LOS ANGELES RIVER
MASTER PLAN UPDATE

Hydrology and Hydraulics Workshop

20 March 2019

WELCOME

Source: USACE, Los Angeles District, G-514 - Kelly Pipe Co Mission Road - 9-5-1930, http://cespl.maps.arcgis.com/apps/MapSeries/index.html?appid=e15694dbf7c54f8c96285a0e74039e69

OUTLINE

LA RIVER WATERSHED

- Hydrology
- Hydraulics
- LA River

TIMELINE OF THE LA RIVER

- 1850-2019
- How Did We Get Here?
- Historical Flood Mapping
- February 2, 2019 Storm
- Current Protection Level and Flood Risk
- Brainstorming Ideas

TOOLS AND ANALYSES

- HydroCalc
- Loading Simulation Program in C++
- HEC Hydrologic Modeling System
- Manning's Equation
- HEC River Analysis System

SOLUTIONS AND OPPORTUNITIES

- Evaluations
- Worksession Breakout
  - Modeling the Theories Ourselves
- Advanced Modeling

WRAP UP

- Discussion
- What Have We Learned?
- What Needs More Study/Analysis?
- Other Resources

OVERVIEW

Source: OLIN

LA RIVER HYDROLOGY AND HYDRAULICS (H&H)

WATERSHED CONDITIONS

- Topography
- Geology & Soils
- Vegetation Cover & Land Use
- Climate/Precipitation

INFRASTRUCTURE

- Spreading grounds
- Detention basins
- Channels
- Storm Drains

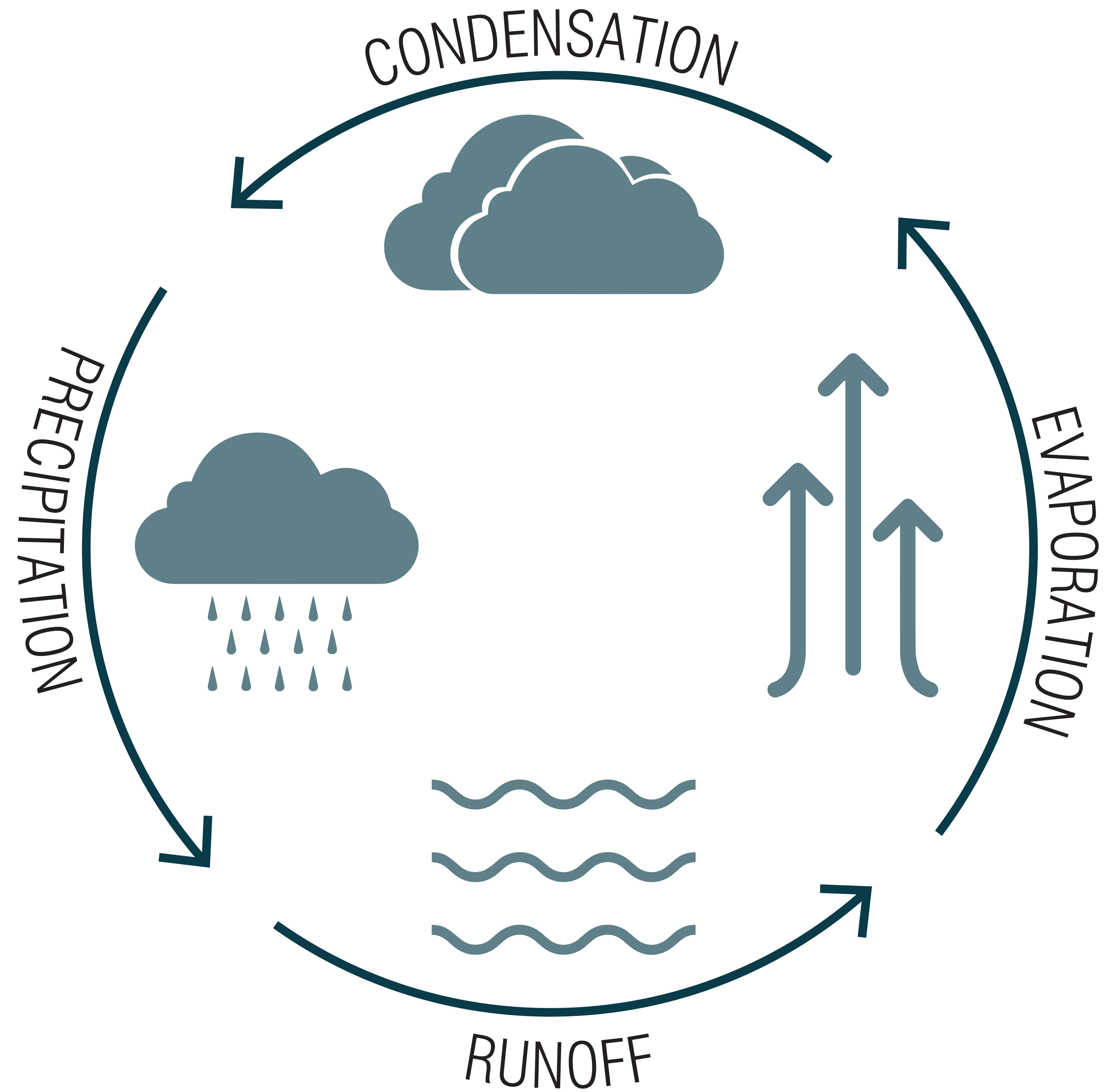
OVERVIEW

HYDROLOGY

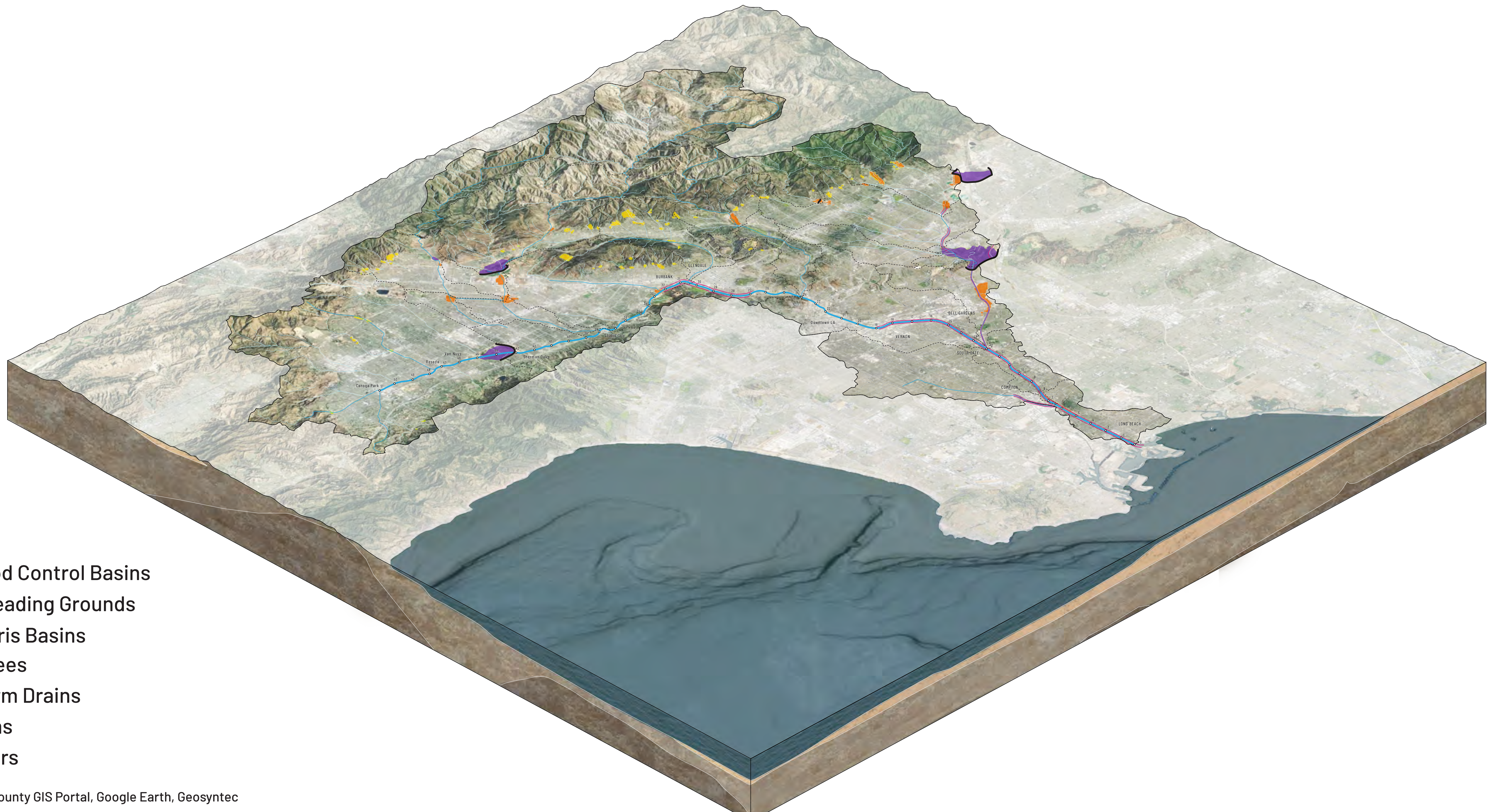
HYDRAULICS

LA RIVER

THE HYDROLOGICAL CYCLE



THE LA RIVER WATERSHED

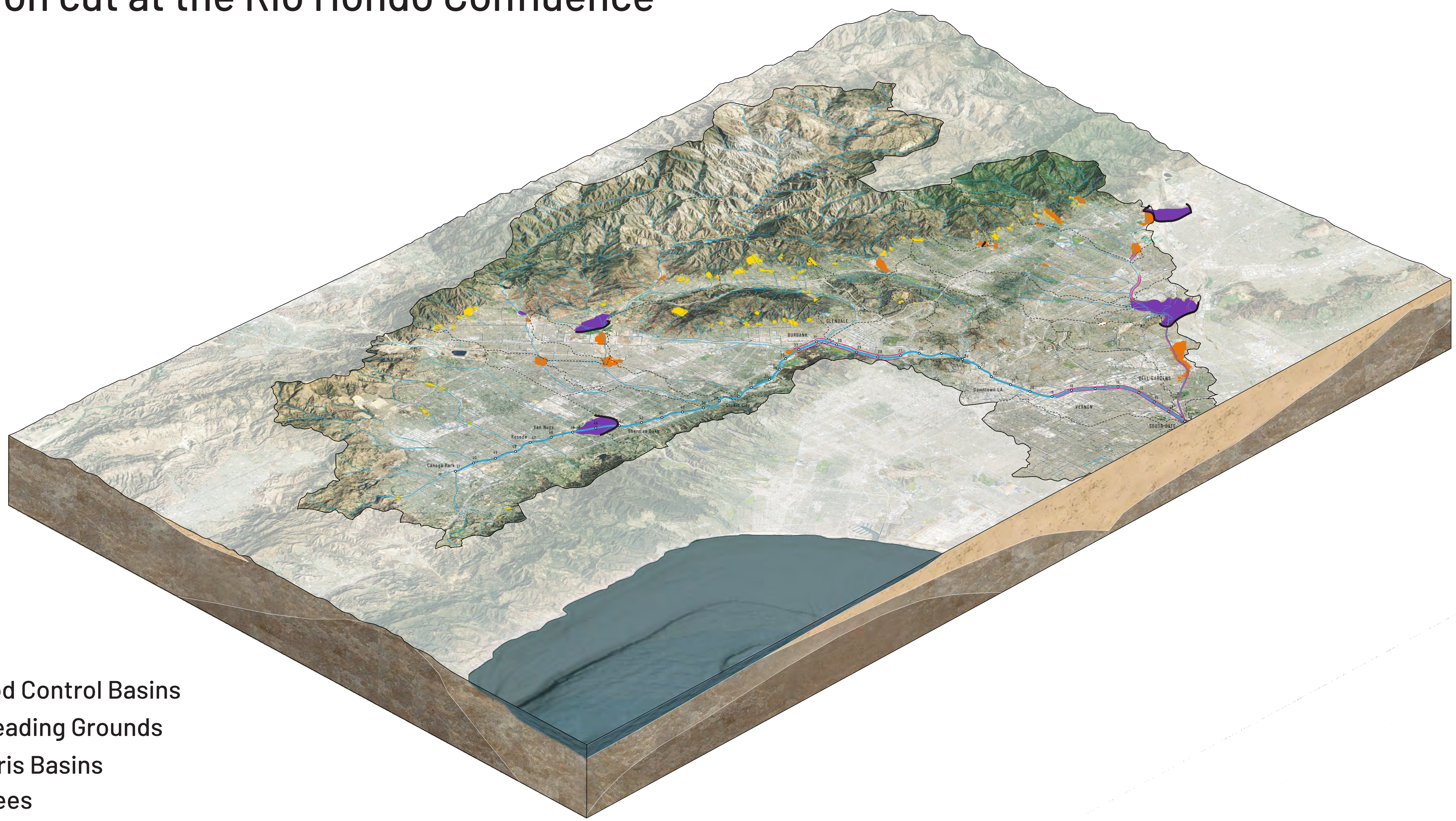


Flood Control Basins
Spreading Grounds
Debris Basins
Levees
Storm Drains
Dams
Rivers

Source: LA County GIS Portal, Google Earth, Geosyntec

THE LA RIVER WATERSHED

Section cut at the Rio Hondo Confluence

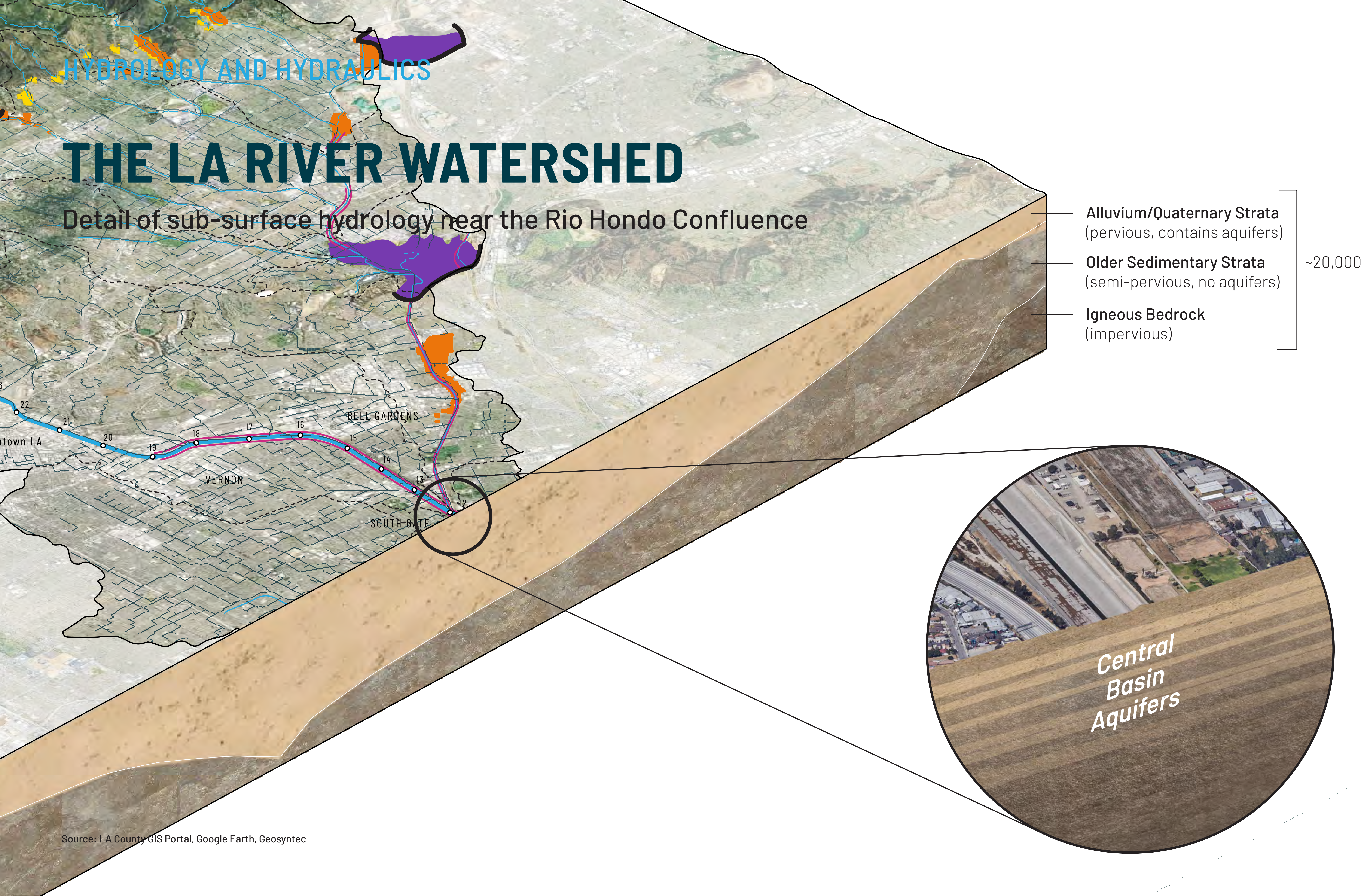


- Flood Control Basins
- Spreading Grounds
- Debris Basins
- Levees
- Storm Drains
- Dams
- Rivers

Source: LA County GIS Portal, Google Earth, Geosyntec

THE LA RIVER WATERSHED

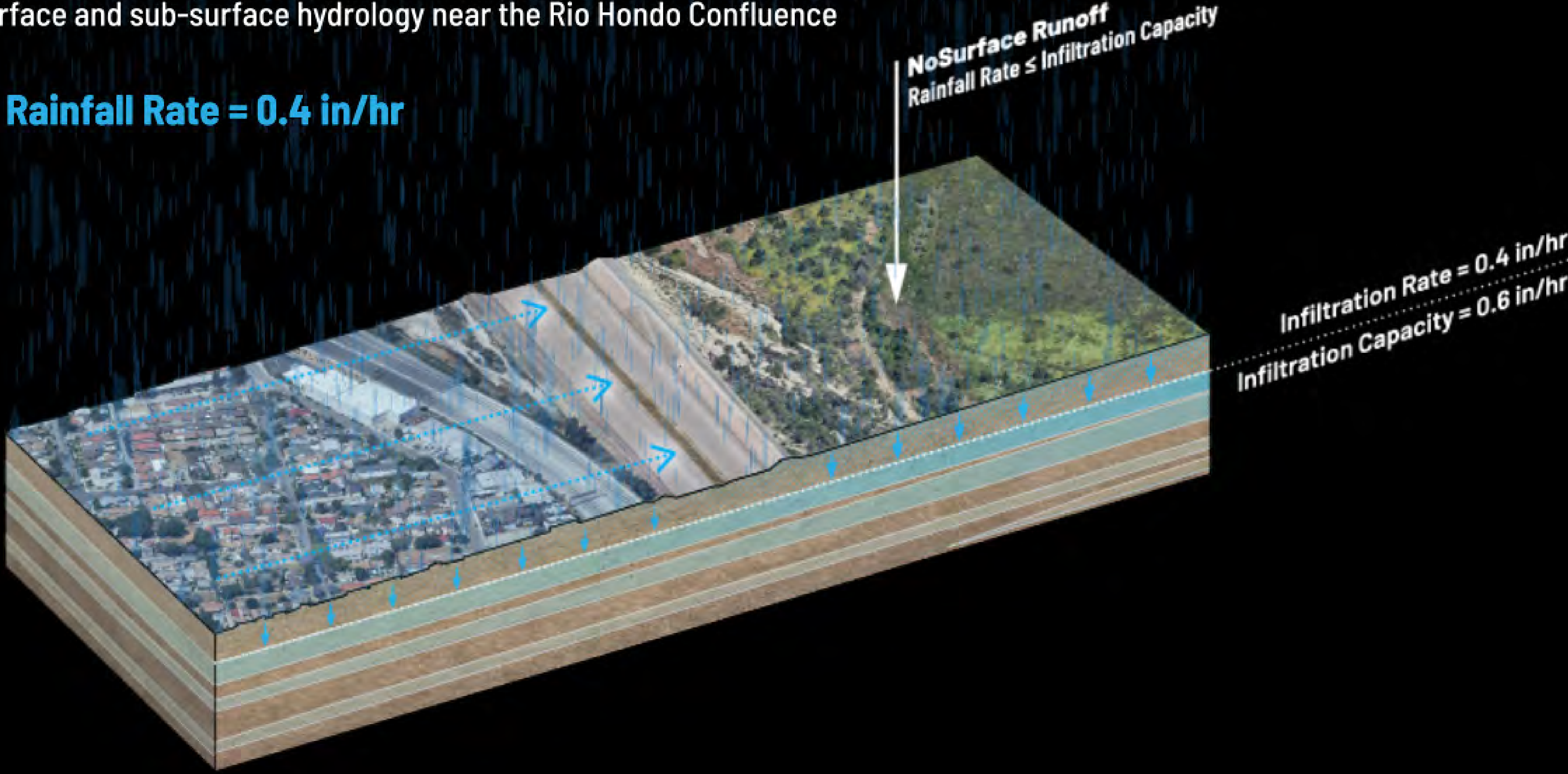
Detail of sub-surface hydrology near the Rio Hondo Confluence



Source: LA County GIS Portal, Google Earth, Geosyntec

SOIL-WATER PROCESSES

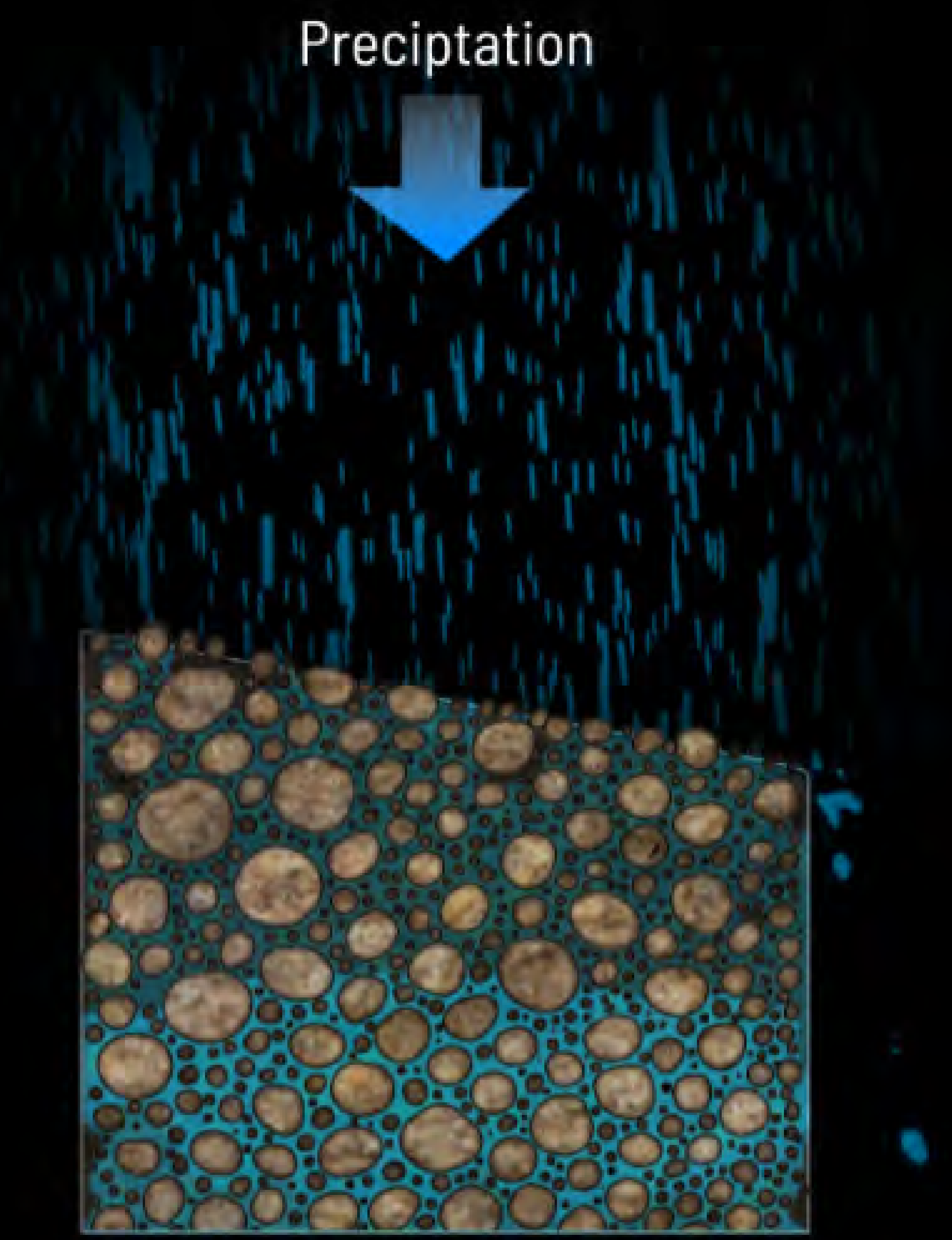
Surface and sub-surface hydrology near the Rio Hondo Confluence

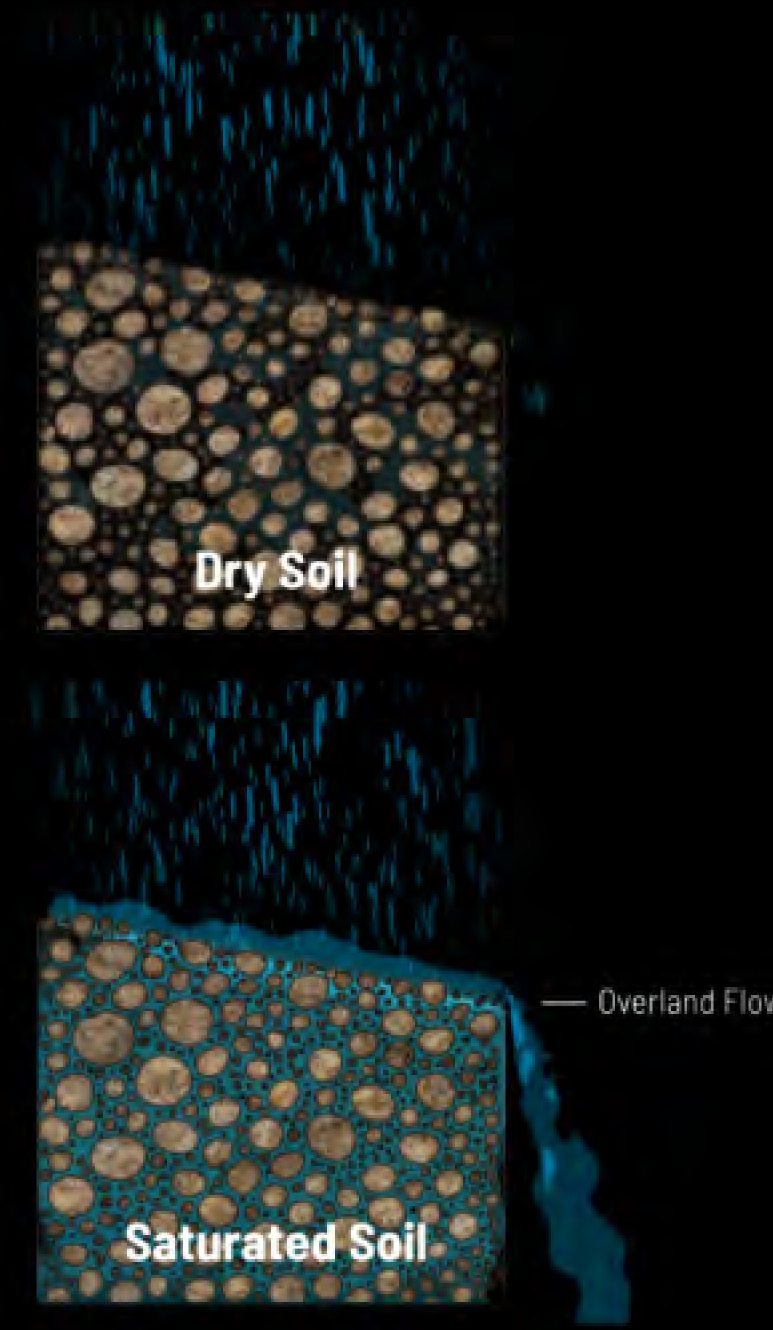


Geosyntec, OLIN

SOIL-WATER PROCESSES

Infiltration rate of soil decreases as it becomes saturated





Geosyntec, OLIN

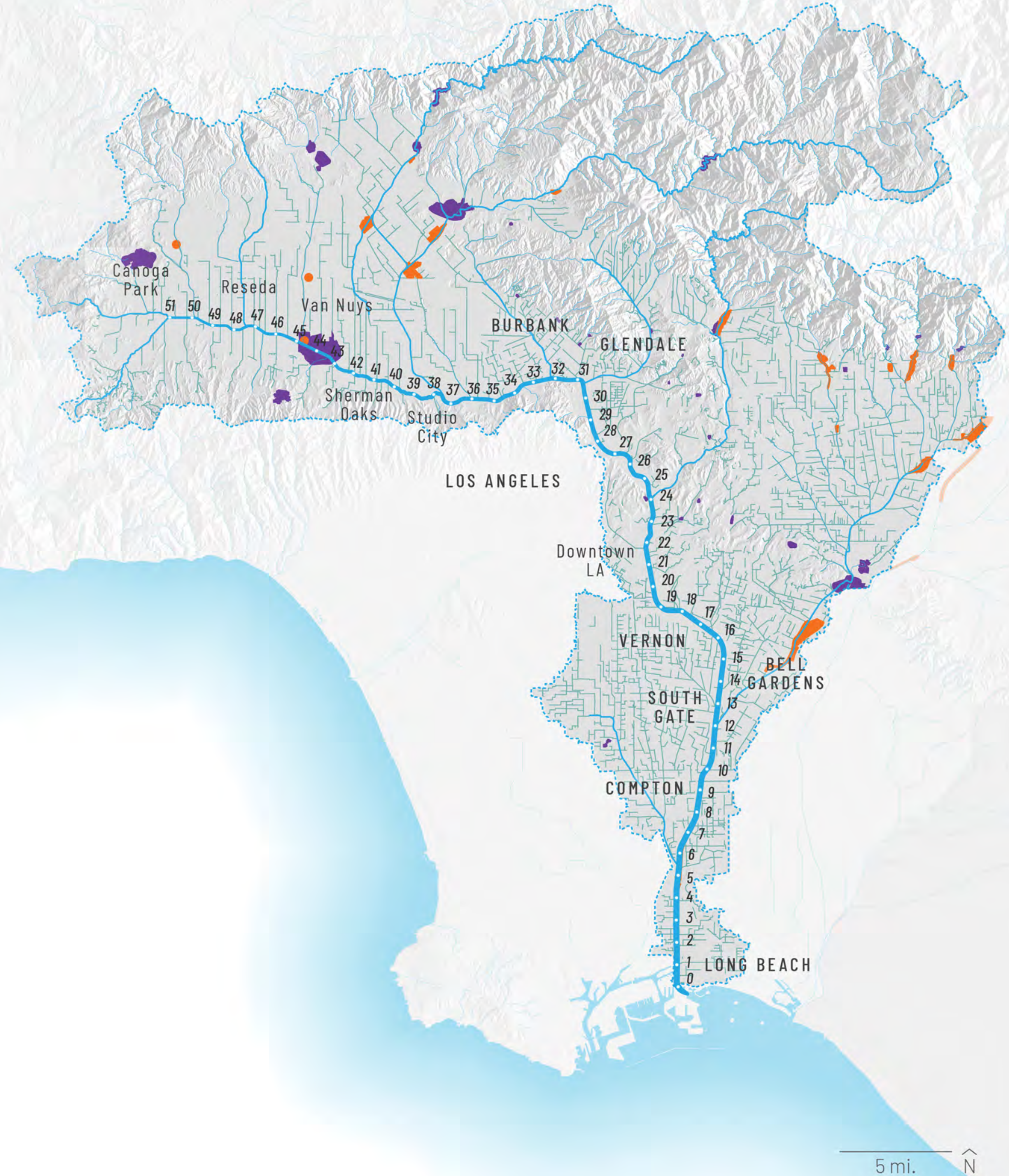
OVERVIEW

HYDROLOGY

HYDRAULICS

LA RIVER

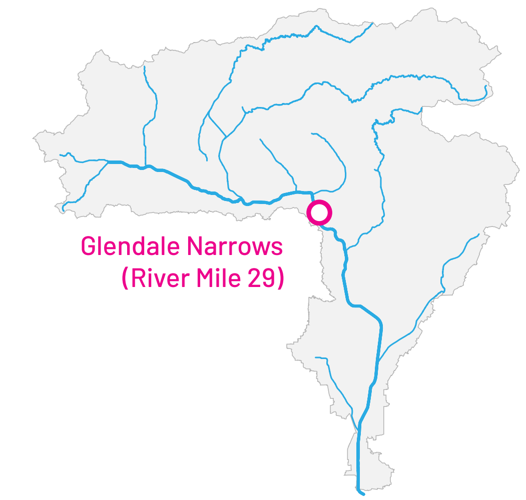
HYDRAULIC FLOOD SYSTEM



- Spreading Grounds
- Flood Control Basins
- Storm Drains
- Streams and Channels

Source: LA County GIS Portal

HYDRAULICS - CHANNEL CAPACITY



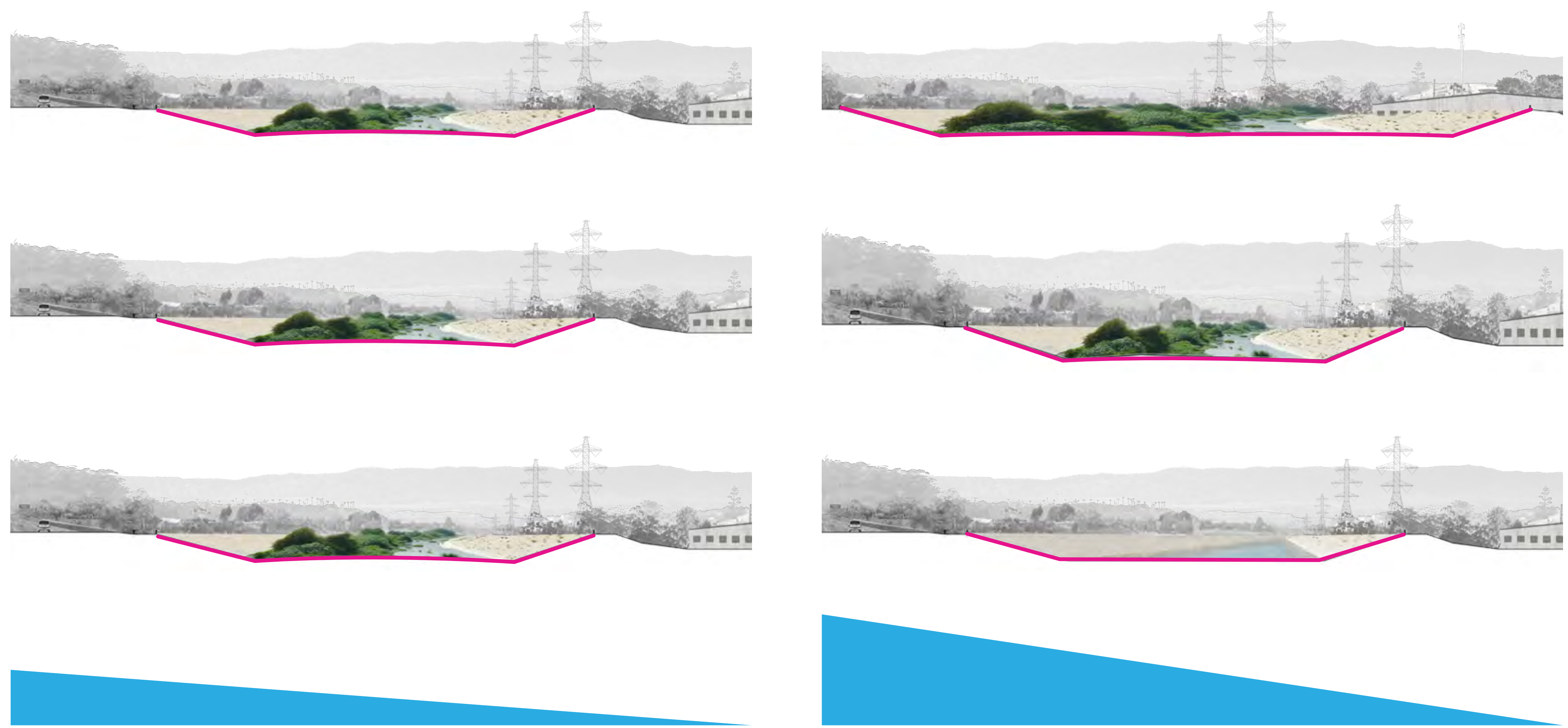
LOWER CAPACITY / HIGHER CAPACITY

AREA

DEPTH
Hydraulic radius

ROUGHNESS
Manning's n

SLOPE



Source: Geosyntec, OLIN

HYDRAULICS - BRIDGES

Los Feliz Blvd on 2 February 2019

Upstream of Bridge

Downstream of Bridge

Source: Geosyntec

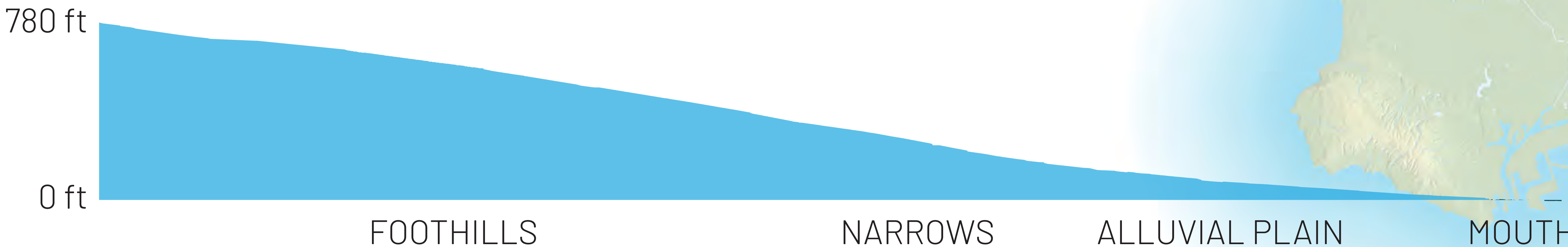
OVERVIEW

HYDROLOGY

HYDRAULICS

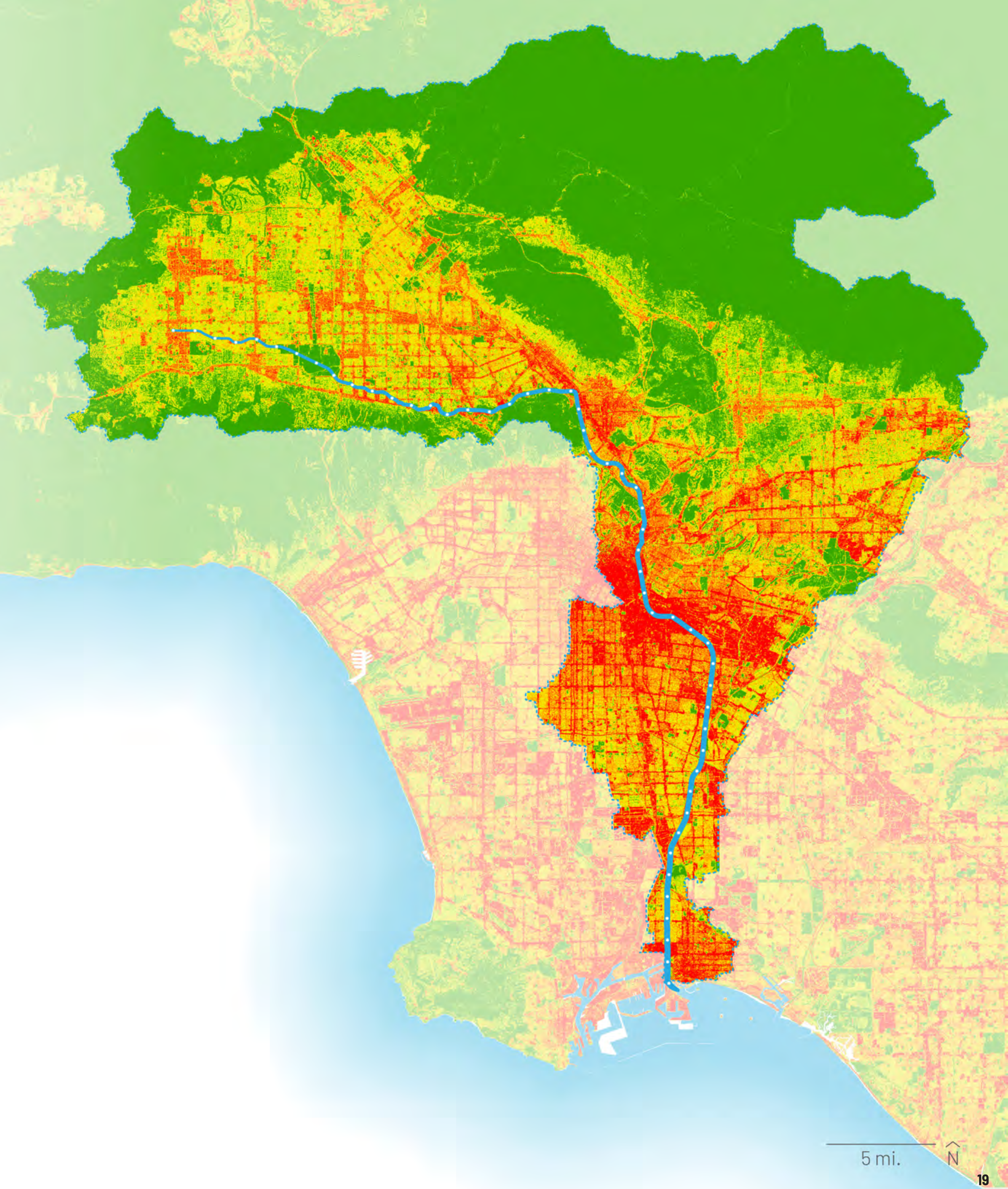
LA RIVER

THE LA RIVER DROPS 780 FEET IN JUST 51 MILES



Source: U.S. Geological Survey, 2013, USGS NED 1 arc-second 2013

LA RIVER WATERSHED IMPERVIOUSNESS



0% Impervious

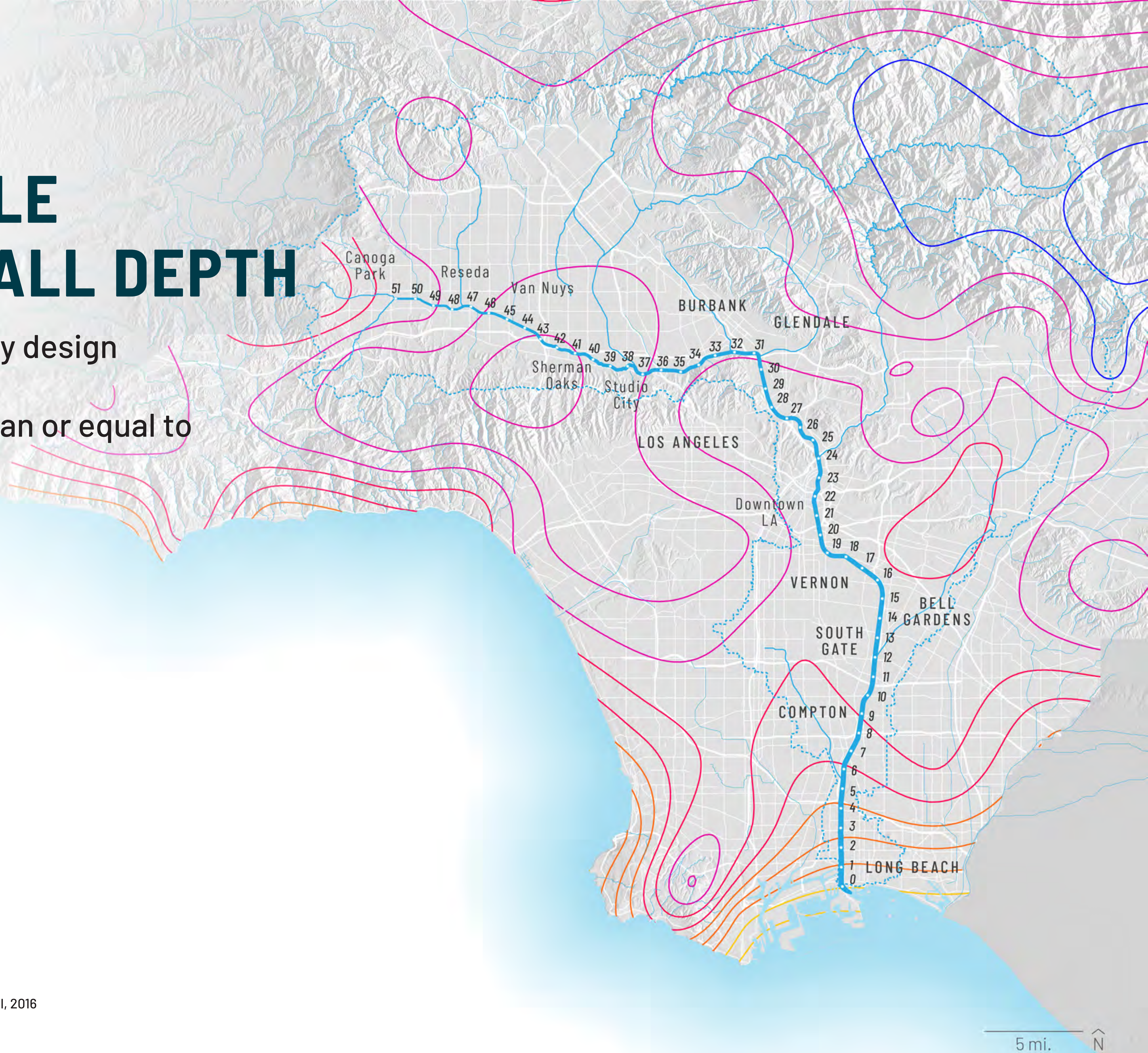
100% Impervious

Source: LA County GIS Data Portal, NLCD 2011 Impervious Surface

85TH PERCENTILE 24-HOUR RAINFALL DEPTH

Commonly used for water quality design

85 percent of storms are less than or equal to the 85th percentile rain event.



Total Rainfall (inches)

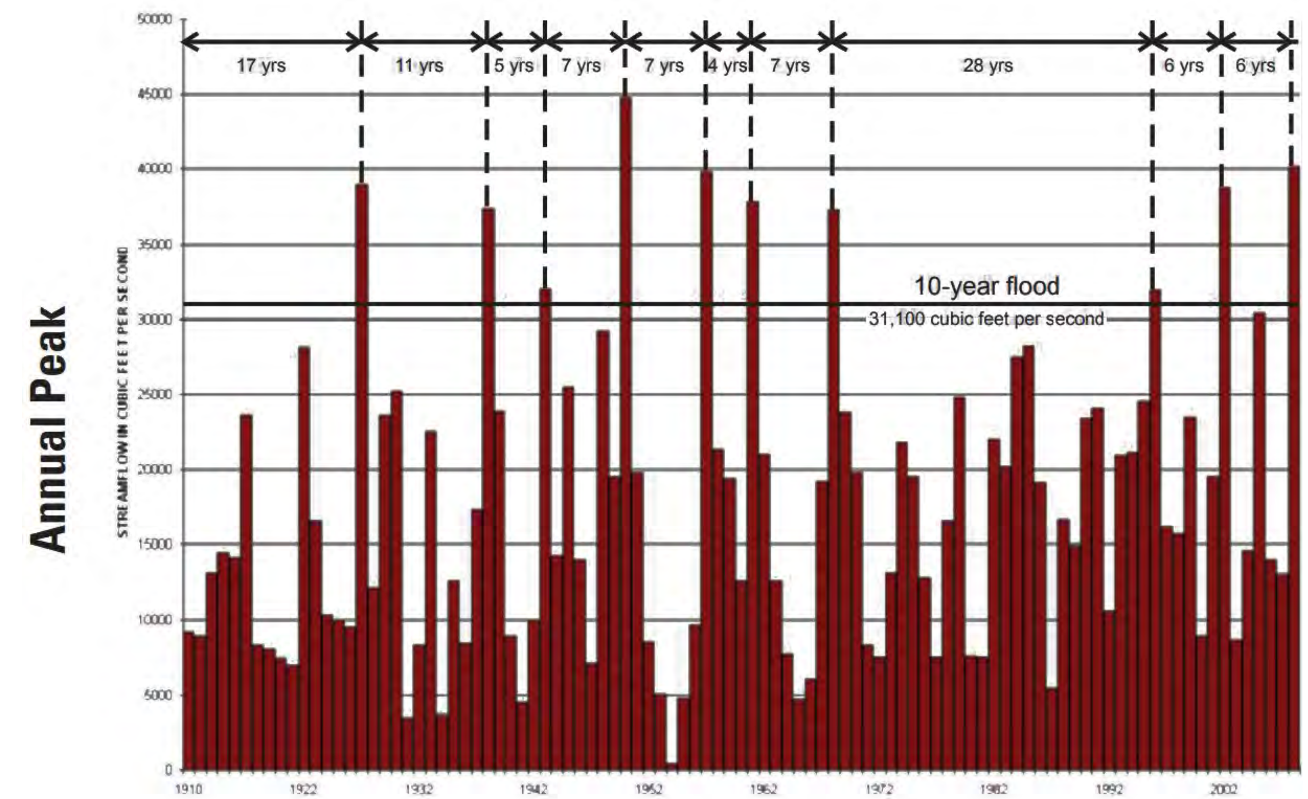
- 0.20 - 0.45
- 0.45 - 0.70
- 0.70 - 0.95
- 0.95 - 1.20
- 1.20 - 1.45

Source: Los Angeles County GIS Data Portal, 85th and 95th Percentile Rainfall, 2016

STORM PROBABILITY

Defining the 100 year storm:

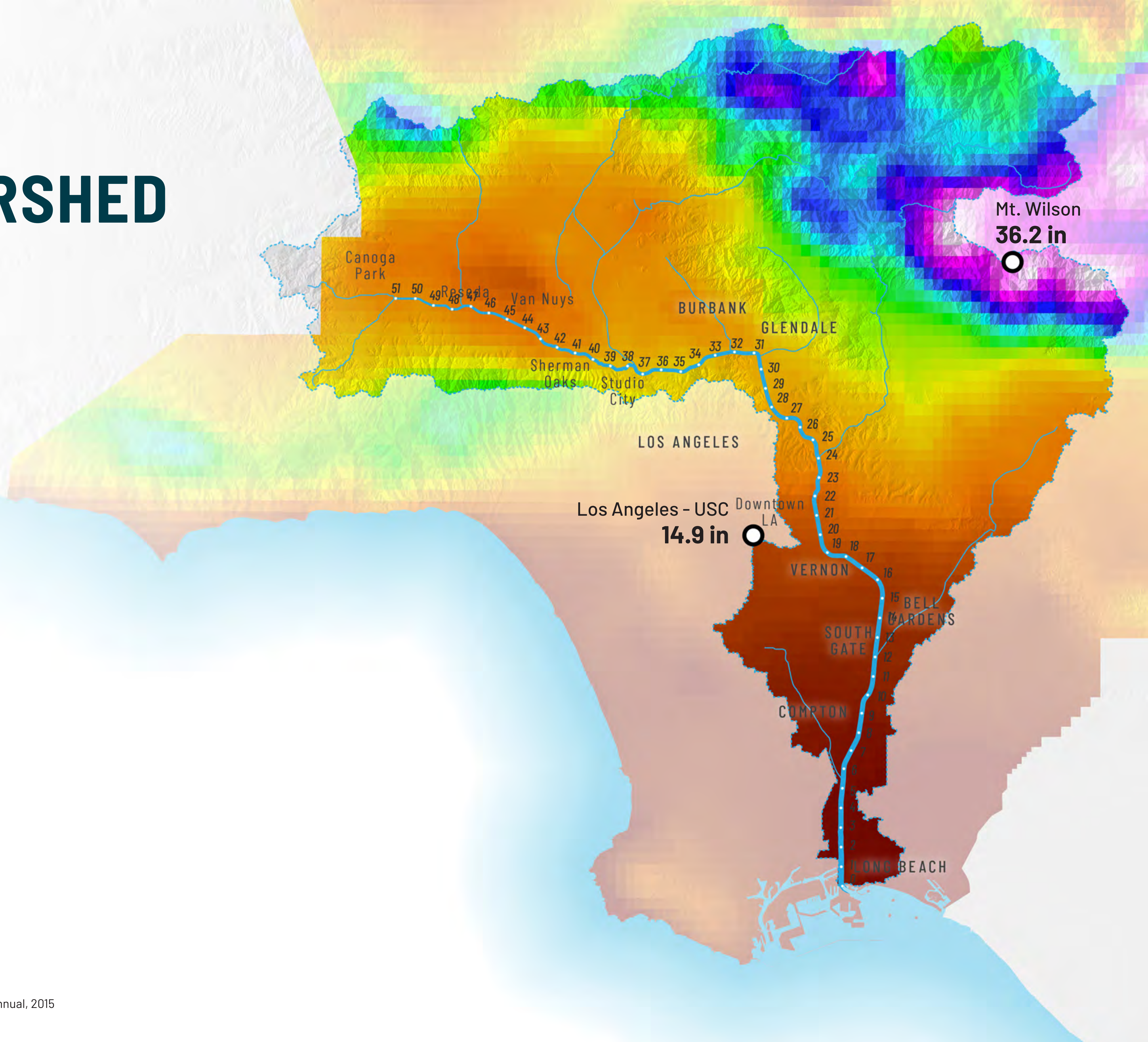
- A storm that happens once every 100 years on average.
- A storm that has a 1% probability of happening in any given year.
- Two 100-year events can happen in back-to-back years or even the same year.
- Over 30 years (i.e., the length of standard home mortgage), the probability of having a 100-year event is 25%.
- Climate change is likely to increase the frequency of extreme events.



Incidence of the 10-year flood for the Embarras River at Ste. Marie, IL (03345500). The variability in time between "10-year floods" ranges from 4 to as many as 28 years between floods.

Source: Modified from 100-Year Flood-It's All About Chance, USGS, April 2010, https://pubs.usgs.gov/gip/106/pdf/100-year-flood-handout-042610.pdf.

