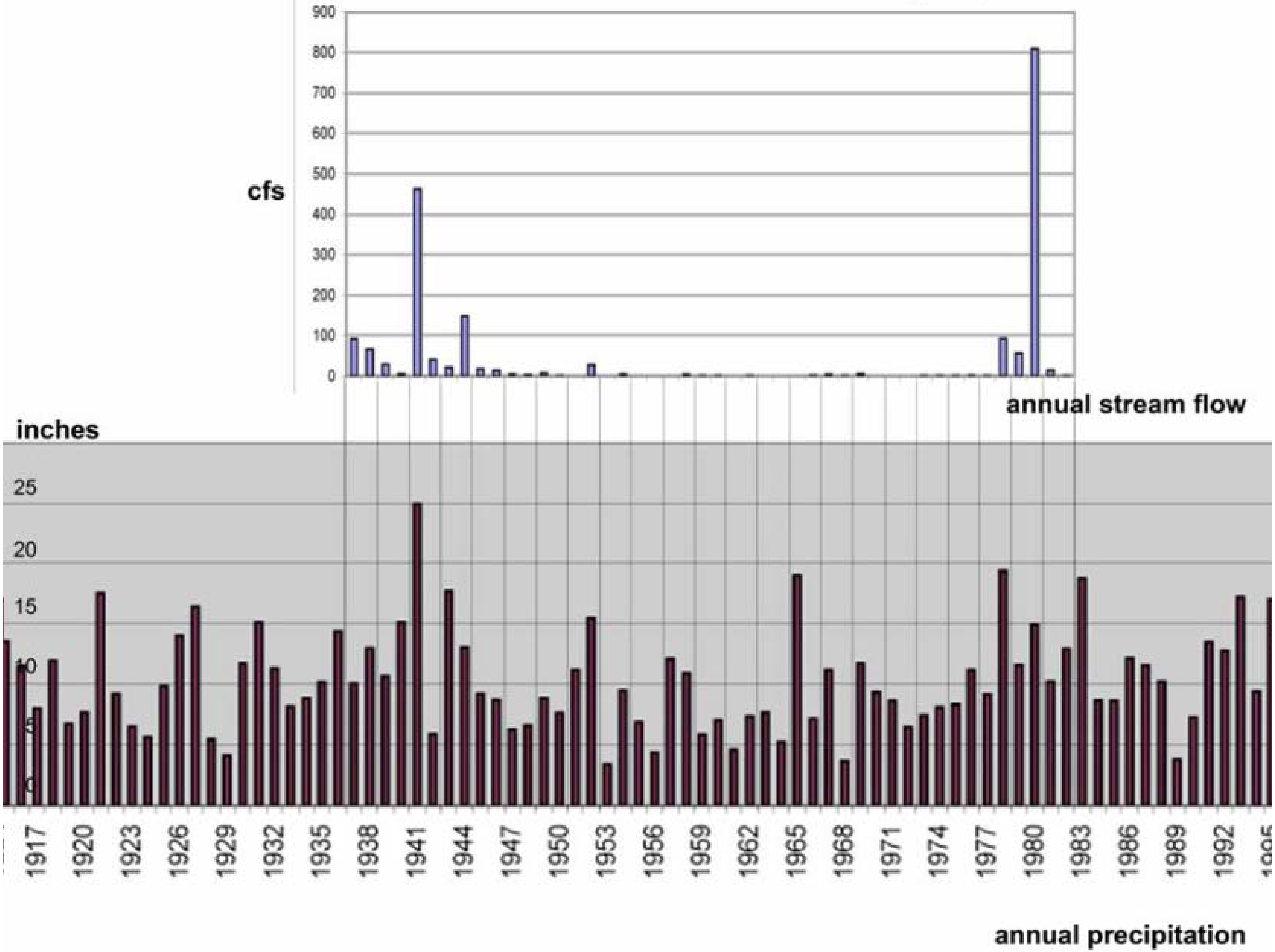
Table 3_Flood Frequency Analysis

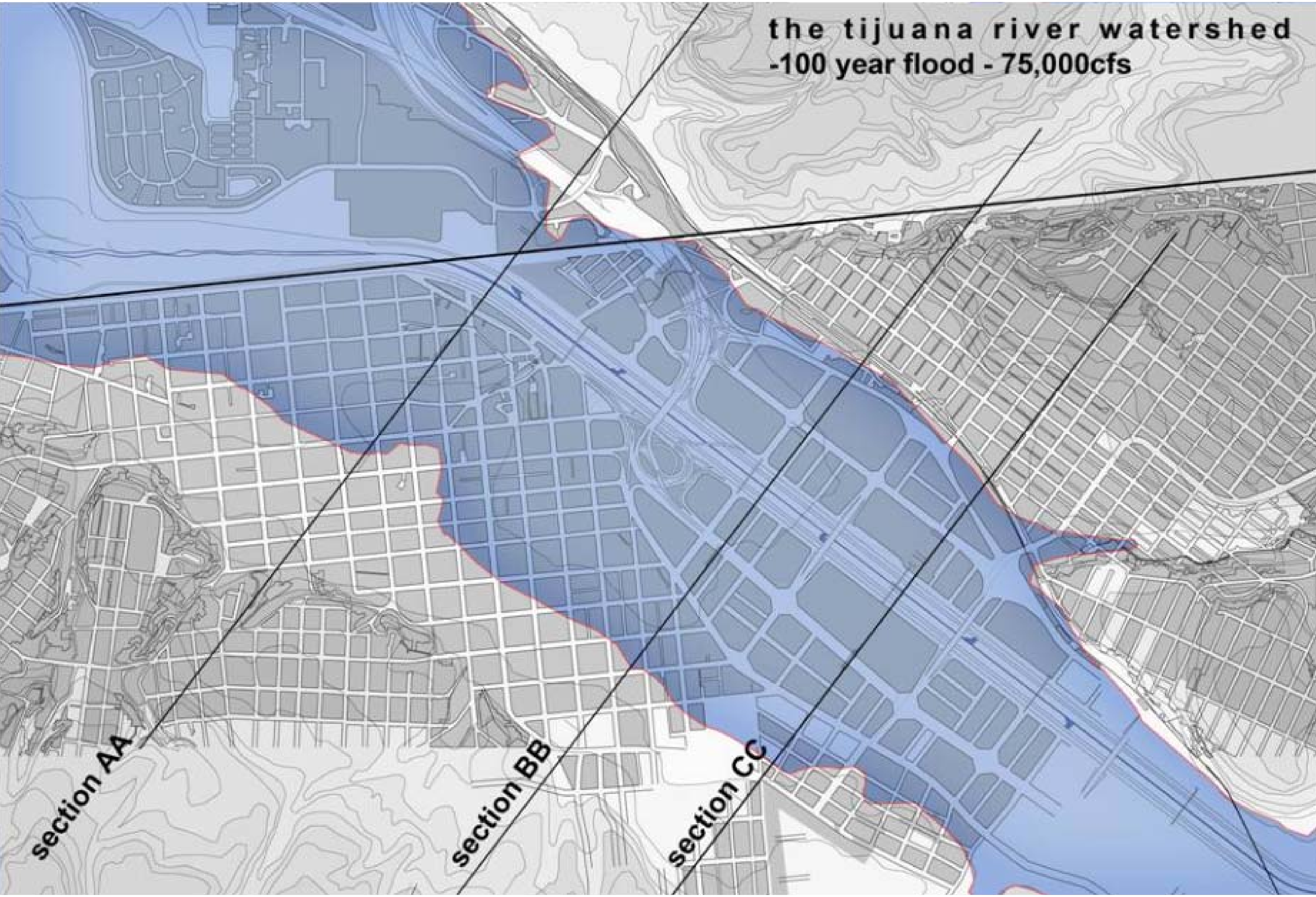