LA RIVER WATERSHED MEAN ANNUAL PRECIPITATION 1981-2010



38.7 in / 983 mm

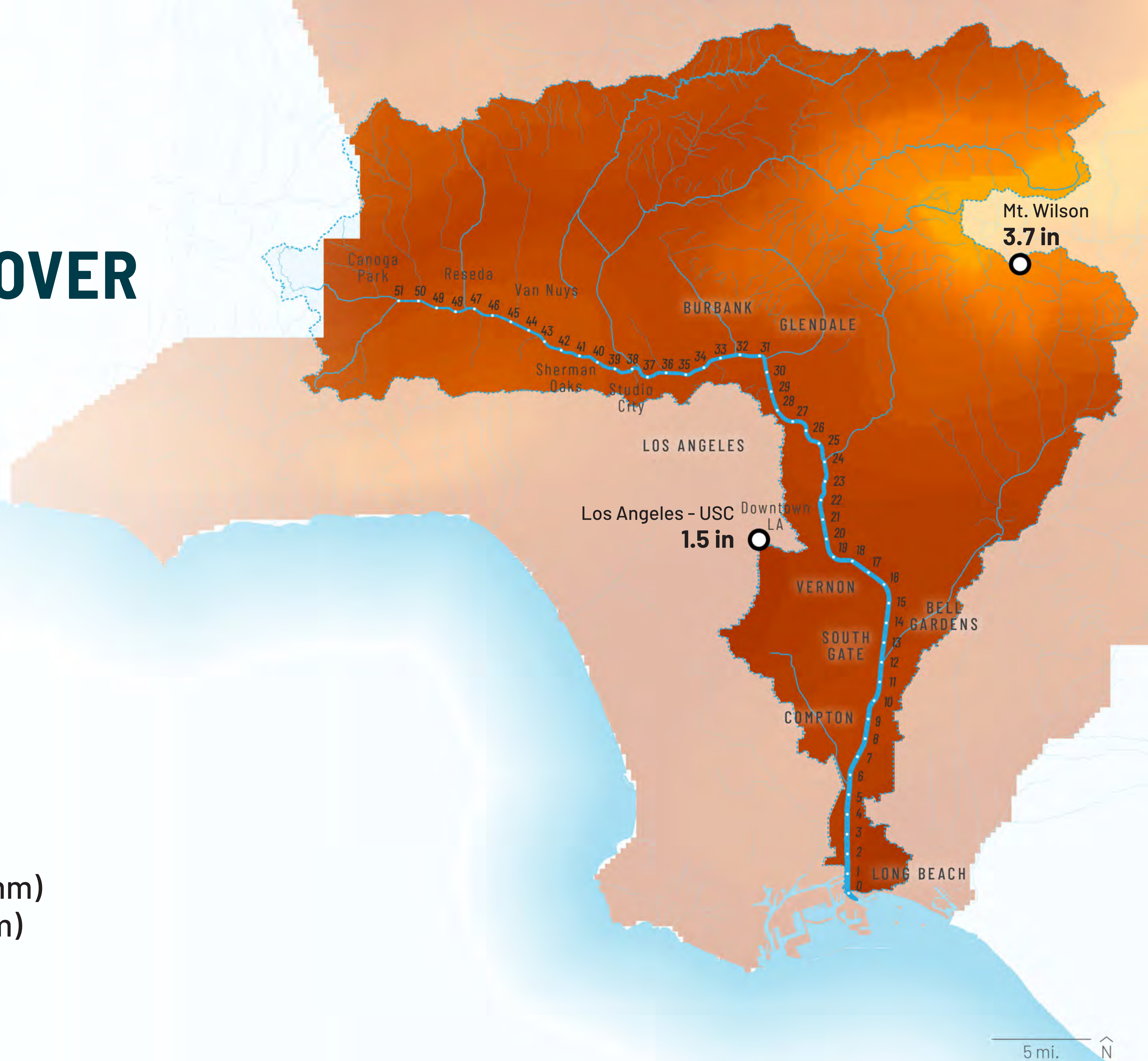
Mt Wilson

Los Angeles - USC

12.9 in / 327 mm

Source: PRISM Climate Group, Oregon State University, 30-yr Normal Precipitation: Annual, 2015

1-YEAR STORM PRECIPITATION OVER 24 HOURS



23.0 in / 584 mm

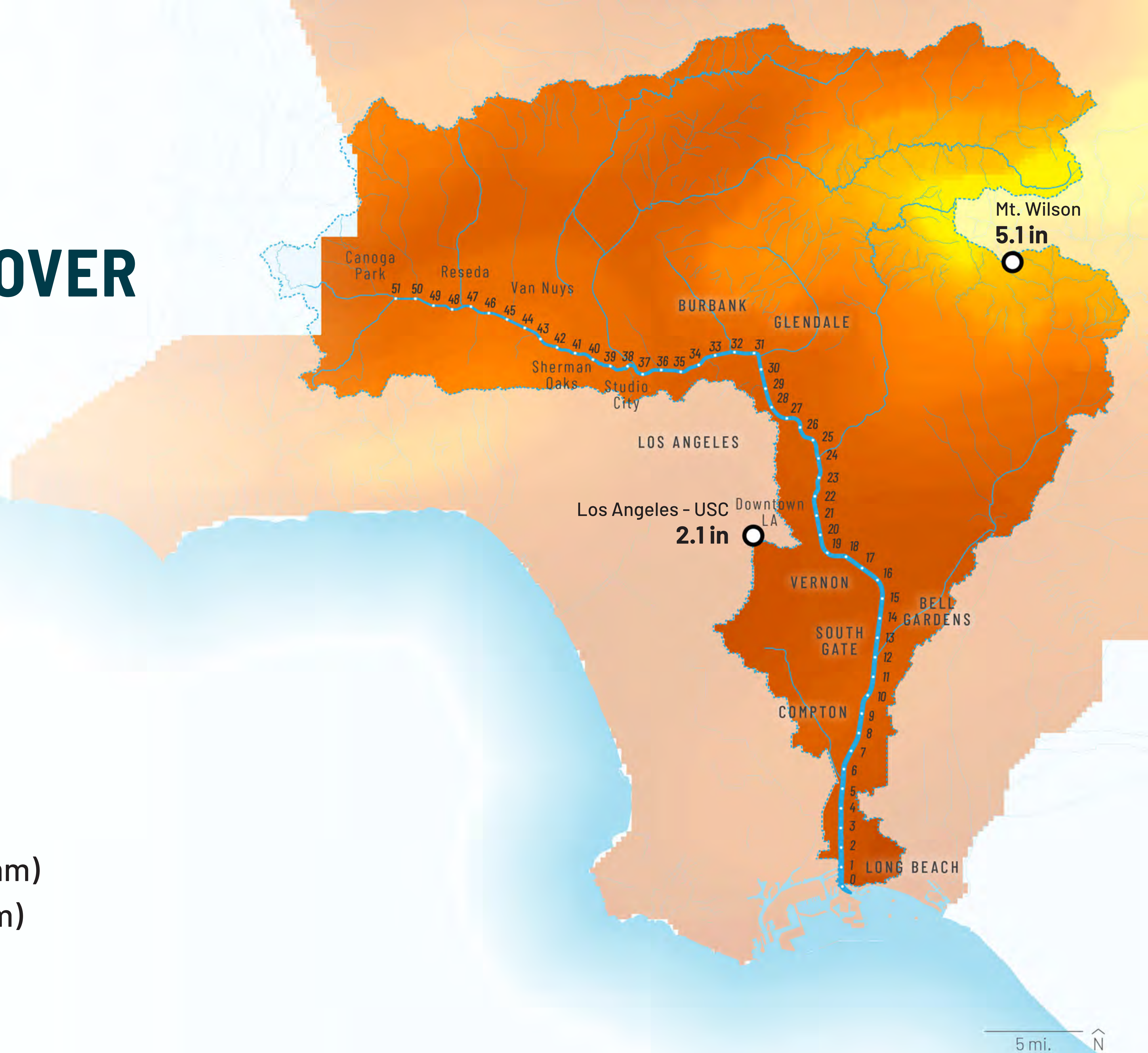
Max Rainfall (4.6 in / 116 mm)

Min Rainfall (0.7 in / 19 mm)

0.0 in / 0 mm

Source: Los Angeles County GIS Data Portal, Rainfall Intensity, 2011

2-YEAR STORM PRECIPITATION OVER 24 HOURS



23.0 in / 584 mm

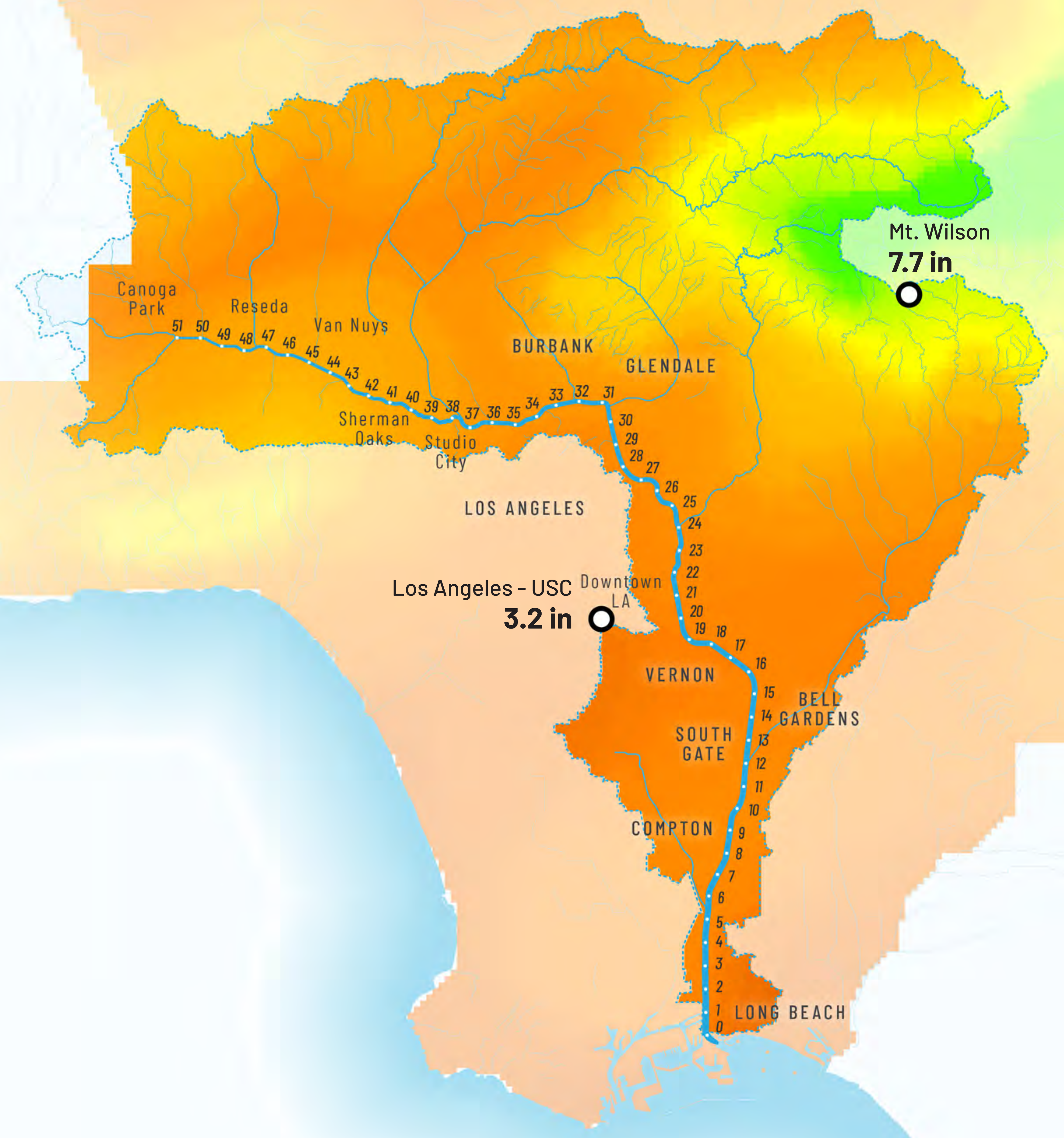
Max Rainfall (6.3 in /159 mm)

Min Rainfall (1.0 in / 25 mm)

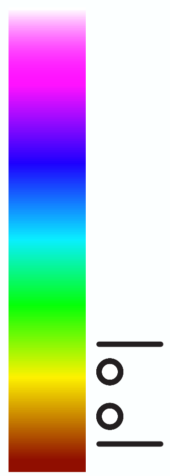
0.0 in / 0 mm

Source: Los Angeles County GIS Data Portal, Rainfall Intensity, 2011

5-YEAR STORM PRECIPITATION OVER 24 HOURS



23.0 in / 584 mm



Max Rainfall (9.4 in / 239 mm)

Min Rainfall (1.5 in / 38 mm)

0.0 in / 0 mm

Source: Los Angeles County GIS Data Portal, Rainfall Intensity, 2011

10-YEAR STORM PRECIPITATION OVER 24 HOURS

23.0 in / 584 mm

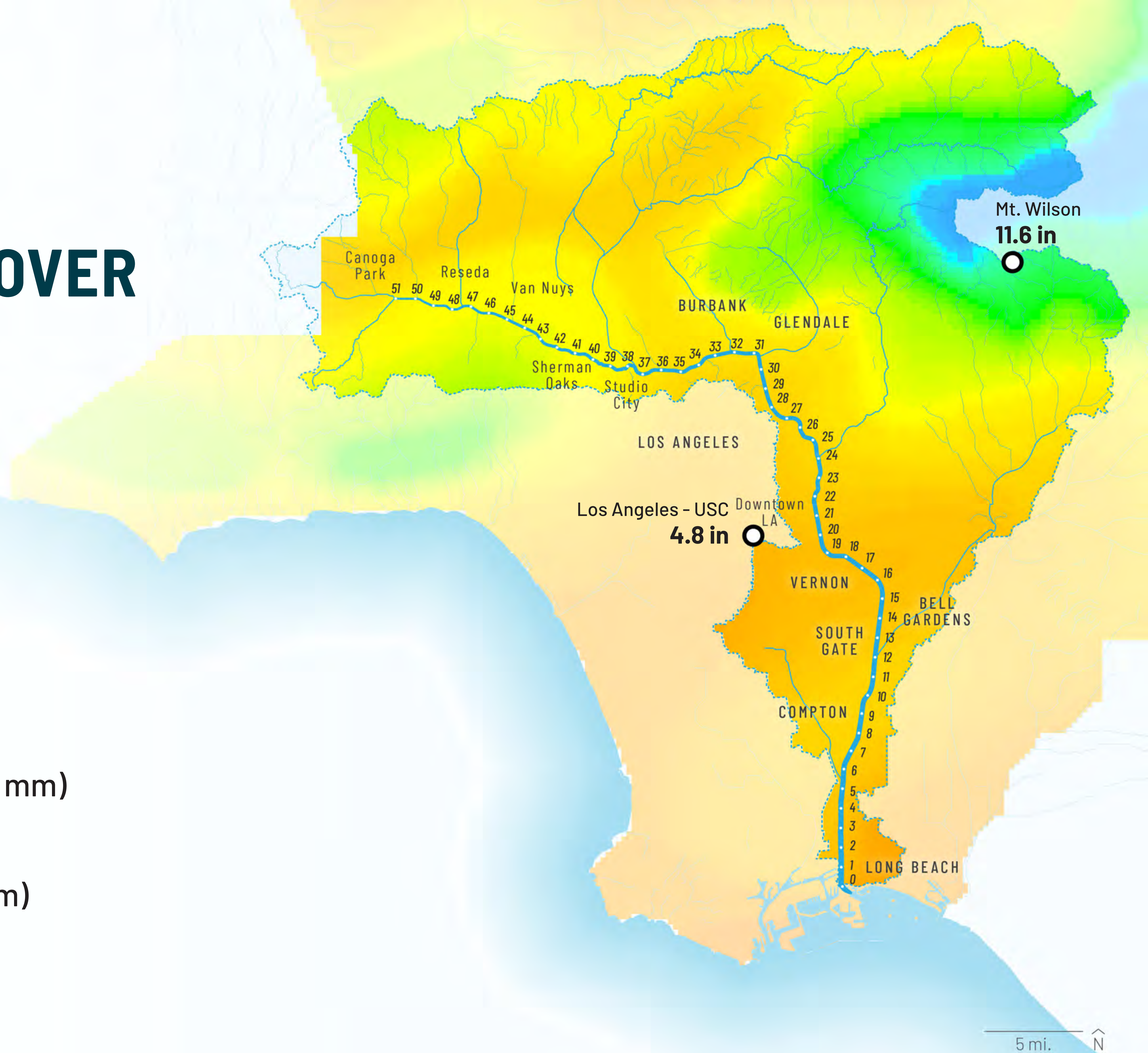
Max Rainfall (11.5 in / 293 mm)

Min Rainfall (1.8 in / 47 mm)

0.0 in / 0 mm

Source: Los Angeles County GIS Data Portal, Rainfall Intensity, 2011

25-YEAR STORM PRECIPITATION OVER 24 HOURS



23.0 in / 584 mm

Max Rainfall (14.2 in / 360 mm)

Min Rainfall (2.3 in / 58 mm)

0.0 in / 0 mm

Source: Los Angeles County GIS Data Portal, Rainfall Intensity, 2011

50-YEAR STORM PRECIPITATION OVER 24 HOURS

23.0 in / 584 mm

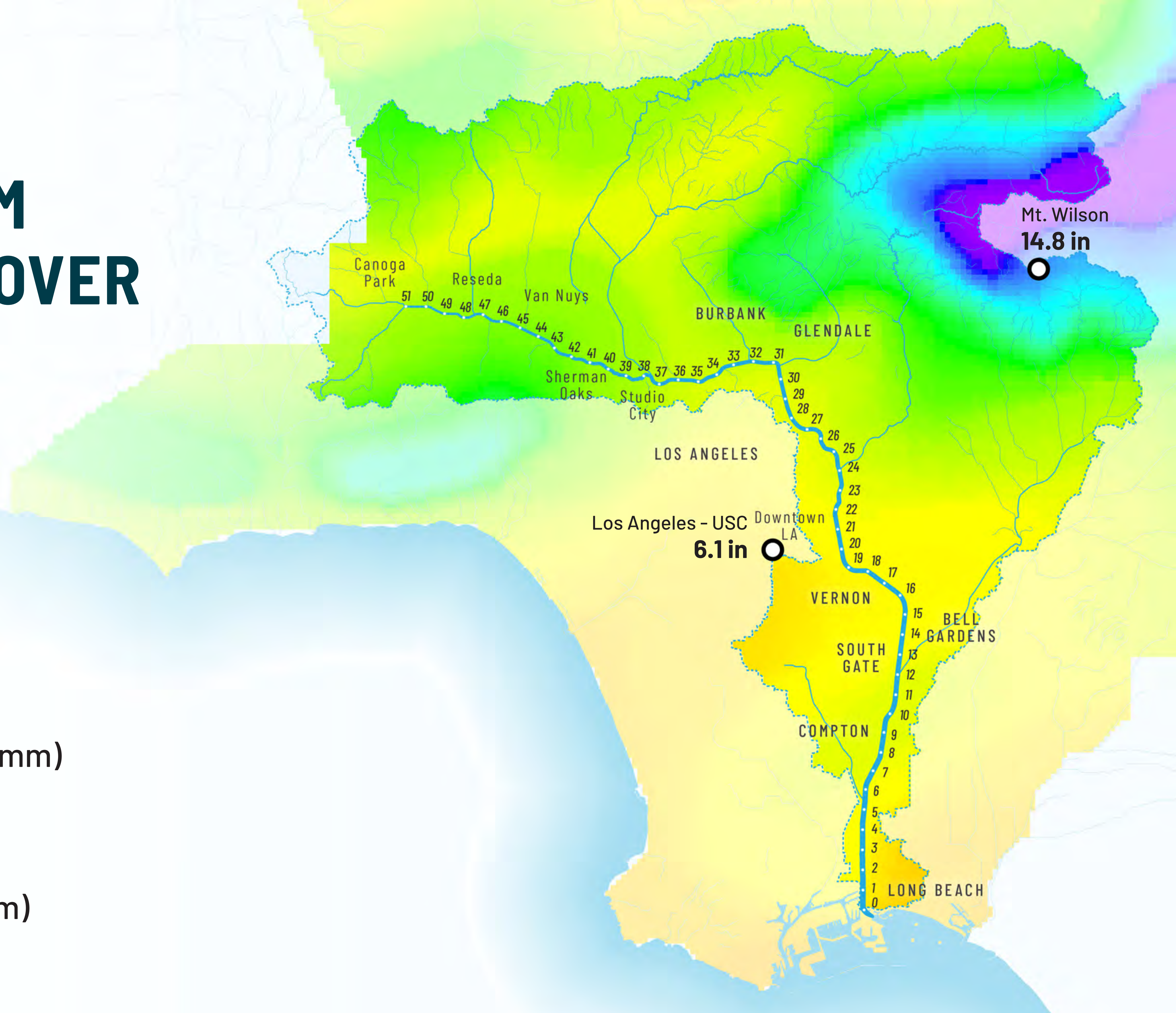
Max Rainfall (16.1 in / 410 mm)

Min Rainfall (2.5 in / 66 mm)

0.0 in / 0 mm

Source: Los Angeles County GIS Data Portal, Rainfall Intensity, 2011

100-YEAR STORM PRECIPITATION OVER 24 HOURS



23.0 in / 584 mm

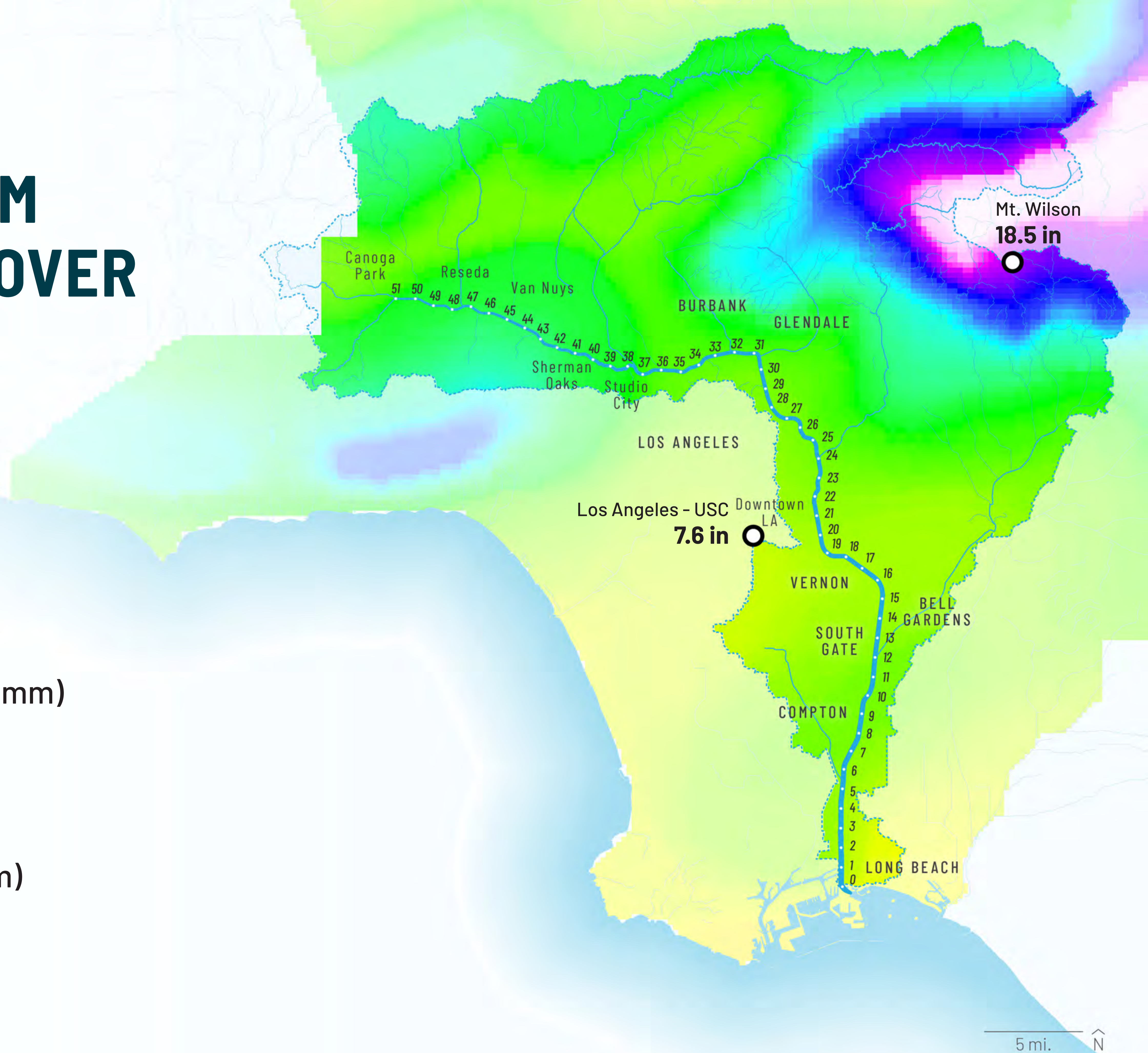
— Max Rainfall (18.1 in / 460 mm)

— Min Rainfall (2.9 in / 74 mm)

0.0 in / 0 mm

Source: Los Angeles County GIS Data Portal, Rainfall Intensity, 2011

500-YEAR STORM PRECIPITATION OVER 24 HOURS



23.0 in / 584 mm

— Max Rainfall (22.6 in / 574 mm)

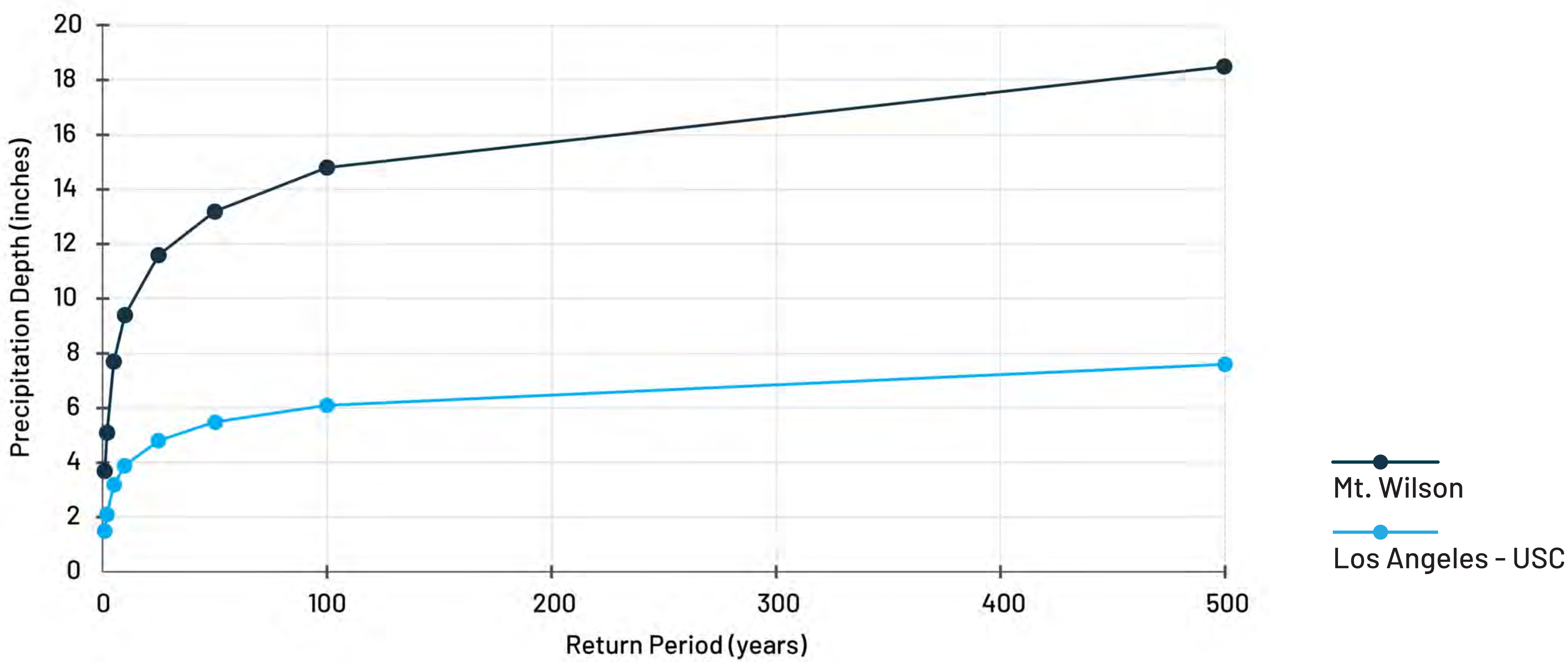
— Min Rainfall (3.6 in / 92 mm)

0.0 in / 0 mm

Source: Los Angeles County GIS Data Portal, Rainfall Intensity, 2011

STORM RETURN PERIODS

24-hour Precipitation Depth versus Return Period



Source: Los Angeles County GIS Data Portal, Rainfall Intensity, 2011

EXTREME EVENTS HAPPEN

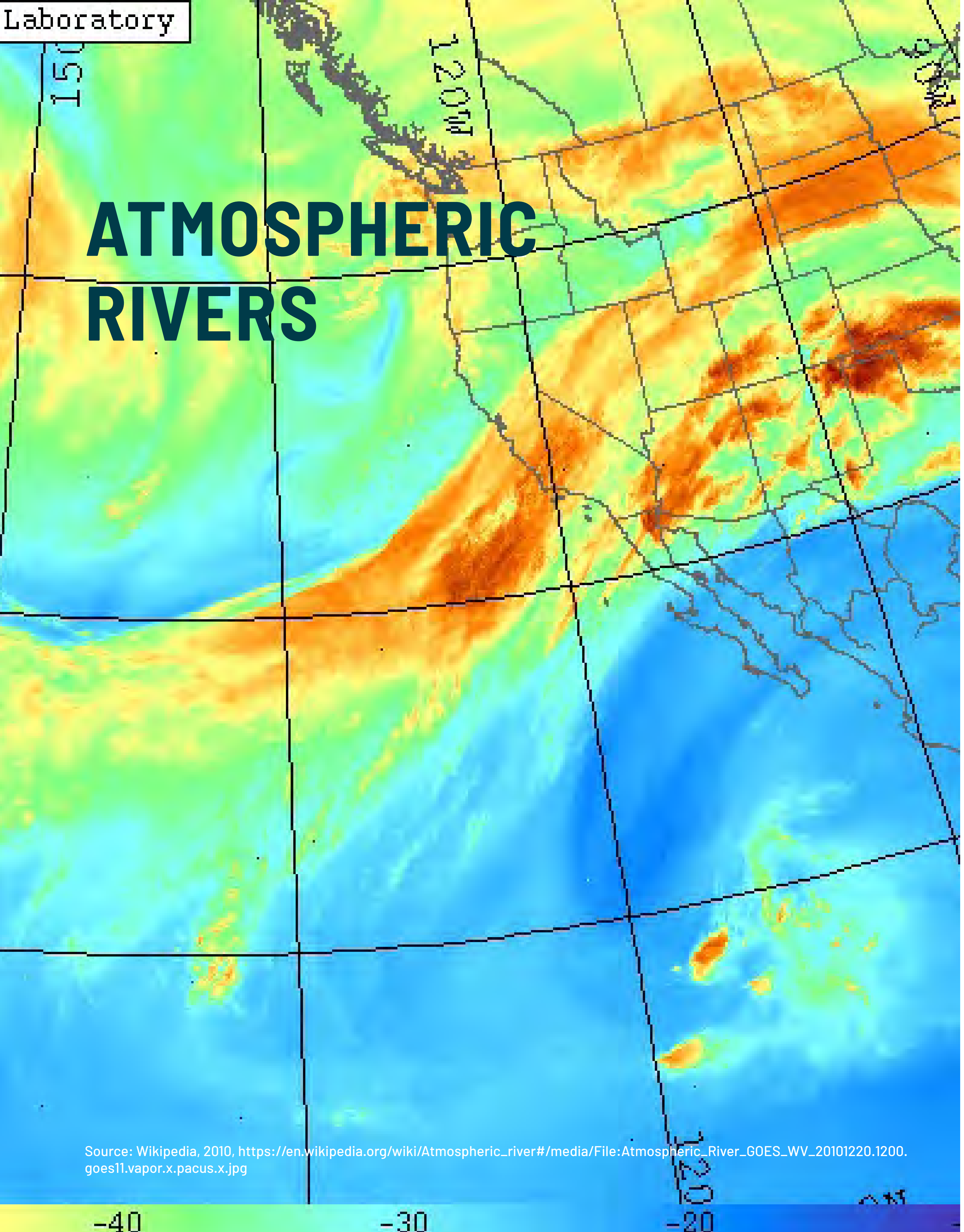
SUPERSTORM SANDY

Source: Jolliffe, R., Flickr User, 2012, https://flic.kr/p/dpcGmB

HURRICANE HARVEY

Source: Chandler, J., Flickr User, 2017, https://flic.kr/p/Y487SD

ATMOSPHERIC RIVERS



Source: Wikipedia, 2010, https://en.wikipedia.org/wiki/Atmospheric_river#/media/File:Atmospheric_River_GOES_WV_20101220.1200.goes11.vapor.x.pacus.x.jpg

Los Angeles Times

$2.75 DESIGNATED AREAS HIGHER © 2019 WSCE MONDAY, FEBRUARY 18, 2019 latimes.com

ALLEN J. SCHABEN Los Angeles Times

CHILDREN play at the Whittier Narrows Recreation Area. Officials with the U.S. Army Corps of Engineers say that the 60-year-old Whittier Narrows Dam could fail in the event of a very large, very rare storm.

This could leave us all wet

California's 'other big one' — a mega-storm of biblical scope — could swamp cities in the L.A. Basin, experts say

By Louis Sahagun

Scientists call it California's "other big one," and they say it could cause three times as much damage as a major earthquake ripping along the San Andreas fault.

Although it might sound absurd to those who still recall five years of withering drought and mandatory water restrictions, researchers and engineers warn that California may be due for rain of biblical proportions — or what experts call an ARkStorm.

This rare mega-storm — which some say is rendered all the more inevitable because of climate change — would last for weeks and send more than 1.5 million people fleeing as floodwaters inundated cities and formed lakes in the Central Valley and Mojave Desert, according to the U.S. Geological Survey. Officials estimate the structural and economic damage from an ARkStorm (for Atmospheric River 1,000) would amount to more than $725 billion statewide.

In heavily populated areas of the Los Angeles Basin, epic runoff from the San Gabriel Mountains could rapidly overwhelm a flood control dam on the San Gabriel River and unleash floodwaters from Pico Rivera to Long Beach, according to a recent analysis by the U.S. Army Corps of Engineers.

In a series of recent public hearings, corps officials told residents that the 60-year-old Whittier Narrows Dam no longer met the agency's tolerable-risk guidelines and could fail in the event of a very large, very rare storm, such as the one that devastated California more than 150 years ago.

Specifically, federal engi-

[See **Mega-storm**, A10]

Whittier Narrows Dam

Sources: U.S. Army Corps of Engineers, Nextzen, OpenStreetMap

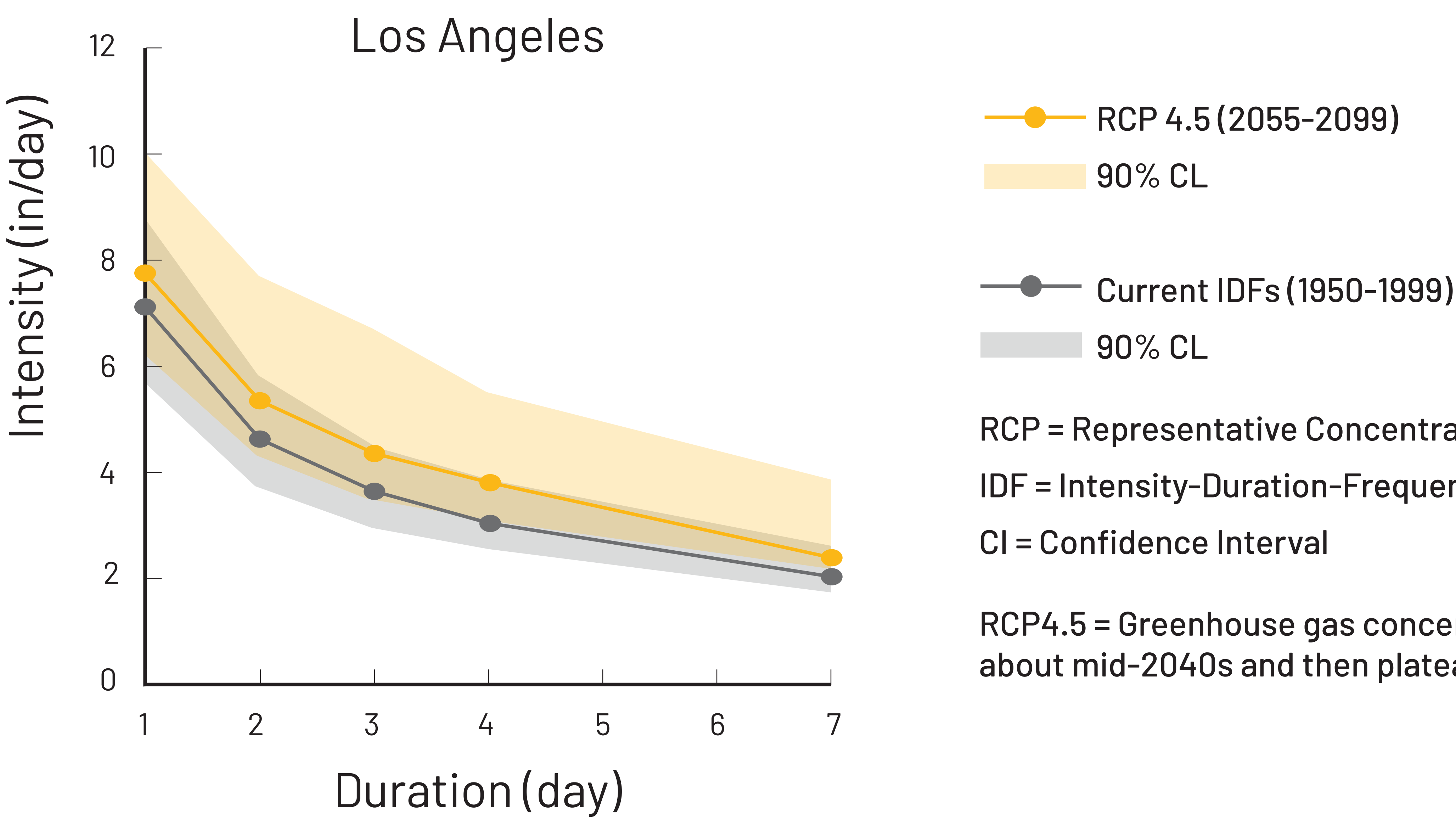
Los Angeles Times

ELECTION 2020

Source: Sahagun, L. LA Times. February 2019, https://www.latimes.com/local/california/la-me-ln-mega-storm-dam-failure-20190218-story.html

CLIMATE CHANGE

Current rainfall design frequencies may underestimate future climate conditions.



RCP = Representative Concentration Pathways

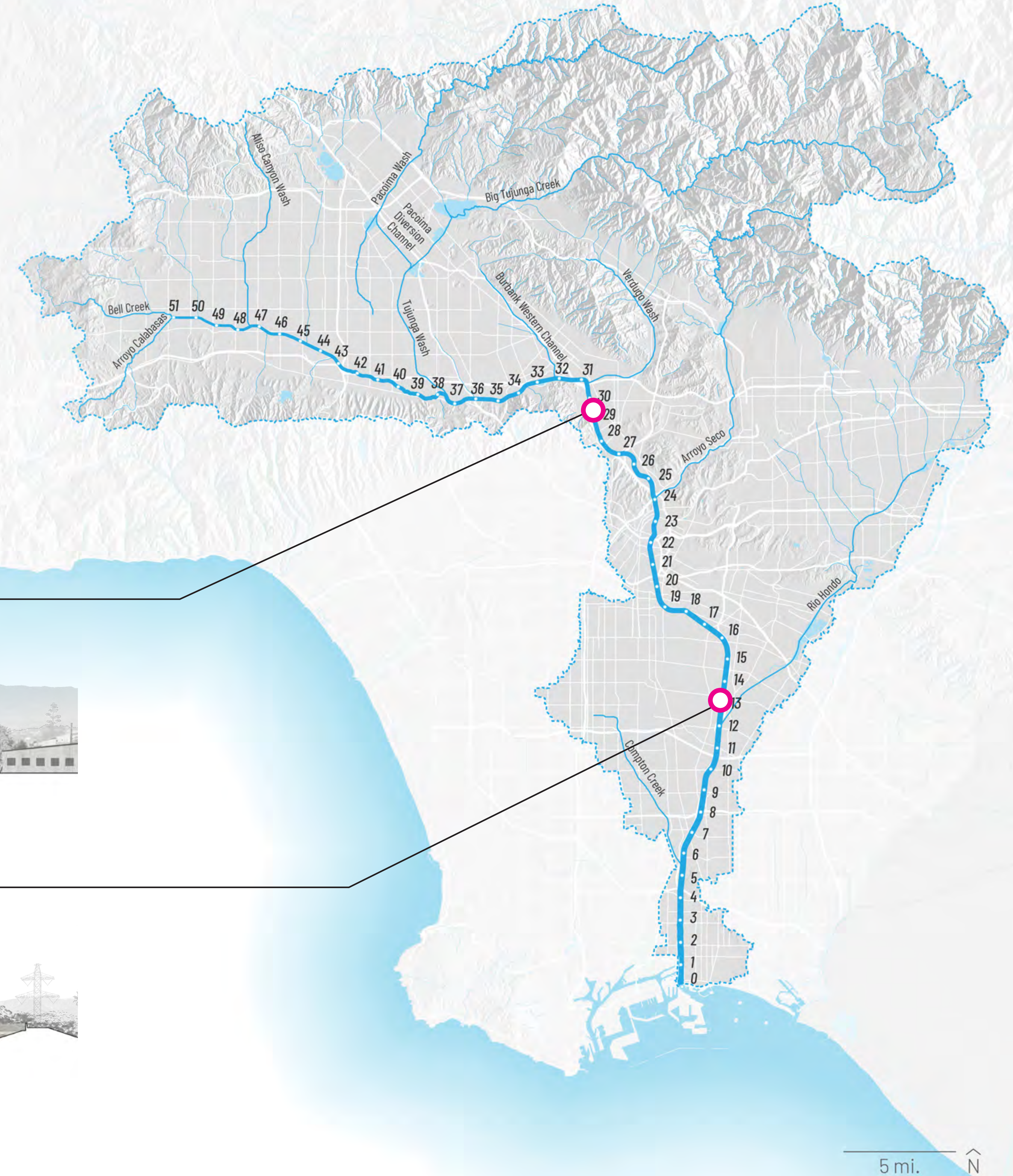
IDF = Intensity-Duration-Frequency

CI = Confidence Interval

RCP4.5 = Greenhouse gas concentrations continue upward until about mid-2040s and then plateau.

Source: Modified from AghaKouchak, Amir, Elisa Ragno, Charlotte Love, and Hamed Moftakhari. (University of California, Irvine). 2018. Projected changes in California's precipitation intensity-duration-frequency curves. California's Fourth Climate Change Assessment, California Energy Commission. Publication Number: CCCA4-CEC-2018-005, Geosyntec, OLIN

ANALYSIS LOCATIONS



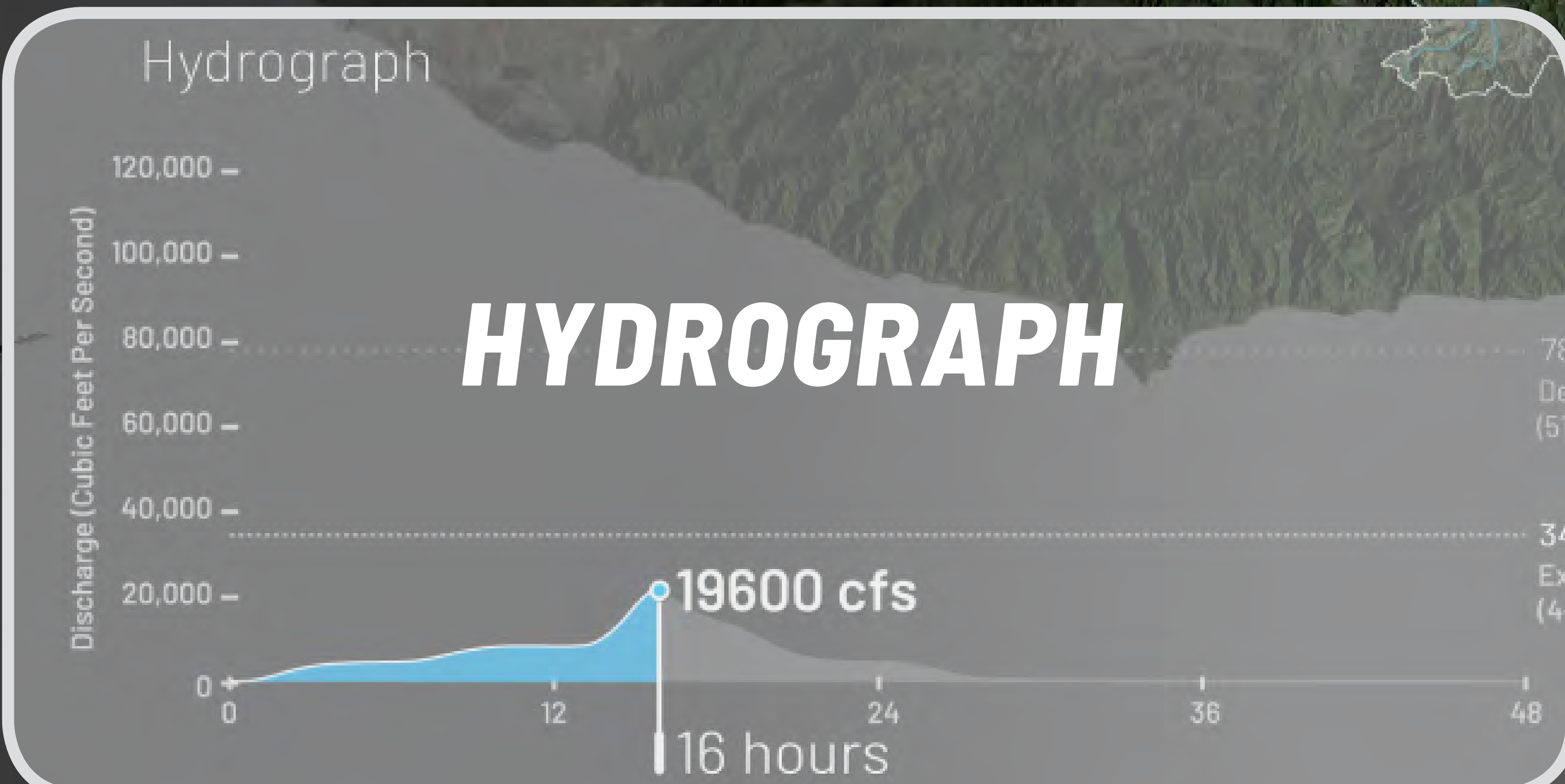
Section at Glendale Narrows (River Mile 29)

Section at Firestone Blvd (River Mile 13)

Source: Geosyntec, OLIN

EXISTING 2-YEAR STORM EVENT

HEC-HMS Model:
Glendale Narrows (River Mile 29)



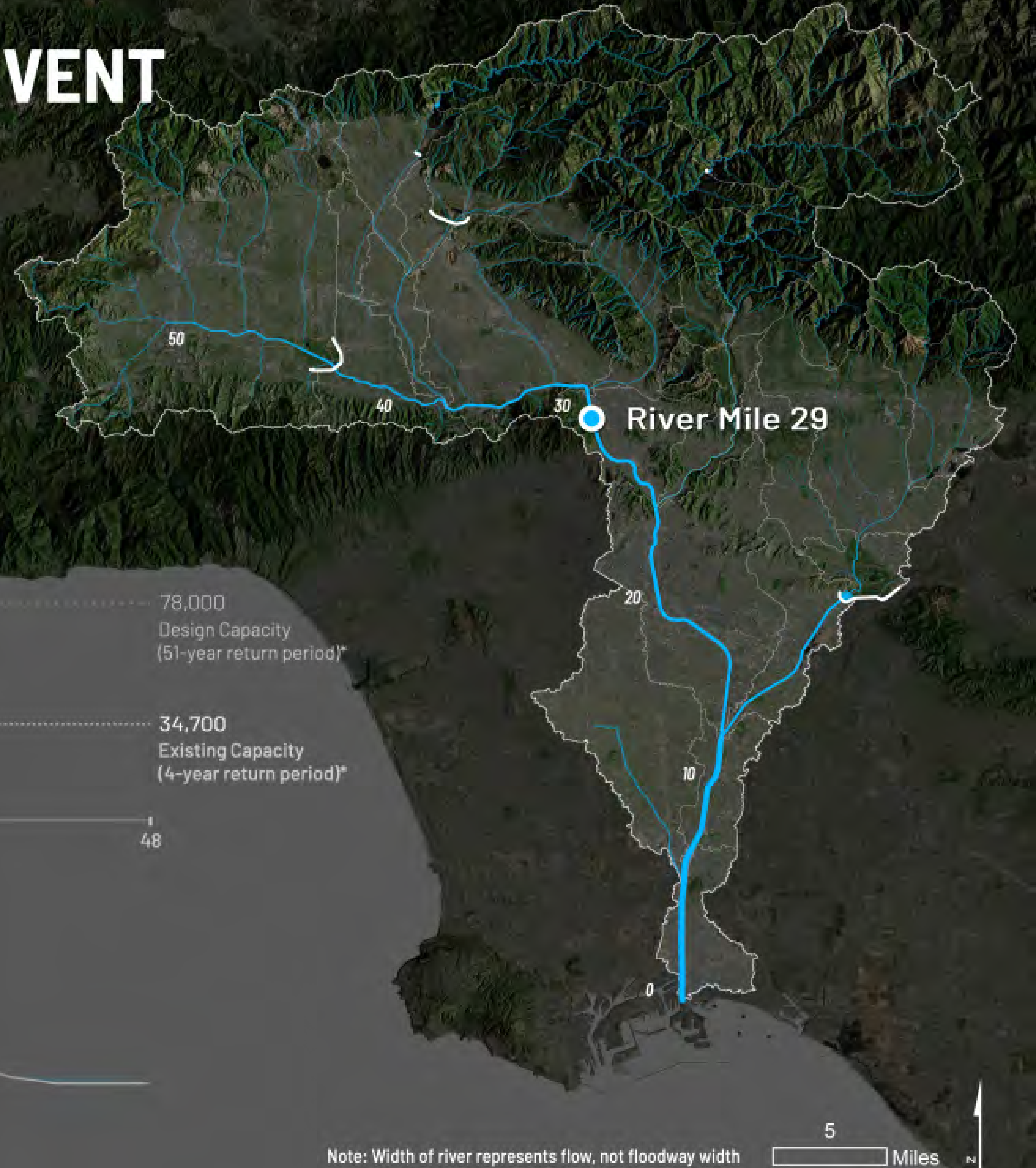
EXISTING 2-YEAR STORM EVENT

HEC-HMS Model: Glendale Narrows (River Mile 29)

Hydrograph

Channel Section

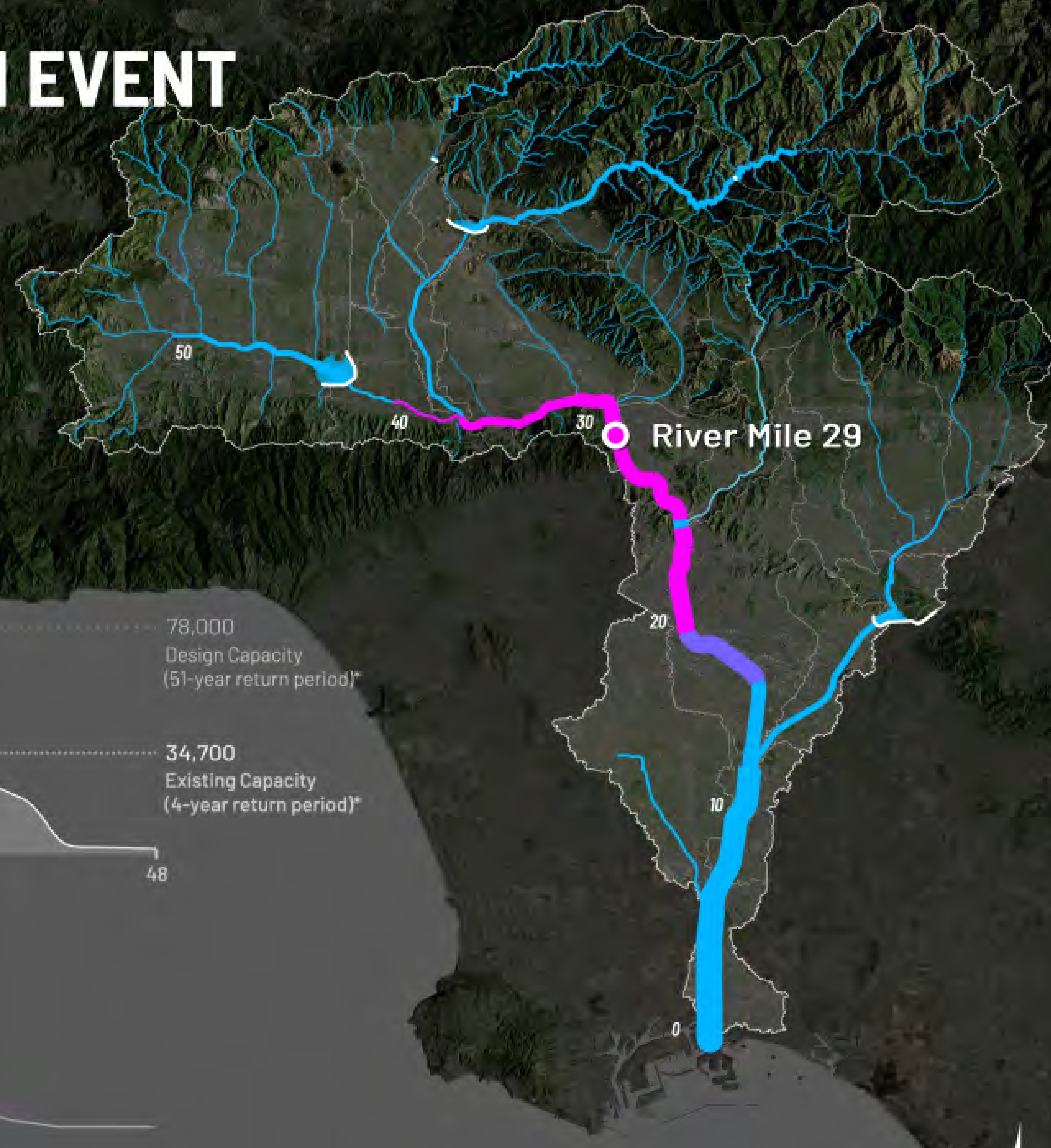
Geosyntec, OLIN



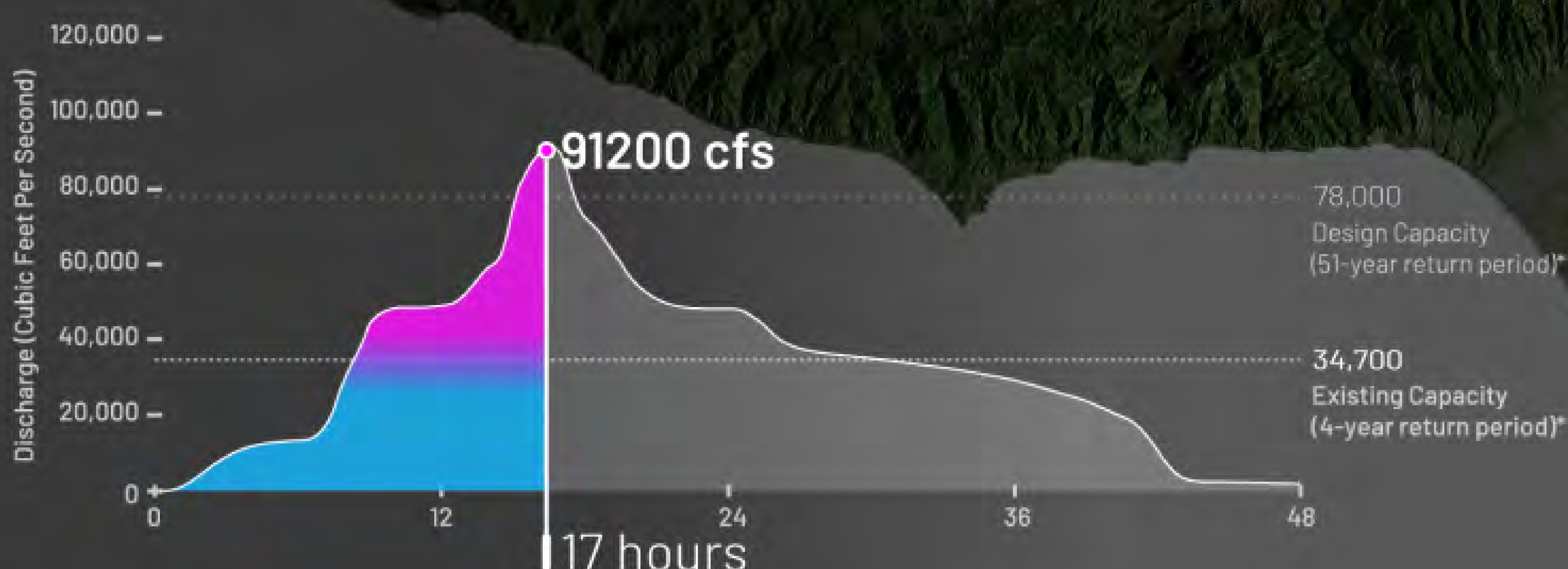
Note: Width of river represents flow, not floodway width

EXISTING 100-YEAR STORM EVENT

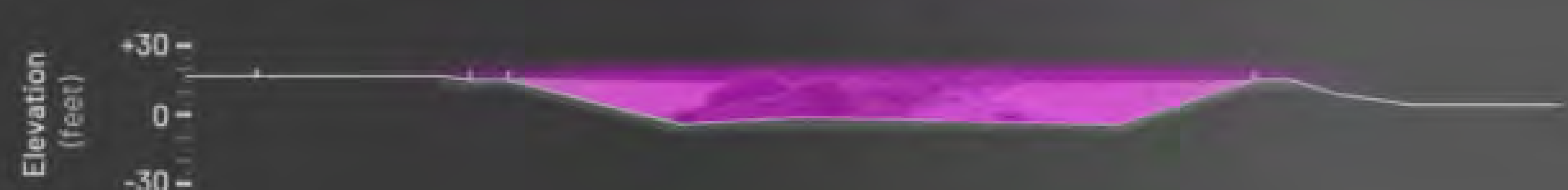
HEC-HMS Model:
Glendale Narrows (River Mile 29)



Hydrograph



Channel Section

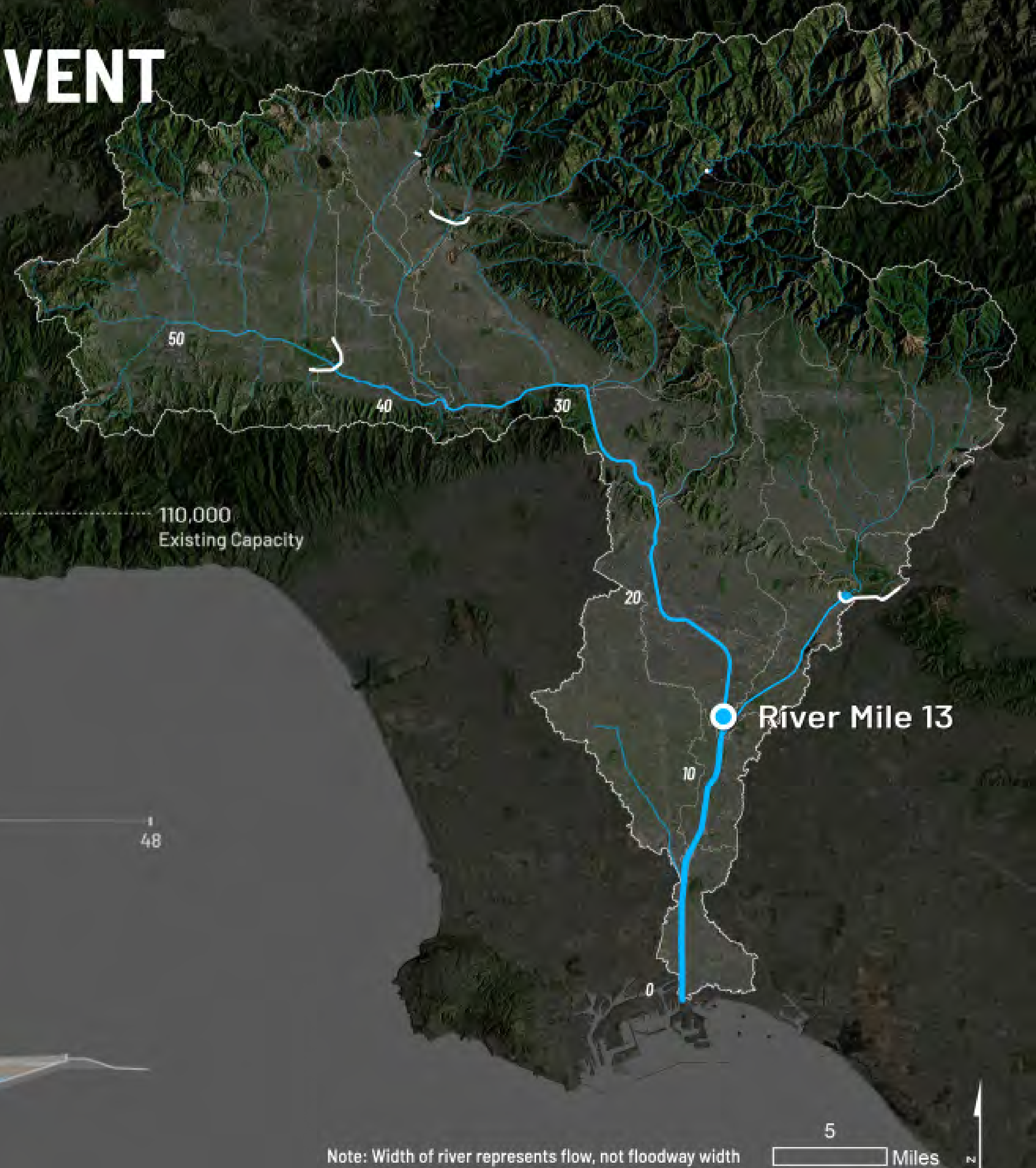


Geosyntec, OLIN

Note: Width of river represents flow, not floodway width

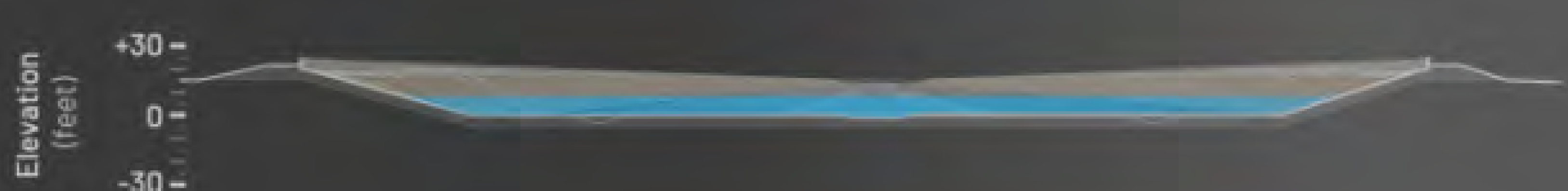
EXISTING 2-YEAR STORM EVENT

HEC-HMS Model:
Firestone Blvd. (River Mile 13)



Hydrograph

Channel Section

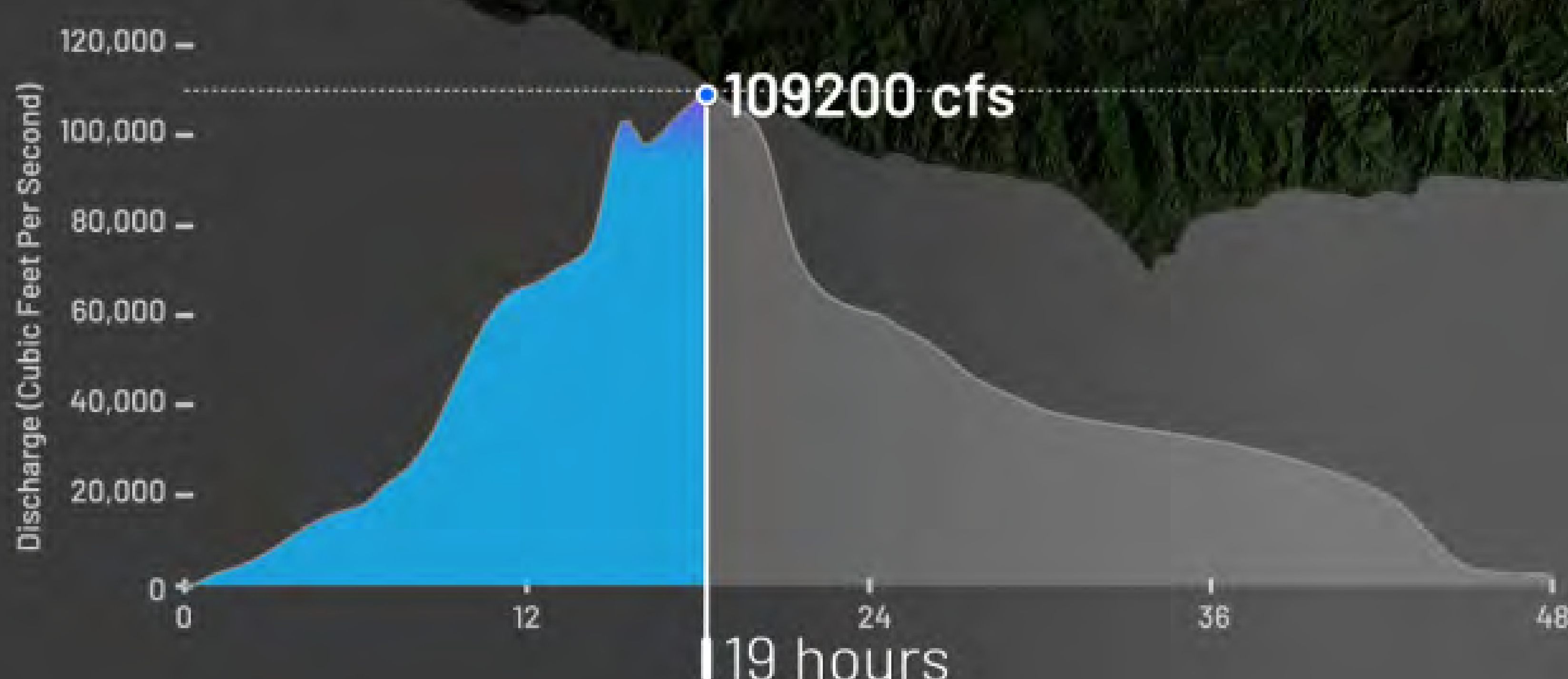


Geosyntec, OLIN

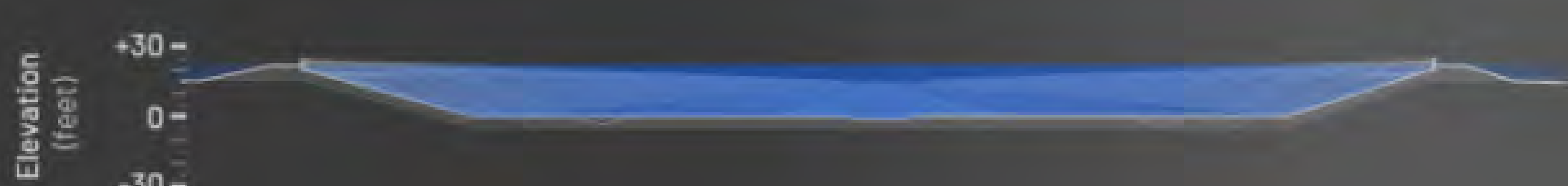
EXISTING 100-YEAR STORM EVENT

HEC-HMS Model:
Firestone Blvd. (River Mile 13)

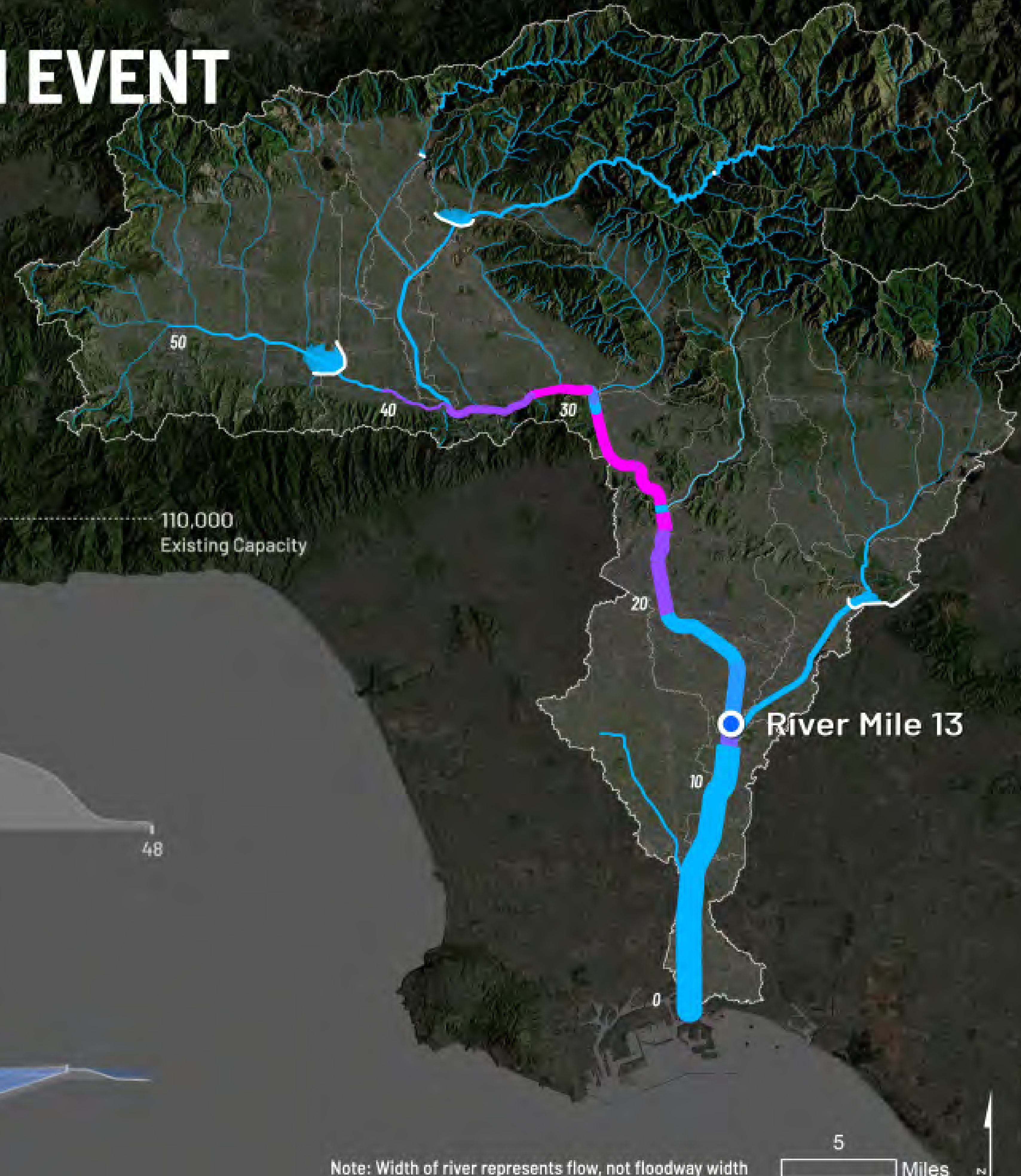
Hydrograph



Channel Section



Geosyntec, OLIN



Note: Width of river represents flow, not floodway width

Q & A AND DISCUSSION

Source: USCAE, Los Angeles District, EHyperionAve1928, http://cespl.maps.arcgis.com/apps/MapSeries/index.html?appid=e15694dbf7c54f8c96285a0e74039e69

TIMELINE OF THE LA RIVER

Source: Corps of Engineers Los Angeles District, 1895-1915, Farmland and the Los Angeles River , https://commons.wikimedia.org/wiki/File:Farmland_and_the_Los_Angeles_River_looking_north_from_Elysian_Park_toward_Mount_Washington,_1895-1915_(CHS-2209).jpg

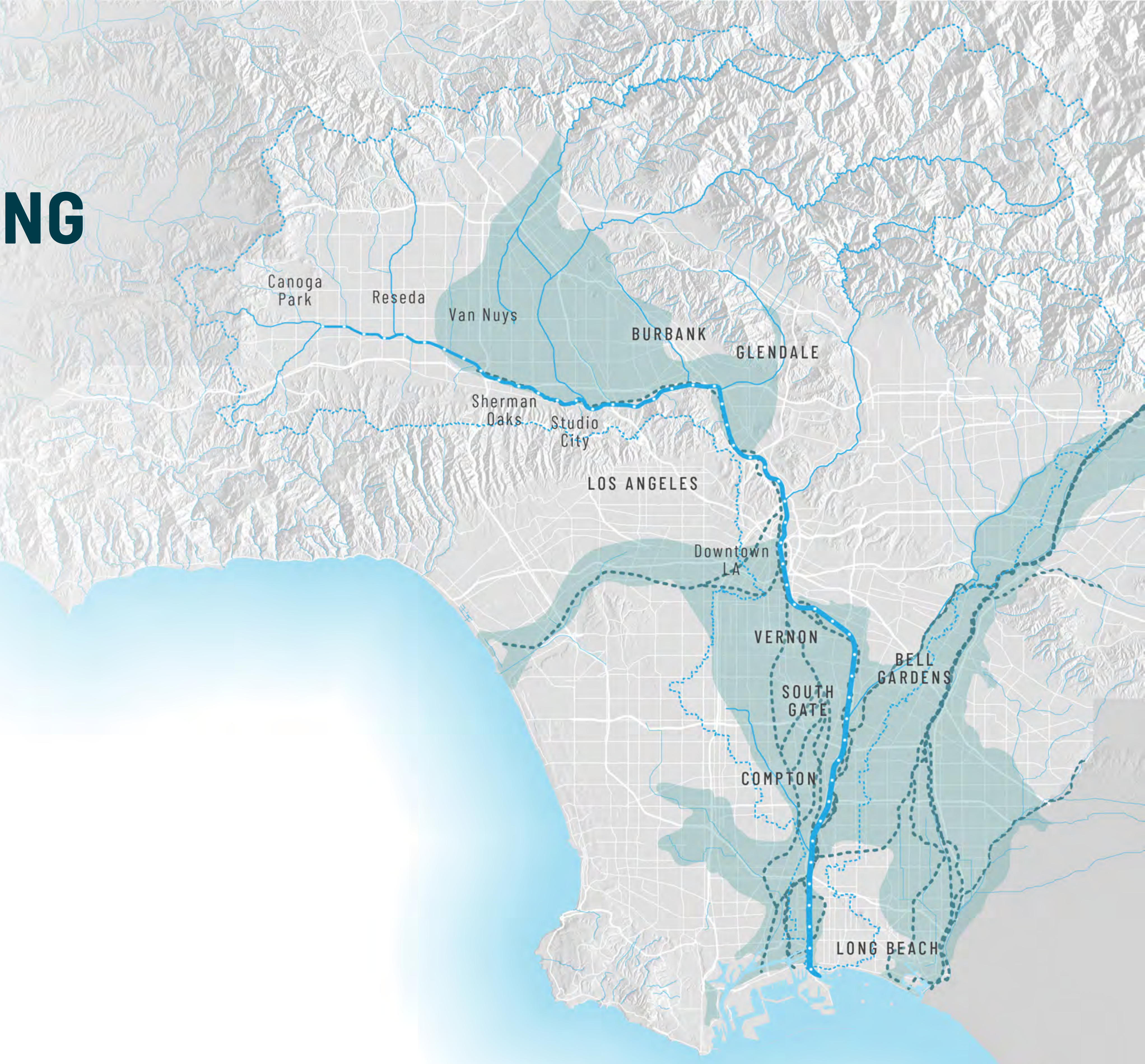
HOW DID WE GET HERE?

HISTORY OF FLOODING AND FLOODPLAINS

A RECENT STORM

CURRENT PROTECTION AND FLOOD RISK

HISTORICAL FLOODING AND RIVER PATHS



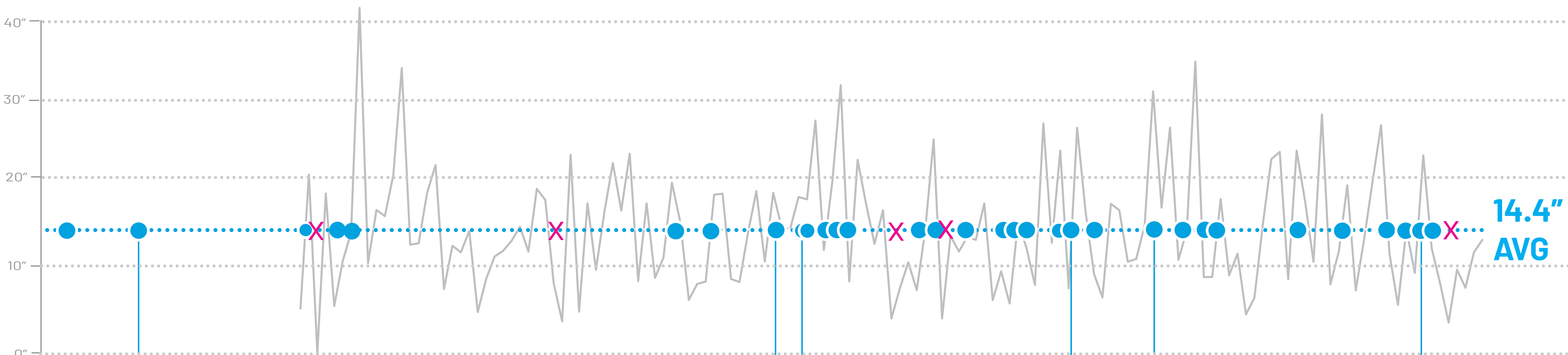
Areas Subject to Inundation

Historical River Paths

Source: Based on Blake Gumprecht, "The Los Angeles River: Its Life, Death, and Possible Rebirth.", 2001, California State University, Northridge Environmental Geography Lab, Historical Ecology, 2008, Geosyntec, OLIN

HISTORICAL RAINFALL EVENTS

- Annual average rainfall (Downtown City of Los Angeles)
- Major storm and flooding events
- X Major droughts



1862
Noachian Deluge of California:
- 30 consecutive days of rain
- **35" in LA City**
- **LA River mouth shifts from Venice to Wilmington**

1934
Major Storm:
- **7.36" in LA in 24 hours**
- 45 deaths regionally

1938
Los Angeles Basin Flood:
- 10" rain
- **115 deaths**
- **5,601 homes lost**
- **$70 million damage**

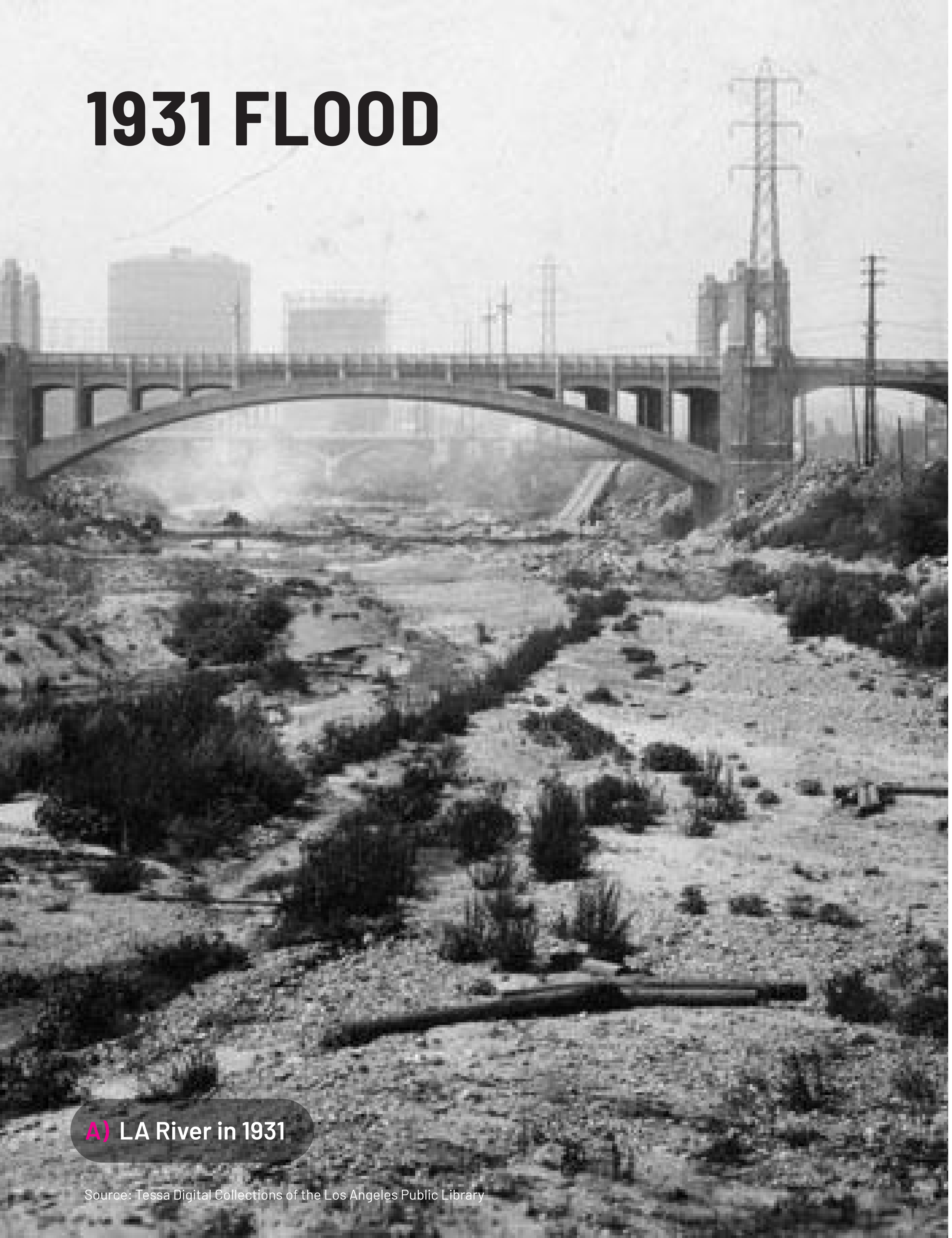
1969
Heavy Rains:
- **13.4" in 10 days**
- 87 deaths in California

1980
6 Storms:
- **12.75" in 9 days**
- 30 deaths regionally

2010
El Nino fuels winter storms:
- downed trees and powerlines
- mud and debris flows prompted evacuation

Source: Western Regional Climate Center, Cooperative Climatological Data Summaries, 2018 & County of Los Angeles Chief Executive Office's Office of Emergency Management, History of Floods, Mudslides, Debris Flows, Landslides in Los Angeles County Operational Area, 2012, https://ceo.lacounty.gov/wp-content/uploads/OEM/HazardsandThreats/Landslides/HAZARDS%20AND%20THREAT%20FLOODS%20-%20MUDSLIDES%20-%20LANDSLIDES%20HISTORY.pdf, Geosyntec, OLIN

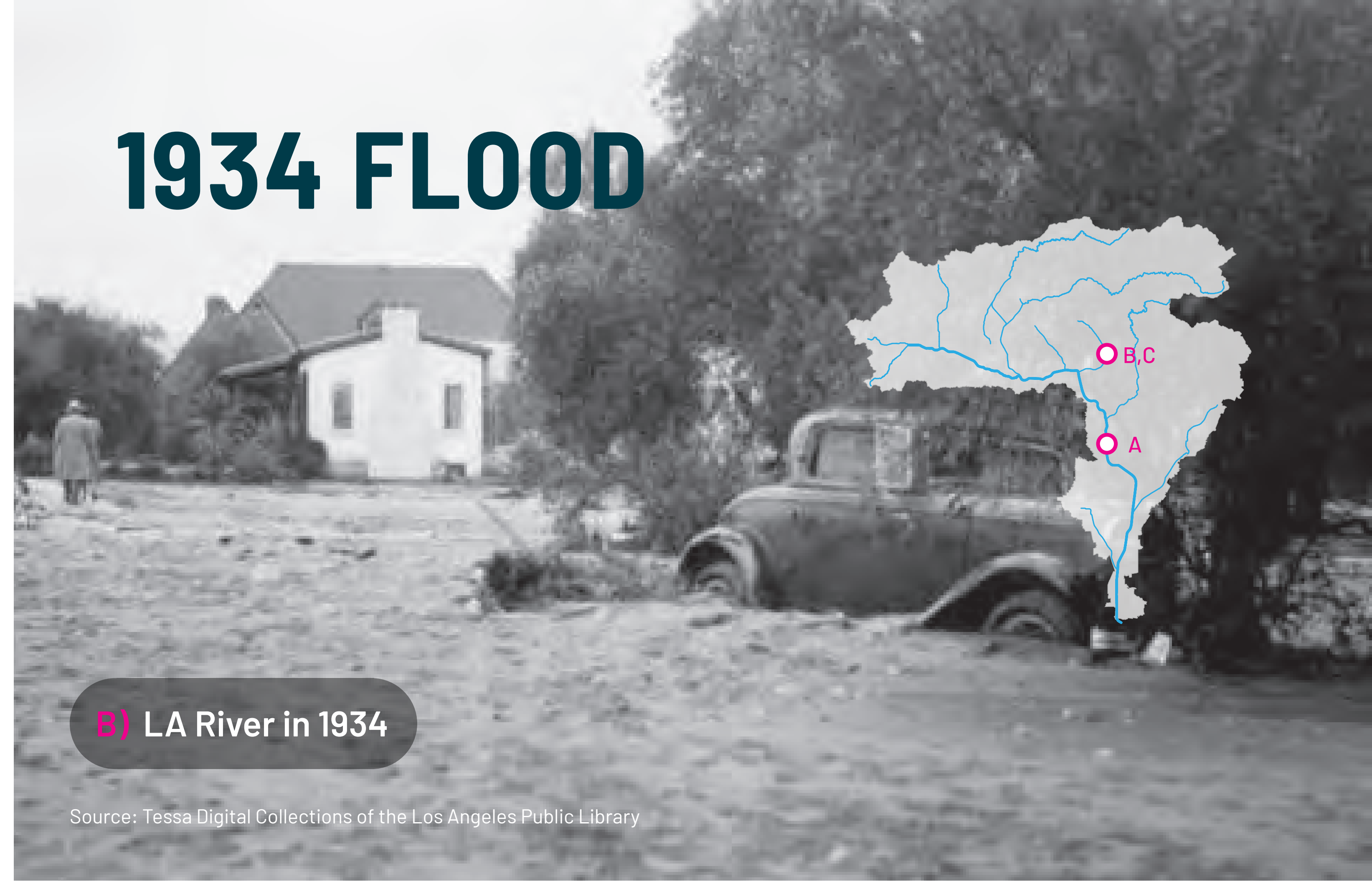
1931 FLOOD



A) LA River in 1931

Source: Tessa Digital Collections of the Los Angeles Public Library

1934 FLOOD



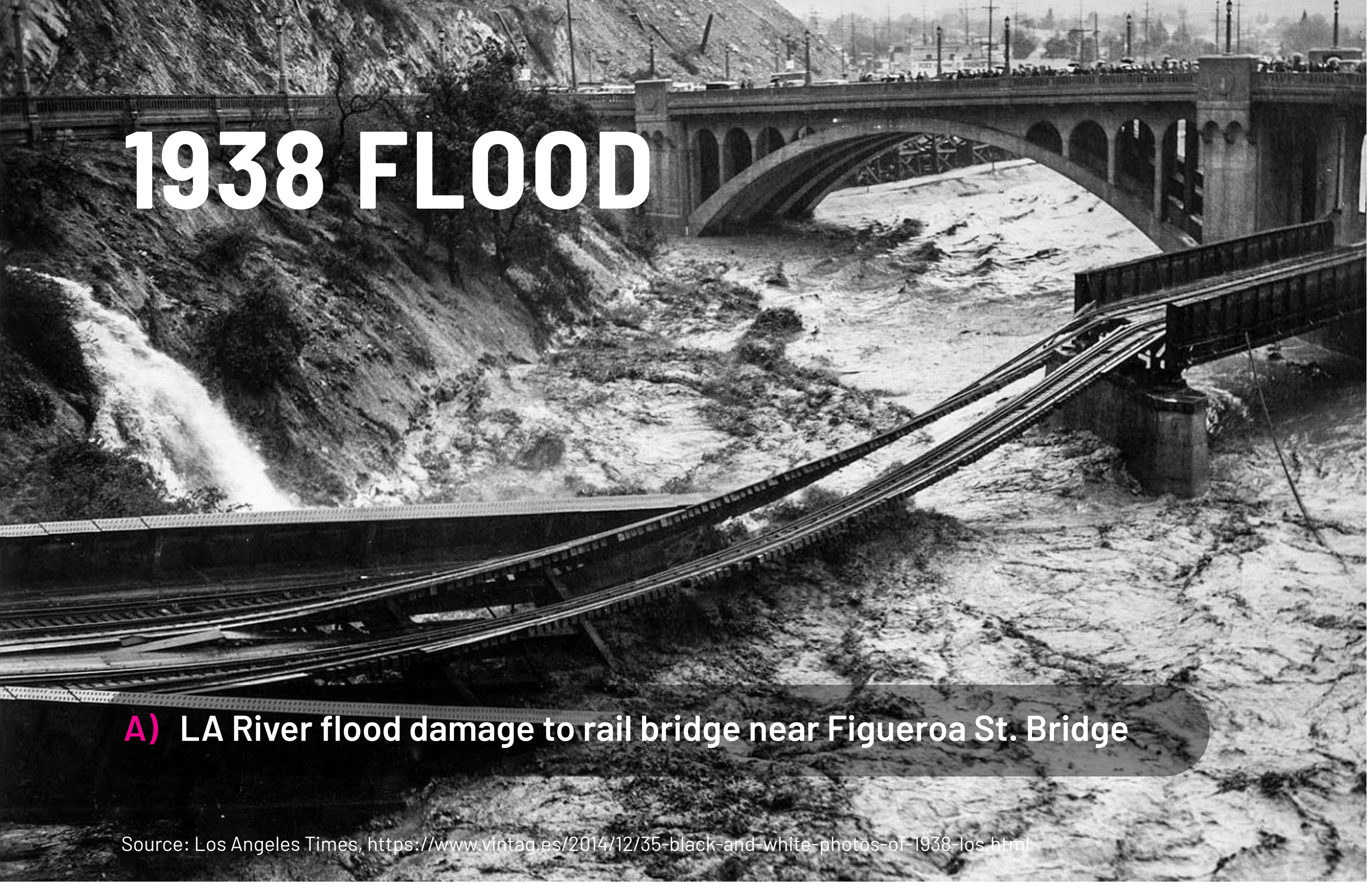
B) LA River in 1934

Source: Tessa Digital Collections of the Los Angeles Public Library

C) LA River in 1934

Source: Tessa Digital Collections of the Los Angeles Public Library

1938 FLOOD

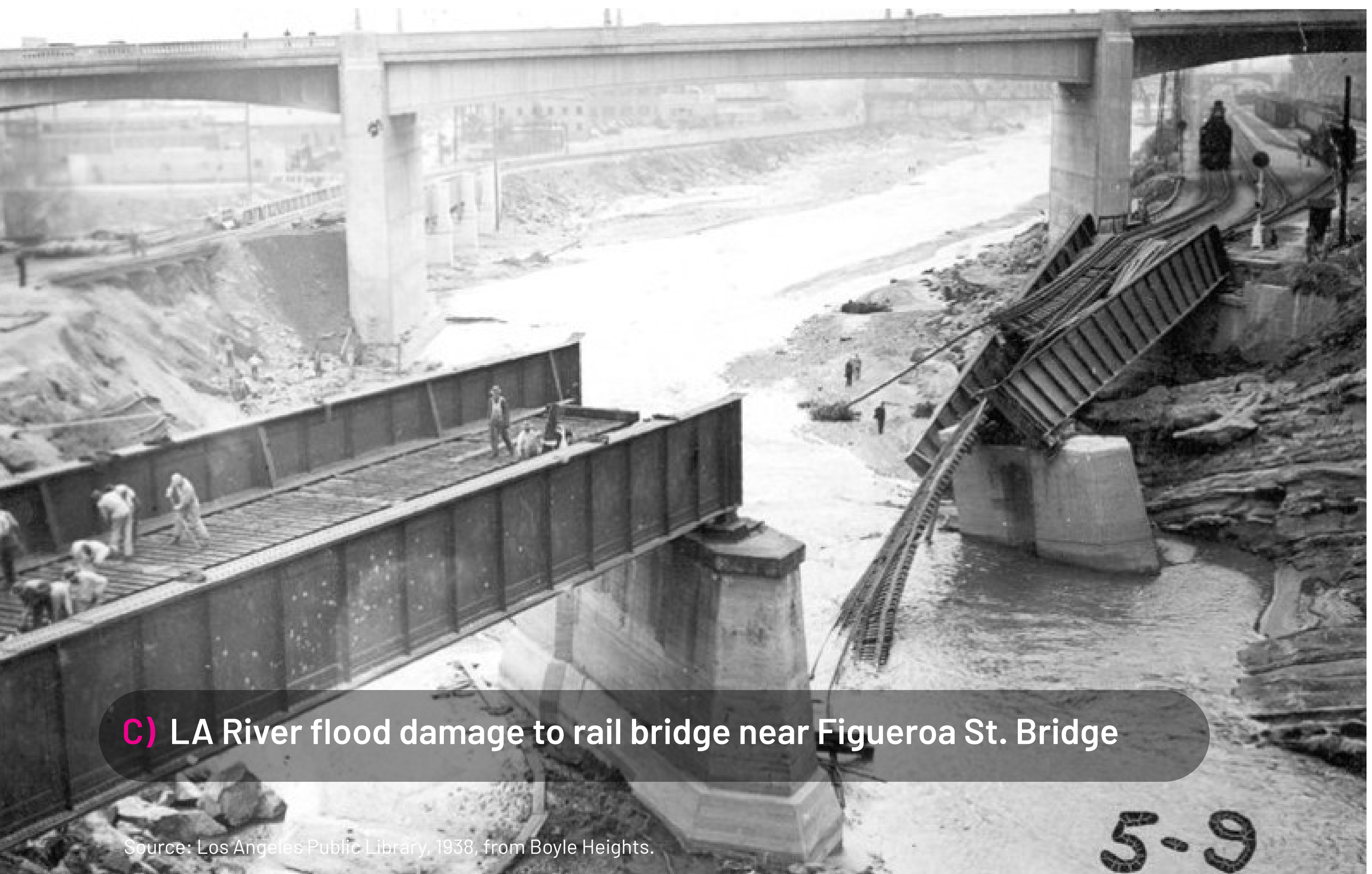


A) LA River flood damage to rail bridge near Figueroa St. Bridge

Source: Los Angeles Times, https://www.vintag.es/2014/12/35-black-and-white-photos-of-1938-los.html

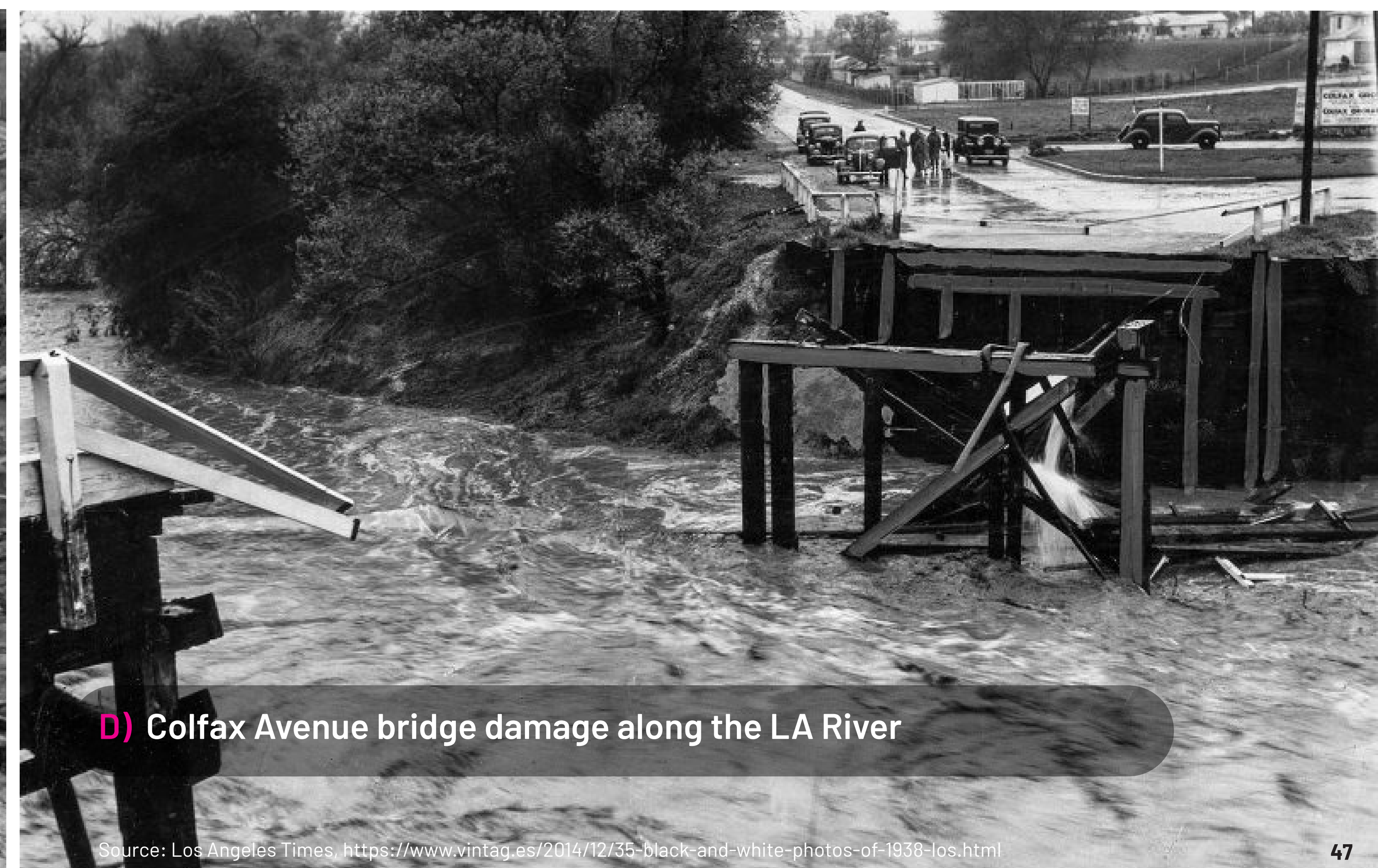
B) Flooding damage along the LA River near Griffith Park

Source: Army Corps of Engineers, 1938, Griffith Park



C) LA River flood damage to rail bridge near Figueroa St. Bridge

Source: Los Angeles Public Library, 1938, from Boyle Heights.



D) Colfax Avenue bridge damage along the LA River

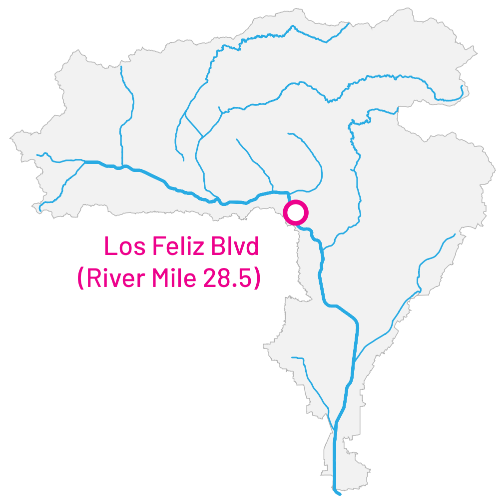
Source: Los Angeles Times, https://www.vintag.es/2014/12/35-black-and-white-photos-of-1938-los.html

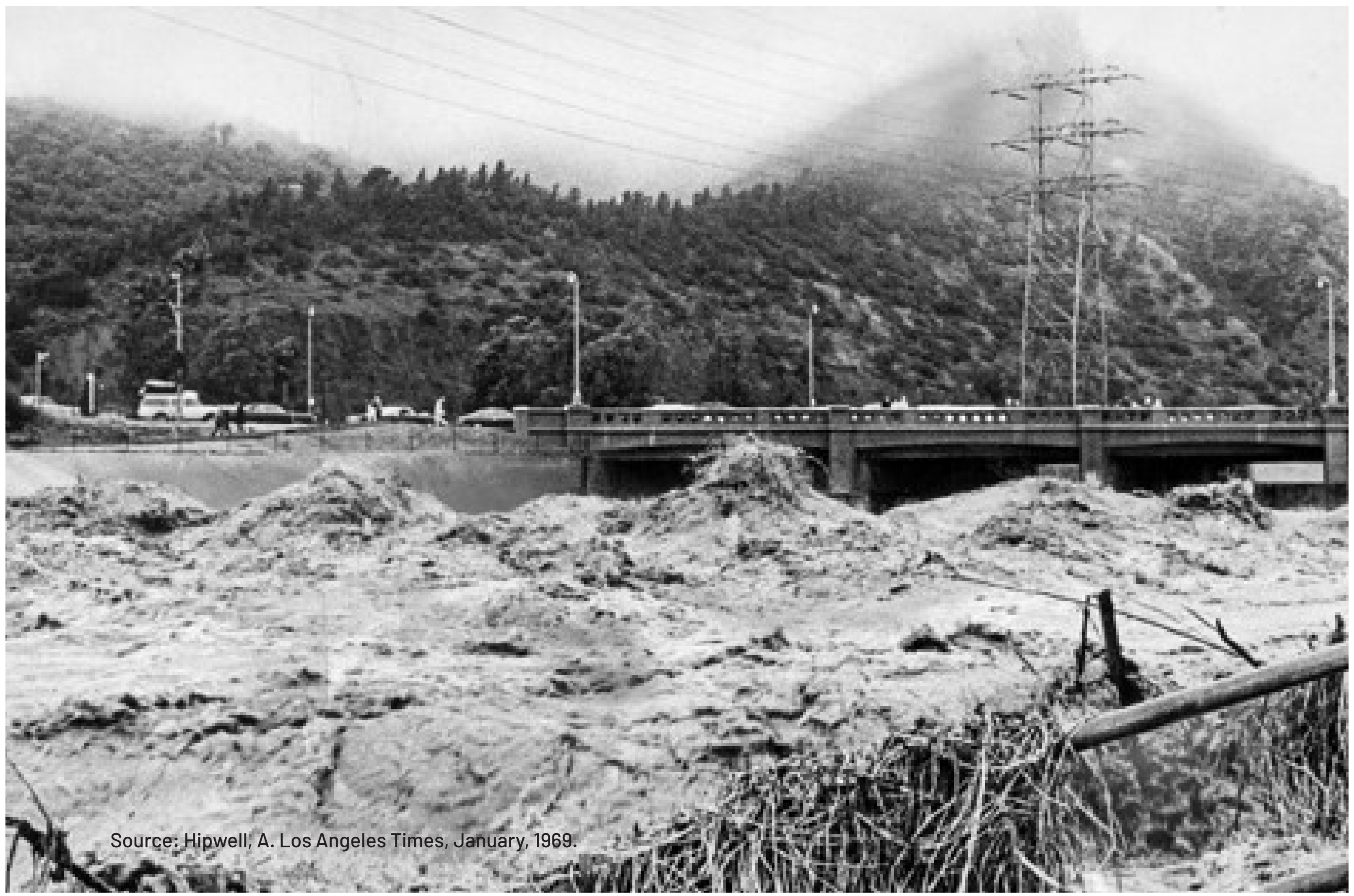
1938 FLOOD

RM 30) Flooding damage at the bend in the LA River near what is now the Ferraro Fields

Source: University of Southern California. Libraries & California Historical Society , View of the flooded Los Angeles River, showing the Griffith Park airport, 1938

1969 FLOOD

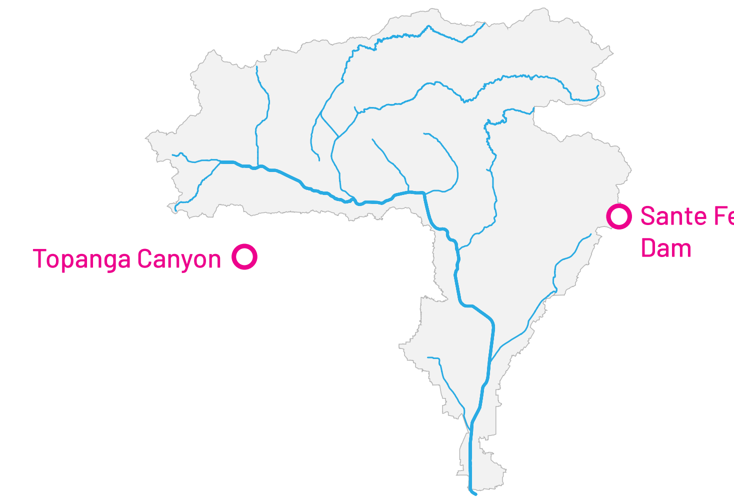




LA River at Los Feliz Boulevard

LA River bridge damage (location unknown)

1980 FLOOD



House along Topanga Canyon, Santa Monica Mountains

San Gabriel River below the Sante Fe Dam

IMPROVEMENTS AFTER THE 1980 FLOOD

Source: OLIN

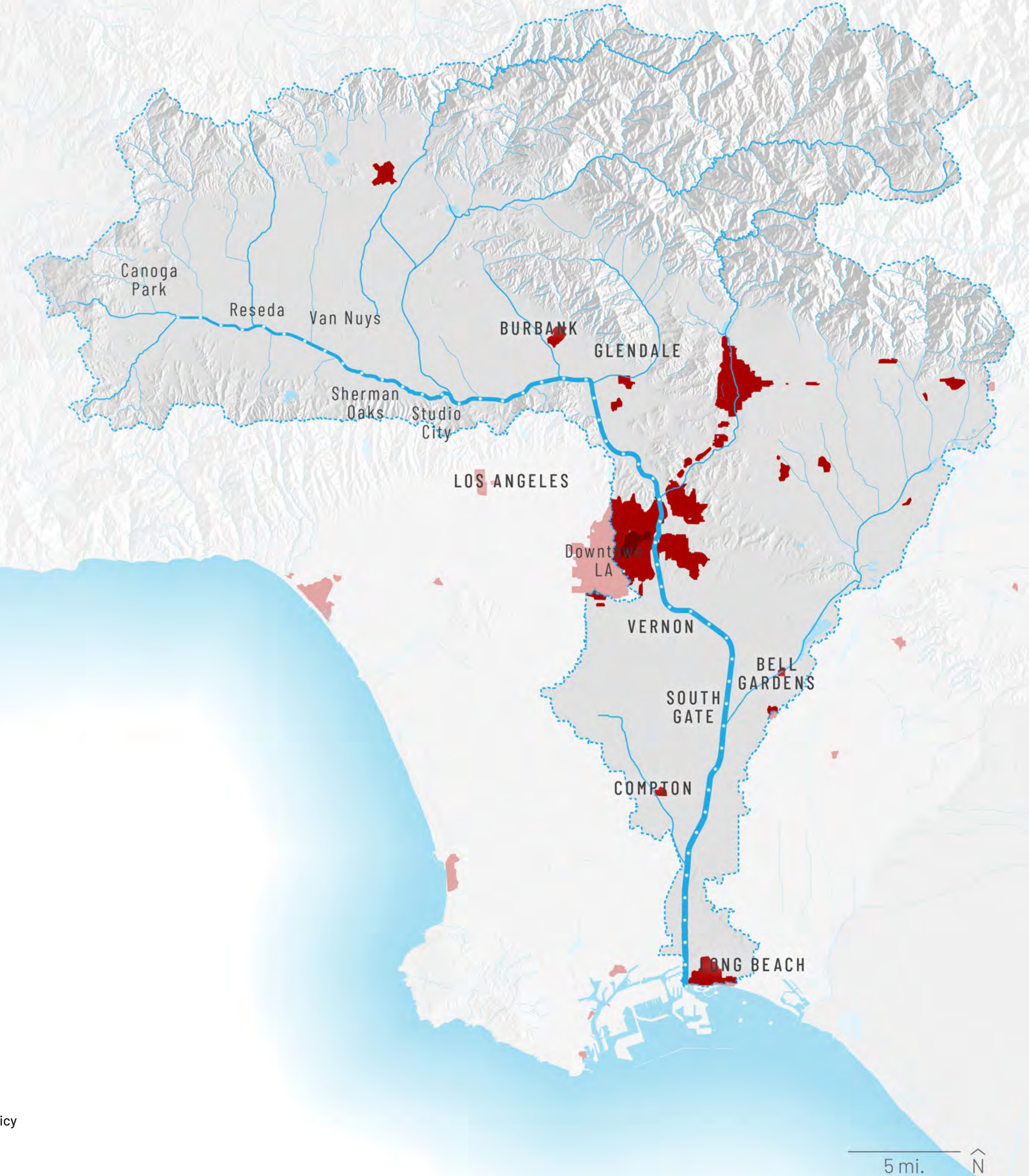
1877 URBAN FOOTPRINT

Historical Urban Footprint

1877

Source: Angel, S., J. Parent, D. L. Civco and A. M. Blei, 2010. Atlas of Urban Expansion, Cambridge MA: Lincoln Institute of Land Policy