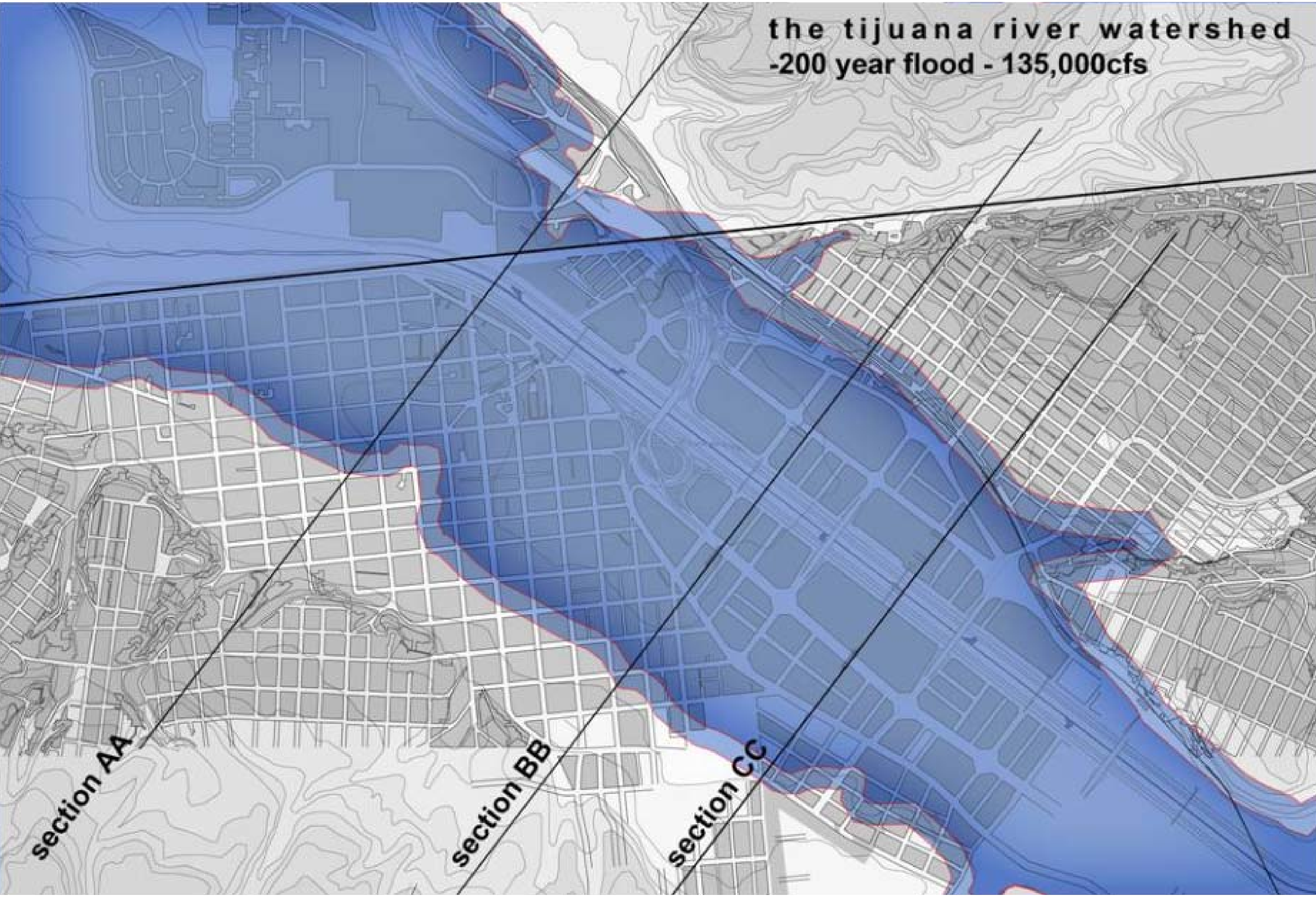
Q200	142710	Design Flood for Concrete Channel
Q100	71355	Estimated 1916 Flood
Q50	35678	
Q20	14271	
Q10	7136	
Q5	3568	
Q2	1427	
Q1.5	634 CFS	