1907 URBAN FOOTPRINT

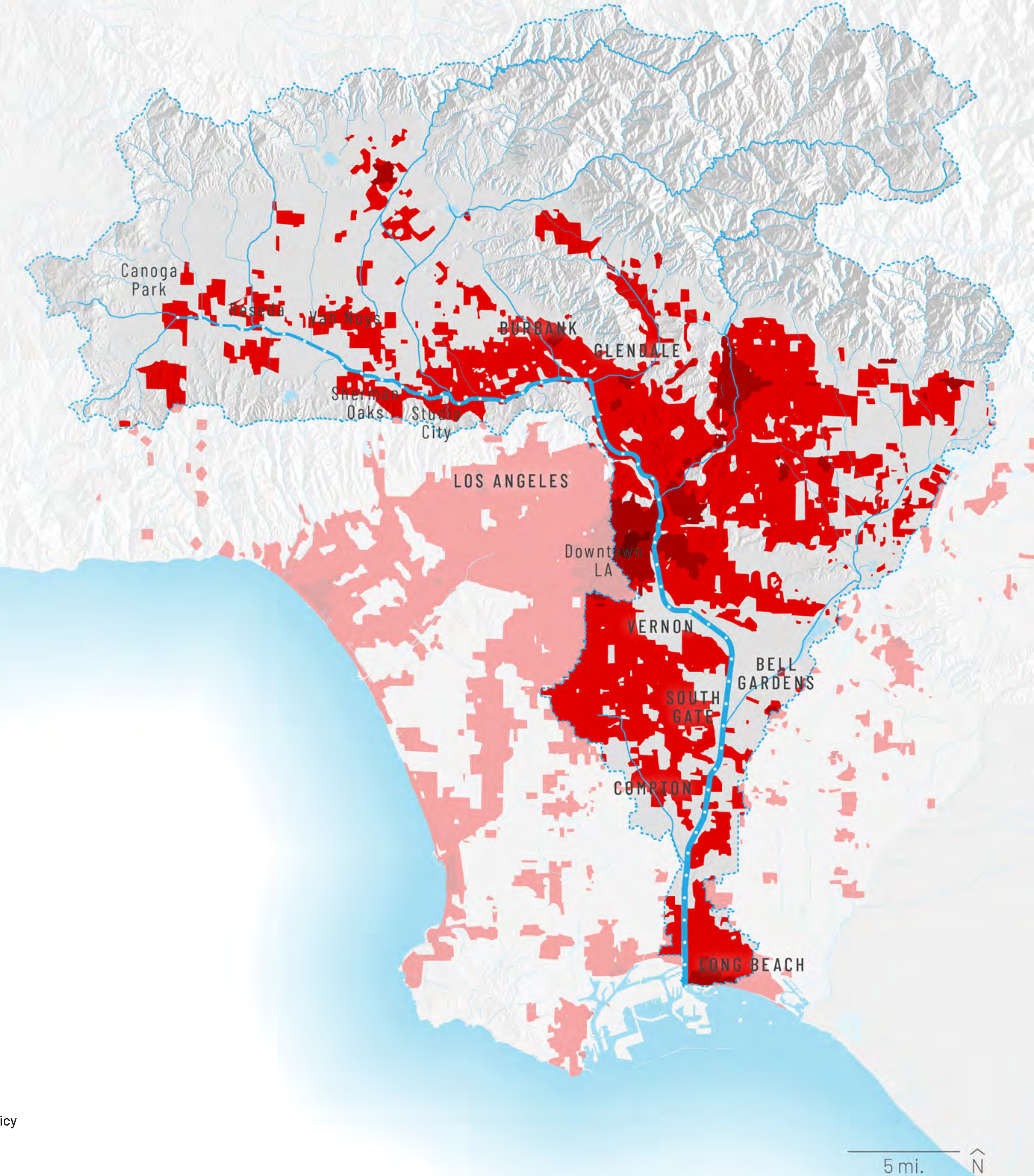


Historical Urban Footprint

- 1877
- 1907

Source: Angel, S., J. Parent, D. L. Civco and A. M. Blei, 2010. Atlas of Urban Expansion, Cambridge MA: Lincoln Institute of Land Policy

1937 URBAN FOOTPRINT

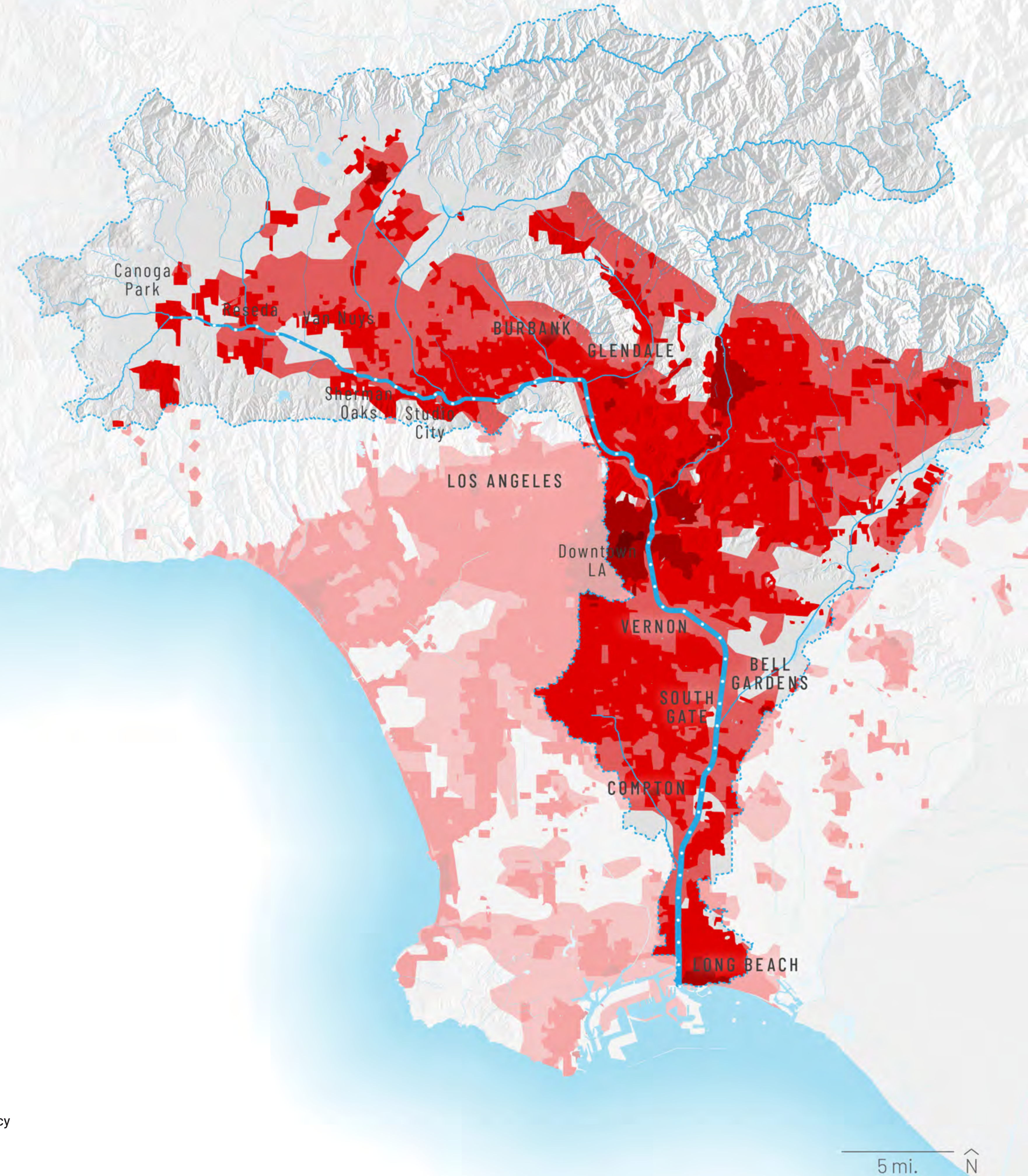


Historical Urban Footprint

- 1877
- 1907
- 1937

Source: Angel, S., J. Parent, D. L. Civco and A. M. Blei, 2010. Atlas of Urban Expansion, Cambridge MA: Lincoln Institute of Land Policy

1950 URBAN FOOTPRINT

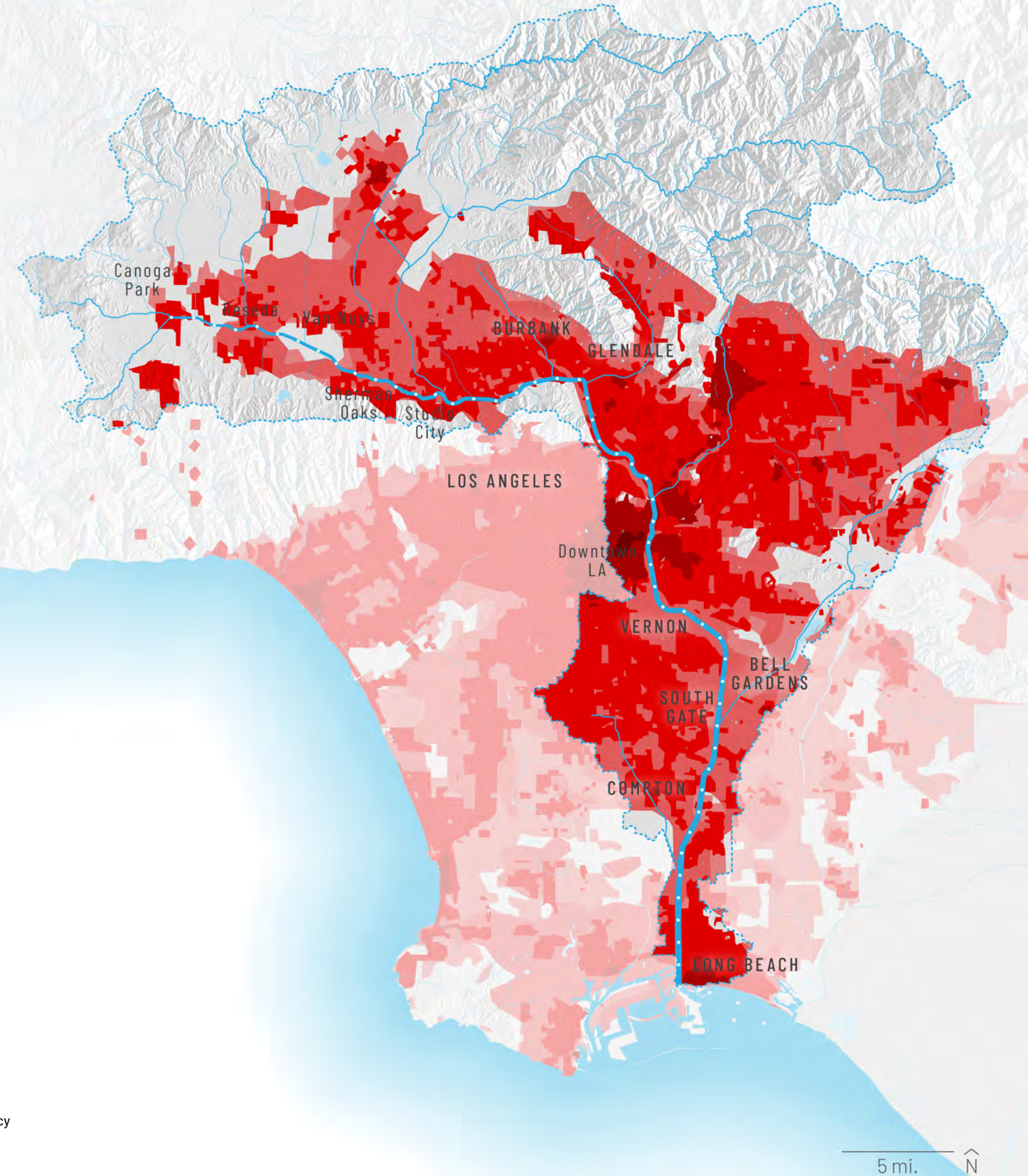


Historical Urban Footprint

- 1877
- 1907
- 1937
- 1950

Source: Angel, S., J. Parent, D. L. Civco and A. M. Blei, 2010. Atlas of Urban Expansion, Cambridge MA: Lincoln Institute of Land Policy

1970 URBAN FOOTPRINT

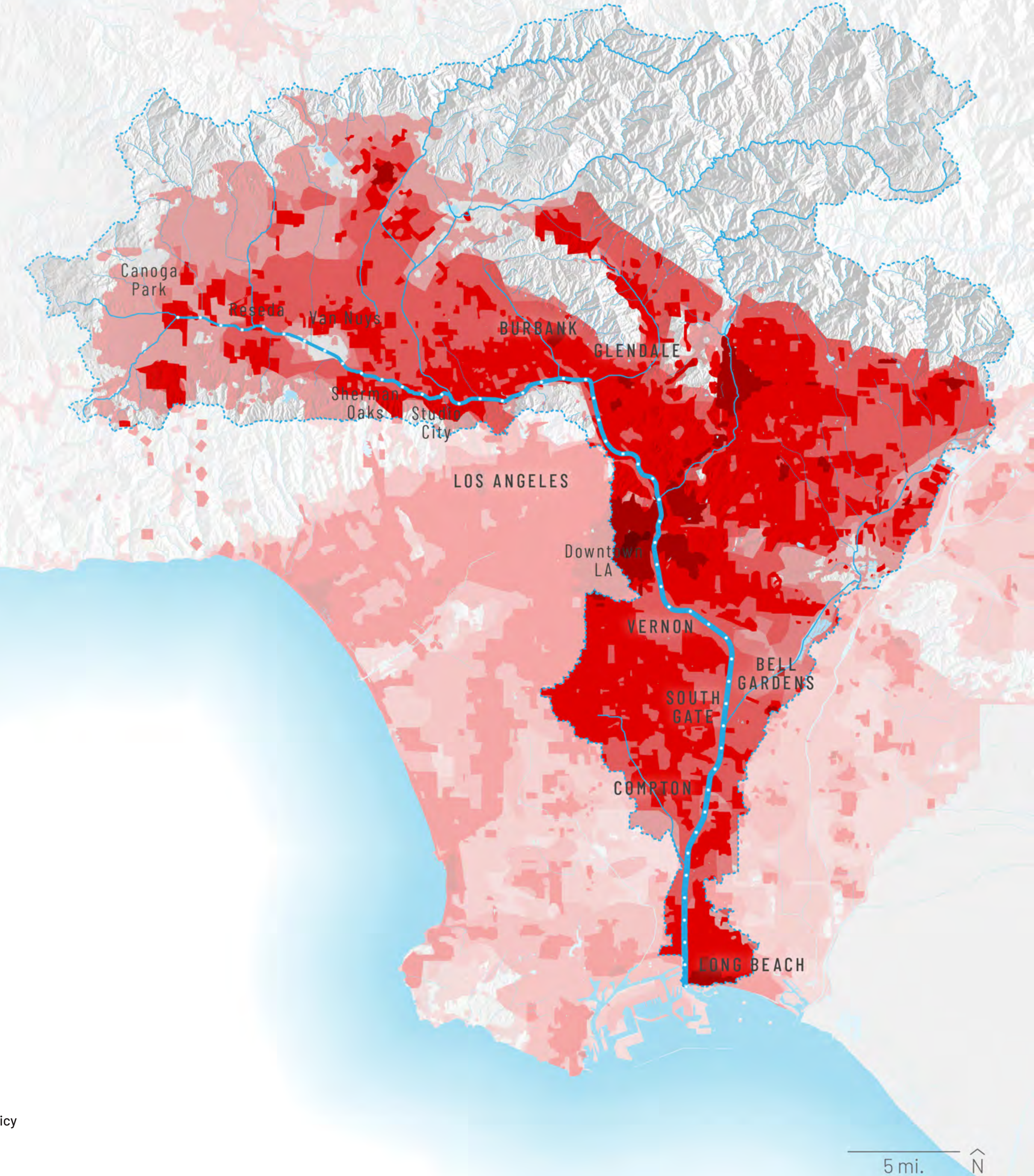


Historical Urban Footprint

- 1877
- 1907
- 1937
- 1950
- 1970

Source: Angel, S., J. Parent, D. L. Civco and A. M. Blei, 2010. Atlas of Urban Expansion, Cambridge MA: Lincoln Institute of Land Policy

2010 URBAN FOOTPRINT

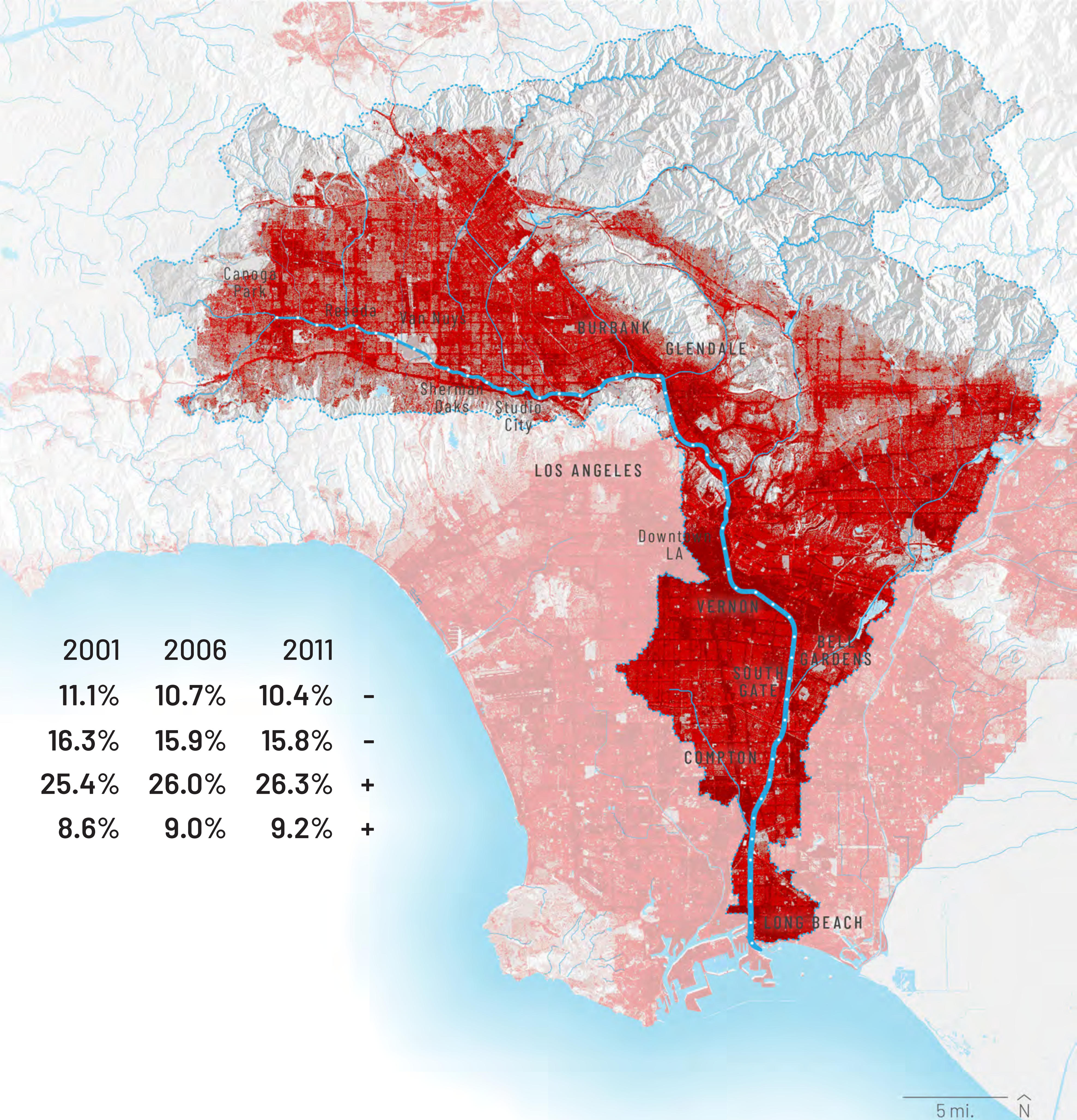


Historical Urban Footprint

- 1877
- 1907
- 1937
- 1950
- 1970
- 2010

Source: Angel, S., J. Parent, D. L. Civco and A. M. Blei, 2010. Atlas of Urban Expansion, Cambridge MA: Lincoln Institute of Land Policy

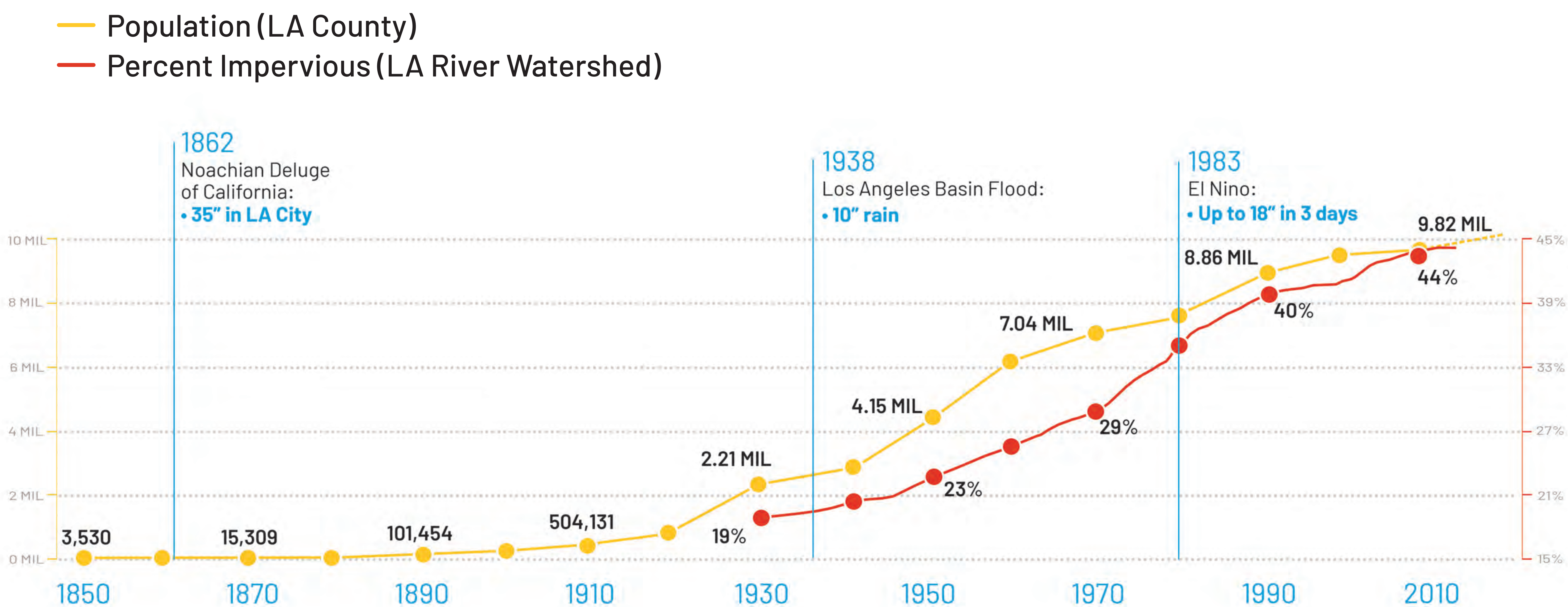
NEARLY ALL OF THE LA RIVER CORRIDOR IS DEVELOPED



Developed Land Cover of the LA River Watershed	2001	2006	2011	
Developed, Open Space	11.1%	10.7%	10.4%	-
Developed, Low Intensity	16.3%	15.9%	15.8%	-
Developed, Medium Intensity	25.4%	26.0%	26.3%	+
Developed, High Intensity	8.6%	9.0%	9.2%	+

Source: National Land Cover Database 2011

LA COUNTY POPULATION AND DEVELOPMENT



Source: Cheyenne Cummings, "Analysis and Implications of Impervious Surface Change Due to Urbanization in the Los Angeles River" (master's thesis, California State University Dominguez Hills, 2016). "Historical General Population City & County of Los Angeles", *Los Angeles Almanac,* 1850-2010, http://www.laalmanac.com/population/po02.php

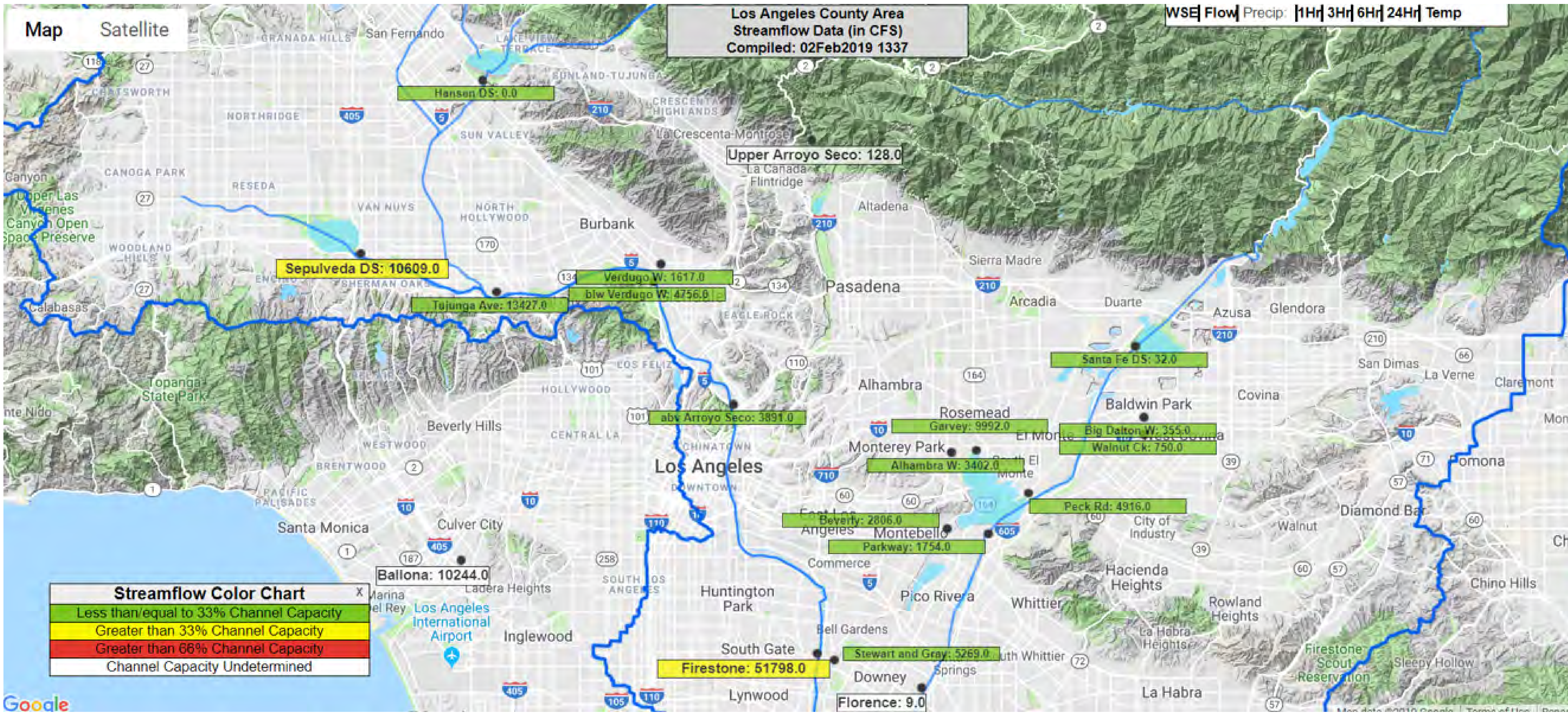
HOW DID WE GET HERE?

- HISTORY OF FLOODING AND FLOODPLAINS
- A RECENT STORM
- CURRENT PROTECTION AND FLOOD RISK

CONTEXT - RECENT STORM (FEB 2, 2019)

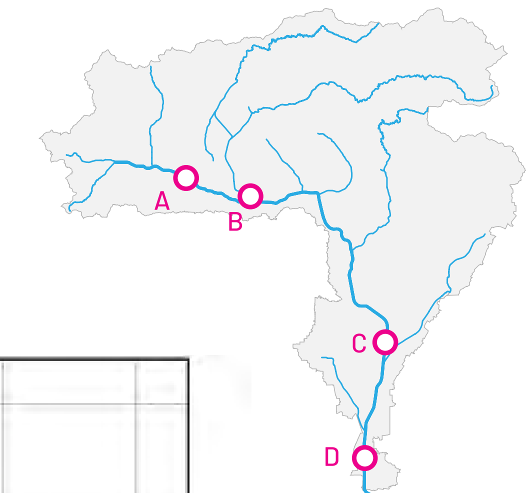
ABC News 7, Rain Swollen Los Angeles River Roars in Glendale:
https://abc7.com/weather/video-rain-swollen-los-angeles-river-roars-in-glendale/5118212/

FLOW RATES ON 2 FEBRUARY 2019, 1:37 PM

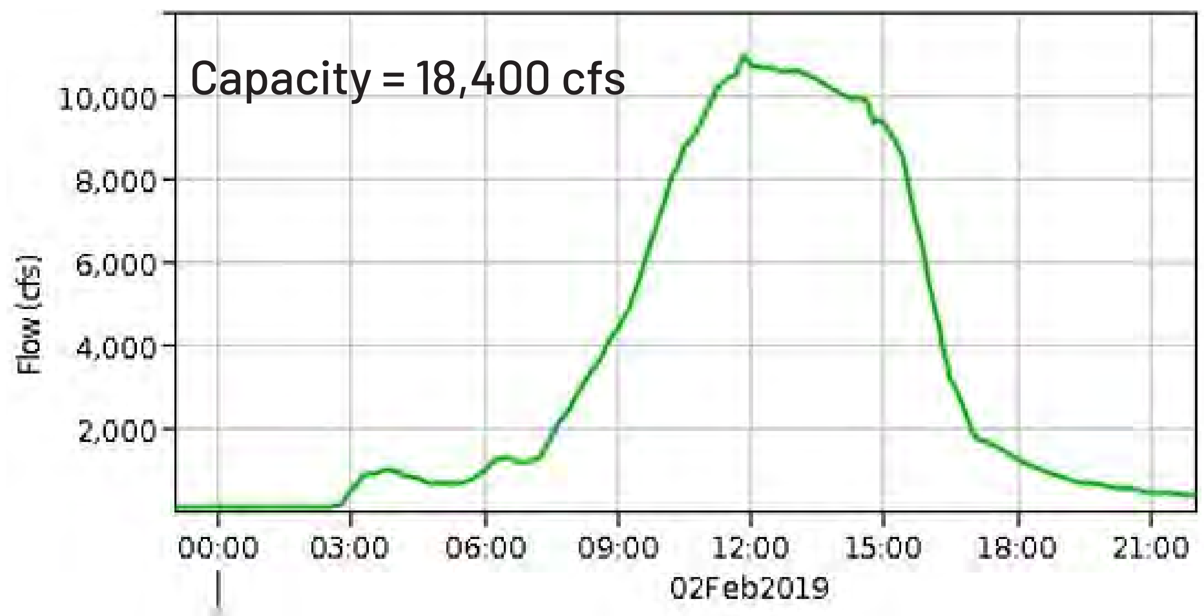


Source: Los Angeles County Area Streamflow Data, Accessed Feb 2, 2019, http://resreg.spl.usace.army.mil/cgi-bin/gMap.cgi?larF

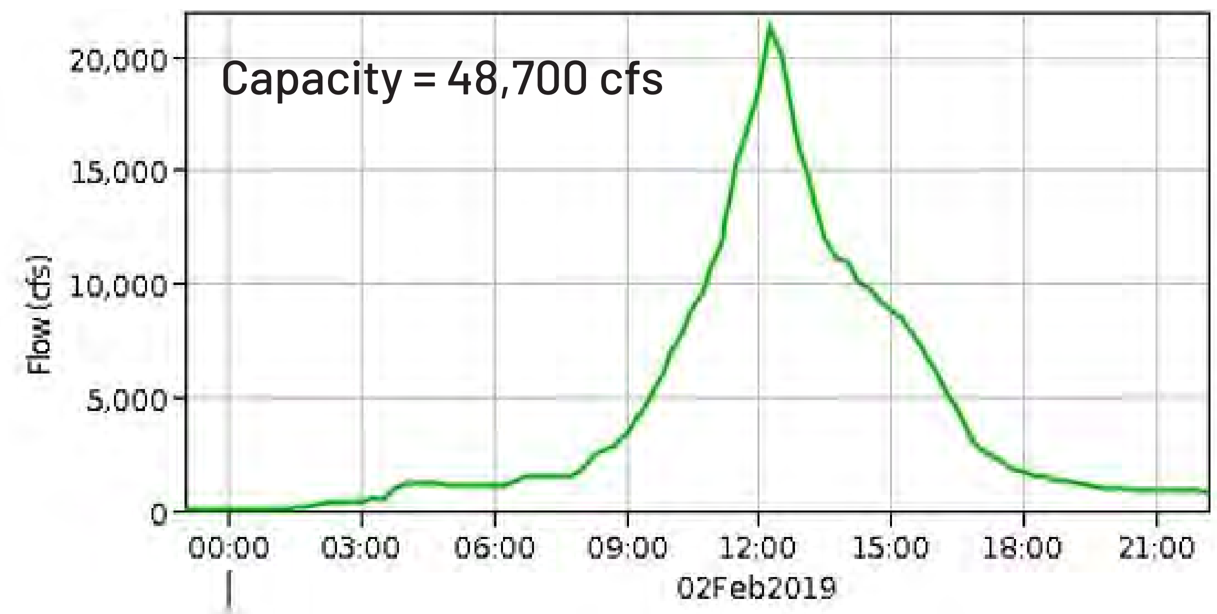
FLOW RATES ON 2 FEBRUARY 2019



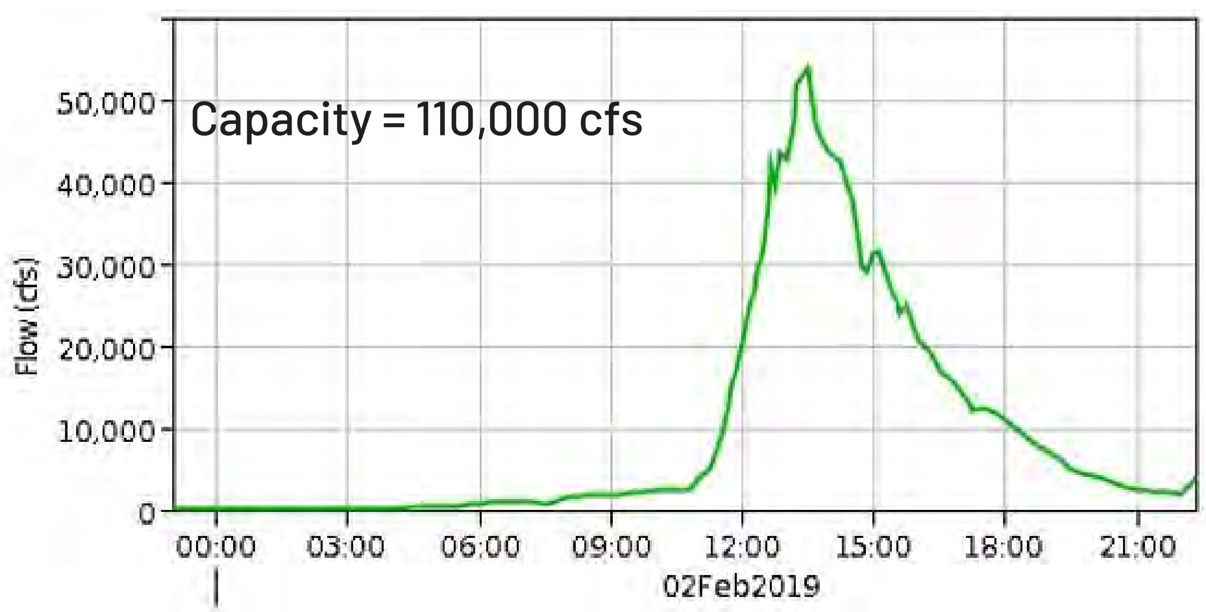
A) Sepulveda DS-LAR (~River Mile 41)



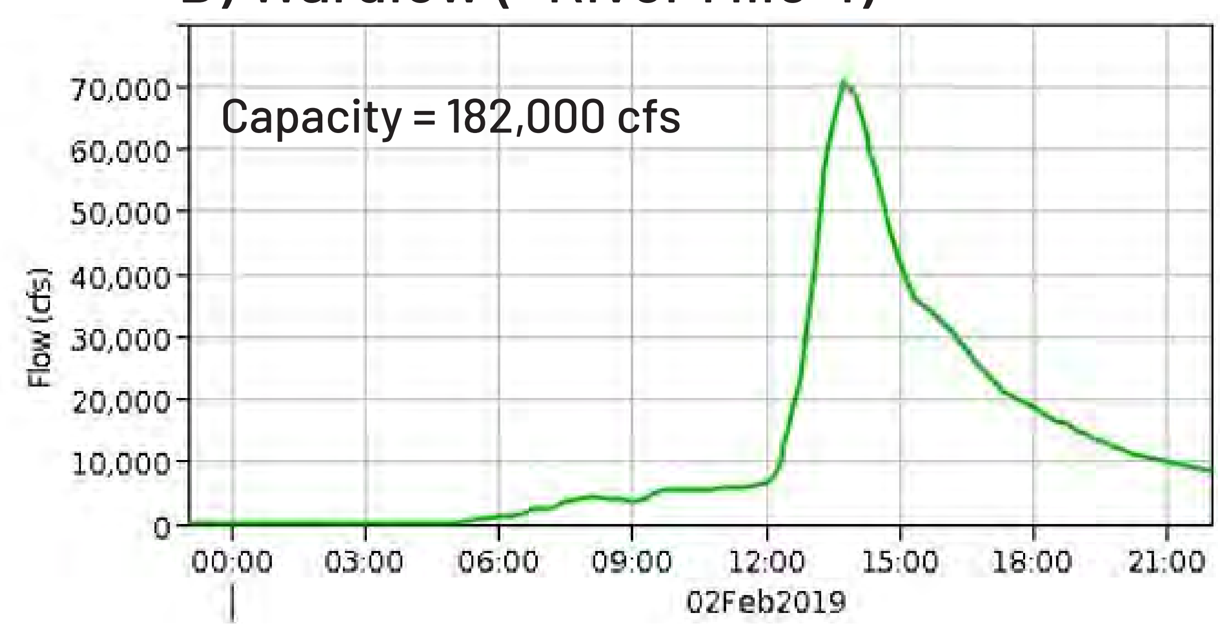
B) Tujunga (~River Mile 37.5)



C) Firestone Blvd-LAR (~River Mile 13)

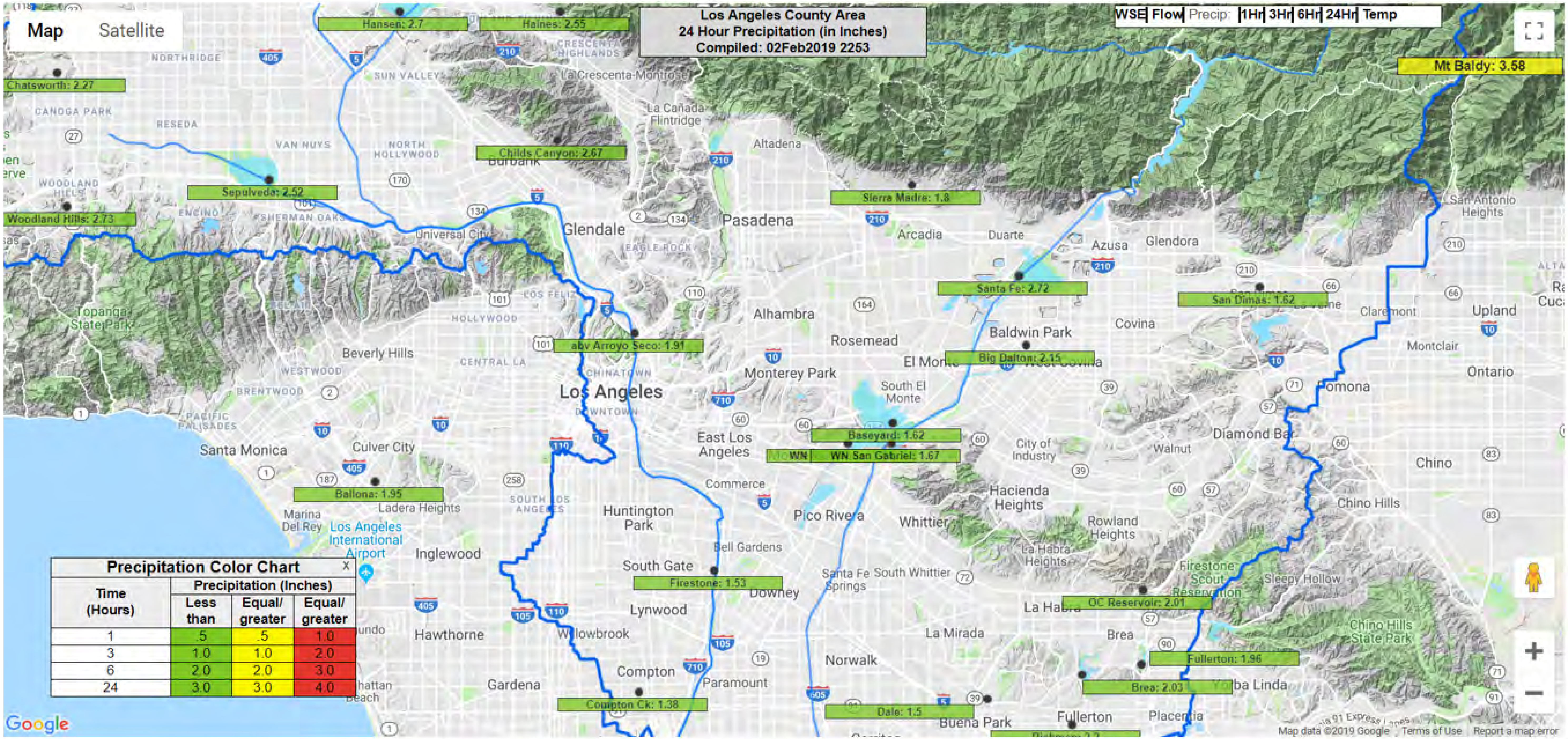


D) Wardlow (~River Mile 4)



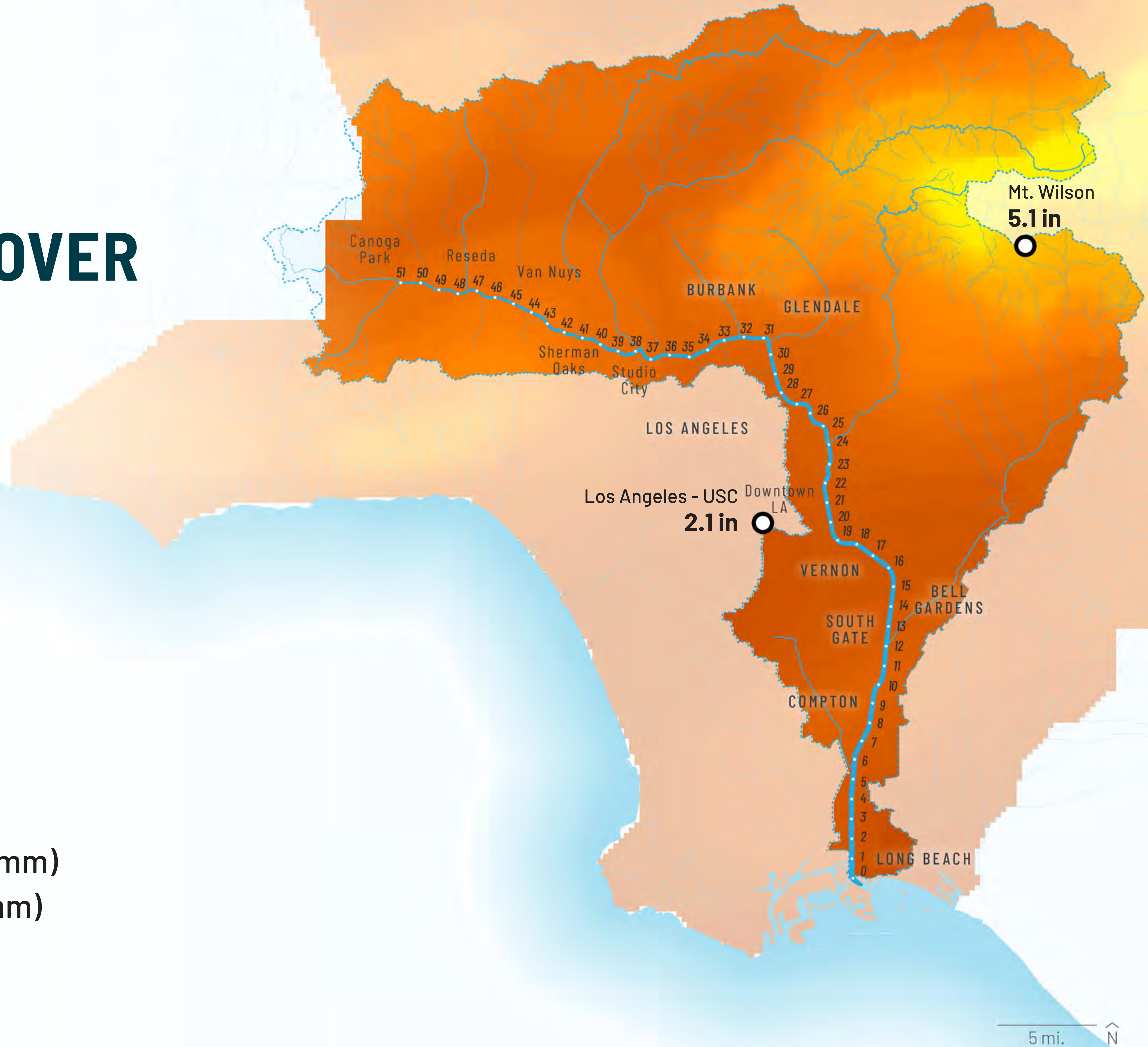
Source: Los Angeles County Area Streamflow Data, Accessed Feb 2, 2019, http://resreg.spl.usace.army.mil/cgi-bin/gMap.cgi?larF

HOW MUCH RAIN FELL?



Source: Los Angeles County Area Streamflow Data, Accessed Feb 2, 2019, http://resreg.spl.usace.army.mil/cgi-bin/gMap.cgi?larF

2-YEAR STORM PRECIPITATION OVER 24 HOURS



23.0 in / 584 mm

Max Rainfall (6.25 in /159 mm)

Min Rainfall (1.00 in / 25 mm)

0.0 in / 0 mm

Source: Los Angeles County GIS Data Portal, Rainfall Intensity, 2011

HOW DID WE GET HERE?

HISTORY OF FLOODING AND FLOODPLAINS

A RECENT STORM

CURRENT PROTECTION AND FLOOD RISK

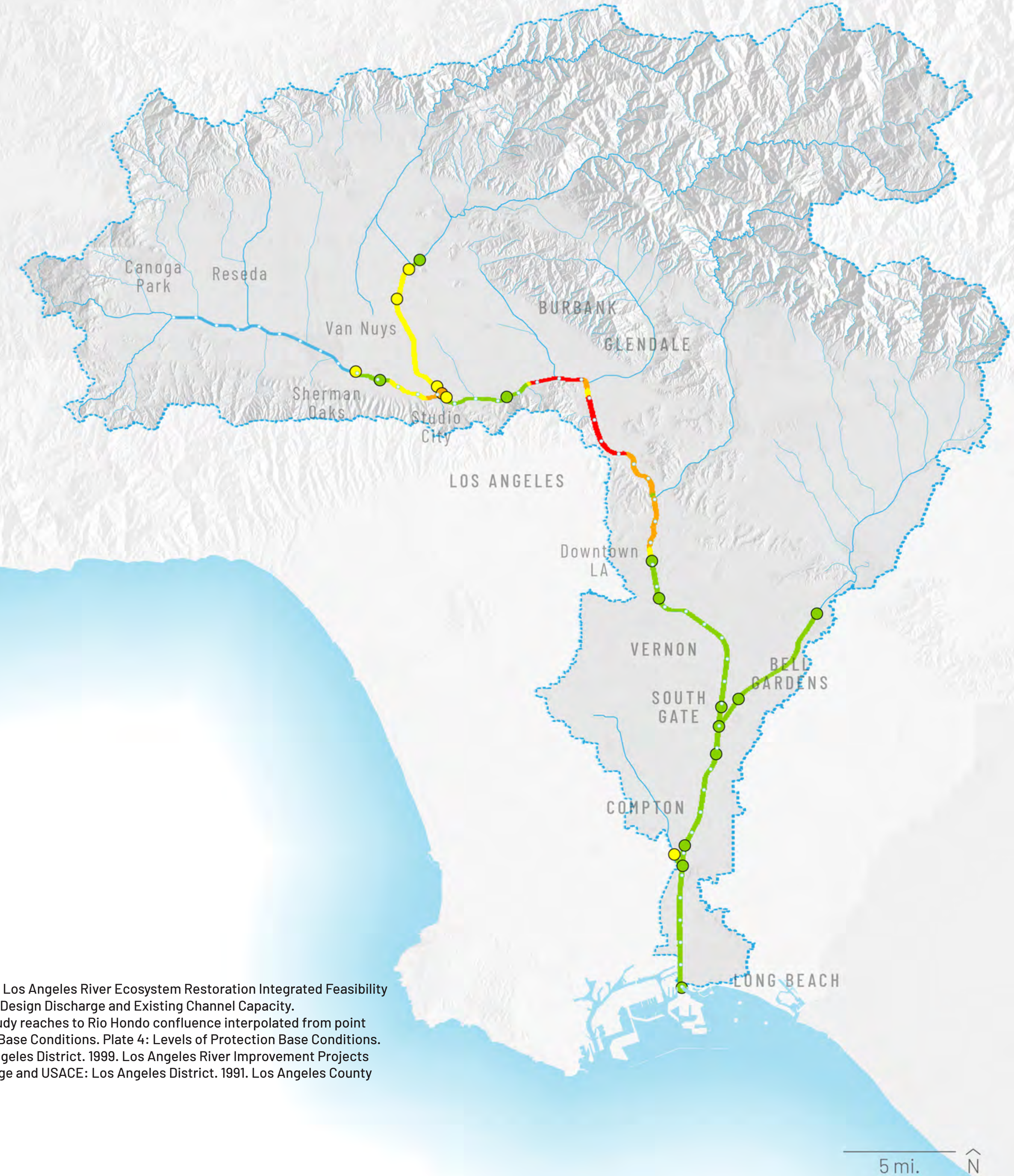
CURRENT PROTECTION LEVEL

Level of Protection (interpolated) [1]

- < 10 yr
- < 50 yr
- < 100 yr
- > 100 yr

Level of Protection (point data) [2,3]

- < 10 yr
- < 50 yr
- < 100 yr
- > 100 yr



Footnotes:
1. Level of channel protection within ARBOR Study reaches from U.S. Army Corps of Engineers (USACE): Los Angeles District. 2015. Los Angeles River Ecosystem Restoration Integrated Feasibility Report, Final Feasibility Report and Environmental Impact Statement/Environmental Impact Report, Appendix E. Table 17: Original Design Discharge and Existing Channel Capacity.
2. Level of channel protection from downstream of Sepulveda to upstream of ARBOR Study reaches and downstream of ARBOR Study reaches to Rio Hondo confluence interpolated from point locations within USACE: Los Angeles District. 1991. Los Angeles County Drainage Area: Review, Part I Hydrology Technical Report: Base Conditions. Plate 4: Levels of Protection Base Conditions.
3. Level of channel protection from Rio Hondo confluence to Pacific Ocean interpolated from point locations within USACE: Los Angeles District. 1999. Los Angeles River Improvement Projects Including Rio Hondo and Compton Creek. Final Design Memorandum No. 3 & No 5. Table A-2: Revised Maximum Deliverable Discharge and USACE: Los Angeles District. 1991. Los Angeles County Drainage Area: Review, Part II Hydrology Report, Project Alternatives. Plate 11: NED Plan Levels of Protection.

Source: Geosyntec, OLIN

Q & A AND DISCUSSION

Source: OLIN

IDEAS TO...