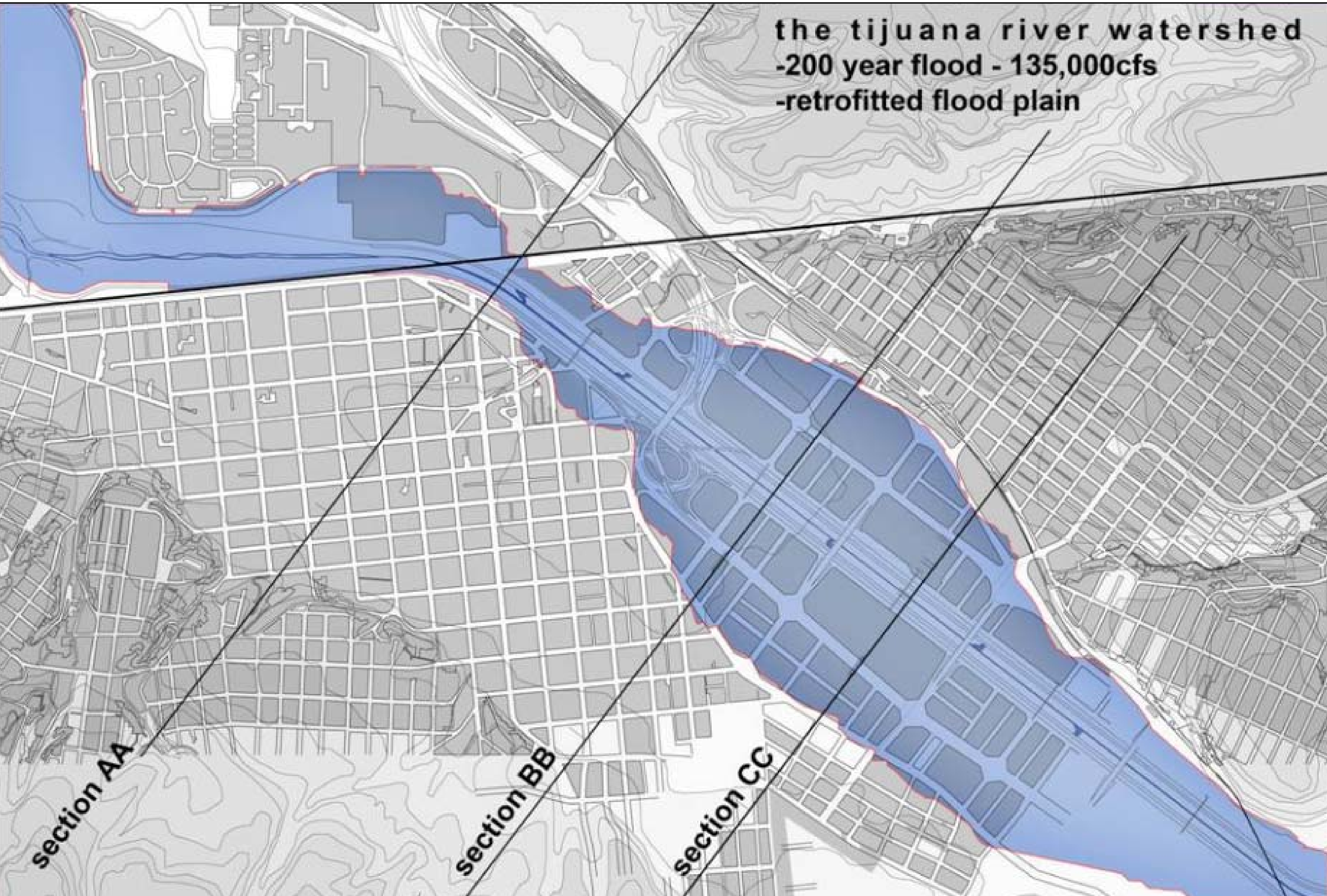
Flood Frequency Analysis

the tijuana river watershed
precipitation vs. streamflow




the tijuana river watershed
-100 year flood - 75,000cfs
section AA
section BB
section CC


the tijuana river watershed
-200 year flood - 135,000cfs
section AA
section BB
section CC



the tijuana river watershed
-200 year flood - 135,000cfs
-retrofitted flood plain
section AA
section BB
section CC