REDUCE FLOWS INTO THE CHANNEL

INCREASE CHANNEL CAPACITY

TOOLS AND ANALYSES

Source: OLIN

HYDROLOGY & HYDRAULICS MODELING TOOLS

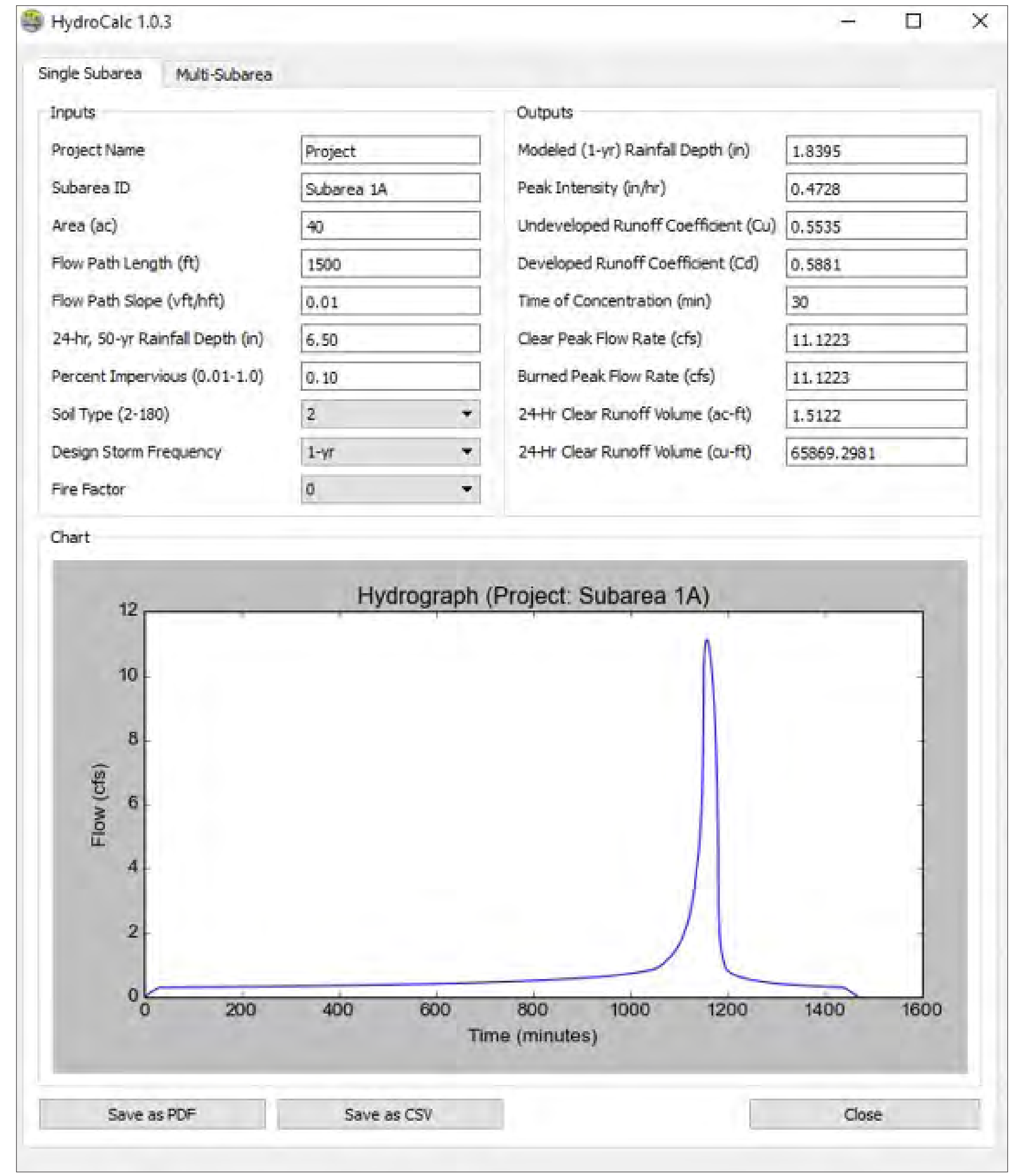
	HYDROLOGY			*HYDRAULICS*	
	UNIT HYDROLOGY	*LARGER WATERSHED*		*CHANNELS*	
	HYDROCALC	**LSPC**	**HEC-HMS**	**MANNING'S**	**HEC-RAS**
NAME	HydroCalc	Loading Simulation Program C++	Hydrologic Engineering Center - Hydrologic Modeling System	Manning's Equation	Hydrologic Engineering Center - River Analysis System
	HYDROCALC	**LSPC**	**HEC-HMS**	**MANNING'S**	**HEC-RAS**

H&H MODELING TOOLS

	HYDROLOGY			HYDRAULICS	
	UNIT HYDROLOGY	LARGER WATERSHED		CHANNELS	
	HYDROCALC	LSPC	HEC-HMS	MANNING'S	HEC-RAS
NAME	HydroCalc	Loading Simulation Program C++	Hydrologic Engineering Center - Hydrologic Modeling System	Manning's Equation	Hydrologic Engineering Center - River Analysis System
DEVELOPER	LA County Public Works	LA County Public Works	US Army Corps of Engineers	Robert Manning	US Army Corps of Engineers
DATE	2018	2013	2018	1889	2018
PURPOSE	Modified Rational Method for local scale flood and drainage analyses	Designed for water quality best management practice	Designed explicitly for flood risk management	Uniform and steady-state analysis of channels	Varying and unsteady analysis of channels and floodplains
	HYDROCALC	LSPC	HEC-HMS	MANNING'S	HEC-RAS

HYDROCALC

- Developed by LA County Public Works
- Modified Rational Method
- Local scale flood analyses
- Drainage anaylses
- Easy to use interface



Source: http://dpw.lacounty.gov/wrd/publication/Engineering/hydrology/HydroCalc.zip

HYDROCALC

H&H MODELING TOOLS

	HYDROLOGY			HYDRAULICS	
	UNIT HYDROLOGY	LARGER WATERSHED		CHANNELS	
	HYDROCALC	LSPC	HEC-HMS	MANNING'S	HEC-RAS
NAME	HydroCalc	Loading Simulation Program C++	Hydrologic Engineering Center - Hydrologic Modeling System	Manning's Equation	Hydrologic Engineering Center - River Analysis System
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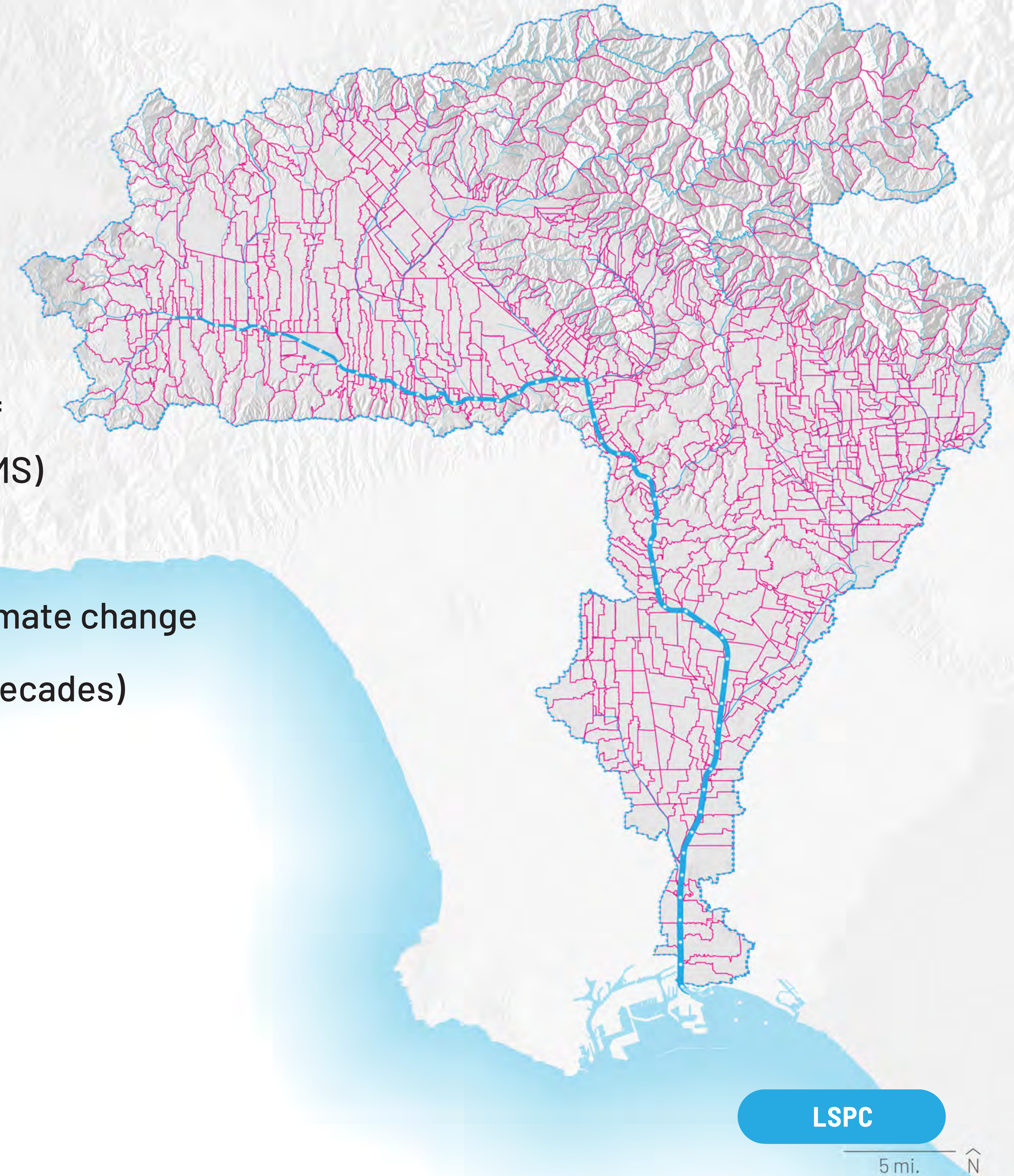
	HYDROCALC	LSPC	HEC-HMS	MANNING'S	HEC-RAS

LOADING SIMULATION PROGRAM IN C++ (LSPC)

- Developed by LA County Public Works as part of Watershed Management Modeling System (WMMS)
- Primarily for water quality
- Modified to assess supply benefits including climate change
- Evaluates long-term time-series (i.e., years to decades)



Source: LA County Public Works

H&H MODELING TOOLS

	HYDROLOGY			HYDRAULICS	
	UNIT HYDROLOGY	LARGER WATERSHED		CHANNELS	
	HYDROCALC	**LSPC**	**HEC-HMS**	**MANNING'S**	**HEC-RAS**
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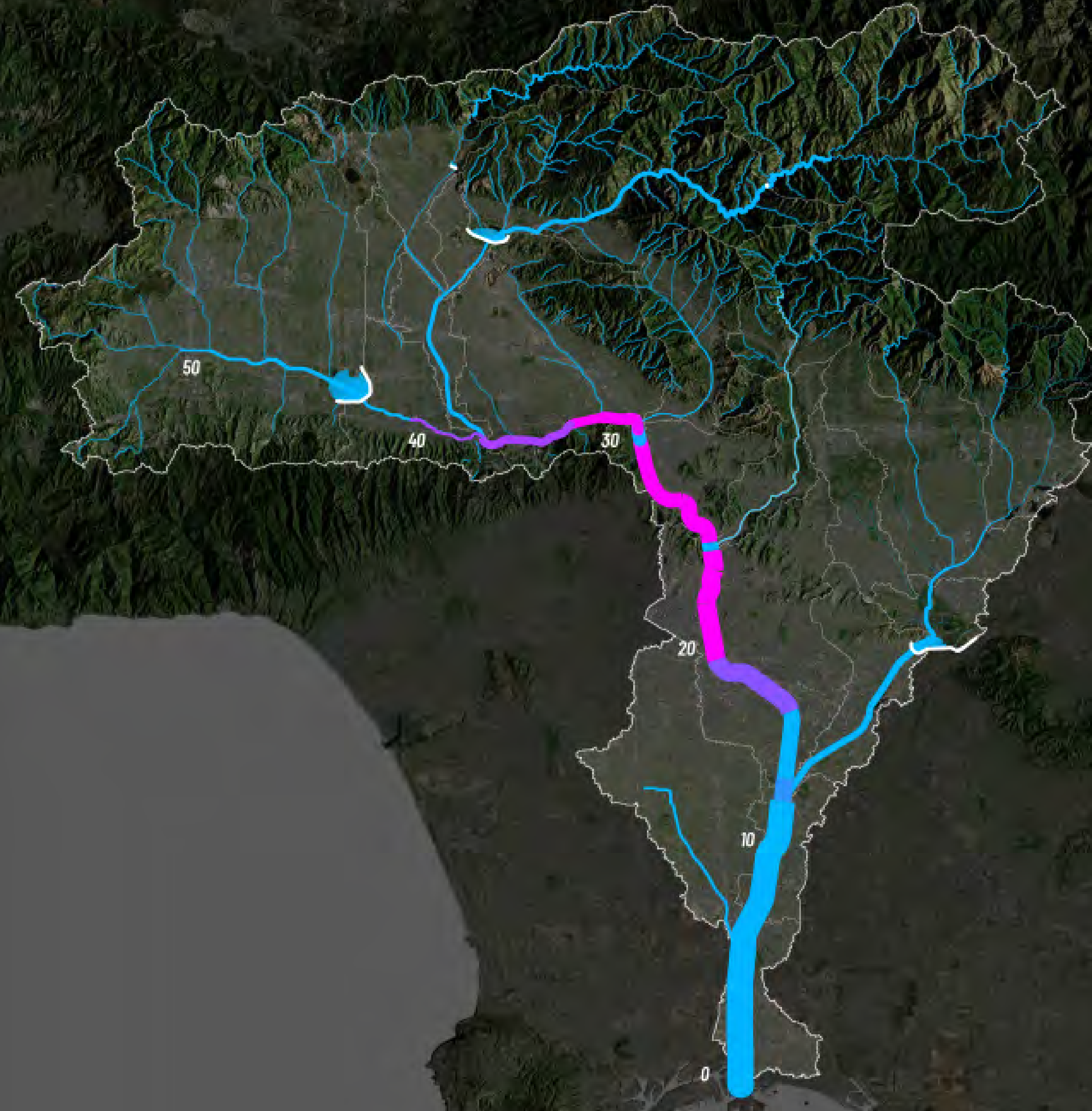
	HYDROCALC	LSPC	HEC-HMS	MANNING'S	HEC-RAS

HEC-HMS

Precipitation runoff simulation

- Event based precipitation events (e.g., 2-year, 100-year, ...)
- Infiltration
- Surface runoff
- Routing through drains and channels
- Flood control basins



U.S. Army Corps of Engineers, Los Angeles District. Los Angeles County Drainage Area (LACDA): Hydrologic Analysis. 2010. Figure 5: LACDA - HEC-HMS Model Schematic.

HEC-HMS

H&H MODELING TOOLS

	HYDROLOGY			HYDRAULICS
	UNIT HYDROLOGY	LARGER WATERSHED		CHANNELS
	HYDROCALC	LSPC	HEC-HMS	MANNING'S	HEC-RAS
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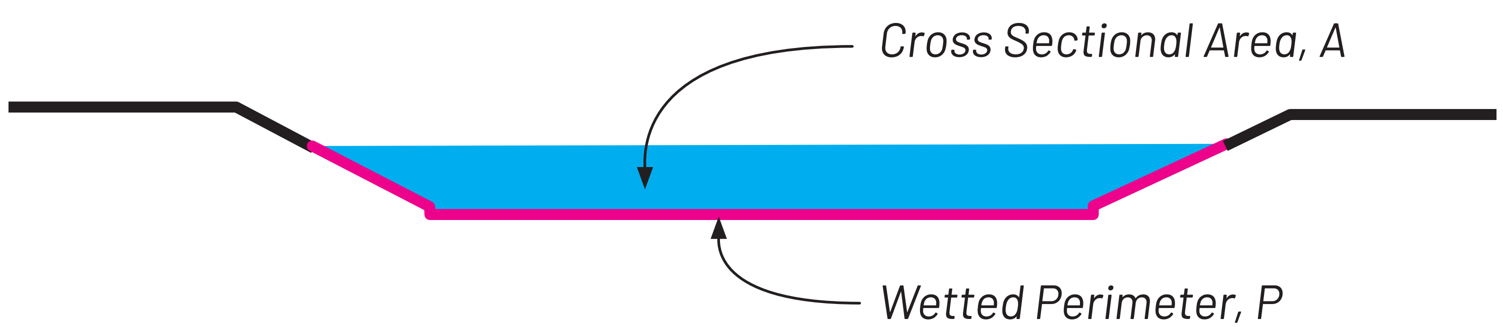
	HYDROCALC	LSPC	HEC-HMS	MANNING'S	HEC-RAS

MANNING'S EQUATION

Empirically derived in 1889

$$Q = \frac{K\,A\,R^{2/3}\,S^{1/2}}{n}$$

Q = *flow rate*
A = *cross-sectional area of flow*
P = *wetted perimeter*
R = *hydraulic radius* = *A/P*
S = *slope of the channel at the point of measurement*
n = *surface roughness (based upon channel material and condition)*
K = *constant dependent upon units*



- Online Calculator: http://onlinecalc.sdsu.edu/onlinechannel01.php

n = 0.06

Dense Vegetation

n = 0.03

Well-maintained Vegetation

n = 0.016

Concrete

Source: Geosyntec, OLIN

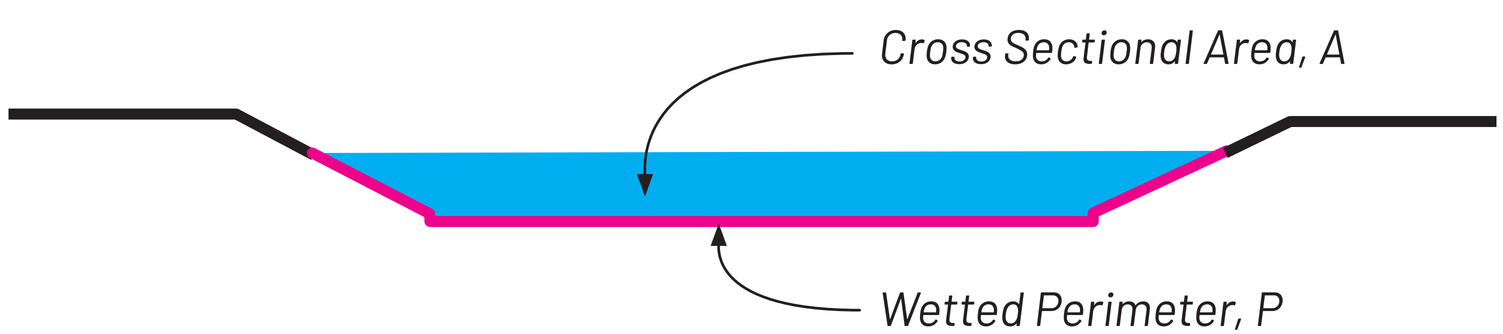
MANNING'S

MANNING'S EQUATION

Empirically derived in 1889

$$Q = \frac{K A R^{2/3} S^{1/2}}{n}$$

Q = flow rate
A = cross-sectional area of flow
P = wetted perimeter
R = hydraulic radius = A/P
S = slope of the channel at the point of measurement
n = surface roughness (based upon channel material and condition)
K = constant dependent upon units



- Online Calculator: http://onlinecalc.sdsu.edu/onlinechannel01.php

Manning's n for Channels (Chow, 1959)

Type of Channel and Description	Minimum	Normal	Maximum
4. Excavated or Dredged Channels			
a. Earth, straight, and uniform			
1. clean, recently completed	0.016	0.018	0.020
2. clean, after weathering	0.018	0.022	0.025
3. gravel, uniform section, clean	0.022	0.025	0.030
4. with short grass, few weeds	0.022	0.027	0.033
b. Earth, winding, and sluggish			
1. no vegetation	0.023	0.025	0.030
2. grass, some weeds	0.025	0.030	0.033
3. dense weeds or aquatic plants in deep channels	0.030	0.035	0.040
4. earth bottom and rubble sides	0.028	0.030	0.035
5. stony bottom and weedy banks	0.025	0.035	0.040
6. cobble bottom and clean sides	0.030	0.040	0.050
e. Channels not maintained, weeds and brush uncut			
1. dense weeds, high as flow depth	0.050	0.080	0.120
2. clean bottom, brush on sides	0.040	0.050	0.080
3. same as above, highest stage of flow	0.045	0.070	0.110
4. dense brush, high stage	0.080	0.100	0.140
5. Lined or Constructed Channels			
c. Concrete			
1. trowel finish	0.011	0.013	0.015
2. float finish	0.013	0.015	0.016
3. finished, with gravel on bottom	0.015	0.017	0.020
d. Concrete bottom float finish with sides of:			
1. dressed stone in mortar	0.015	0.017	0.020
2. random stone in mortar	0.017	0.020	0.024
3. cement rubble masonry, plastered	0.016	0.020	0.024
4. cement rubble masonry	0.020	0.025	0.030
5. dry rubble or riprap	0.020	0.030	0.035
e. Gravel bottom with sides of:			
1. formed concrete	0.017	0.020	0.025
2. random stone mortar	0.020	0.023	0.026

Source: Geosyntec, OLIN

MANNING'S

MANNING'S EQUATION

Does not account for upstream/downstream effects or hydraulic structures (e.g., bridges)

$$Q = \frac{K\,A\,R^{2/3}\,S^{1/2}}{n}$$

Variable		Dense Vegetation	Well-maintained Grasses	Concrete
constant	K	1.49 ft $^{1/3}$/s	1.49 ft $^{1/3}$/s	1.49 ft $^{1/3}$/s
cross-sectional area of flow	A	4,000 ft^2	4,000 ft^2	4,000 ft^2
hydraulic radius	R	15	15	15
slope of the channel	S	0.005	0.005	0.005
surface roughness	n	0.06	0.03	0.016
flow rate	Q	43,000 cfs	85,000 cfs	160,000 cfs

Source: Geosyntec, OLIN

MANNING'S

H&H MODELING TOOLS

	HYDROLOGY			HYDRAULICS	
	UNIT HYDROLOGY	LARGER WATERSHED		CHANNELS	
	HYDROCALC	LSPC	HEC-HMS	MANNING'S	HEC-RAS
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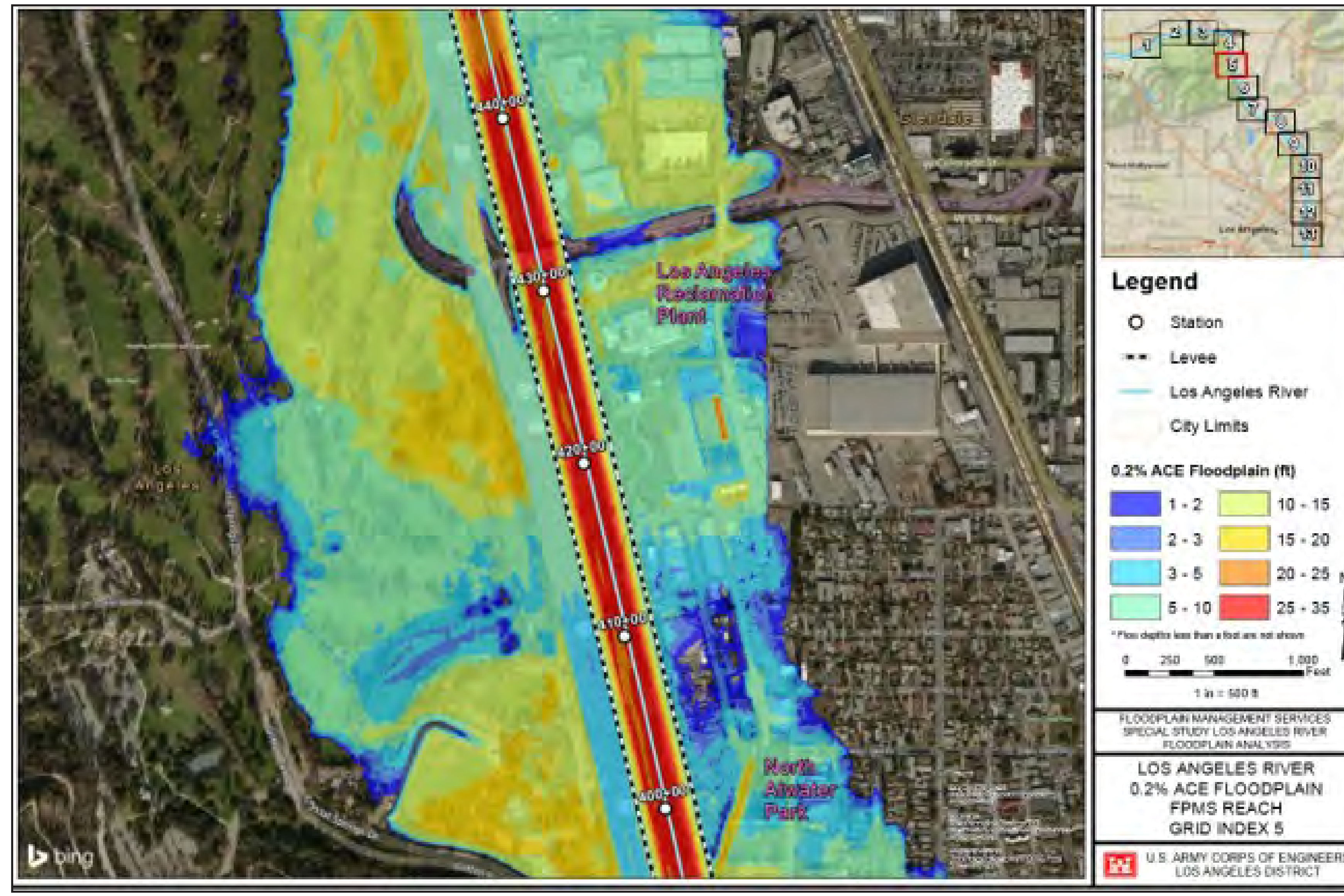
HYDROCALC LSPC HEC-HMS MANNING'S HEC-RAS

HEC-RAS

- Steady and unsteady hydraulic computations for network of open channels and floodplain
- 1-D – Energy equation
- 2-D – Shallow water equation
- Combine 1D/2D

  (i.e., 1-D for channel, 2-D for floodplain)
- Accounts for upstream and downstream conditions



Source: USACE, Los Angeles River 0.2% ACE Floodplain FPMS Reach Grid Index 5.

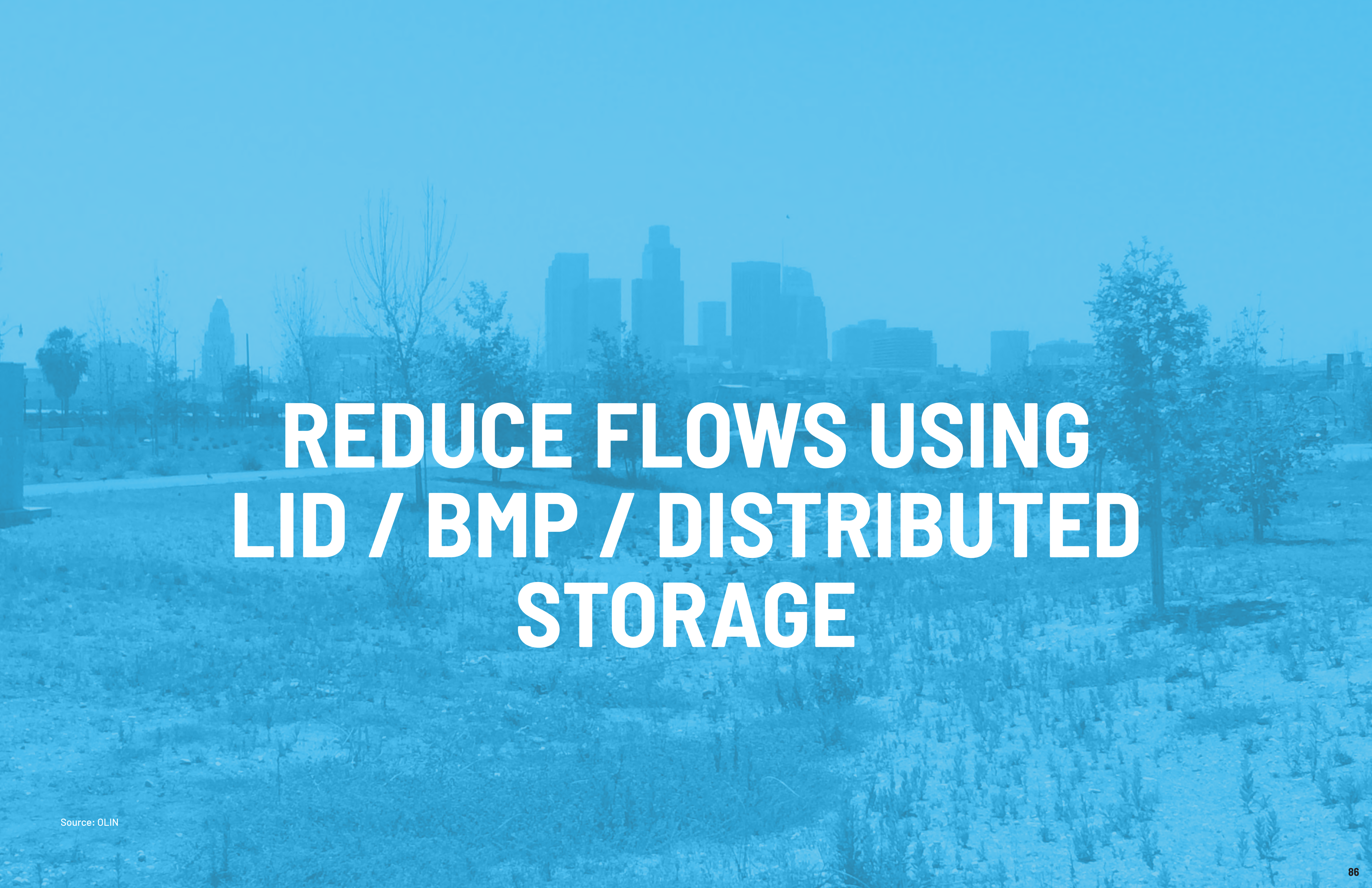
HEC-RAS

Q & A AND DISCUSSION

Source: OLIN

SOLUTIONS AND OPPORTUNITIES

Source: OLIN



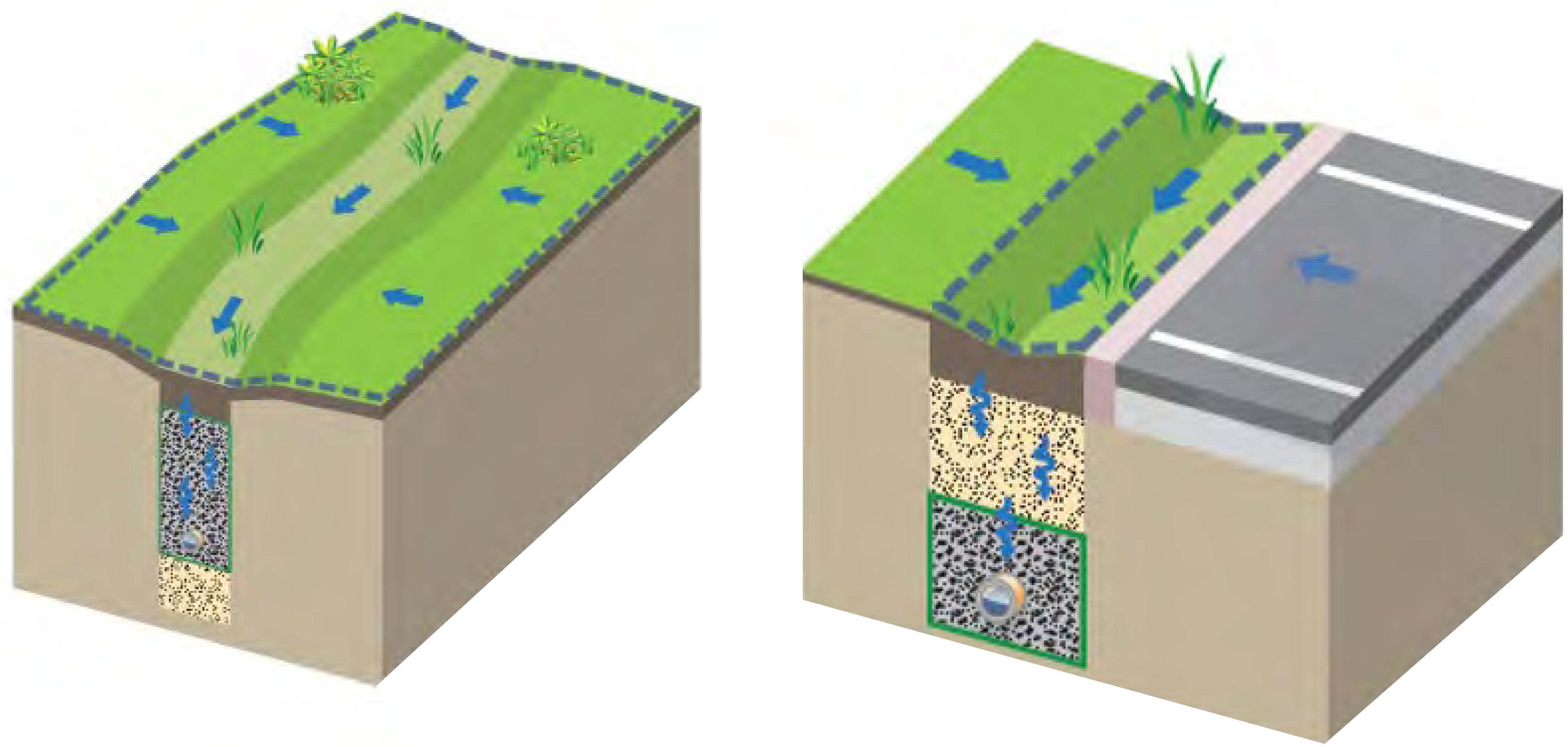
REDUCE FLOWS USING LID / BMP / DISTRIBUTED STORAGE

Source: OLIN

LOW IMPACT DEVELOPMENT (LID) EXAMPLES

Capture and retain the 85th percentile precipitation event runoff

- Standalone Bioretention
- Bioretention + Drywells
- Pervious Pavement + Drywells
- Water Quality
- Conservation



Source: Geosyntec

GREEN STREETS

Green infrastructure along, on, and within the public right-of-way

- Rain Gardens
- Bioretention
- Permeable Pavement
- Infiltration Trench
- Drywells

Source: Geosyntec

REGIONAL PROJECTS

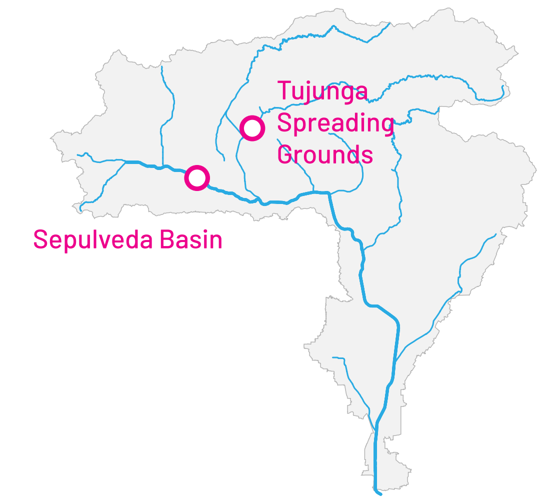
Water quality regional project examples

- Above Ground Retention
- Underground Retention/Cisterns

Source: Geosyntec

REGIONAL PROJECTS

Project Examples



Flood Risk Reduction

Sepulveda Basin

Water Supply

Tujunga Spreading Grounds

Source: Sepulveda Basin Wildlife, https://sepulvedabasinwildlife.org/wildlifeareas.html, & Los Angeles County Public Works

REGIONAL PROJECTS

	WATER QUALITY	WATER SUPPLY	FLOOD
PROJECT FOOTPRINT	0.2 - 15 acres or less	15-160 acres	50+ acres
DESIGN CAPACITY	85th percentile event or smaller	Up to 5 year storm	50 year storm or greater
PRIMARY PURPOSE	Water quality improvement	Water supply benefits	Flood risk reduction
CONSTRUCTION COST	$ $	$ $ $ $ $	$ $ $ $ $

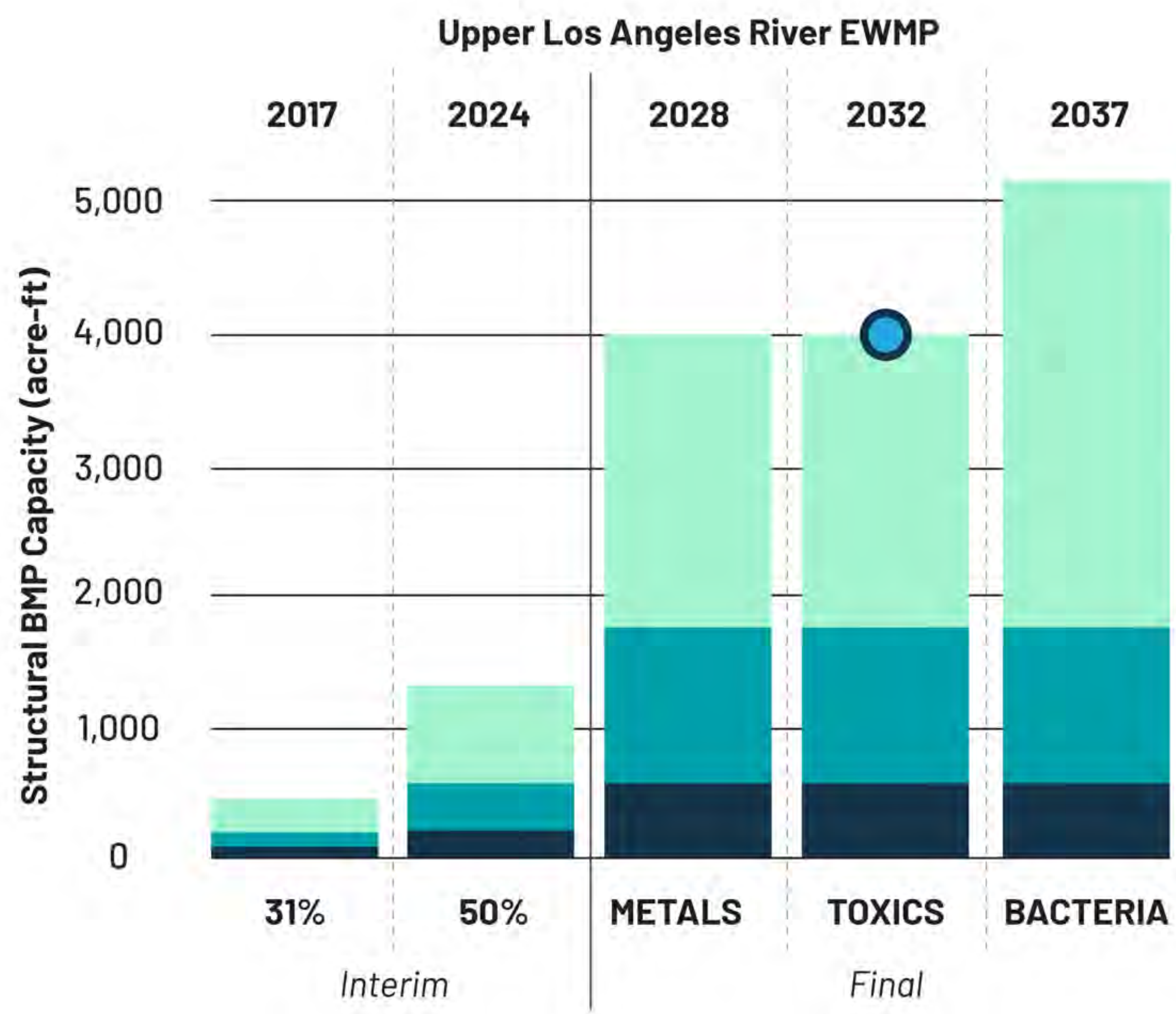
Source: Geosyntec

WATER QUALITY OBJECTIVES

Upper LA River (ULAR) Enhanced Water Quality Management Plan (EWMP)

5,186 AF total in ULAR by 2037

- Total Regional Best Management Practices (BMPs): **3,449 AF**
- Green Streets: **1,196 AF**
- Total LID Best Management Practices (BMPs): **541 AF**
- Residual Toxics Source Control Measures

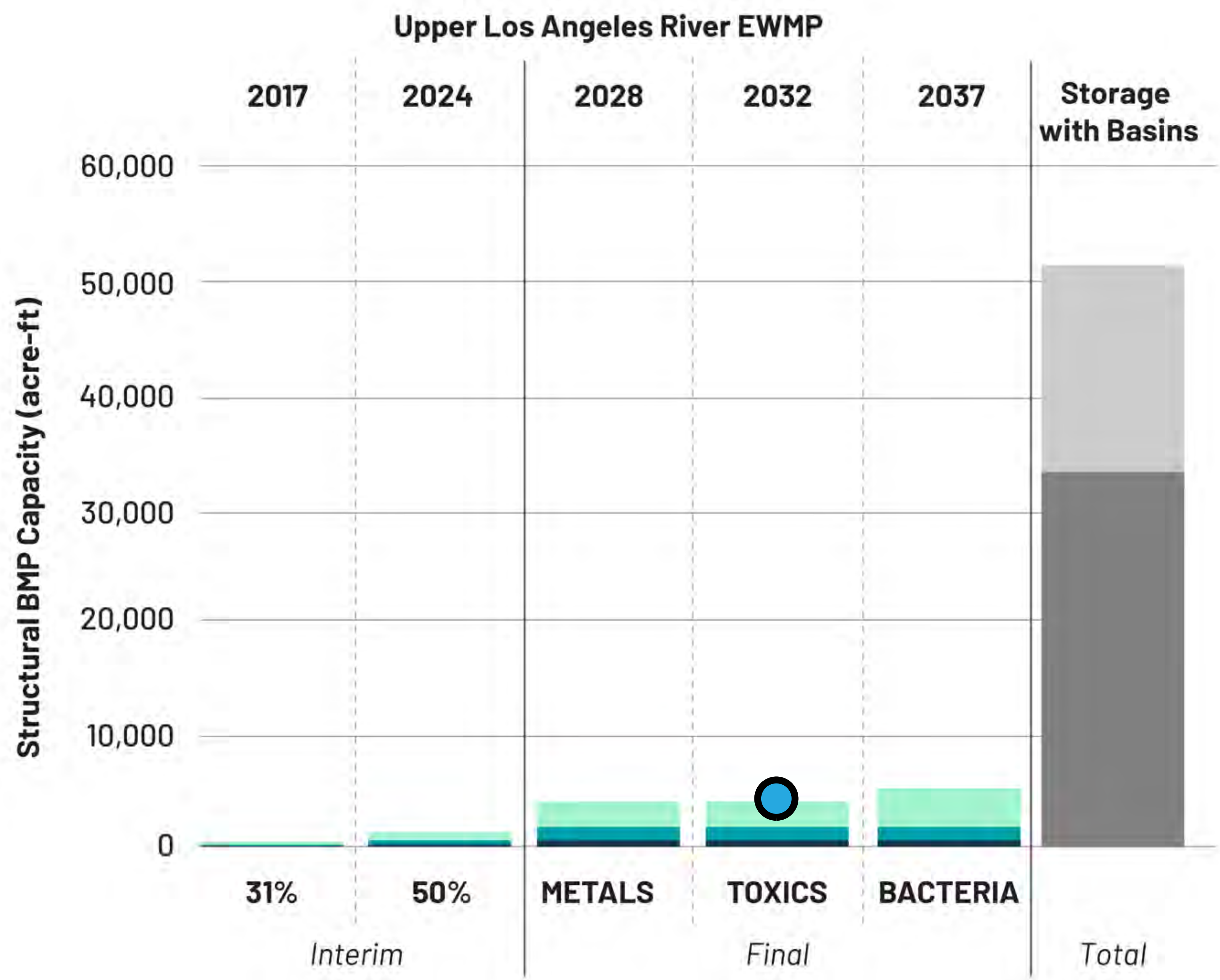


Source: ULAR EWMP (2016), https://www.waterboards.ca.gov/losangeles/water_issues/programs/stormwater/municipal/watershed_management/los_angeles/upper_losangeles/20160127/UpperLARiver_mainbody_revEWMP_Jan2016.pdf

WATER QUALITY OBJECTIVES

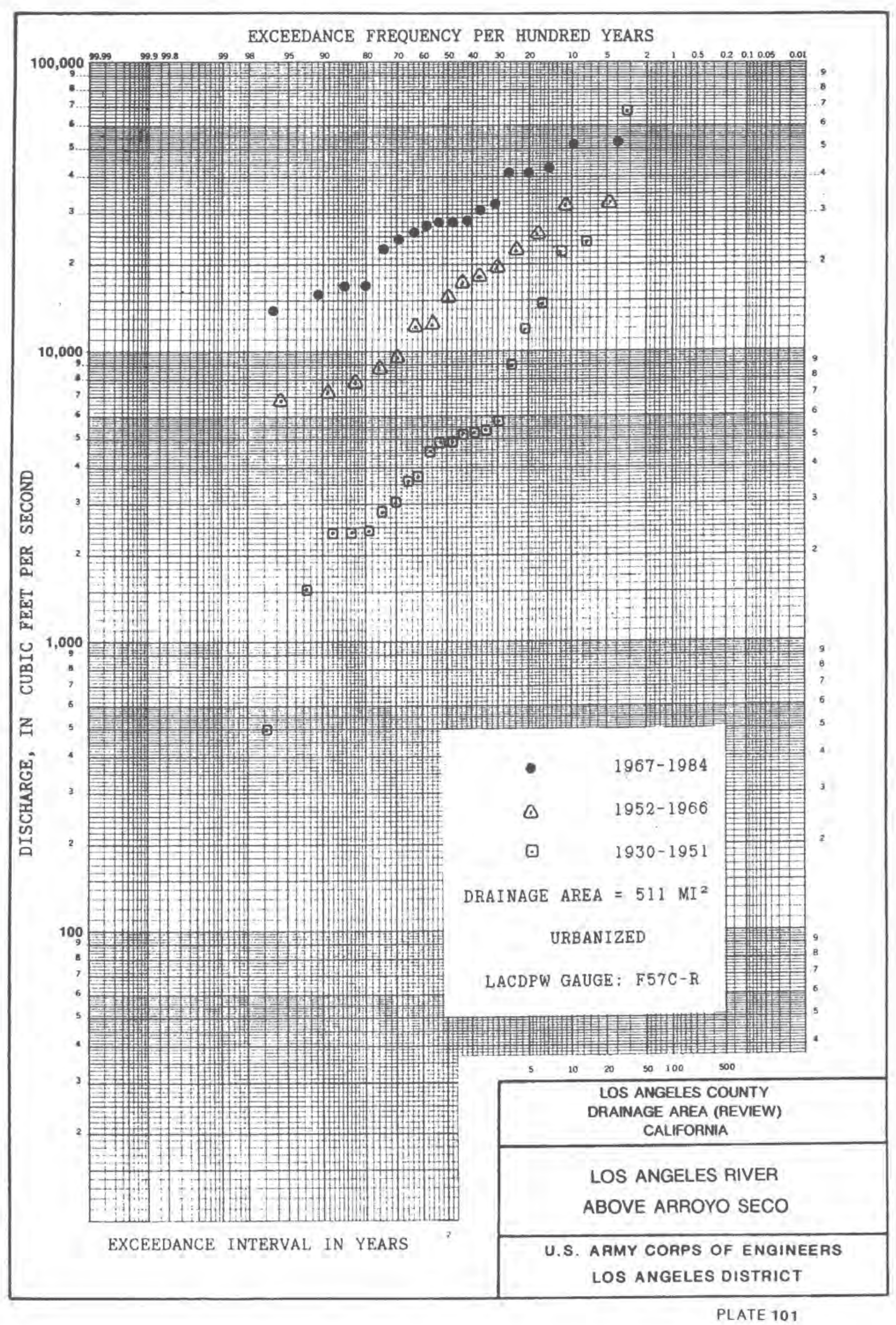
Upper LA River (ULAR) Enhanced Water Quality Management Plan (EWMP)

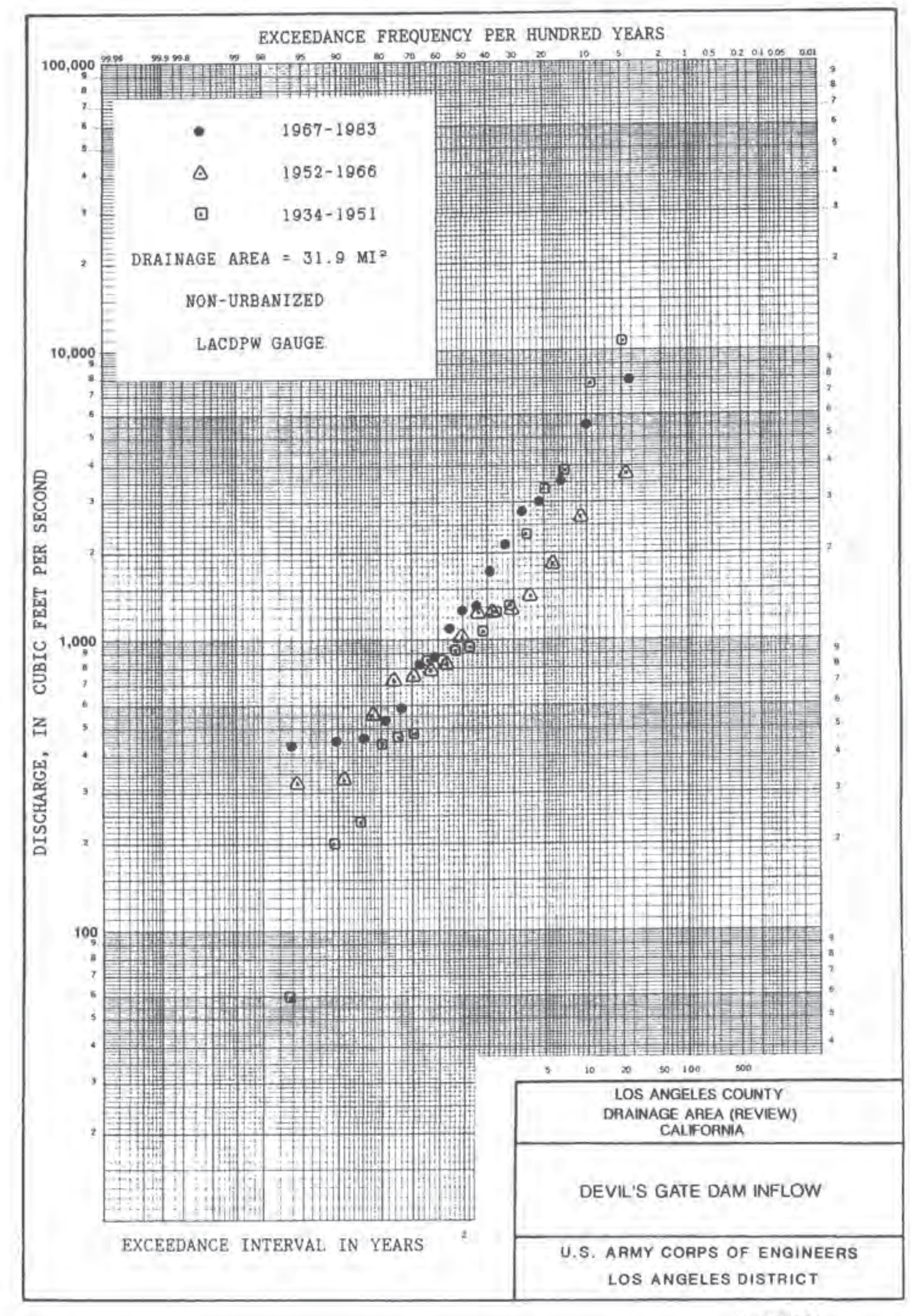
- Sepulveda Basin: **18,127 AF**
- Hansen Basin: **33,348 AF**
- Total Regional Best Management Practices (BMPs): **3,449 AF**
- Green Streets: **1,196 AF**
- Total LID Best Management Practices (BMPs): **541 AF**
- Residual Toxics Source Control Measures



Source: ULAR EWMP (2016), https://www.waterboards.ca.gov/losangeles/water_issues/programs/stormwater/municipal/watershed_management/los_angeles/upper_losangeles/20160127/UpperLARiver_mainbody_revEWMP_Jan2016.pdf

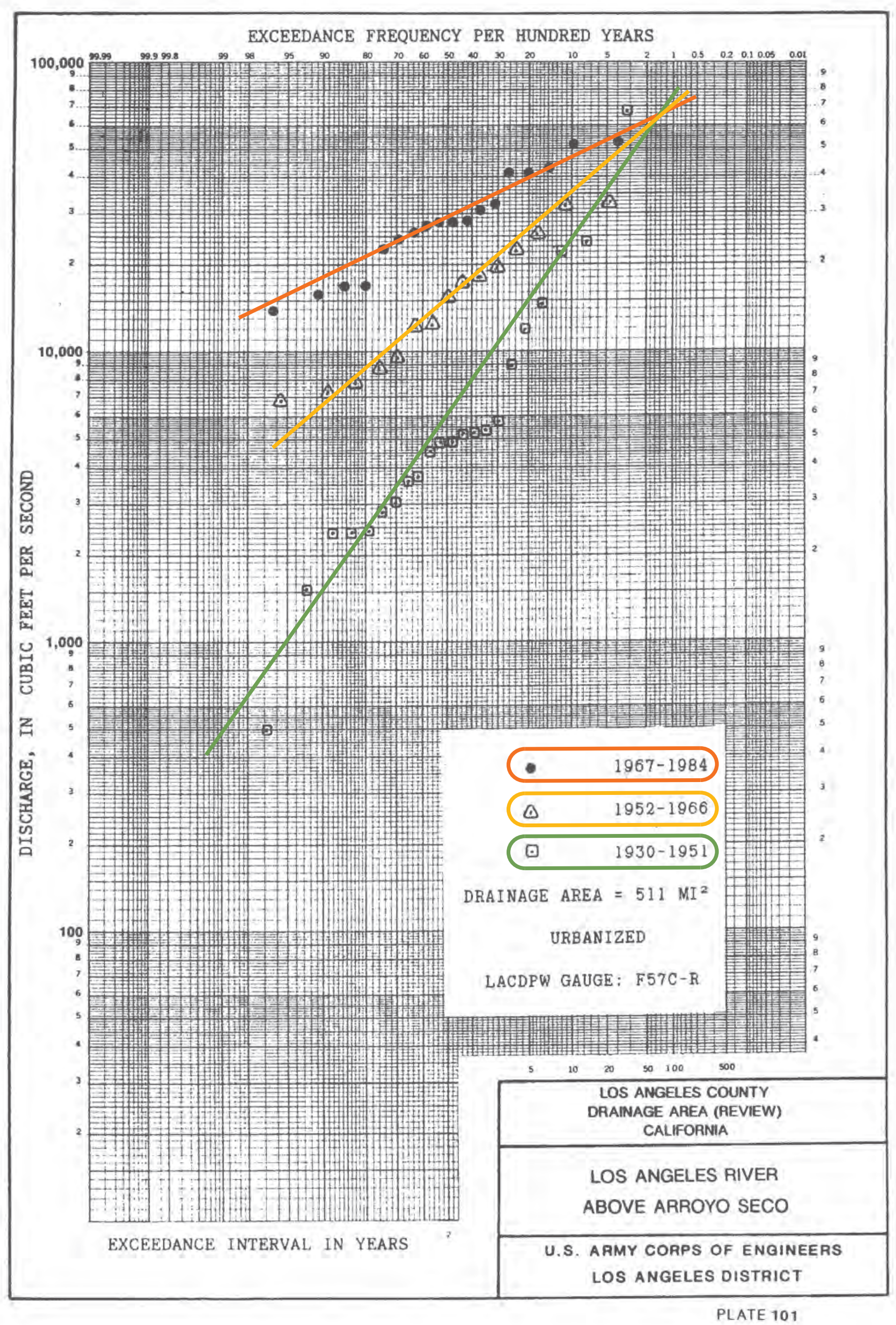
EFFECT OF URBANIZATION

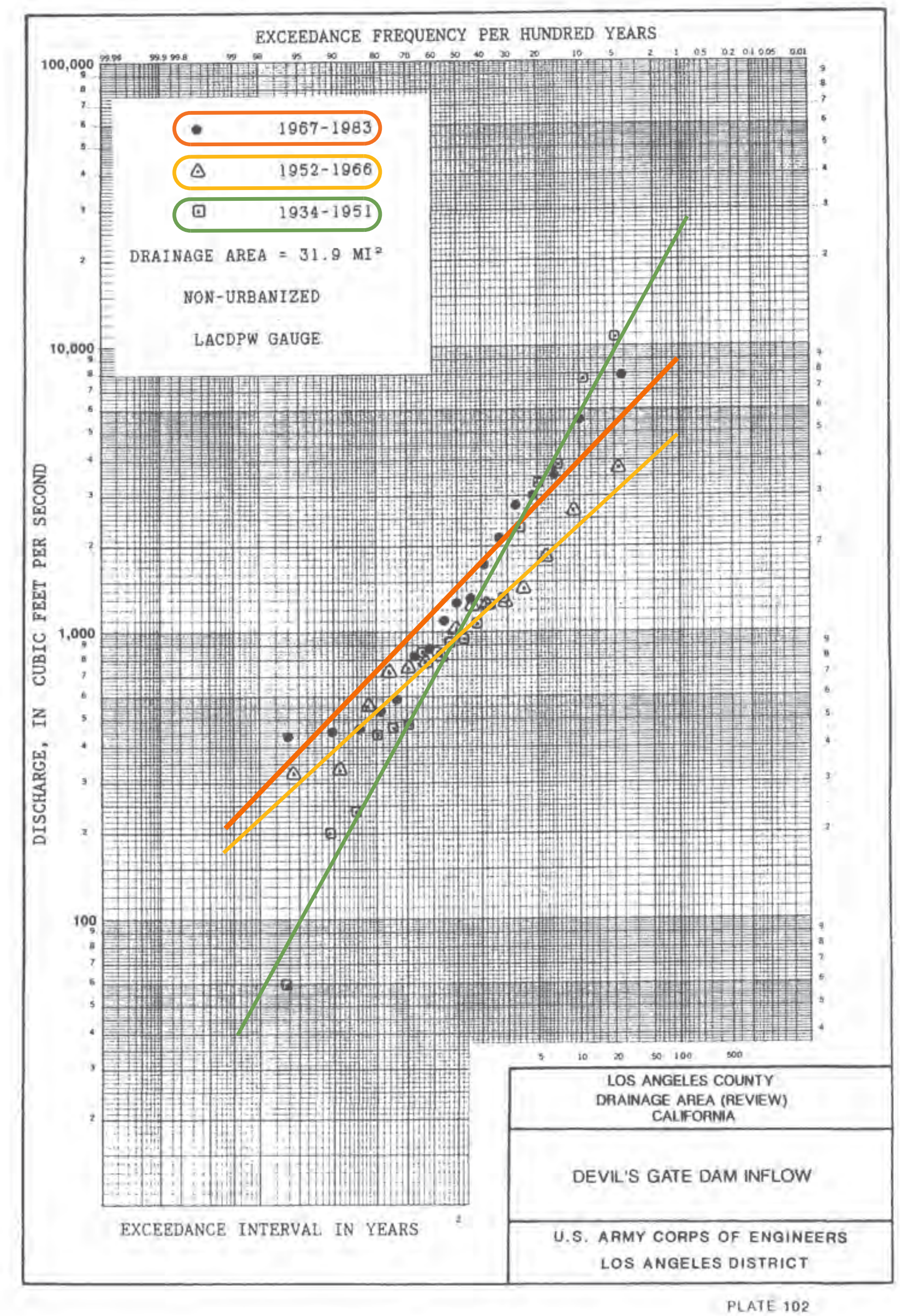




Source: U.S. Army Corps of Engineers: Los Angeles District. 1991. Los Angeles County Drainage Area: Review, Part I, Hydrology Technical Report, Base Conditions

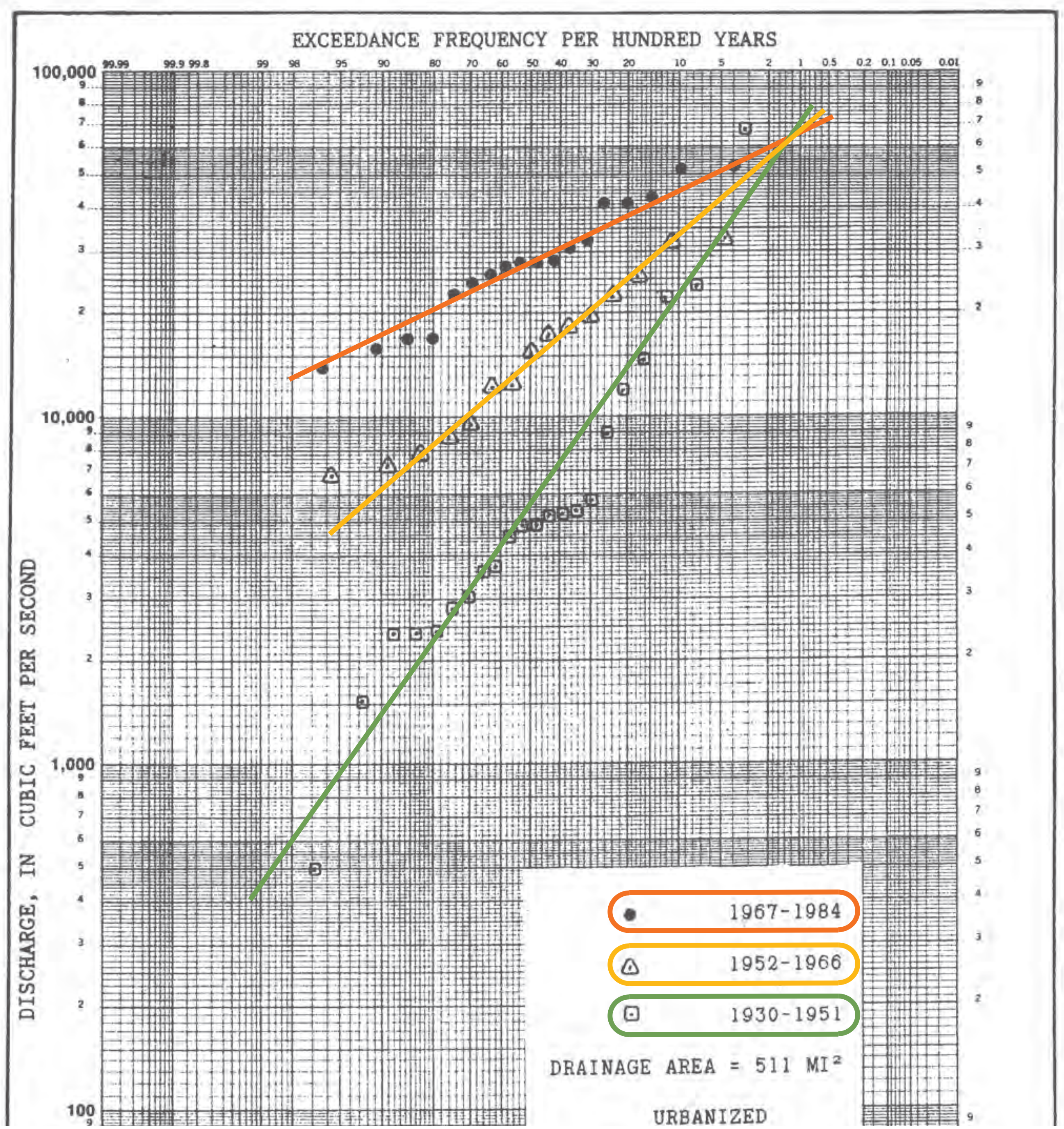
EFFECT OF URBANIZATION

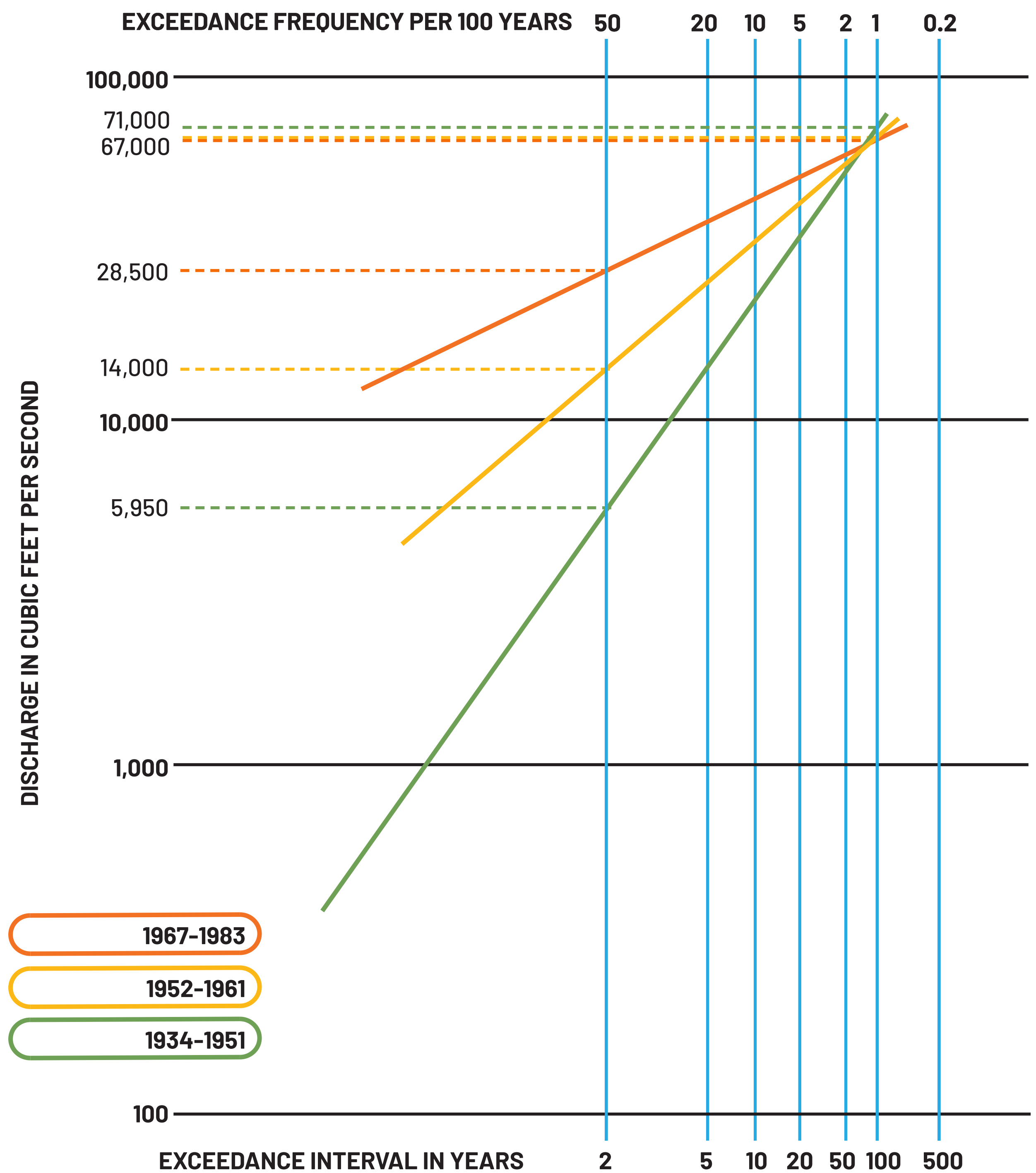




Source: U.S. Army Corps of Engineers: Los Angeles District. 1991. Los Angeles County Drainage Area: Review, Part I, Hydrology Technical Report, Base Conditions, Geosyntec, OLIN

EFFECT OF URBANIZATION





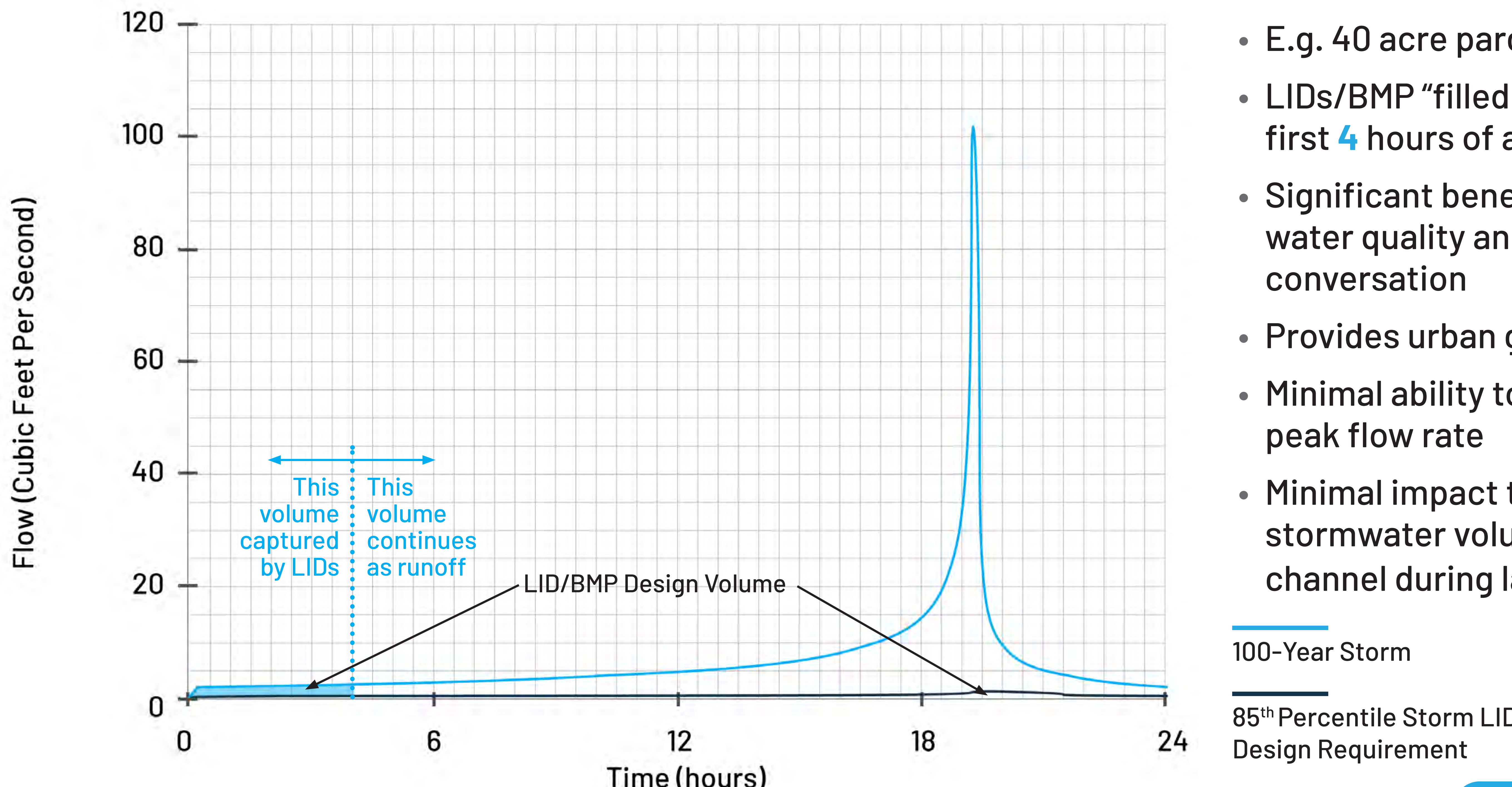
Source: U.S. Army Corps of Engineers: Los Angeles District. 1991. Los Angeles County Drainage Area: Review, Part I, Hydrology Technical Report, Base Conditions, Geosyntec, OLIN

H&H MODELING TOOLS

	HYDROLOGY			HYDRAULICS	
	UNIT HYDROLOGY	LARGER WATERSHED		CHANNELS	
	HYDROCALC	**LSPC**	**HEC-HMS**	**MANNING'S**	**HEC-RAS**
NAME	HydroCalc	Loading Simulation Program C++	Hydrologic Engineering Center - Hydrologic Modeling System	Manning's Equation	Hydrologic Engineering Center - River Analysis System
DEVELOPER	LA County Public Works	LA County Public Works	US Army Corps of Engineers	Robert Manning	US Army Corps of Engineers
DATE	2018	2013	2018	1889	2018
PURPOSE	Modified Rational Method for local scale flood and drainage analyses	Designed for water quality best management practice	Designed explicitly for flood risk management	Uniform and steady-state analysis of channels	Varying and unsteady analysis of channels and floodplains

HYDROCALC LSPC HEC-HMS MANNING'S HEC-RAS

HYDROCALC



Source: http://dpw.lacounty.gov/wrd/publication/Engineering/hydrology/HydroCalc.zip

Hydrograph: Sub Area 1

- E.g. 40 acre parcel
- LIDs/BMP "filled up" within first **4** hours of a storm
- Significant benefit to water quality and water conversation
- Provides urban green space
- Minimal ability to impact peak flow rate
- Minimal impact to reducing stormwater volume in channel during large storm

HYDROCALC

WORKING SESSION BREAK

Source: OLIN

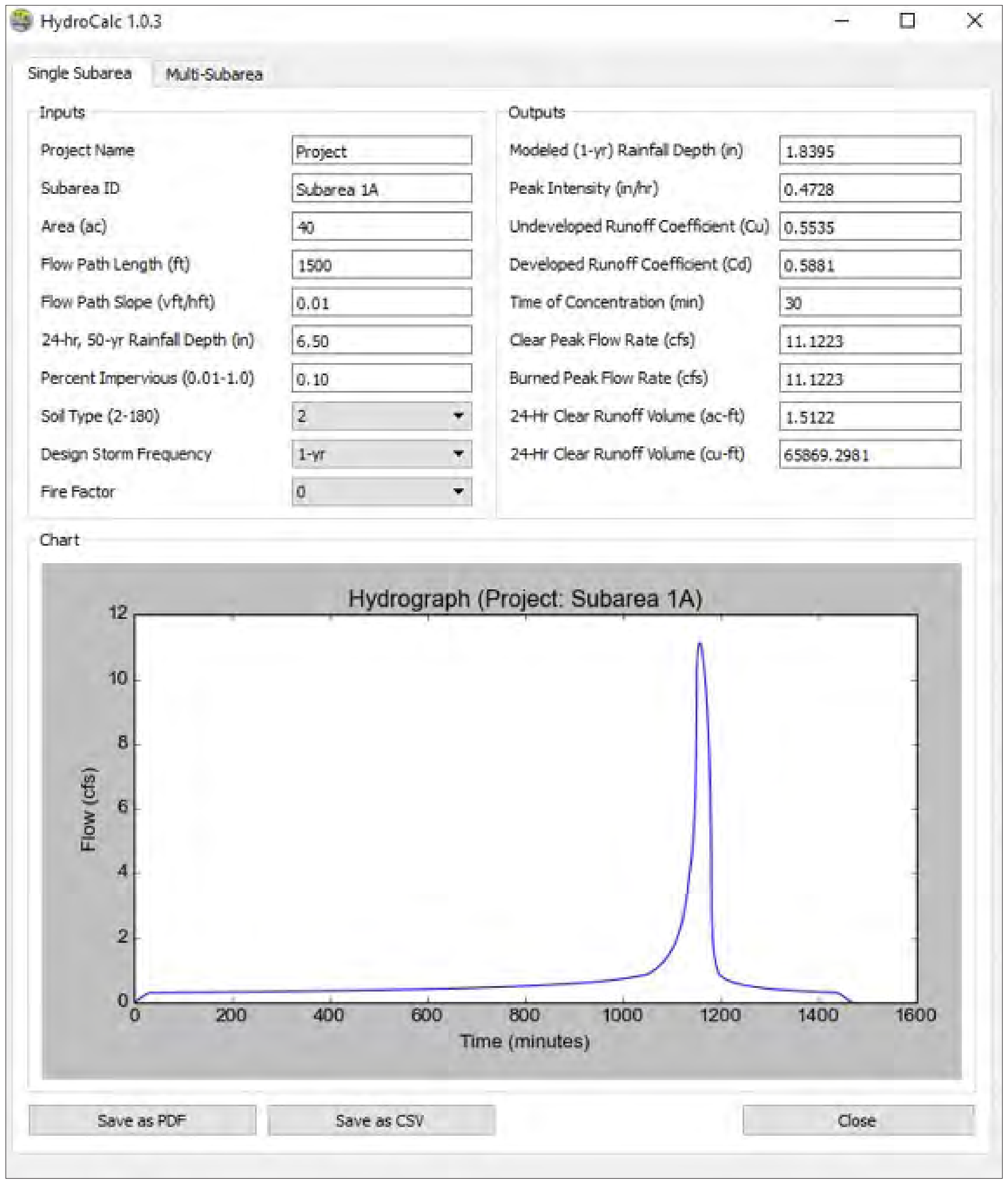
HYDROCALC

HydroCalc Example Sites

Site Locations

Source: Geosyntec, OLIN

HYDROCALC



Source: http://dpw.lacounty.gov/wrd/publication/Engineering/hydrology/HydroCalc.zip

HYDROCALC

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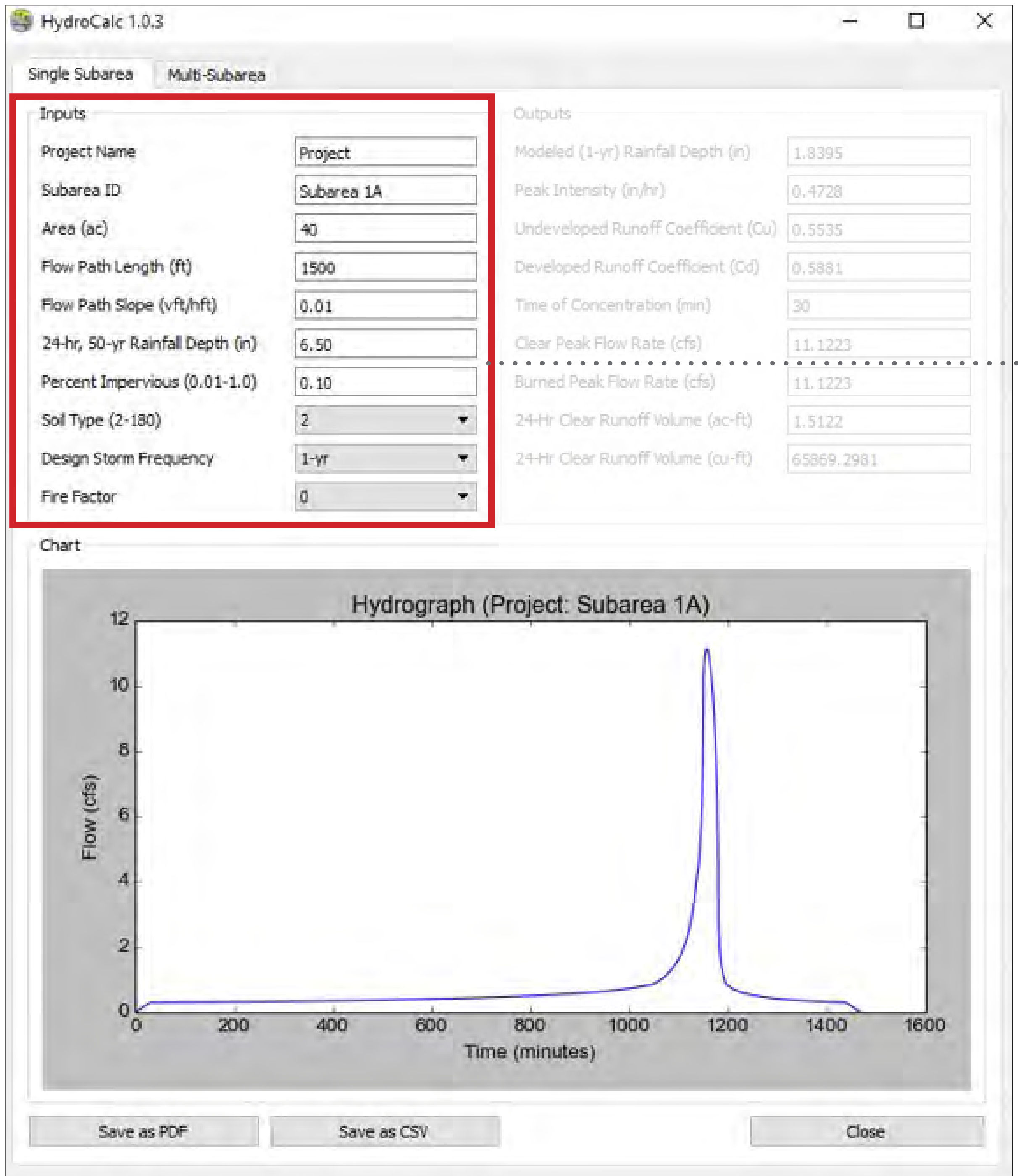
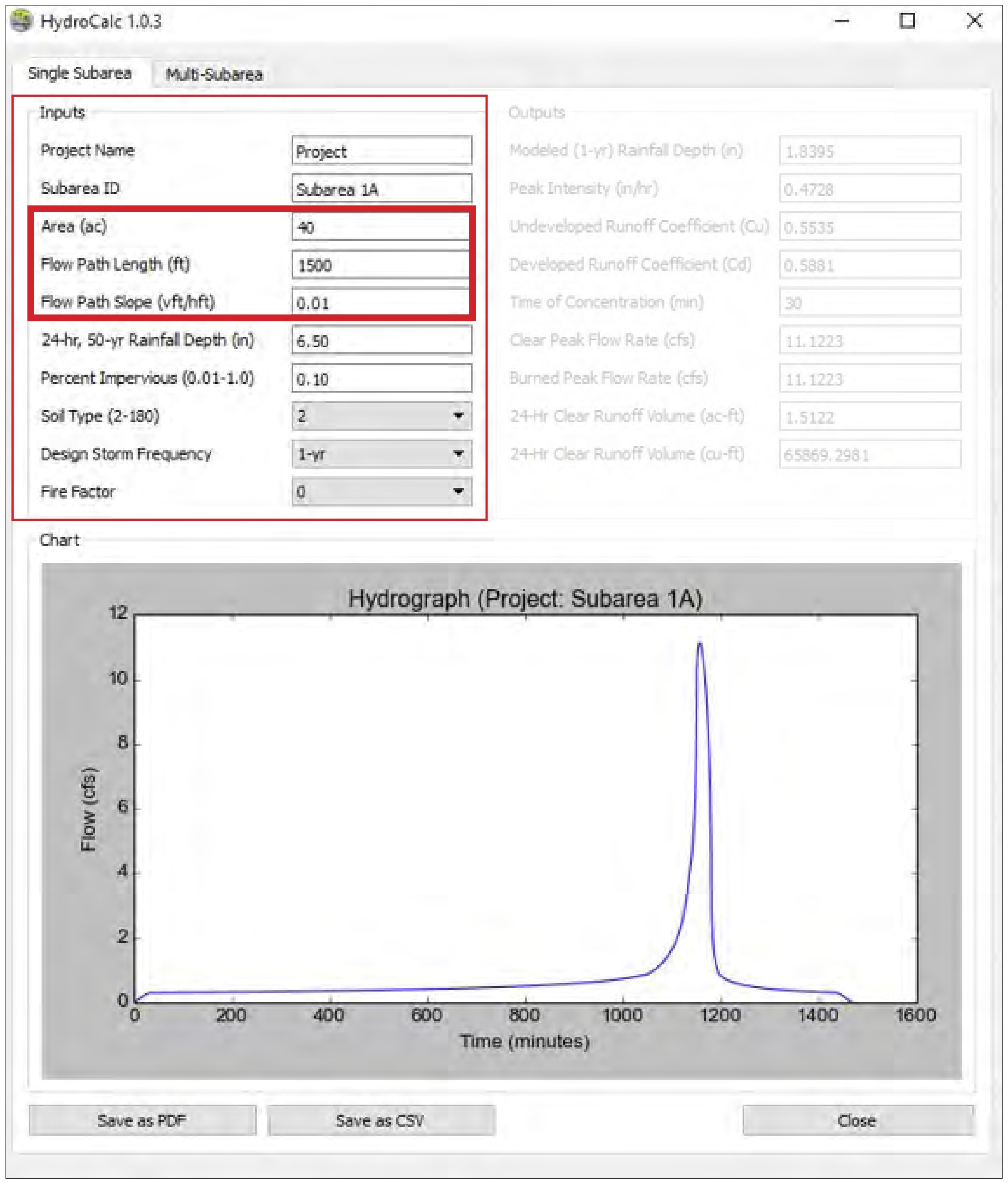


Inputs

Source: http://dpw.lacounty.gov/wrd/publication/Engineering/hydrology/HydroCalc.zip

HYDROCALC

HYDROCALC



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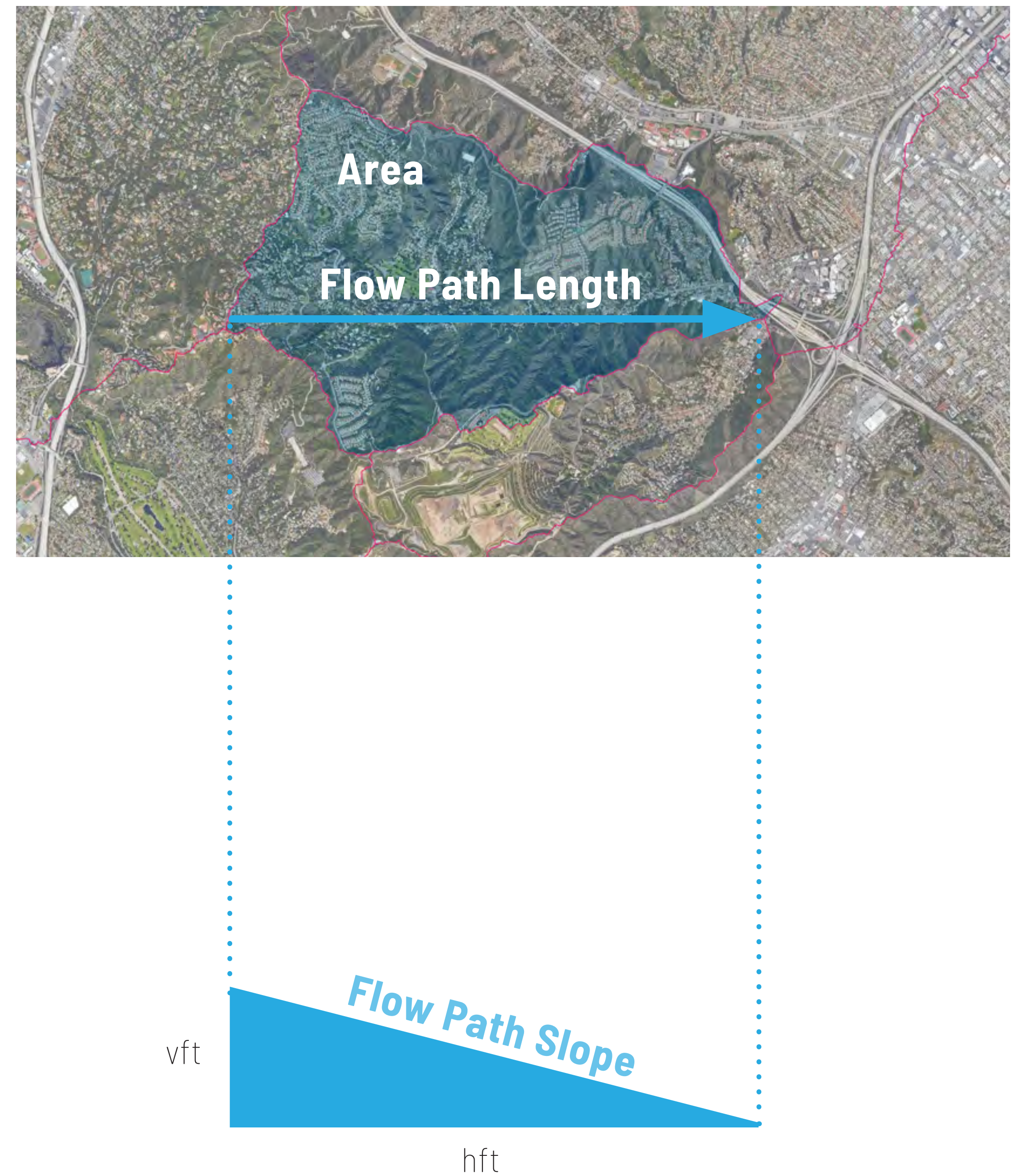
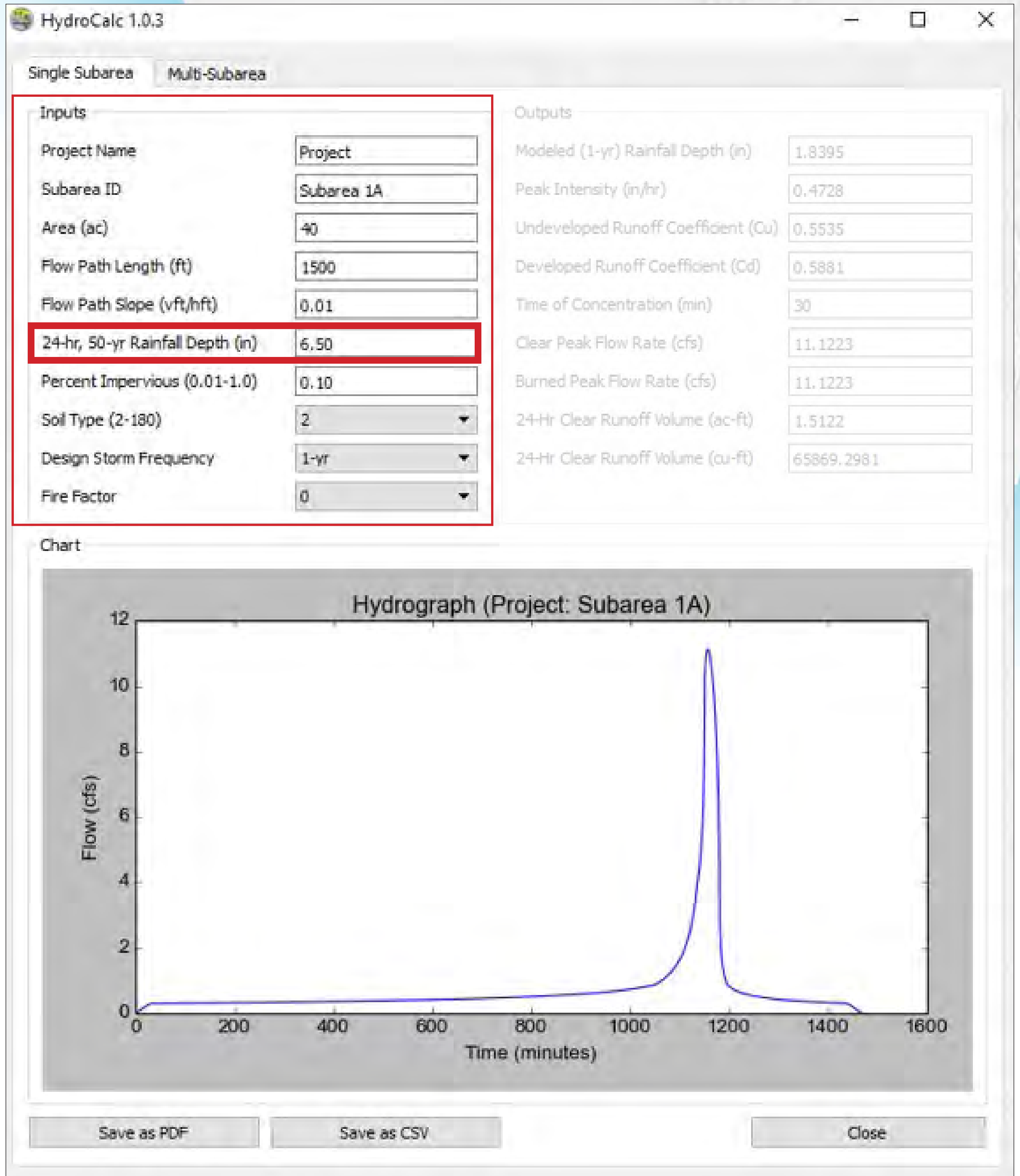
Subarea



HYDROCALC

HYDROLOGY AND HYDRAULICS

HYDROCALC



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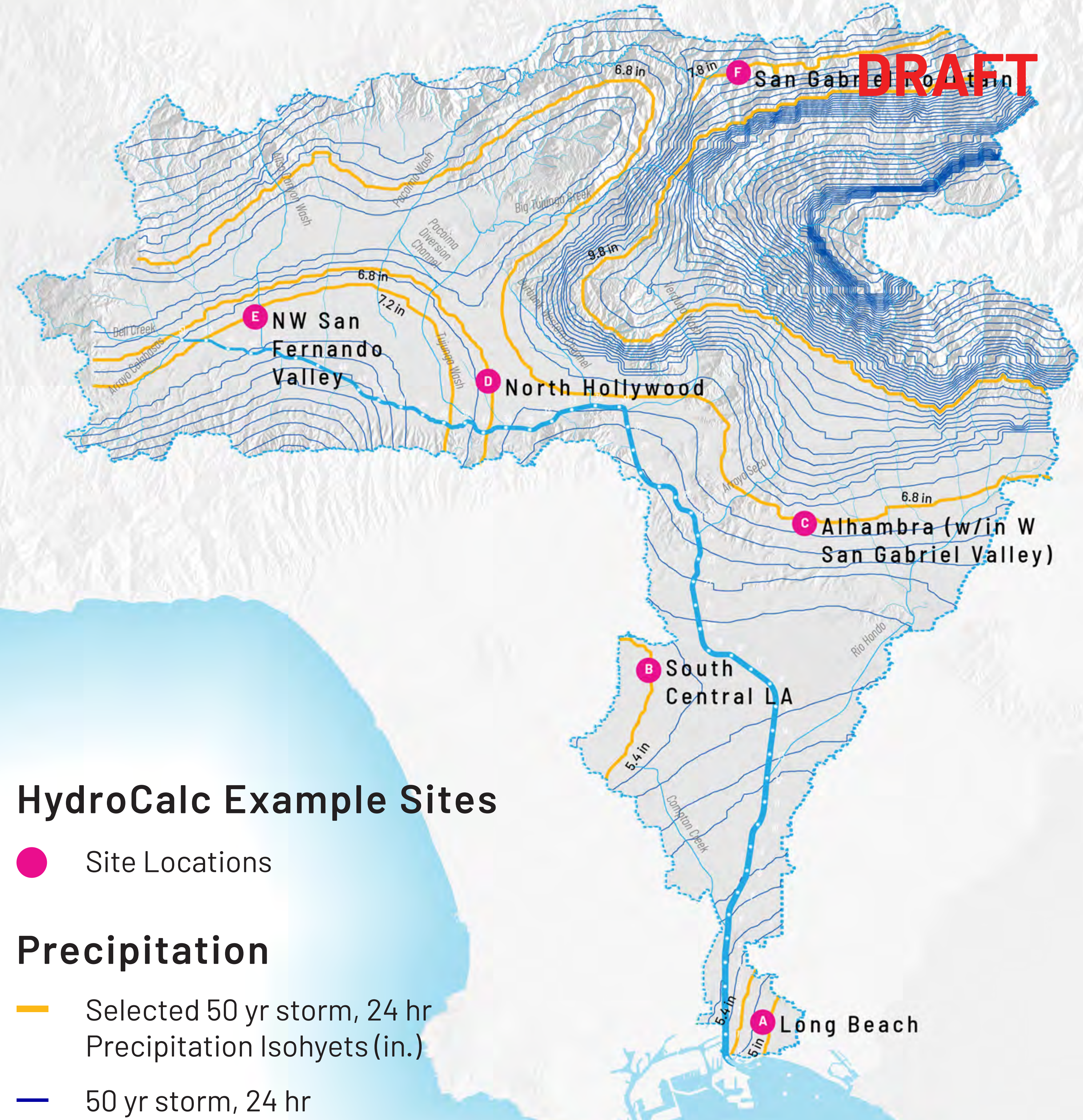


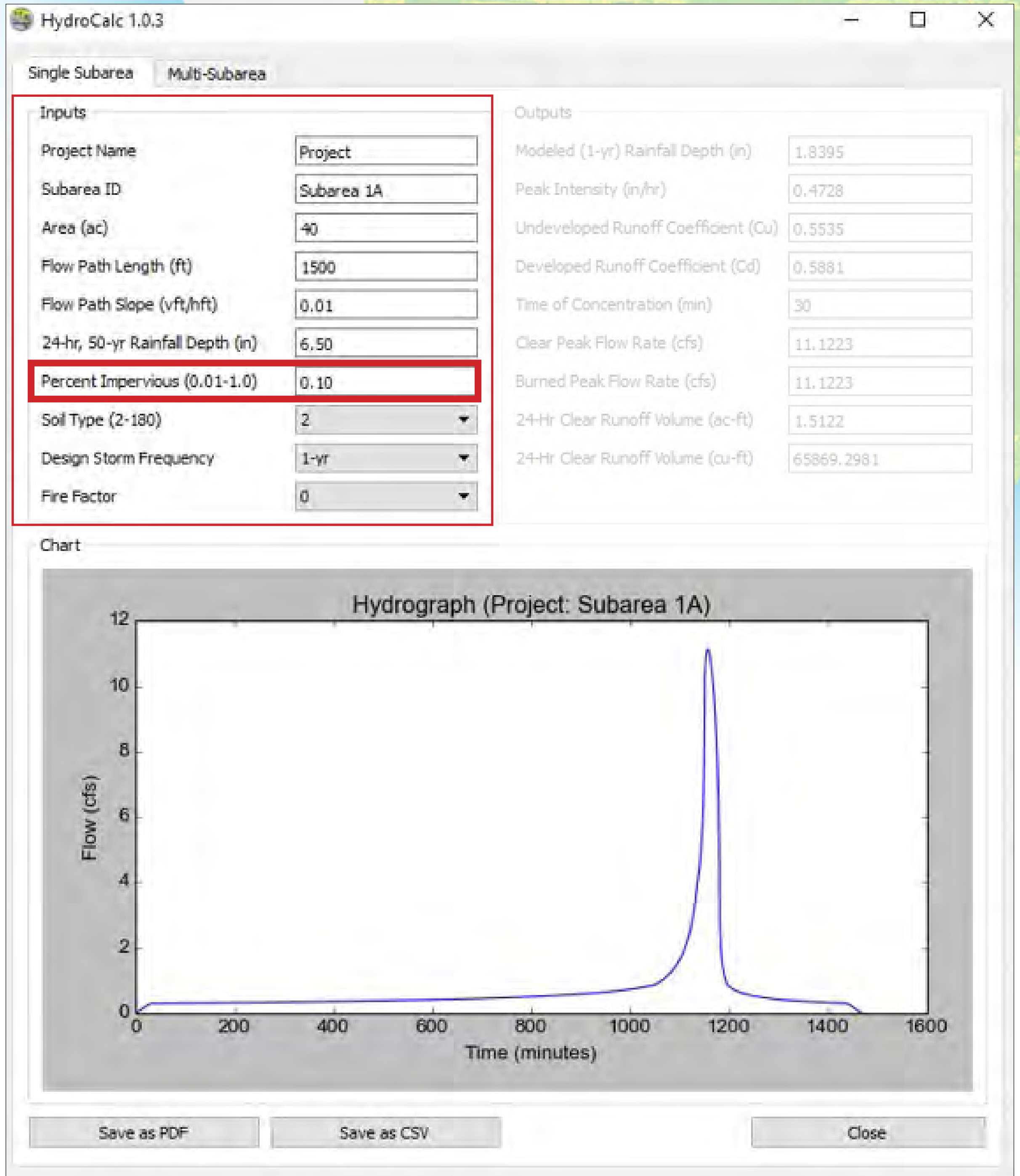
Source: Geosyntec, OLIN, Content modified from http://www.ladpw.org/wrd/publication/Engineering/hydrology/rain_depth.zip

HYDROCALC

5 mi.
N

HYDROLOGY AND HYDRAULICS

HYDROCALC



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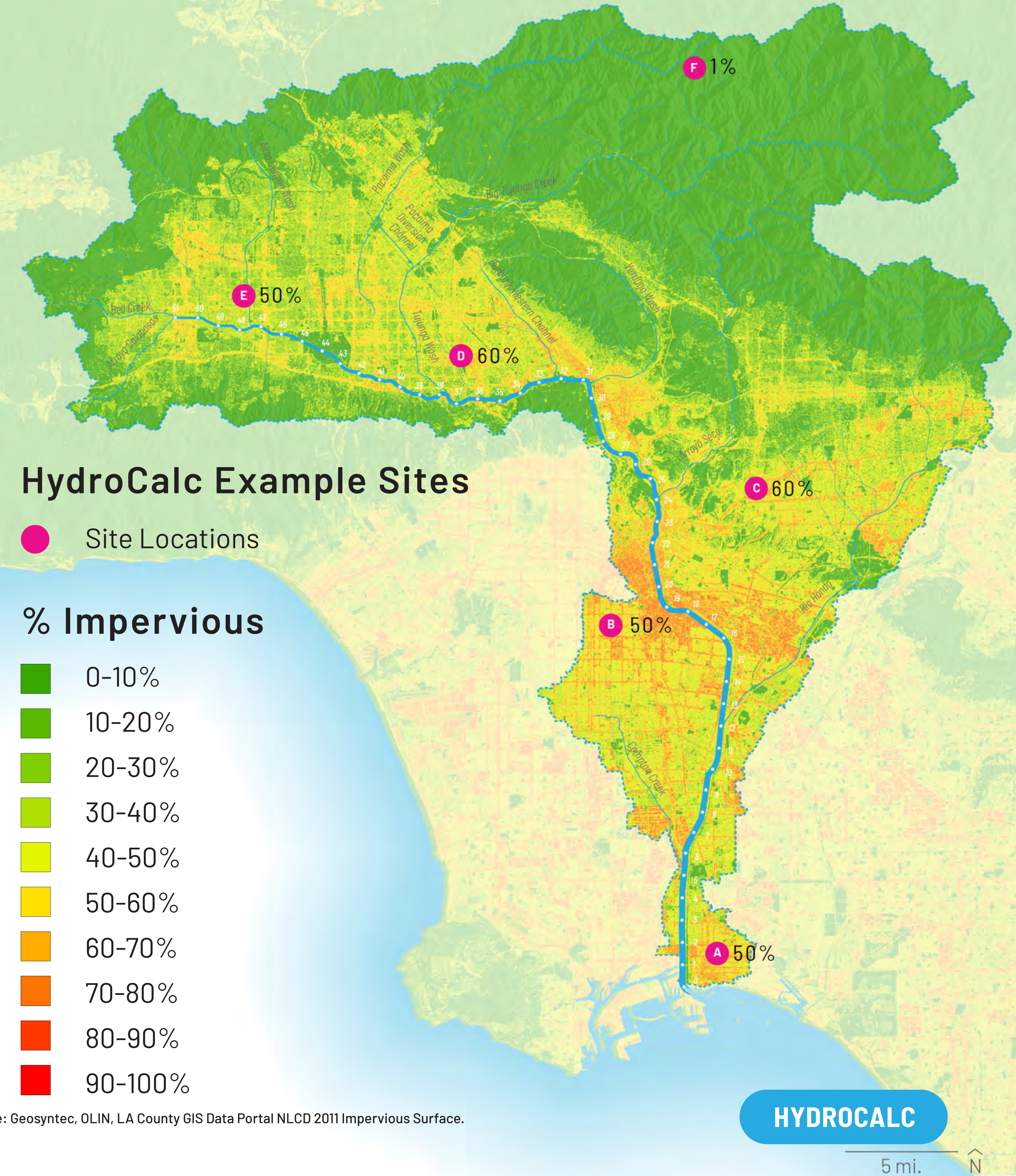
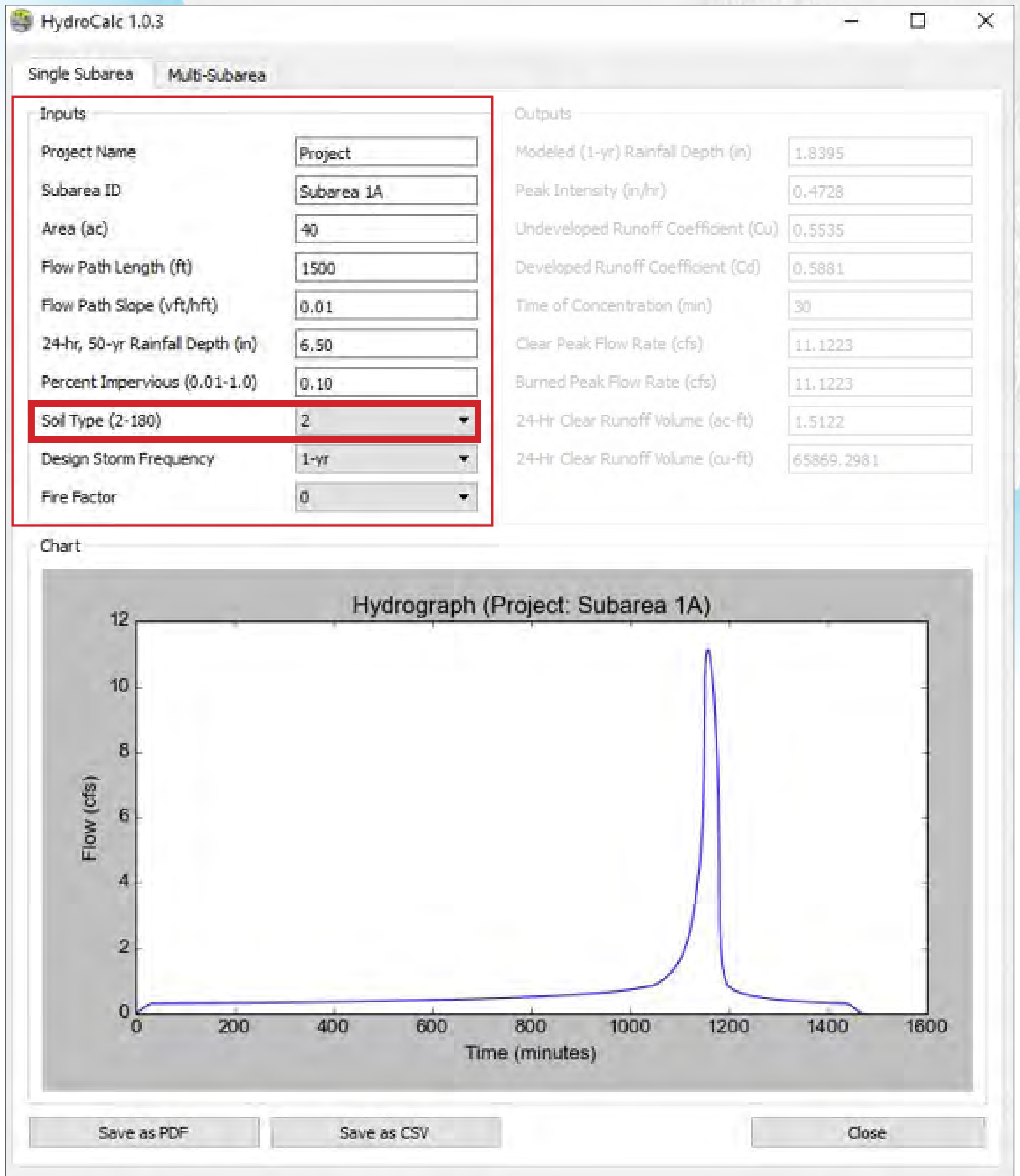


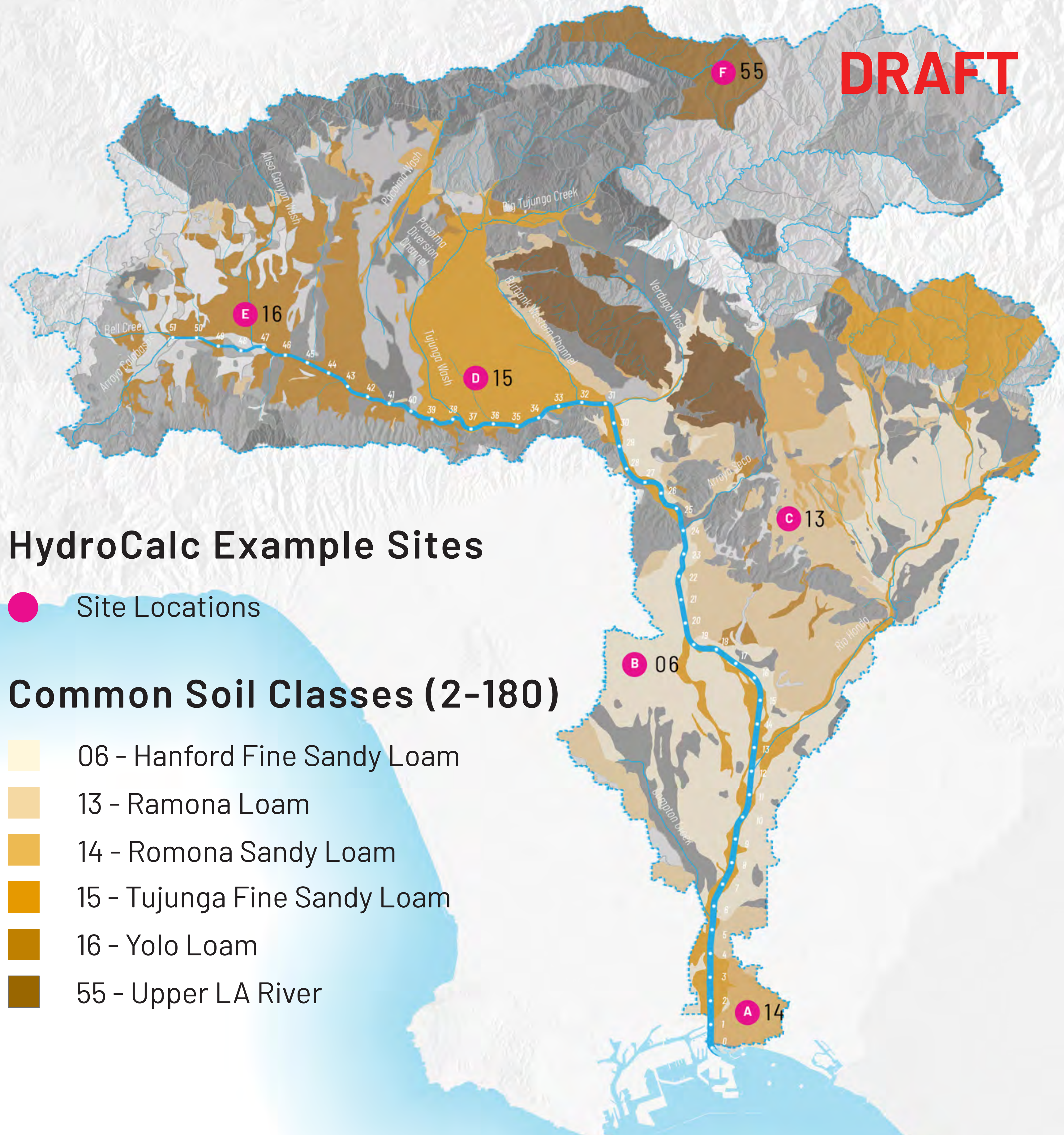
Source: Geosyntec, OLIN, LA County GIS Data Portal NLCD 2011 Impervious Surface.