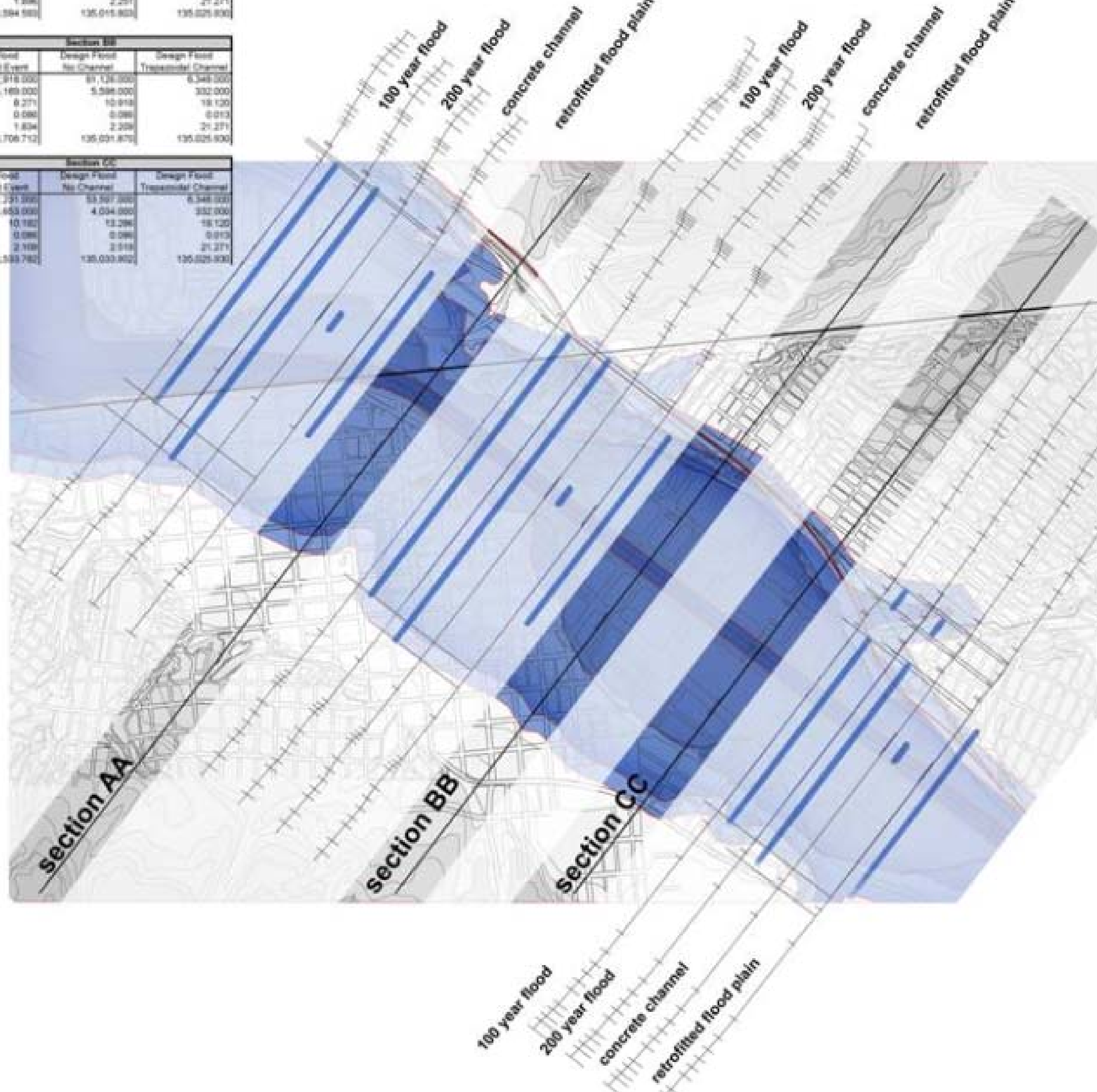

the tijuana river watershed
-200 year flood - 135,000cfs
-retrofitted flood plain
section AA
section BB
section CC

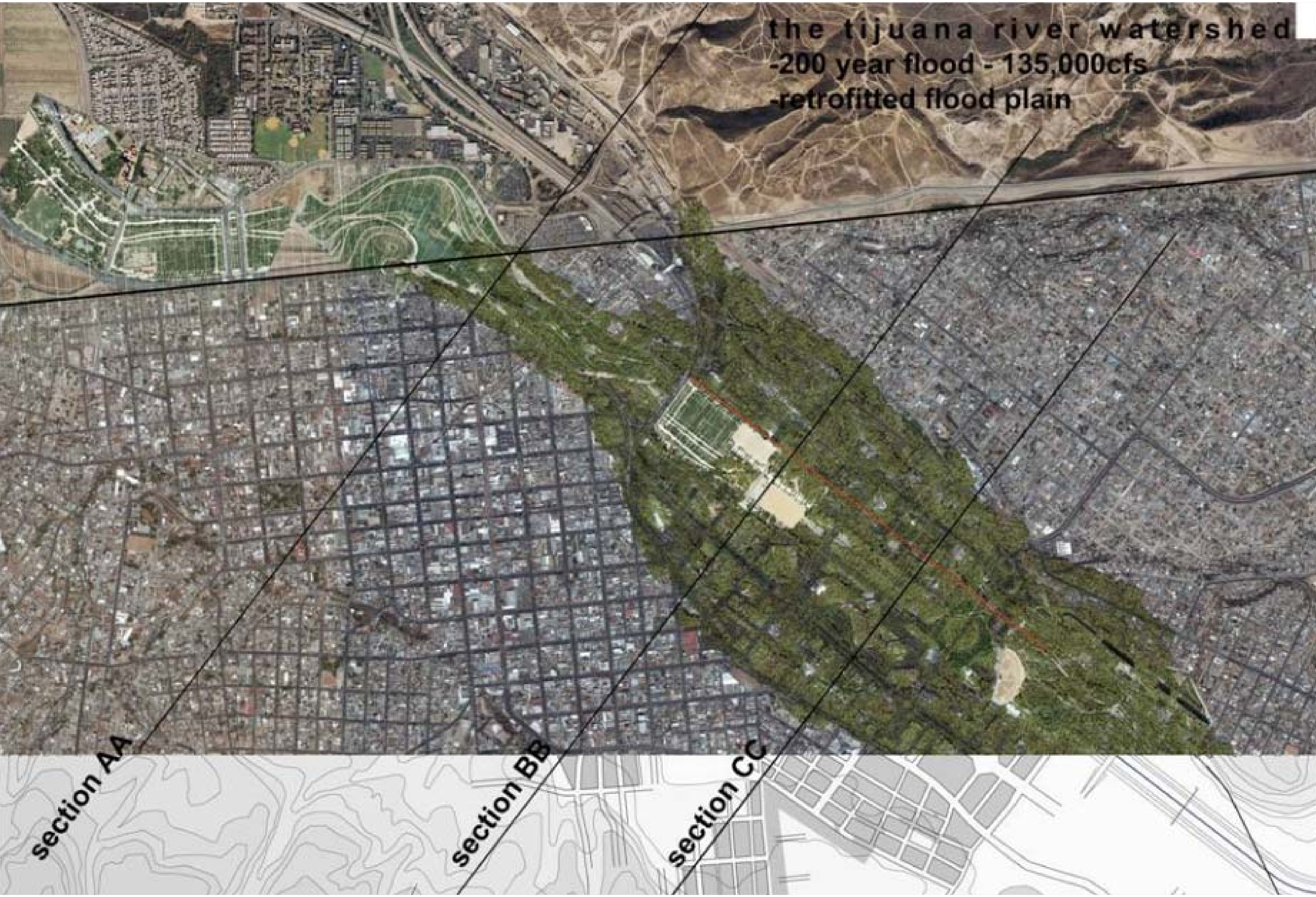
the tijuana river watershed

Section AA	1916 Flood 1% Flood Event	Design Flood No Channel	Design Flood Trapezoidal Channel
A	41,446.000	59,960.000	6,348.000
WP	4,767.000	5,341.000	332.000
R	8.694	11.230	19.120
n	0.086	0.086	0.013
V	1.896	2.251	21.271
Q	78,594.593	135,015.803	135,025.930

Section BB	1916 Flood 1% Flood Event	Design Flood No Channel	Design Flood Trapezoidal Channel
A	42,916.000	61,126.000	6,348.000
WP	5,169.000	5,598.000	332.000
R	8.271	10.918	19.120
n	0.086	0.086	0.013
V	1.834	2.209	21.271
Q	78,706.712	135,031.870	135,025.930

Section CC	1916 Flood 1% Flood Event	Design Flood No Channel	Design Flood Trapezoidal Channel
A	37,231.000	53,597.000	6,348.000
WP	3,653.000	4,034.000	332.000
R	10.192	13.286	19.120
n	0.086	0.086	0.013
V	2.109	2.519	21.271
Q	78,533.782	135,033.902	135,025.930




the tijuana river watershed
-200 year flood - 135,000cfs
-retrofitted flood plain
section AA
section BB
section CC