HYDROCALC

DRAFT



Source: http://dpw.lacounty.gov/wrd/publication/Engineering/hydrology/HydroCalc.zip



HydroCalc Example Sites

- Site Locations

Common Soil Classes (2-180)

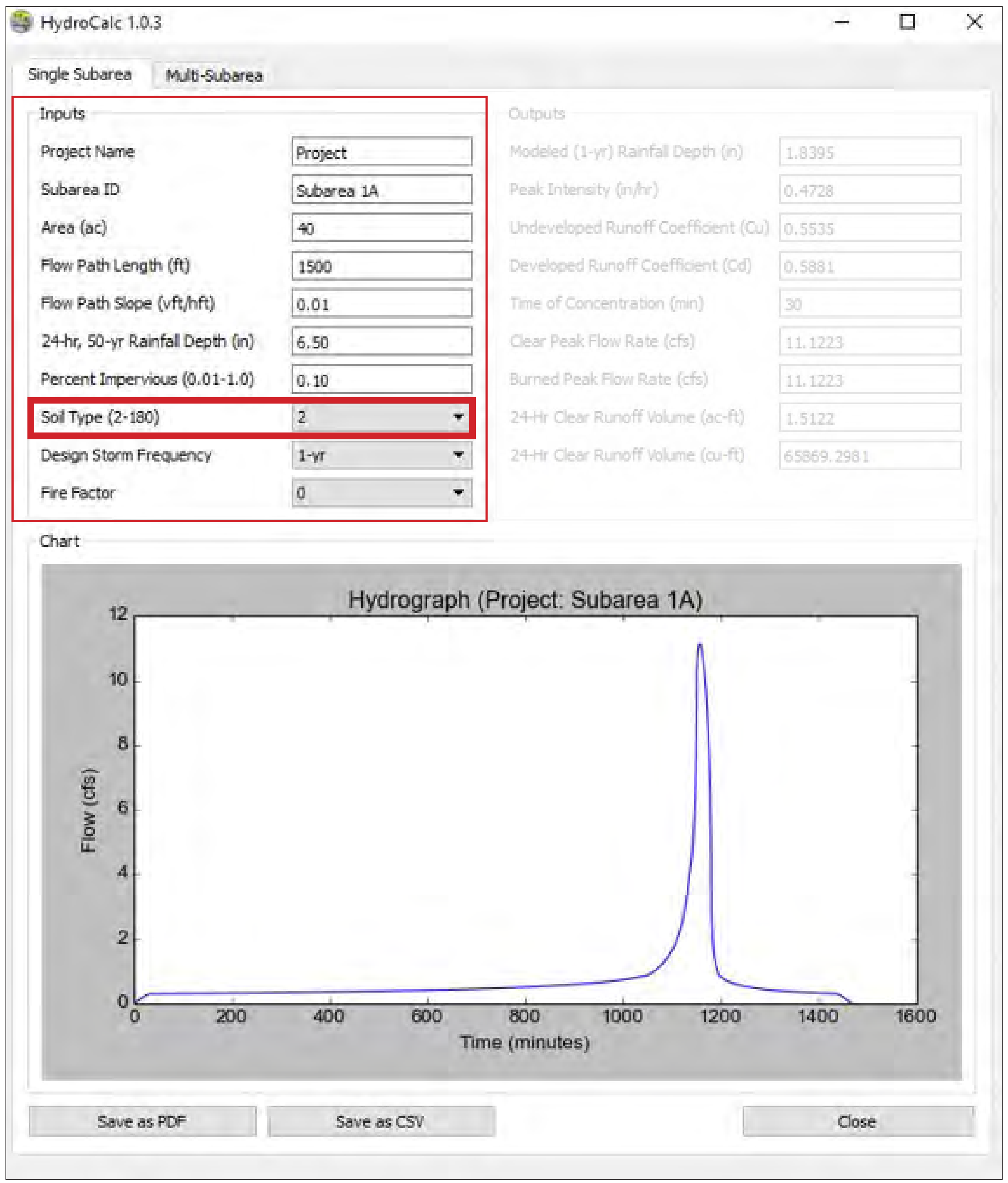
- 06 - Hanford Fine Sandy Loam
- 13 - Ramona Loam
- 14 - Romona Sandy Loam
- 15 - Tujunga Fine Sandy Loam
- 16 - Yolo Loam
- 55 - Upper LA River

Source: Geosyntec, OLIN, Content modified from http://www.ladpw.org/wrd/publication/Engineering/hydrology/soil_types.zip

HYDROCALC

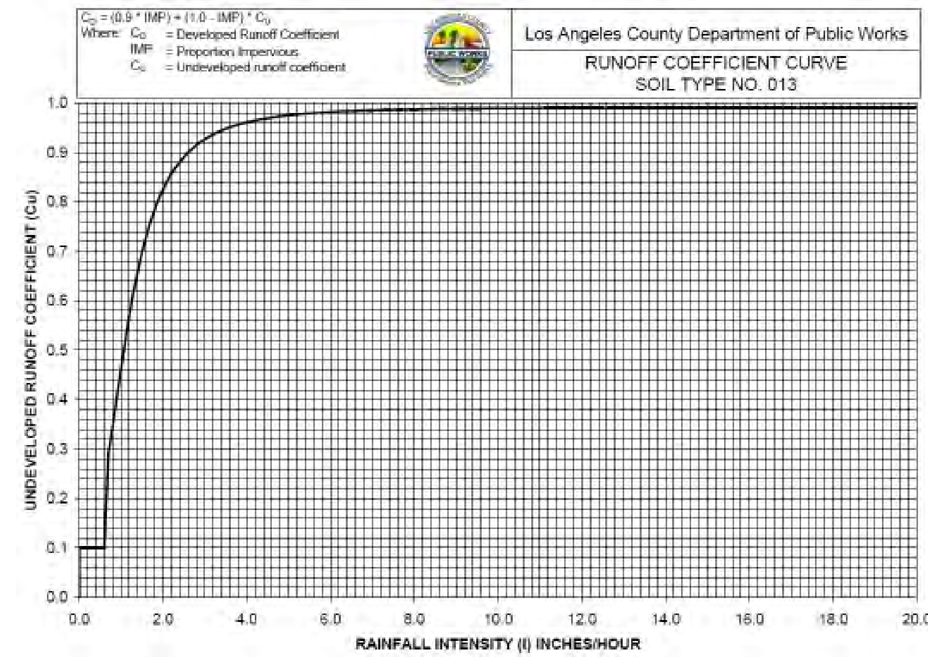
5 mi. N

HYDROCALC

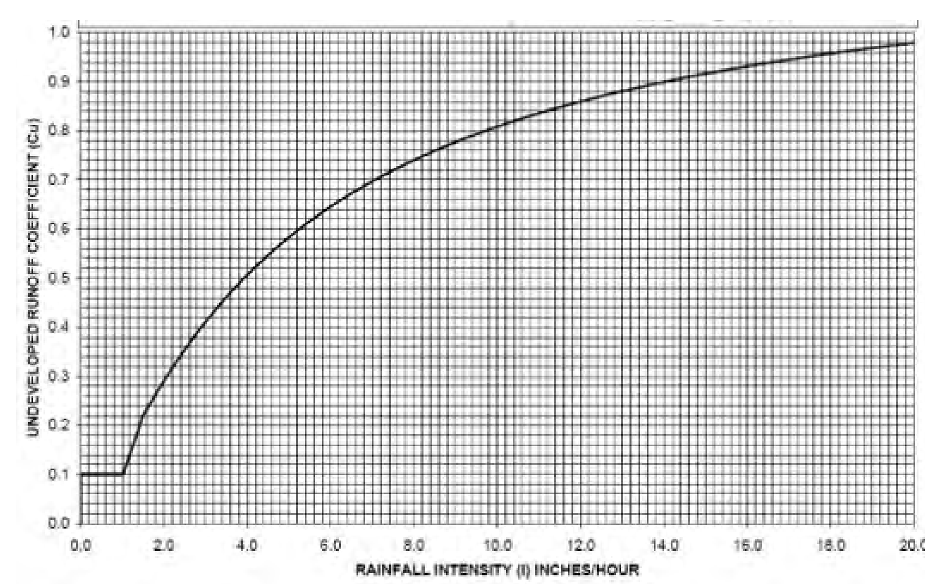


Source: http://dpw.lacounty.gov/wrd/publication/Engineering/hydrology/HydroCalc.zip

13 - Ramona Loam



15 - Tujunga Fine Sandy Loam



HYDROCALC

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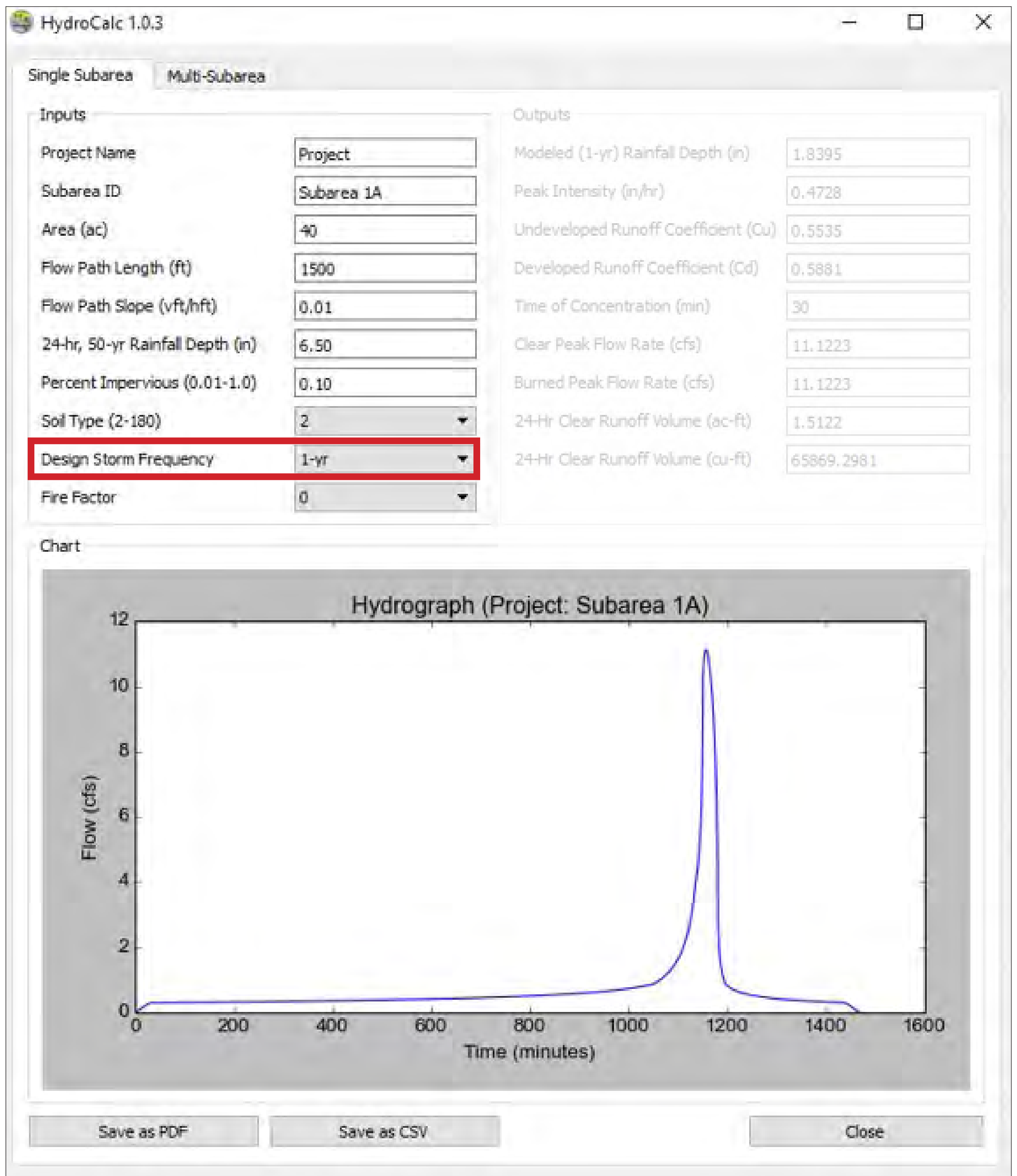

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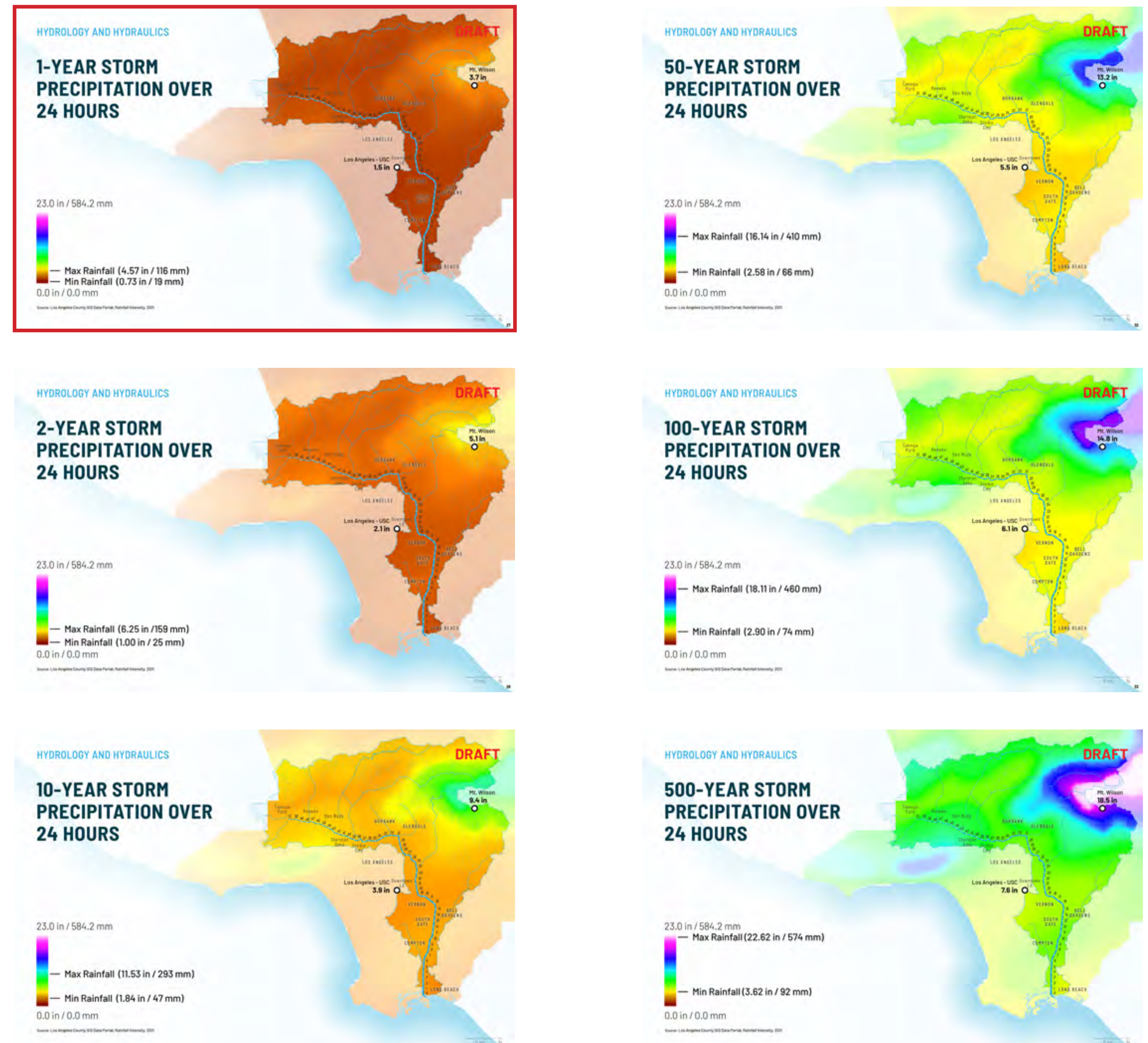
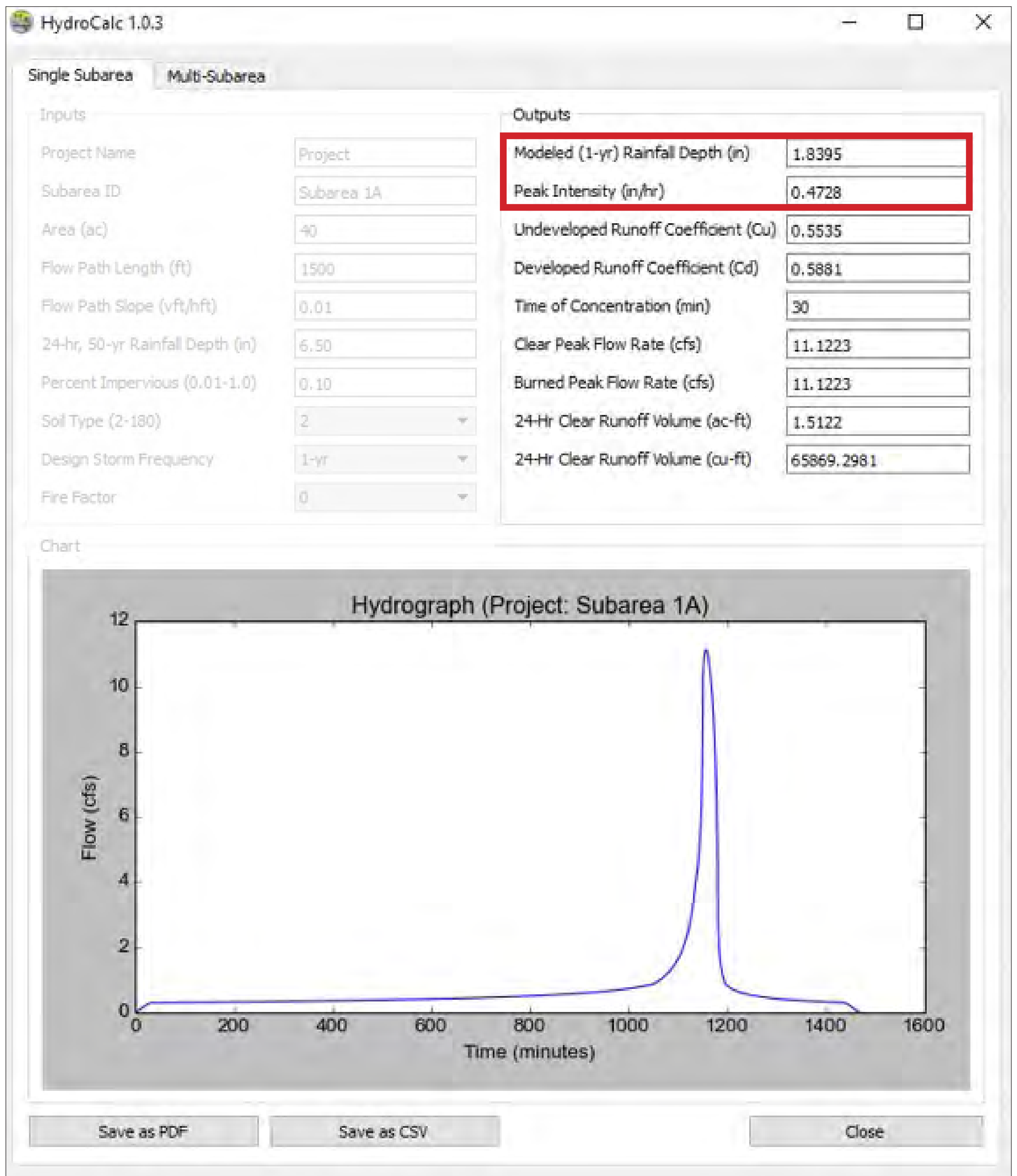


Source: Geosyntec, OLIN, Content modified from Los Angeles County GIS Data Portal, Rainfall Intensity, 2011

HYDROCALC

HYDROCALC



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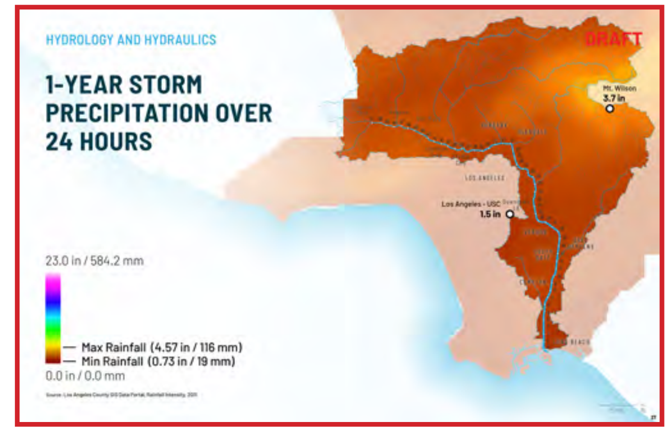
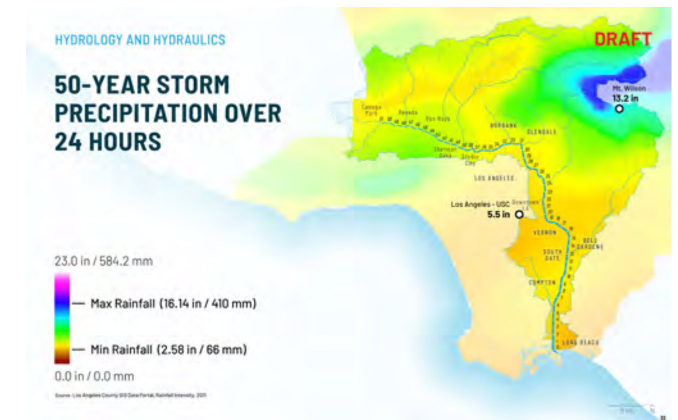
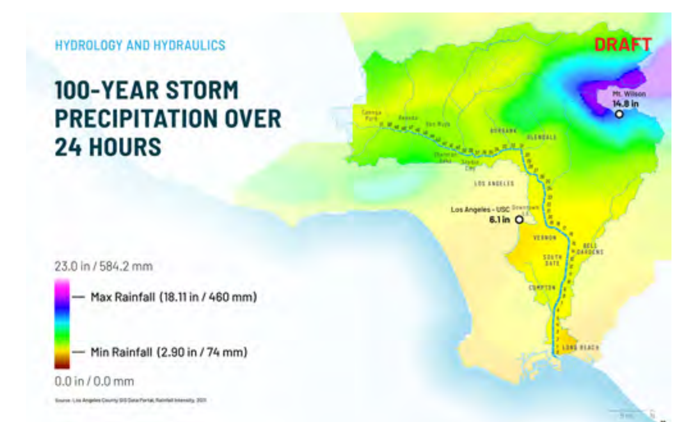
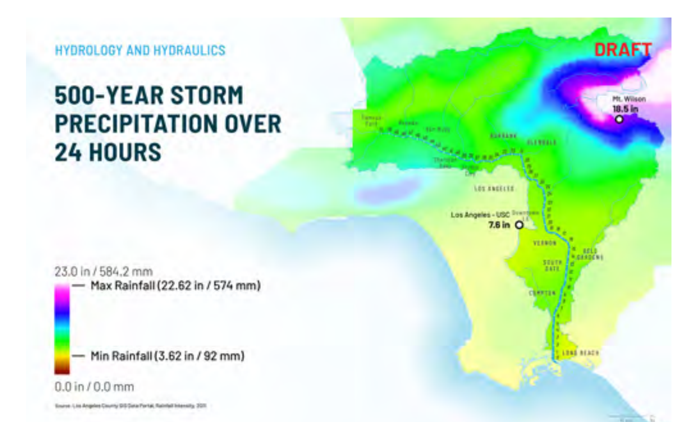


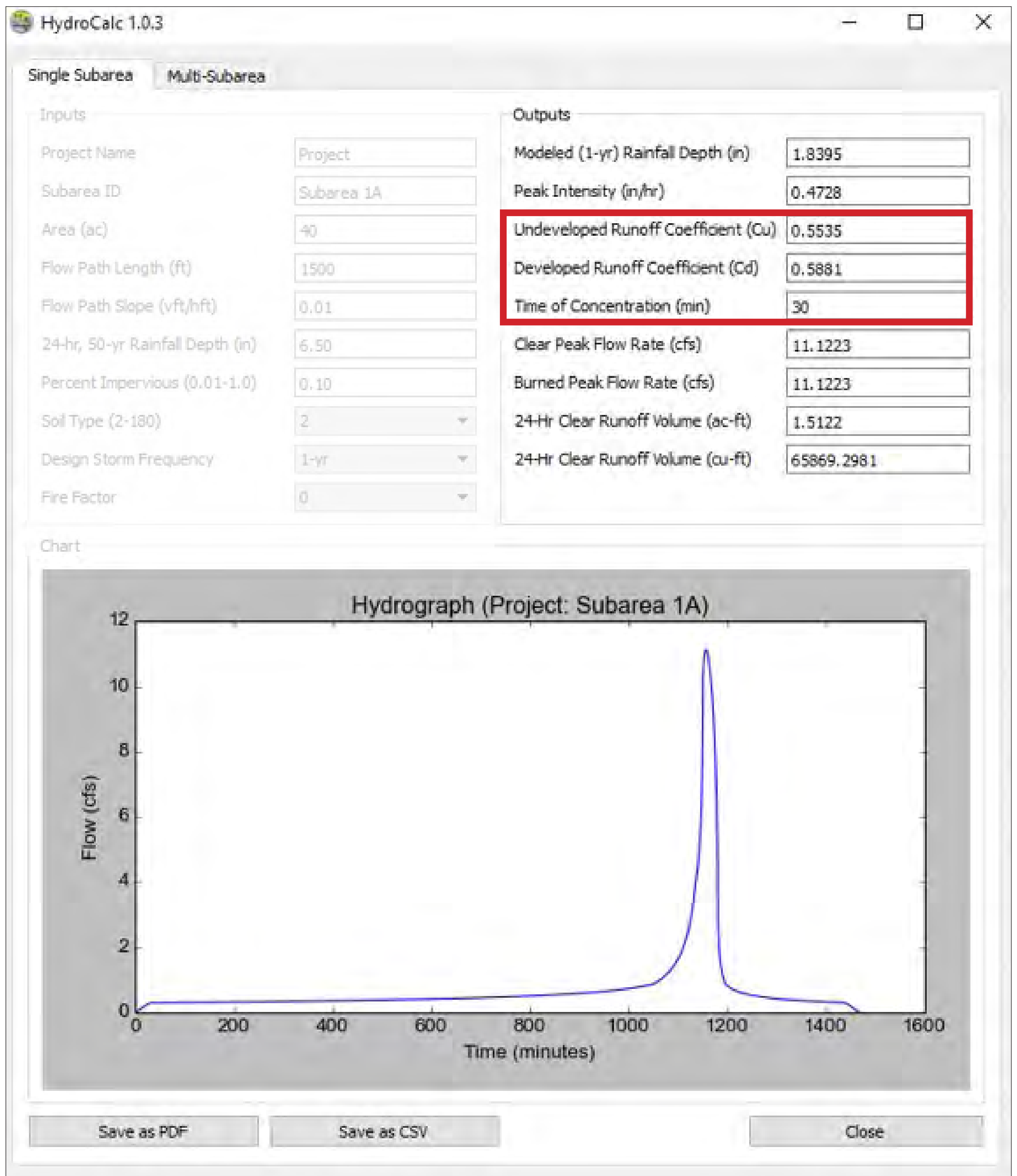






Source: Geosyntec, OLIN, Content modified from Los Angeles County GIS Data Portal, Rainfall Intensity, 2011

HYDROCALC



Source: http://dpw.lacounty.gov/wrd/publication/Engineering/hydrology/HydroCalc.zip

- Fraction of rain that runs off undeveloped surfaces

  - soil type

  - rain intensity

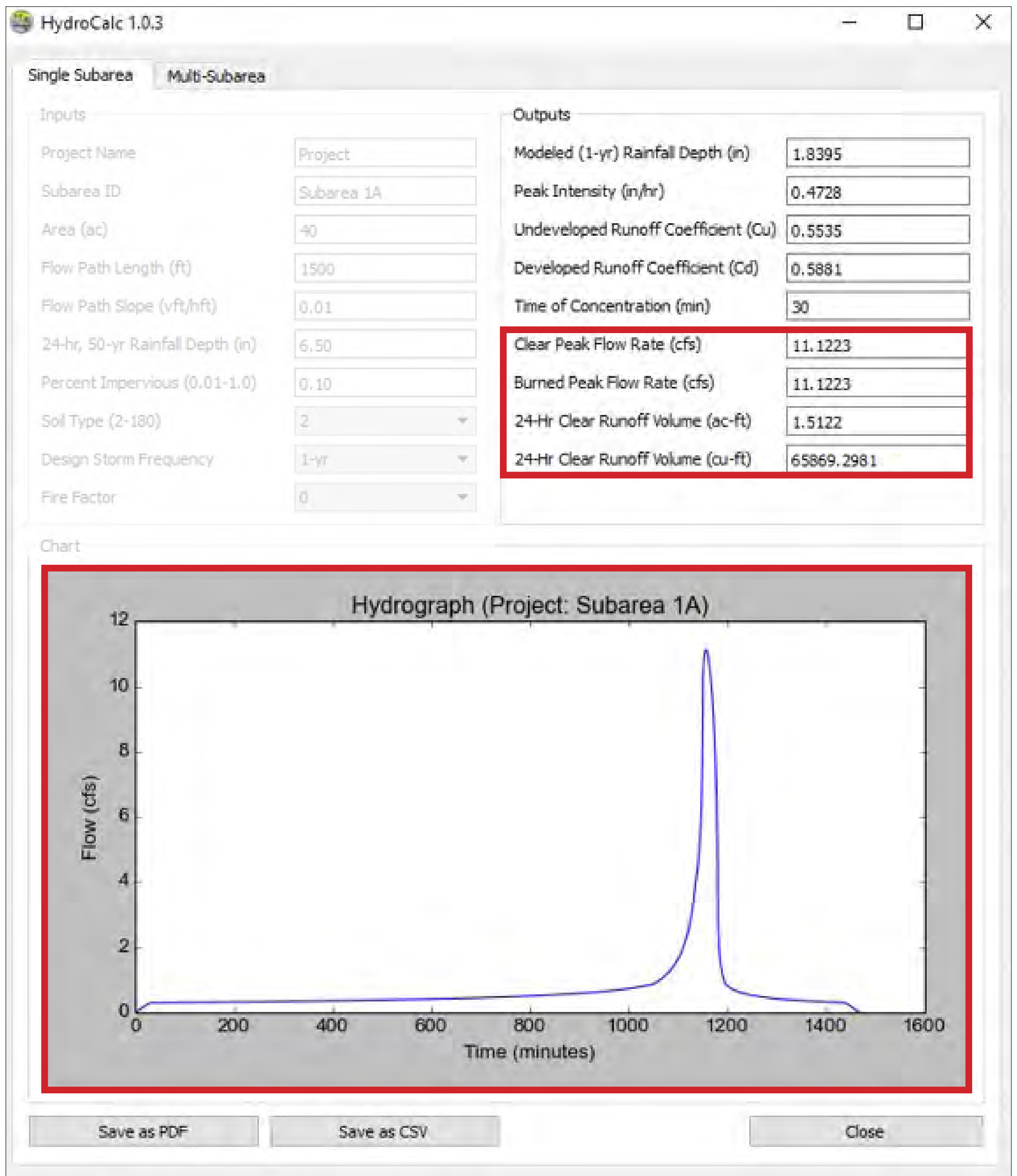
- Fraction of rain that runs off developed surfaces

  - undeveloped surfaces + imperviousness

- Travel time for water from furthest point in subarea

HYDROCALC

HYDROCALC



Source: http://dpw.lacounty.gov/wrd/publication/Engineering/hydrology/HydroCalc.zip

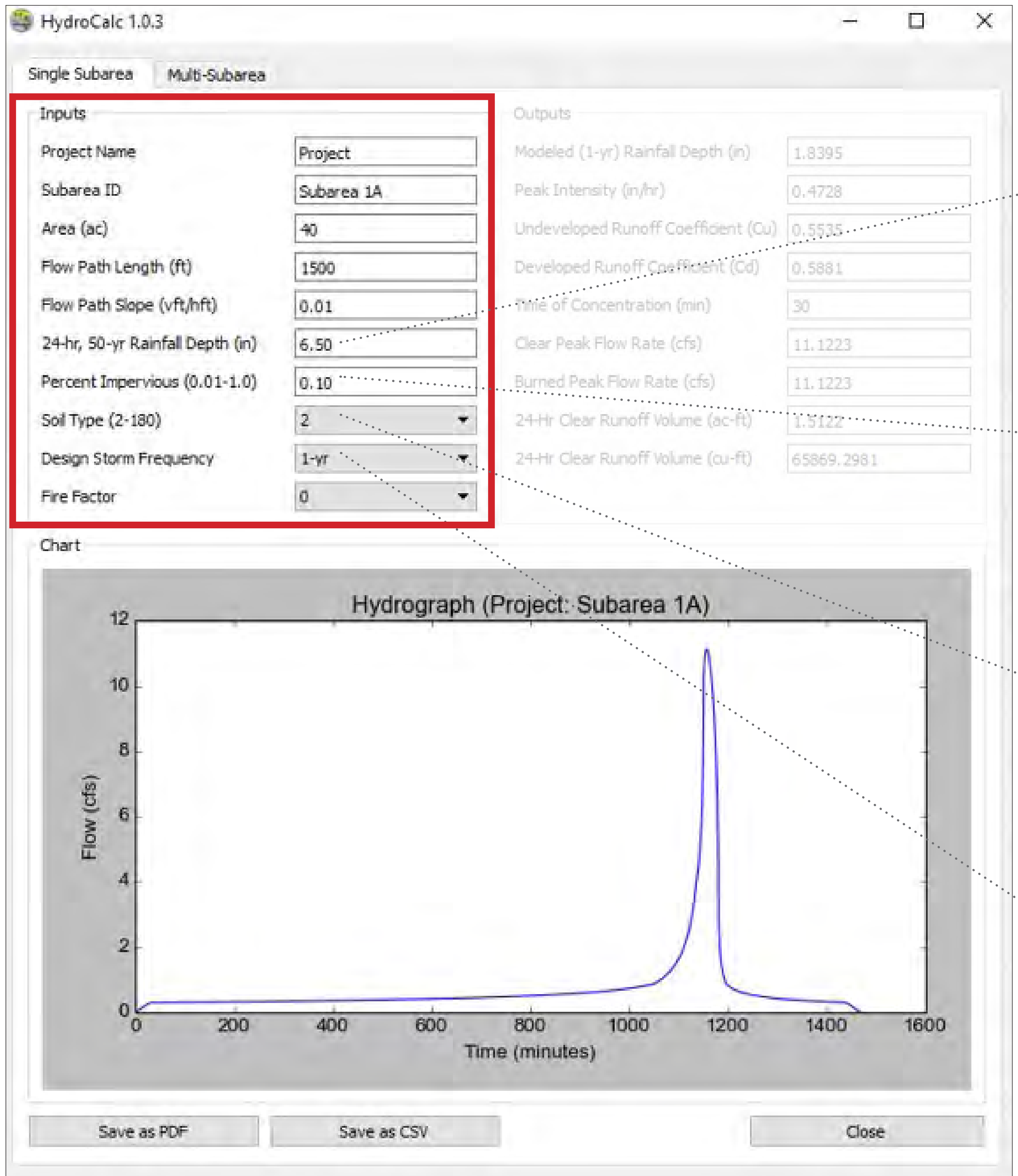
Peak Flow Rates

- Relevant for drainage design and flood risk management
- Will be higher for burned watersheds
  - *debris bulking*
  - *hydro-phobic soil*

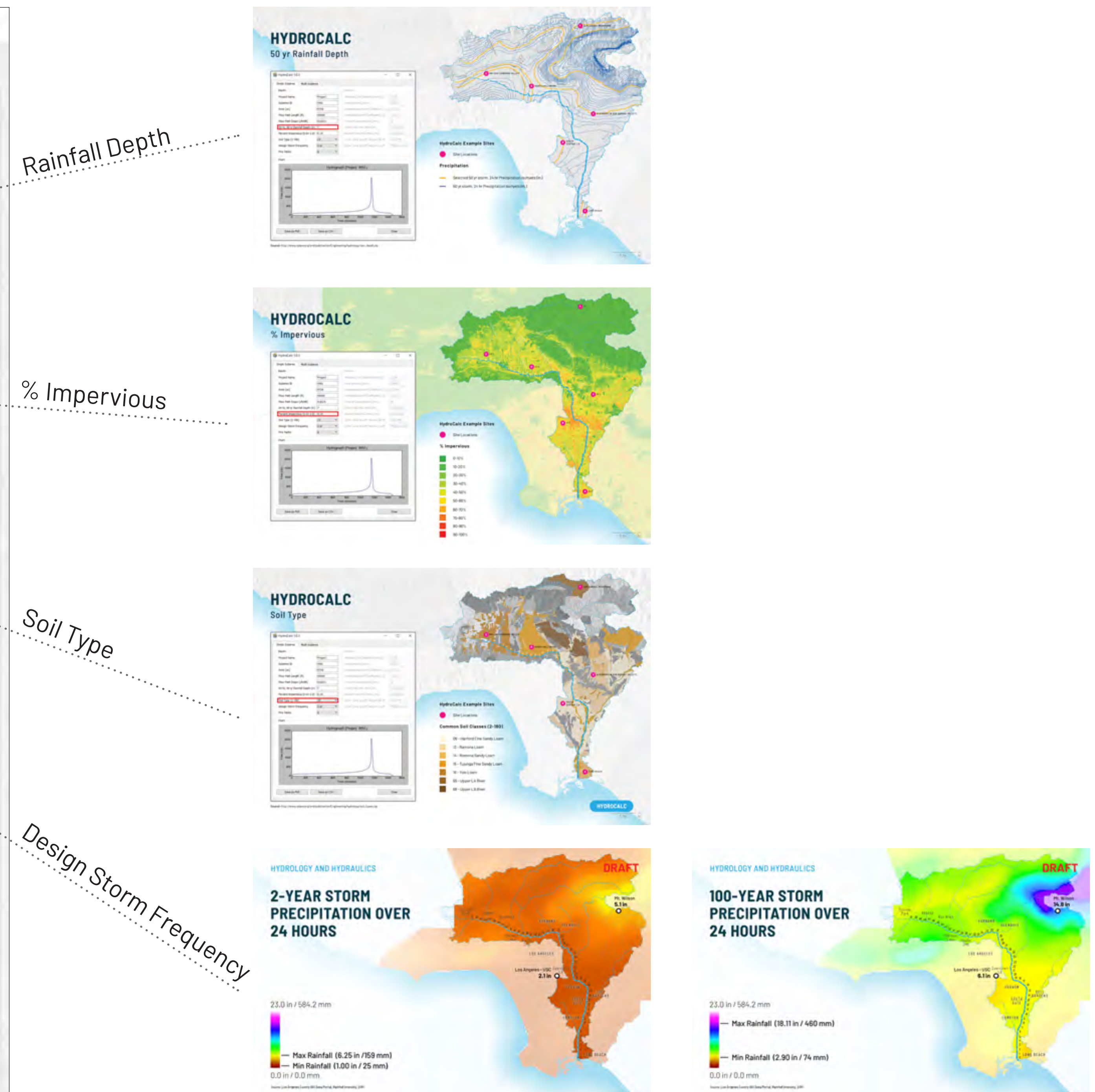
Volumes

- Relevant for LID / BMP design

HYDROLOGY AND HYDRAULICS
HYDROCALC



Source: http://dpw.lacounty.gov/wrd/publication/Engineering/hydrology/HydroCalc.zip



Source: Geosyntec, OLIN, Content modified from http://www.ladpw.org/wrd/publication/Engineering/hydrology/rain_depth.zip; http://www.ladpw.org/wrd/publication/Engineering/hydrology/soil_types.zip; Los Angeles County GIS Data Portal, Rainfall Intensity, 2011

HYDROCALC

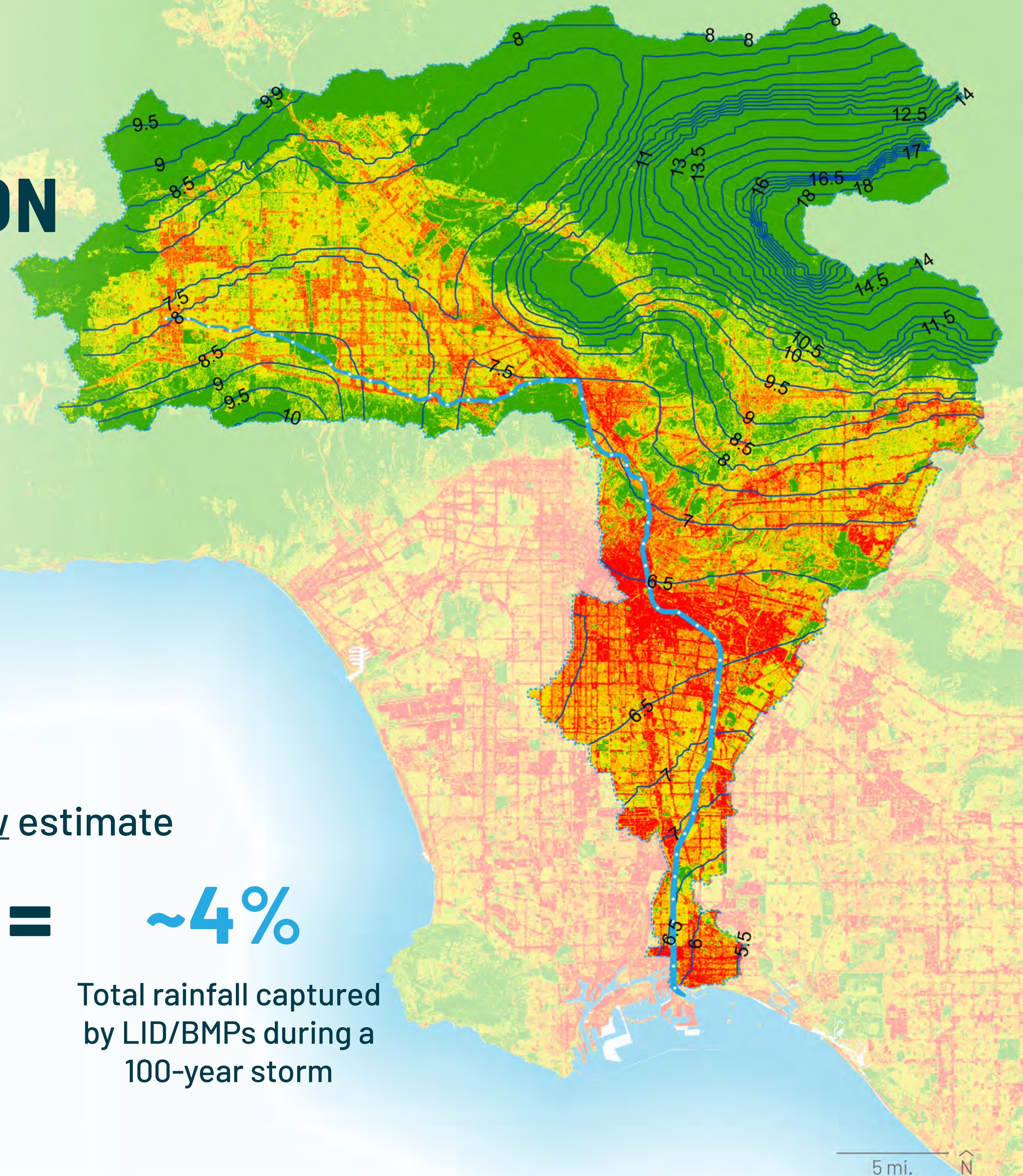
HYDROLOGY AND HYDRAULICS
HYDROCALC

HydroCalc Example Sites

● Site Locations

Source: Geosyntec, OLIN

WATERSHED CALCULATION



0% Impervious

100% Impervious

This is a <u>volume</u> estimate only, not a <u>peak flow</u> estimate

~27%	x	~15%	=	~4%
Percentage of rain that falls on impervious surface		Percentage of rain that LID/BMP captures from a 100-year storm		Total rainfall captured by LID/BMPs during a 100-year storm

Source: LA County GIS Data Portal NLCD 2011 Impervious Surface.

EXAMPLE LOCATIONS

Section at Glendale Narrows (River Mile 29)

Section at Firestone Blvd (River Mile 13)

Source: Geosyntec, OLIN

NARROWS ARBOR REACHES

Some sections only manage to the 4-year storm

Table 17: Original Design Discharge and Existing Channel Capacity

Reach[(a)]	River Stations	Design[(b)] Discharge ft³/s	Design Return Period[(e)] yr	Current Freeboard Criteria[(c)] ft	Existing[(d)] Channel Capacity ft³/s	Existing Return Period[(e)] yr	100-Year Discharge[(e)] ft³/s
Reach 1	625+77 to 547+45	40,000	12	3	29,300	4	81,000
Reach 2	546+45 to 510+05	40,000	7	3	25,800	3	88,900
Reach 3a	504+93 to 477+85	40,000	7	3	63,000[(f)]	32	88,900
Reach 3b	475+68 to 452+58	78,000	51	3	84,000[(f)]	69	94,600
Reach 4	432+16 to 359+75	78,000	51	3	34,700	4	94,600
Reach 5	358+63 to 271+89	78,000	51	3	34,000	4	94,600
Reach 6a	270+28 to 262+73	78,000	51	2.5	64,500	24	94,600
Reach 6b	257+85 to 144+23	83,700	57	2.5	50,500	11	93,800
Reach 7a	142+91 to 131+22	83,700	57	2.5	135,400[(f)]	>500	93,800
Reach 7b	128+71 to 86+61	104,000	83	3	83,700	32	109,000
Reach 8	86+07 to 10+31	104,000	83	3	89,600	42	109,000

Notes:
(a) Letters a & b in Reach names denote a change in the river due to a confluence or change in channel dimensions.
(b) Original design discharge for clean prismatic channel.
(c) Freeboard from EM 1110-2-1601; 3 feet for leveed sections and 2.5 feet for trapezoidal entrenched sections.
(d) Existing channel capacity with vegetation, sedimentation and freeboard. The values shown are the minimum within the reach. Discharges above these listed do not necessarily cause damages.
(e) Return periods for Design Discharge and Existing Channel Capacity are based on discharge frequency analysis for the 1992 LACDA Feasibility Study.
(f) In some limited reaches the existing channel capacity is greater than the original design discharge because of more than adequate freeboard.
(g) Refer to Plates 21a through 24b to see the floodplains for various return frequency flows within the study limits.

HH Appendix 61 September 2015

Source: U.S. Army Corps of Engineers, Los Angeles District. Los Angeles River Ecosystem Restoration Project, Volume III, Appendix E (HH Appendix). 2015.

H&H MODELING TOOLS

	HYDROLOGY			HYDRAULICS	
	UNIT HYDROLOGY	LARGER WATERSHED		CHANNELS	
	HYDROCALC	LSPC	HEC-HMS	MANNING'S	HEC-RAS
NAME	HydroCalc	Loading Simulation Program C++	Hydrologic Engineering Center - Hydrologic Modeling System	Manning's Equation	Hydrologic Engineering Center - River Analysis System
DEVELOPER	LA County Public Works	LA County Public Works	US Army Corps of Engineers	Robert Manning	US Army Corps of Engineers
DATE	2018	2013	2018	1889	2018
PURPOSE	Modified Rational Method for local scale flood and drainage analyses	Designed for water quality best management practice	Designed explicitly for flood risk management	Uniform and steady-state analysis of channels	Varying and unsteady analysis of channels and floodplains
	HYDROCALC	LSPC	HEC-HMS	MANNING'S	HEC-RAS

LSPC MODEL: LOS ANGELES BASIN STUDY

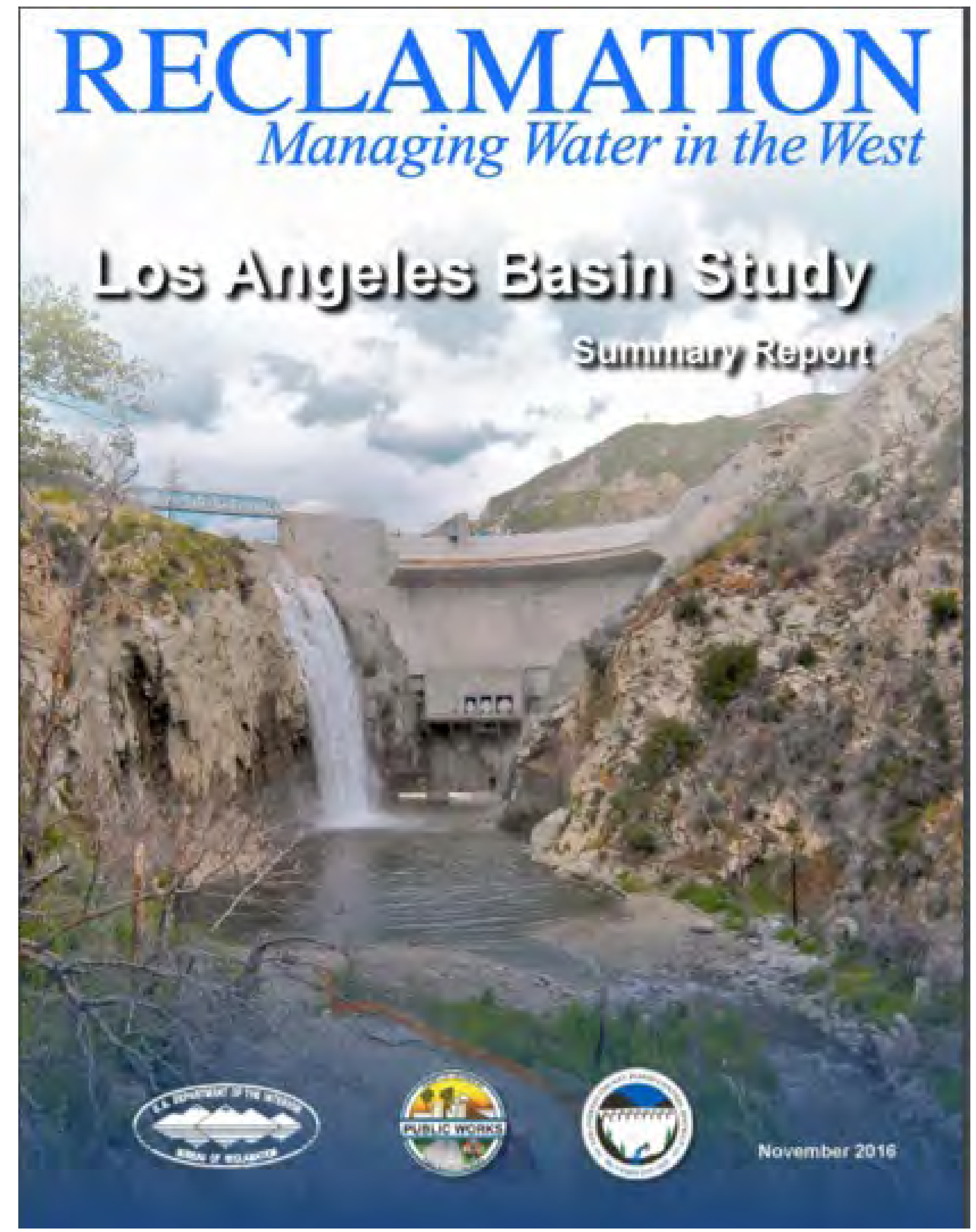
Updated by Reclamation to include LID/BMP

- Supply effects of climate change and LID studied
- Adjusted impervious land-use areas within all subwatersheds to represent widespread LID implementation
- 47 different climate-change projections

Two Levels of LID

- 0.75 inches of storage, 3-day drawdown
- 1.0 inches of storage, 1.5-day drawdown

- **Up to ~48,000 ac-ft/year of additional stormwater conserved in LA River watershed from LID**

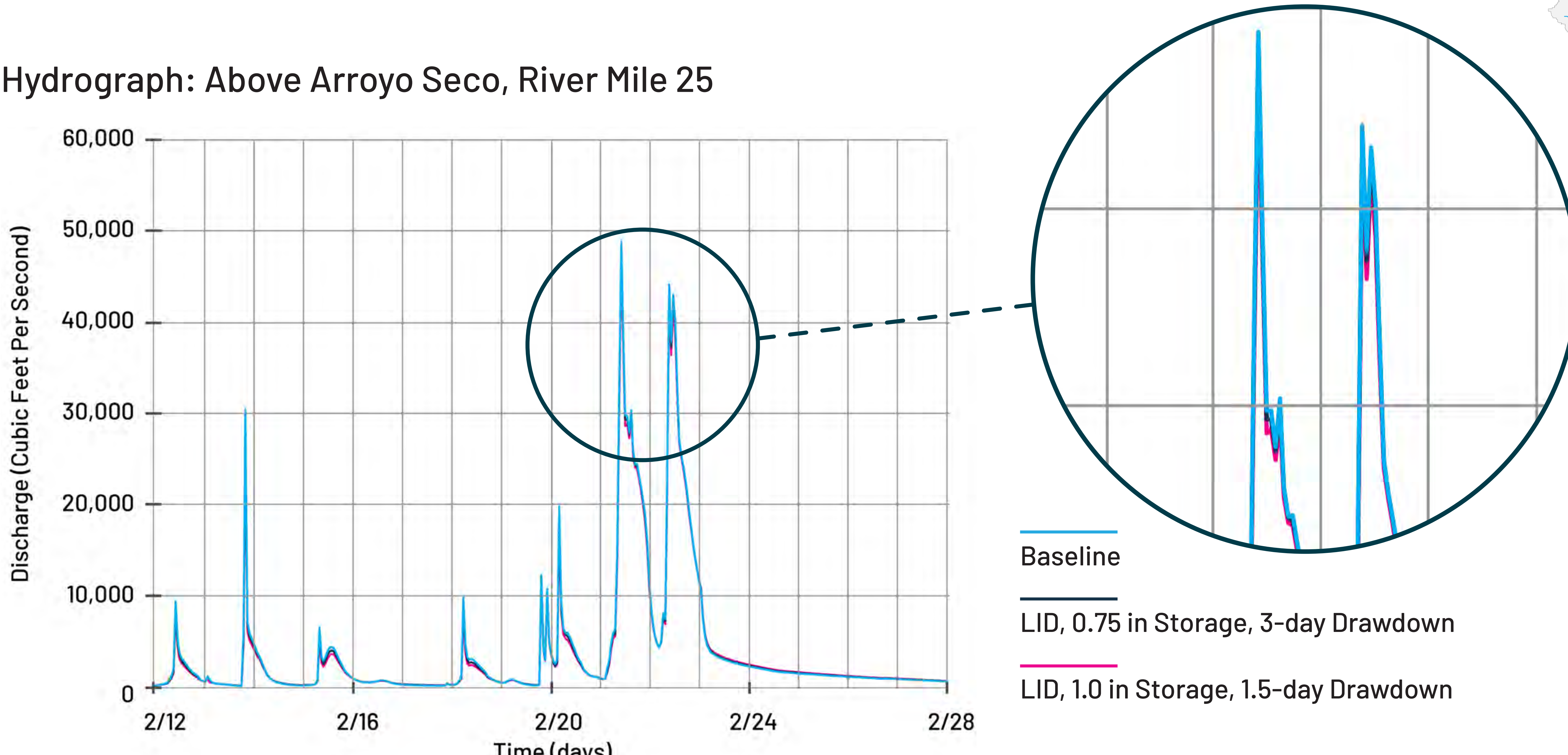


Source: Simes, J. U.S. Department of the Interior & Alexanderson, L., Bradbury, D. County of Los Angeles Public Works, November 2016, https://www.usbr.gov/lc/socal/basinstudies/LABasin.html

LSPC BASIN PLAN RESULTS: FEBRUARY 1998

Similar to Wet February 2019

Hydrograph: Above Arroyo Seco, River Mile 25



Source: USBR, LA County, Geosyntec, OLIN

H&H MODELING TOOLS

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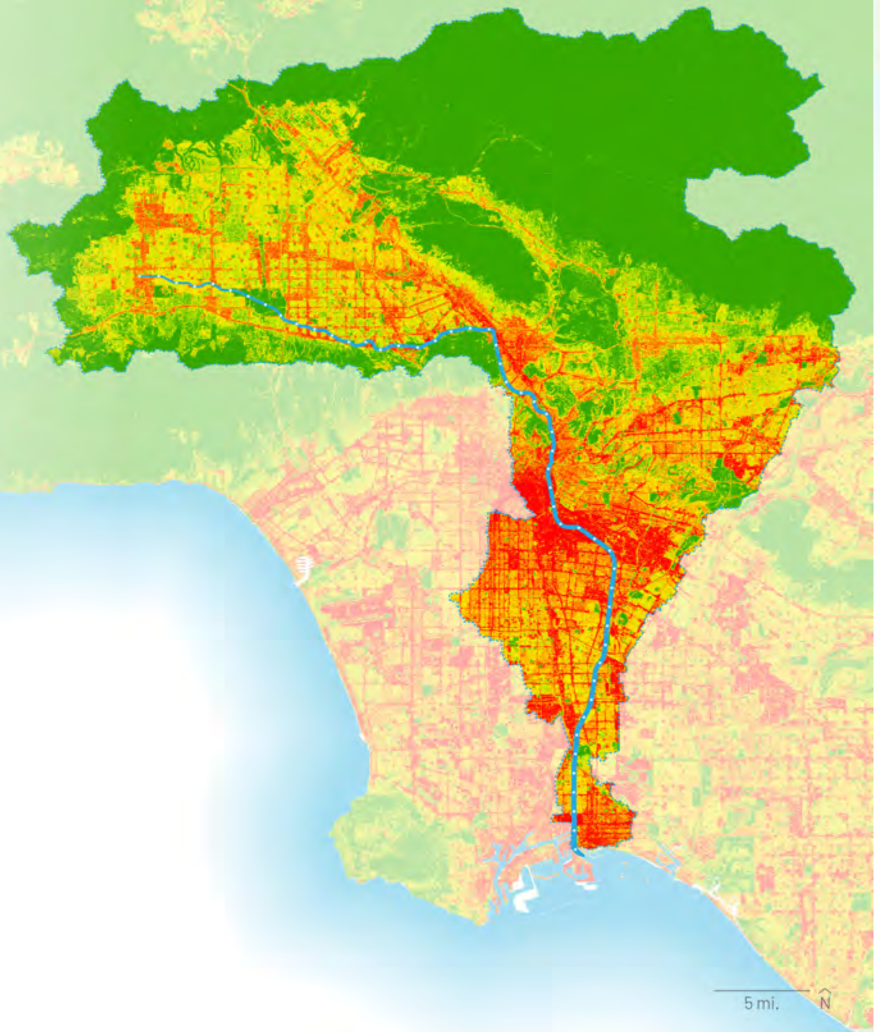
DEVELOPER	LA County Public Works	LA County Public Works	US Army Corps of Engineers	Robert Manning	US Army Corps of Engineers
DATE	2018	2013	2018	1889	2018
PURPOSE	Modified Rational Method for local scale flood and drainage analyses	Designed for water quality best management practice	Designed explicitly for flood risk management	Uniform and steady-state analysis of channels	Varying and unsteady analysis of channels and floodplains
	HYDROCALC	LSPC	HEC-HMS	MANNING'S	HEC-RAS

IMPERVIOUS SURFACE BASELINE

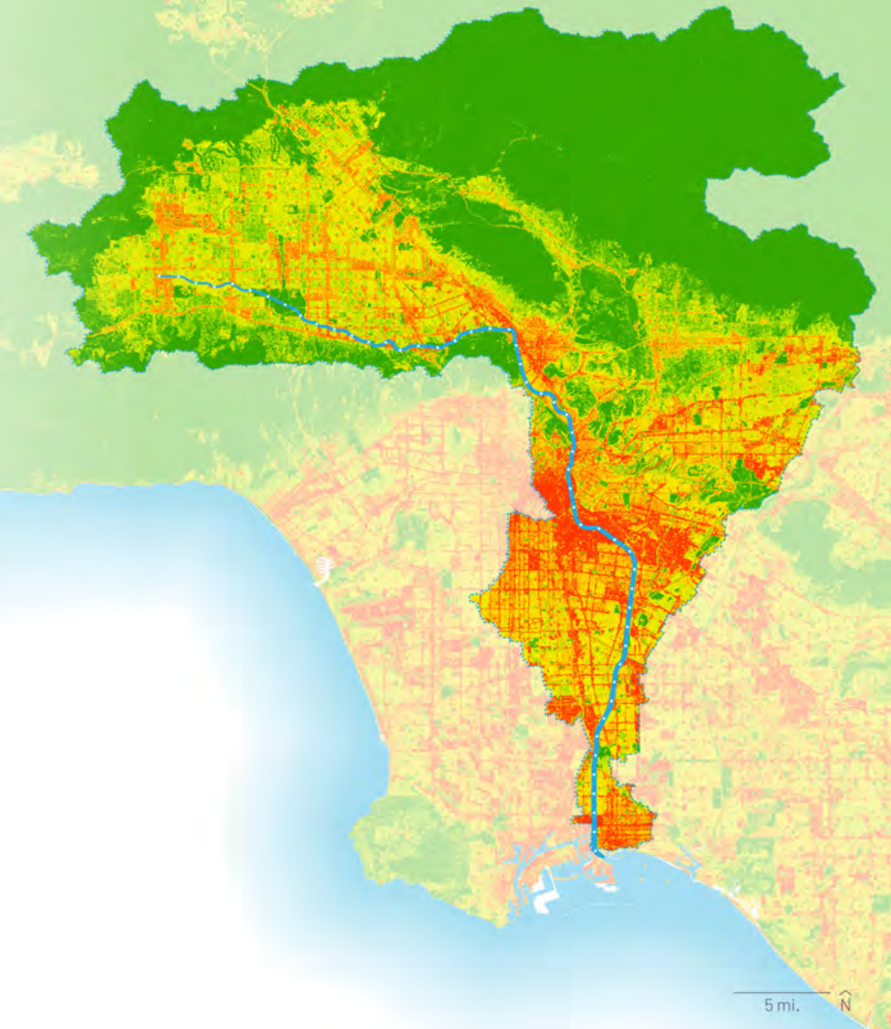


0% Impervious

100% Impervious

Baseline Condition

IMPERVIOUS SURFACE 10% REDUCTION



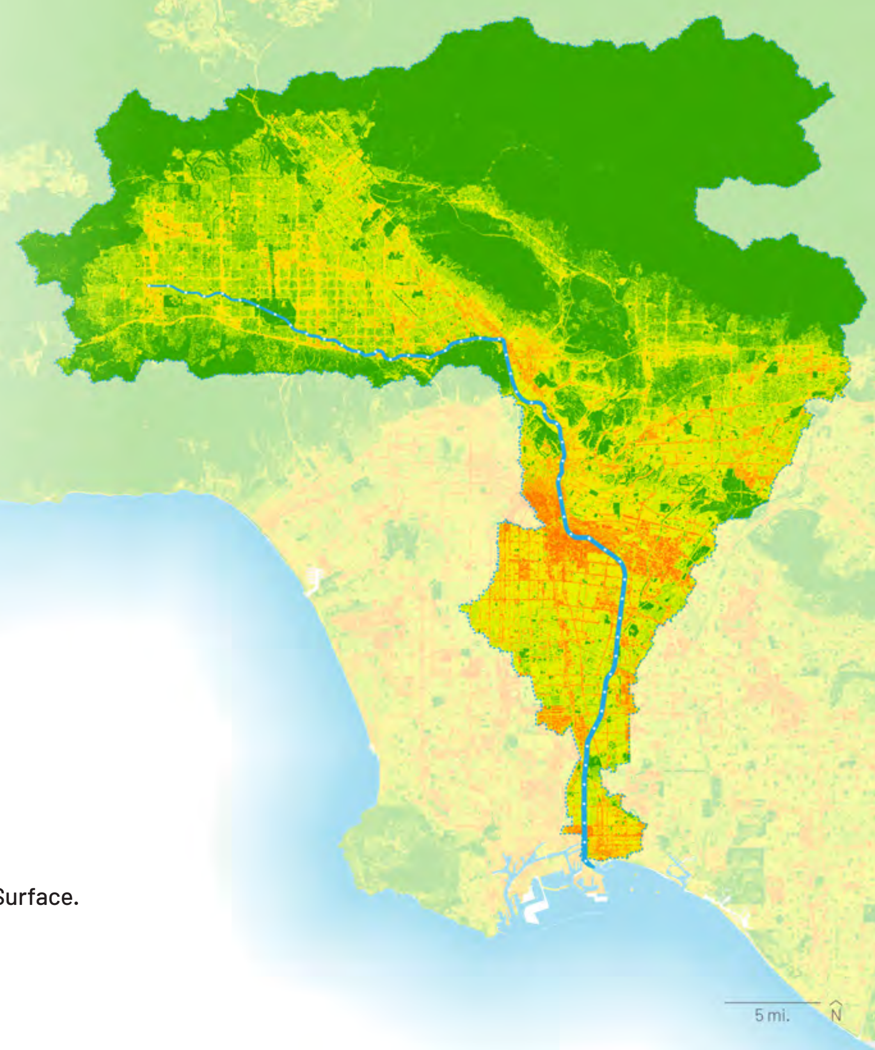
0% Impervious

100% Impervious

Volume Reduction: 1,866 AF

Fraction of 2037 Goals: 36%

IMPERVIOUS SURFACE 28% REDUCTION



0% Impervious

100% Impervious

Volume Reduction: 5,186 AF

Fraction of 2037 Goals: 100%

Source: LA County GIS Data Portal NLCD 2011 Impervious Surface.

IMPERVIOUS SURFACE 50% REDUCTION

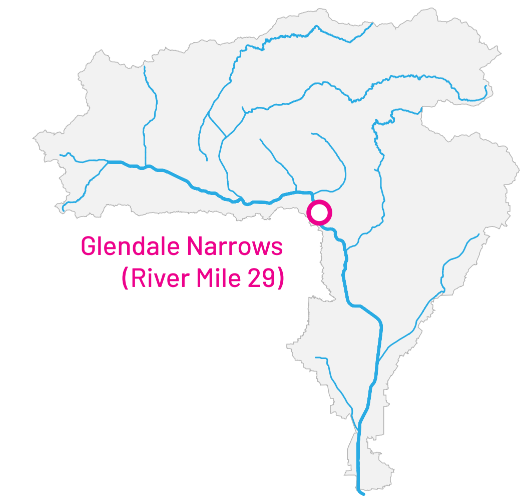
0% Impervious

100% Impervious

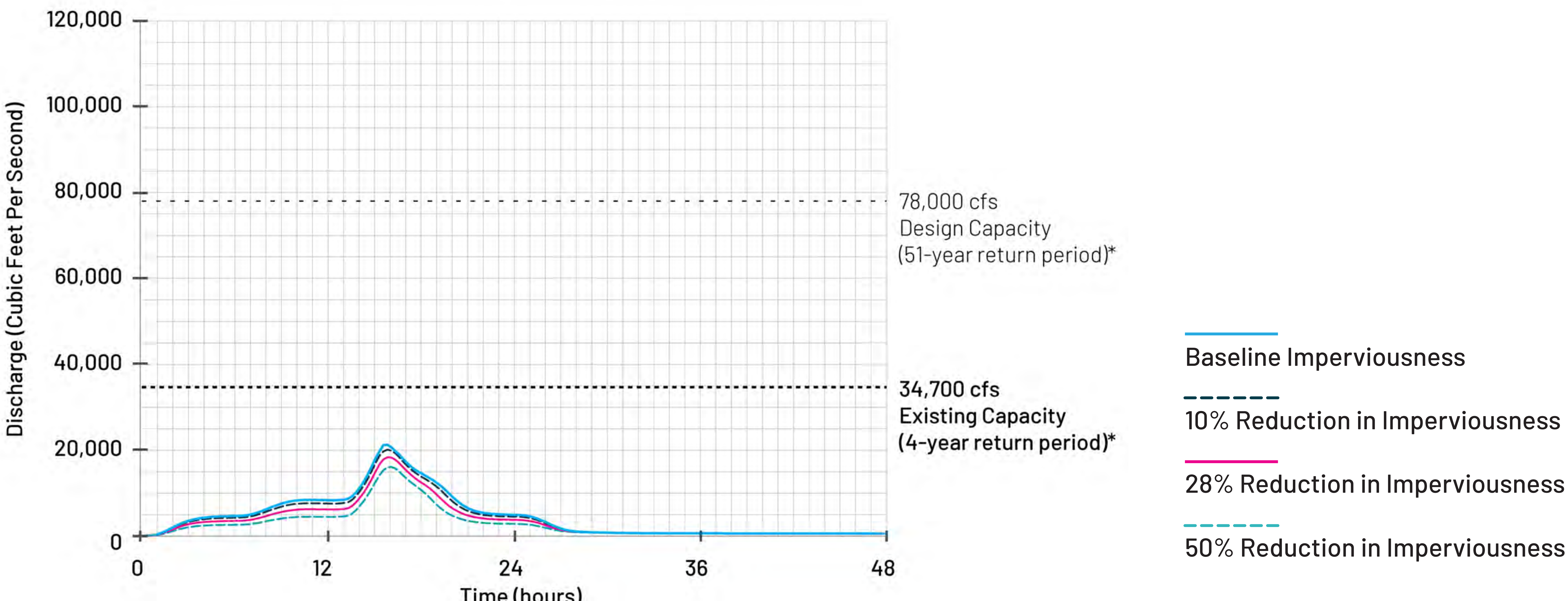
Volume Reduction: 9,331 AF

Fraction of 2037 Goals: 180%

NARROWS 2-YEAR STORM



Hydrograph: Glendale Narrows, River Mile 29

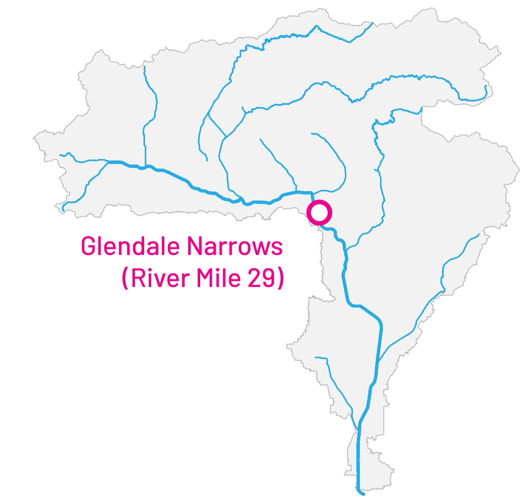


HEC-HMS

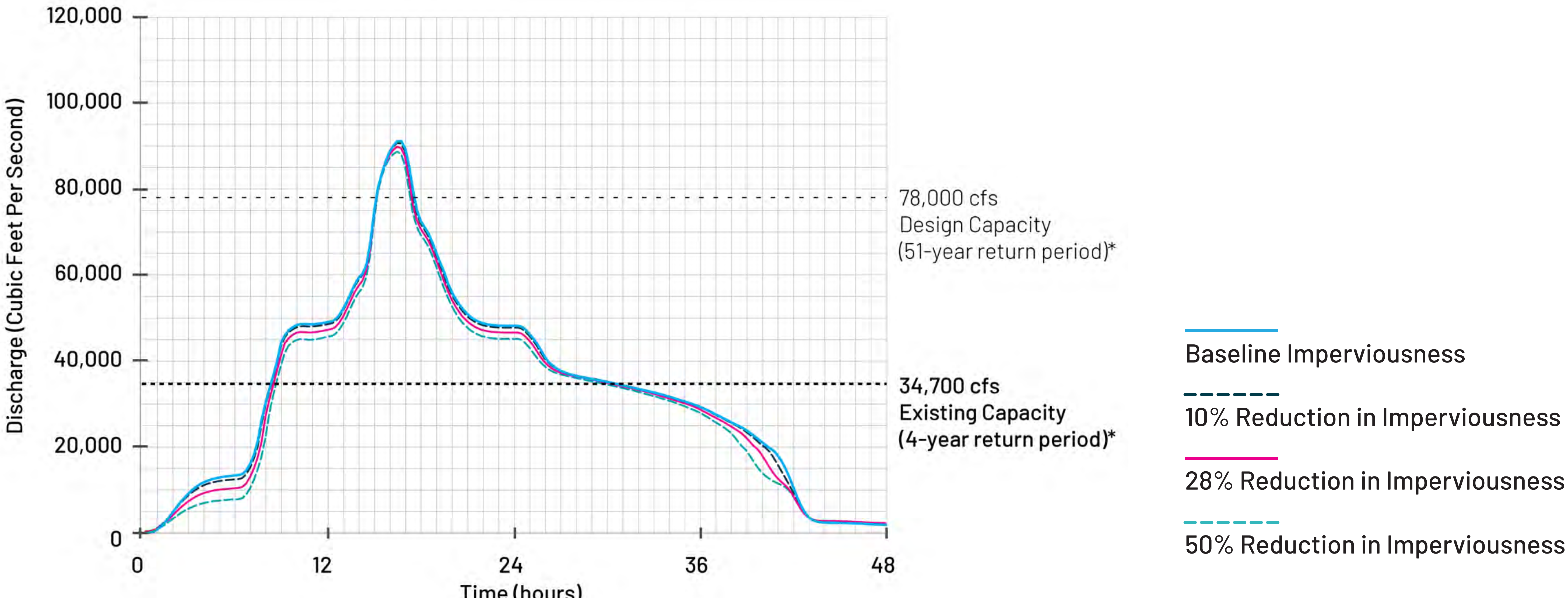
Source: Geosyntec, OLIN

* flow rates and return periods from Table 17 of HH Appendix E (USACE, 2015)

NARROWS 100-YEAR STORM



Hydrograph: Glendale Narrows, River Mile 29

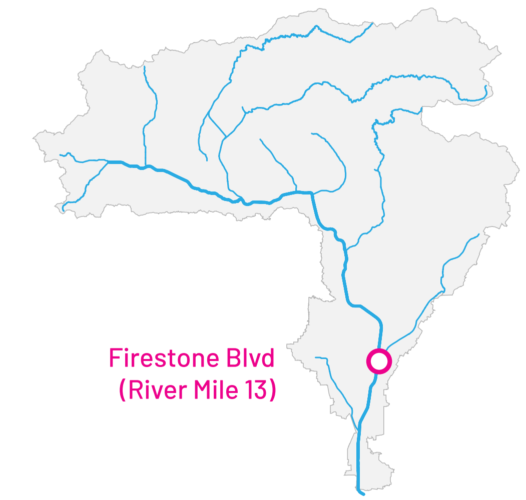


HEC-HMS

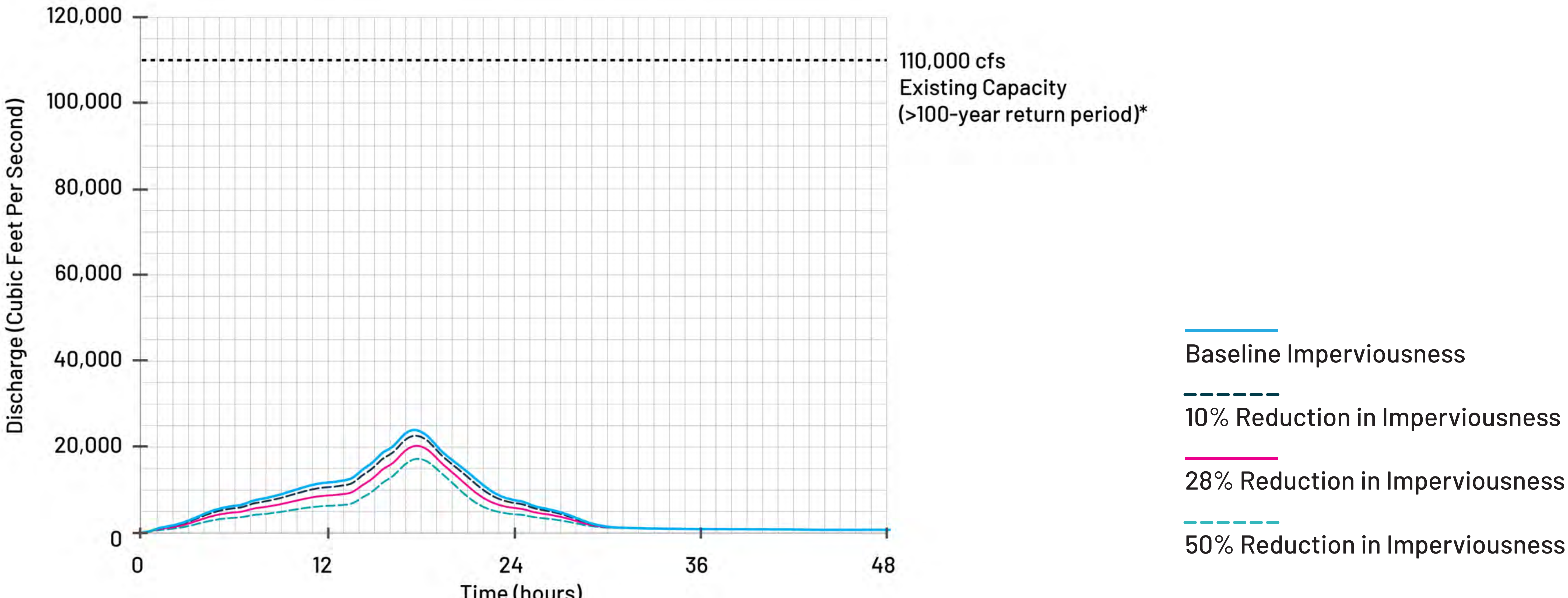
Source: Geosyntec, OLIN

* flow rates and return periods from Table 17 of HH Appendix E (USACE, 2015)

FIRESTONE 2-YEAR STORM



Hydrograph: Firestone Blvd, River Mile 13

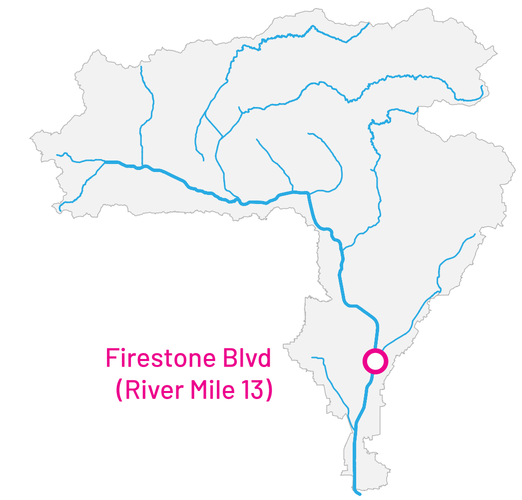


HEC-HMS

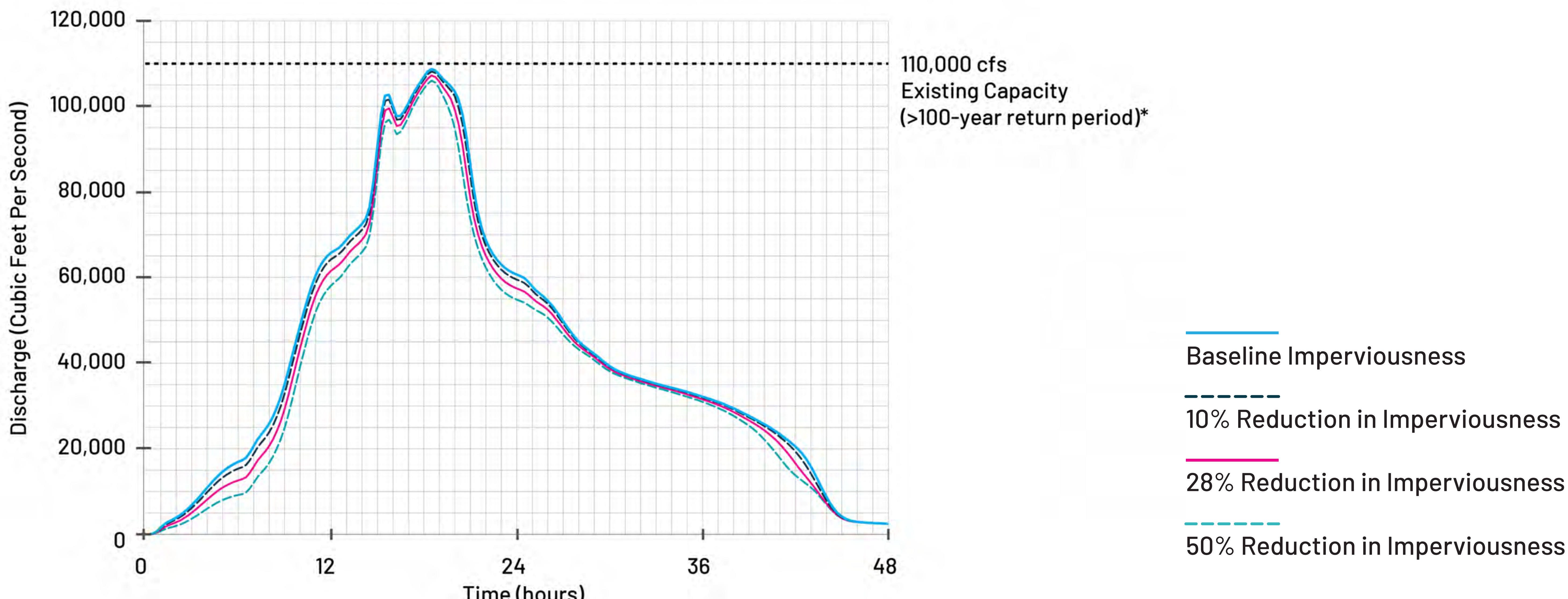
Source: Geosyntec, OLIN

* flow rates and return periods from Table 1 of Part II Hydrology Report (USACE, 1991)

FIRESTONE 100-YEAR STORM



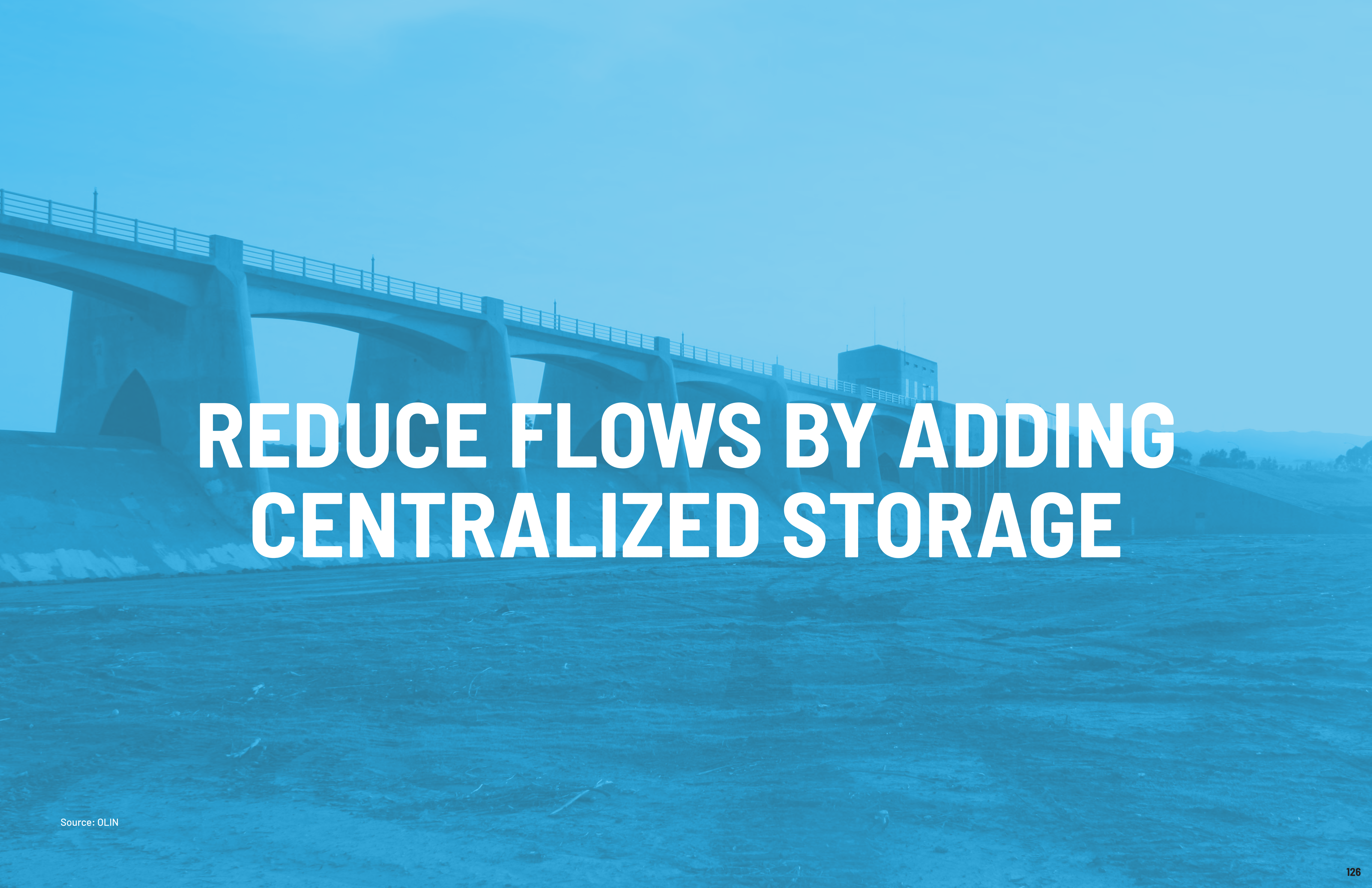
Hydrograph: Firestone Blvd, River Mile 13



HEC-HMS

Source: Geosyntec, OLIN

* flow rates and return periods from Table 1 of Part II Hydrology Report (USACE, 1991)



REDUCE FLOWS BY ADDING CENTRALIZED STORAGE

Source: OLIN

FLOOD CONTROL BASINS

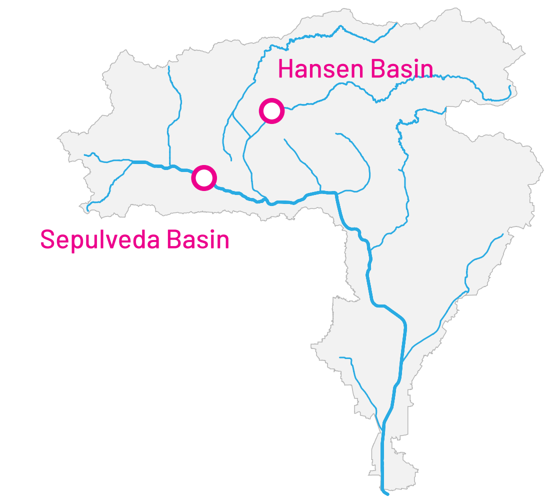
Sepulveda: 18,127 AF

Hansen: 33,348 AF

- Flood Control Basins
- Spreading Grounds
- Debris Basins
- Levees
- Storm Drains
- Dams
- Rivers

Source: LA County GIS Portal, Google Earth, Geosyntec

FLOOD CONTROL BASINS

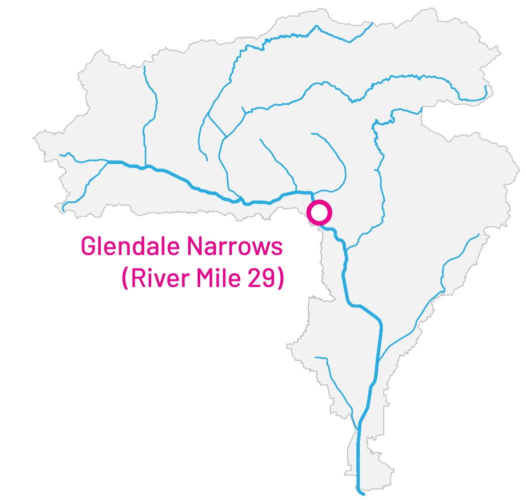


Sepulveda Basin

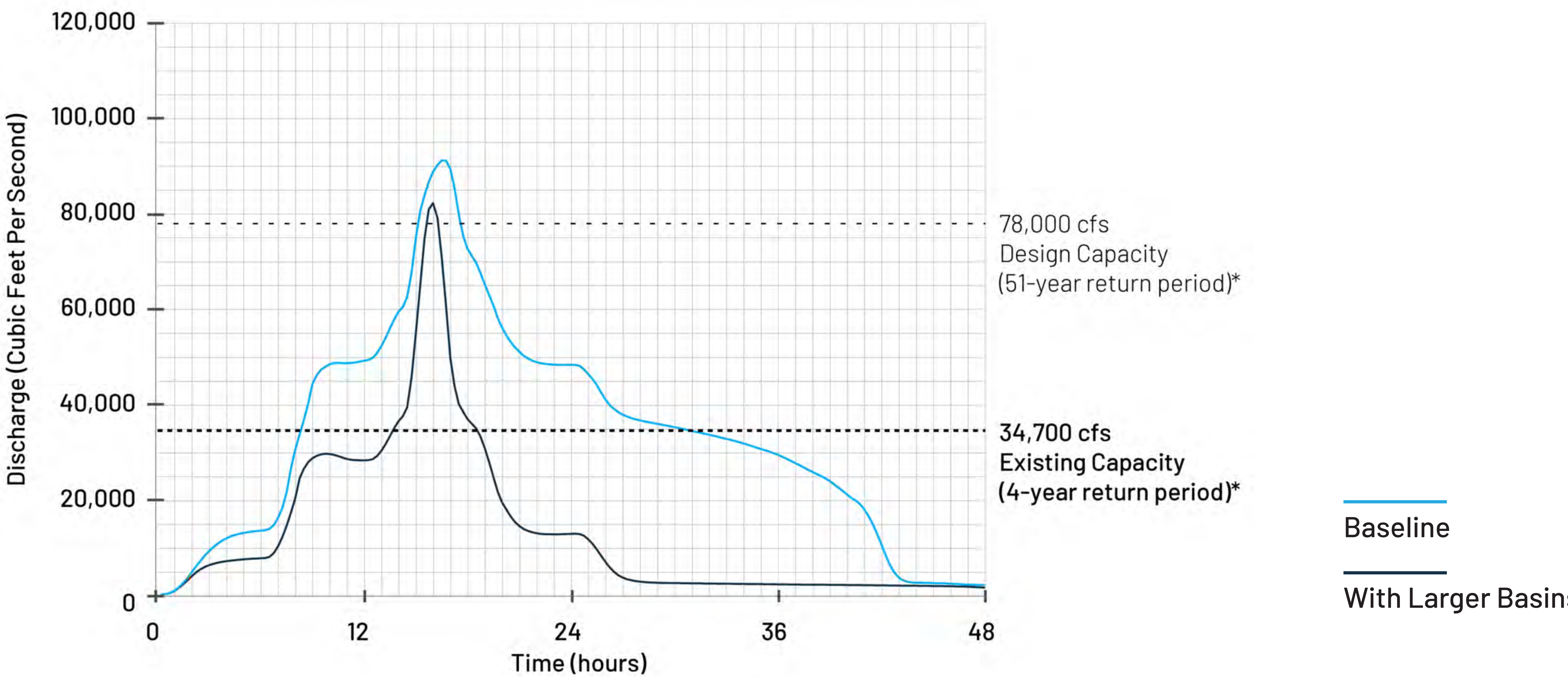
Hansen Basin

Source: Google Earth

NARROWS 100-YEAR STORM WITH LARGER BASINS



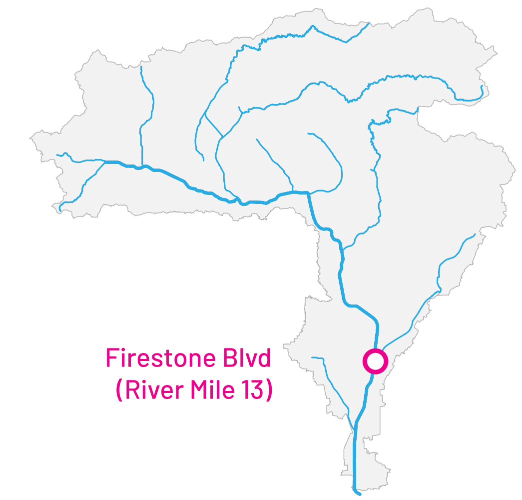
Hydrograph: Glendale Narrows, River Mile 29



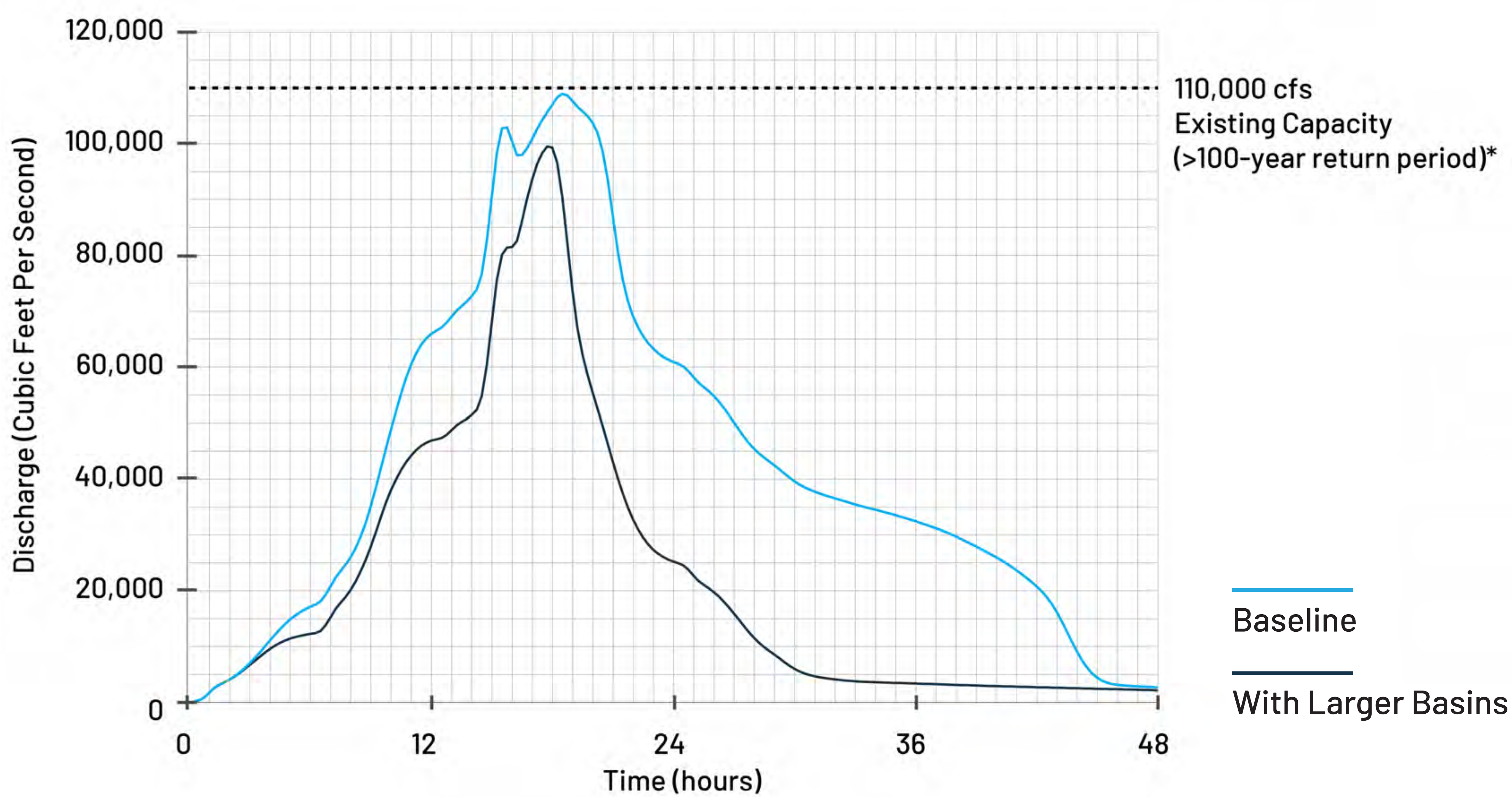
HEC-HMS

Source: Geosyntec, OLIN
Hydrograph assumes Sepulveda and Hansen Basins are enlarged significantly enough that no outflow occurs.
* flow rates and return periods from Table 17 of HH Appendix E (USACE, 2015)

FIRESTONE 100-YEAR STORM WITH LARGER BASINS



Hydrograph: Firestone Blvd, River Mile 13



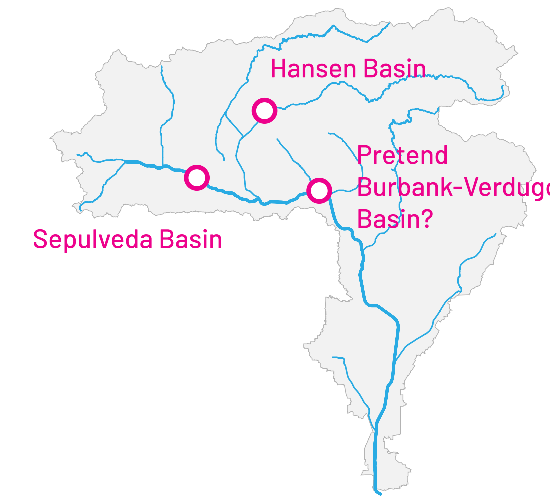
Source: Geosyntec, OLIN

Hydrograph assumes Sepulveda and Hansen Basins are enlarged significantly enough that no outflow occurs.

* flow rates and return periods from Table 1 of Part II Hydrology Report (USACE, 1991)

HEC-HMS

FLOOD CONTROL BASINS



Sepulveda Basin

Hansen Basin

Burbank-Verdugo Basin?

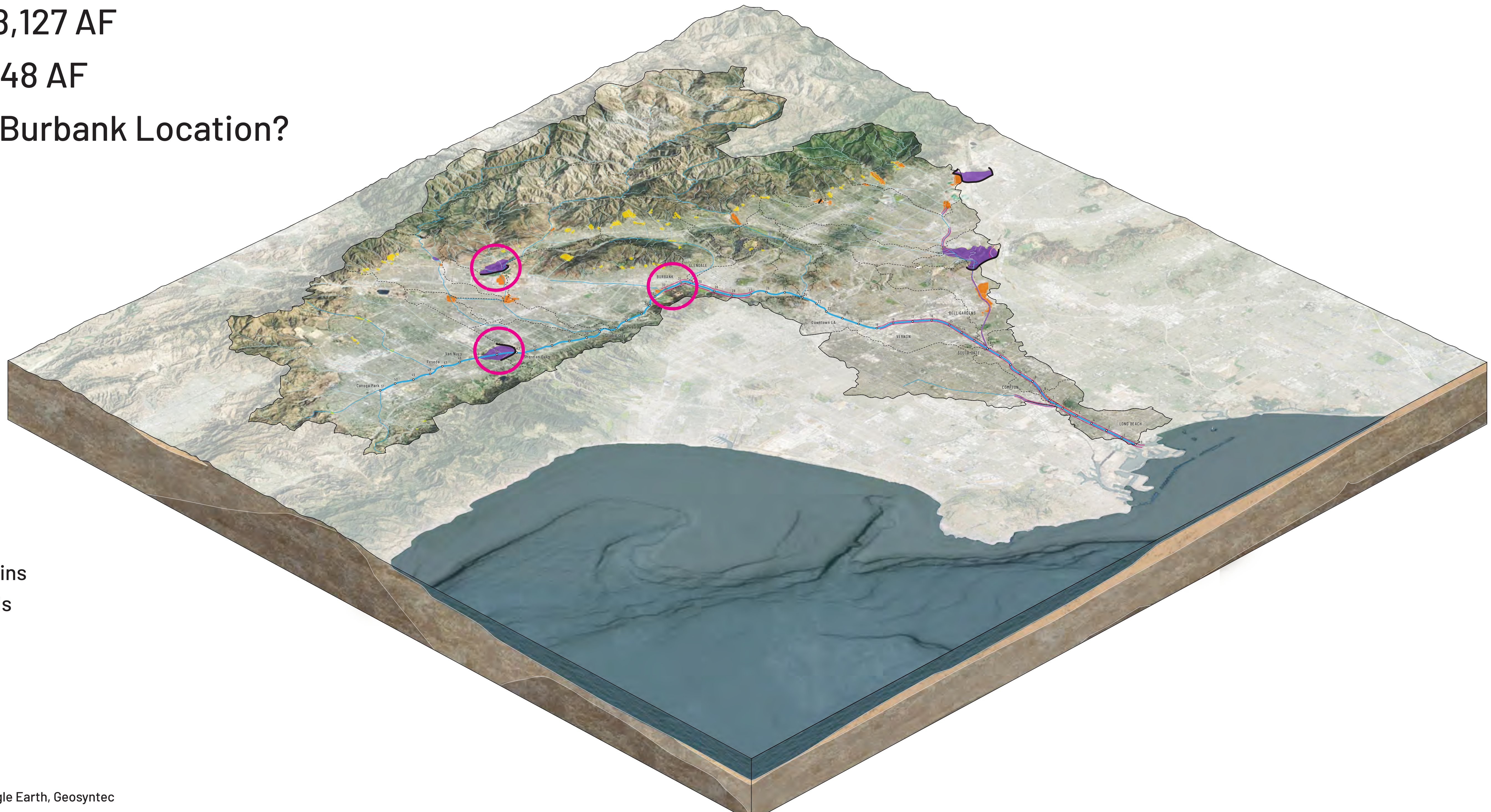
Source: Google Earth

FLOOD CONTROL BASINS

Sepulveda: 18,127 AF

Hansen: 33,348 AF

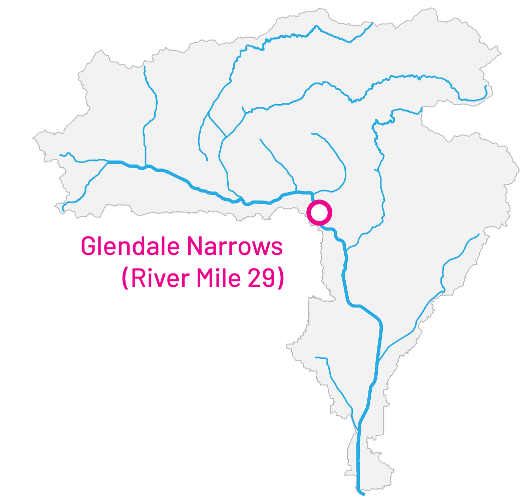
Verdugo and Burbank Location?



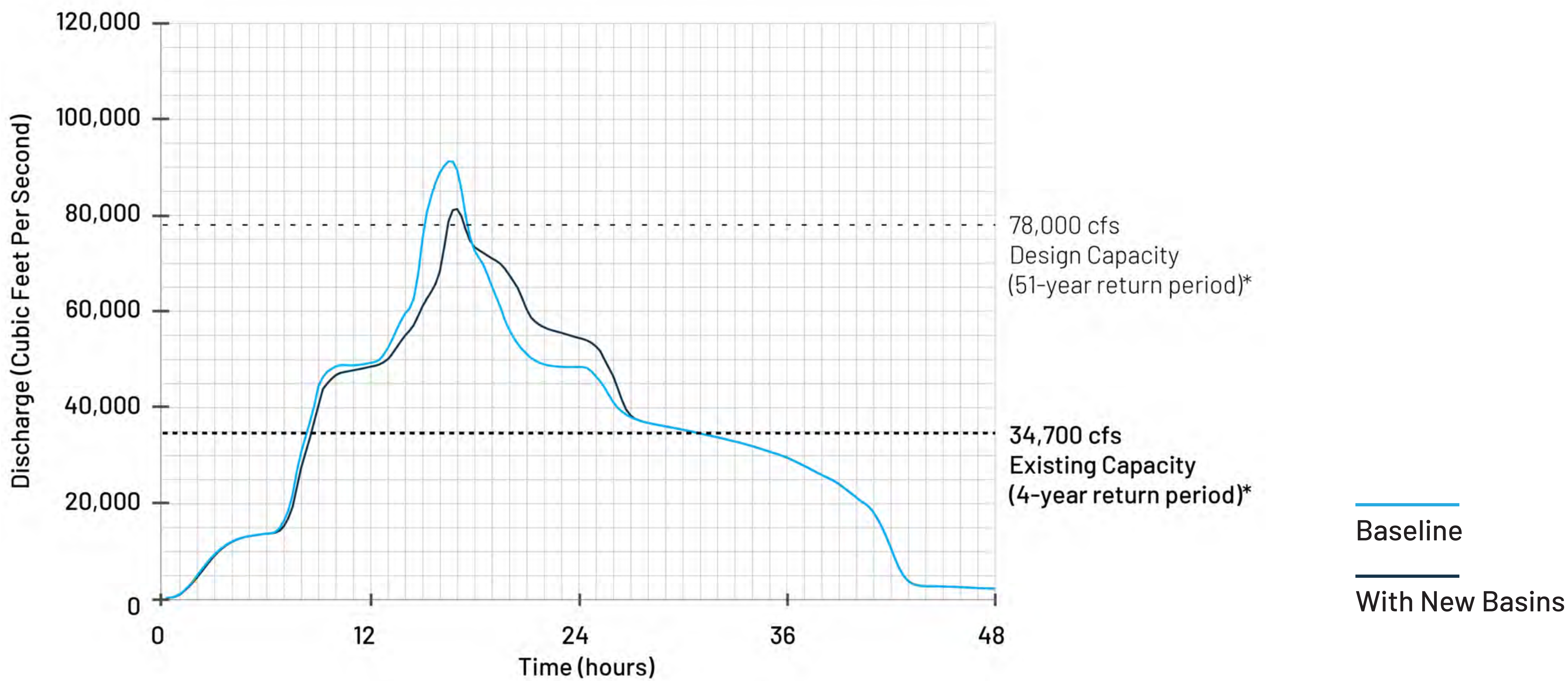
- Flood Control Basins
- Spreading Grounds
- Debris Basins
- Levees
- Storm Drains
- Dams
- Rivers

Source: LA County GIS Portal, Google Earth, Geosyntec

NARROWS 100-YEAR STORM WITH EXTRA BASINS



Hydrograph: Glendale Narrows, River Mile 29



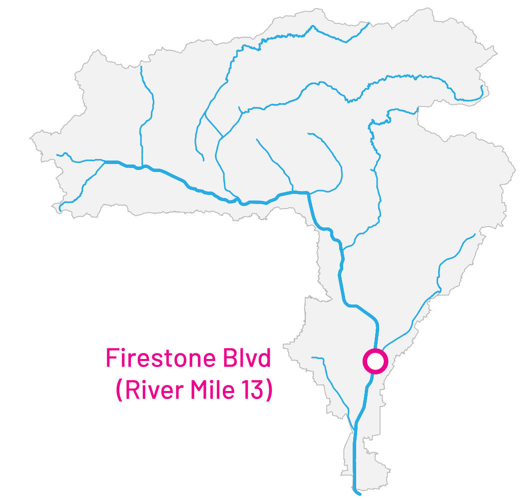
HEC-HMS

Source: Geosyntec, OLIN

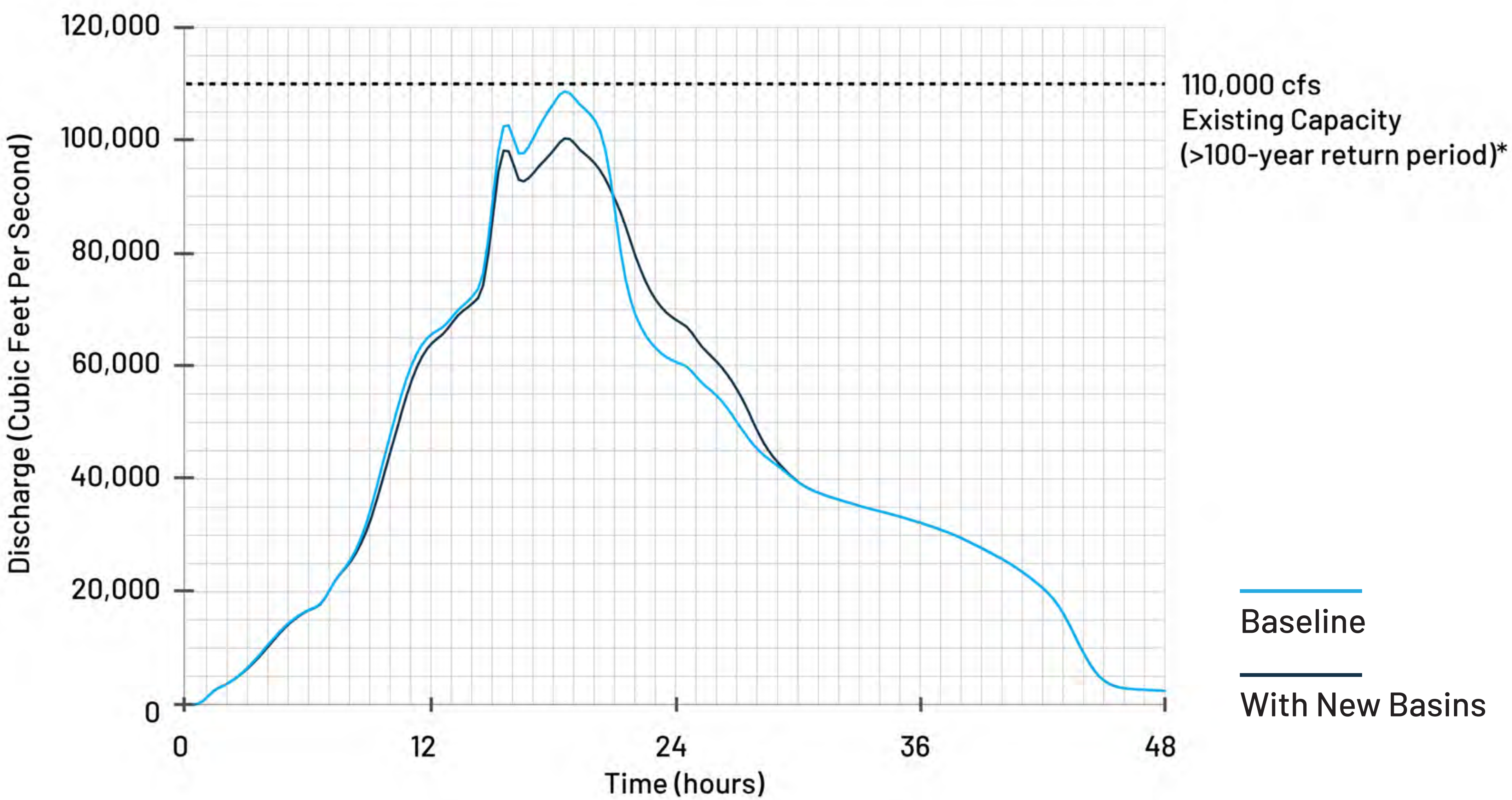
Newly developed Flood Control Basins "modeled" on Burbank and Verdugo Washes, just upstream of confluence with LA River. New basins assume similar operations to Sepulveda.

* flow rates and return periods from Table 17 of HH Appendix E (USACE, 2015)

FIRESTONE 100-YEAR STORM WITH EXTRA BASINS



Hydrograph: Firestone Blvd, River Mile 13



HEC-HMS

Source: Geosyntec, OLIN

Newly developed Flood Control Basins "modeled" on Burbank and Verdugo Washes, just upstream of confluence with LA River. New basins assume similar operations to Sepulveda.

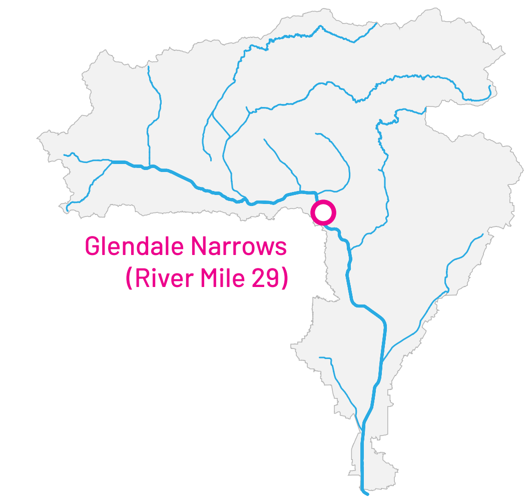
* flow rates and return periods from Table 1 of Part II Hydrology Report (USACE, 1991)

INCREASE CHANNEL CAPACITY BY WIDENING THE CHANNEL

Source: OLIN

INCREASE CHANNEL WIDTH

Need to increase by 2 to 3 times



	Existing	Required
K	1.49 $ft^{1/3}/s$	1.49 $ft^{1/3}/s$
A	4,000 ft^2	9,200 ft^2
R	13.5 ft	15.8 ft
S	0.0044	0.0044
n	0.06	0.06
Q	37,000 cfs	95,000 cfs

Source: Geosyntec, OLIN

MANNING'S

NARROWS ARBOR REACHES

Some sections only manage to the 4-year storm

Table 17: Original Design Discharge and Existing Channel Capacity

Reach[a]	River Stations	Design[b] Discharge	Design Return Period [e]	Current Freeboard Criteria[c]	Existing[d] Channel Capacity	Existing Return Period [e]	100-Year Discharge[e]
		ft^3/s	yr	ft	ft^3/s	yr	ft^3/s
Reach 1	625+77 to 547+45	40,000	12	3	29,300	4	81,000
Reach 2	546+45 to 510+05	40,000	7	3	25,800	3	88,900
Reach 3a	504+93 to 477+85	40,000	7	3	63,000[f]	32	88,900
Reach 3b	475+68 to 452+58	78,000	51	3	84,000[f]	69	94,600
Reach 4	432+16 to 359+75	78,000	51	3	34,700	4	94,600
Reach 5	358+63 to 271+89	78,000	51	3	34,000	4	94,600
Reach 6a	270+28 to 262+73	78,000	51	2.5	64,500	24	94,600
Reach 6b	257+85 to 144+23	83,700	57	2.5	50,500	11	93,800
Reach 7a	142+91 to 131+22	83,700	57	2.5	135,400[f]	>500	93,800
Reach 7b	128+71 to 86+61	104,000	83	3	83,700	32	109,000
Reach 8	86+07 to 10+31	104,000	83	3	89,600	42	109,000

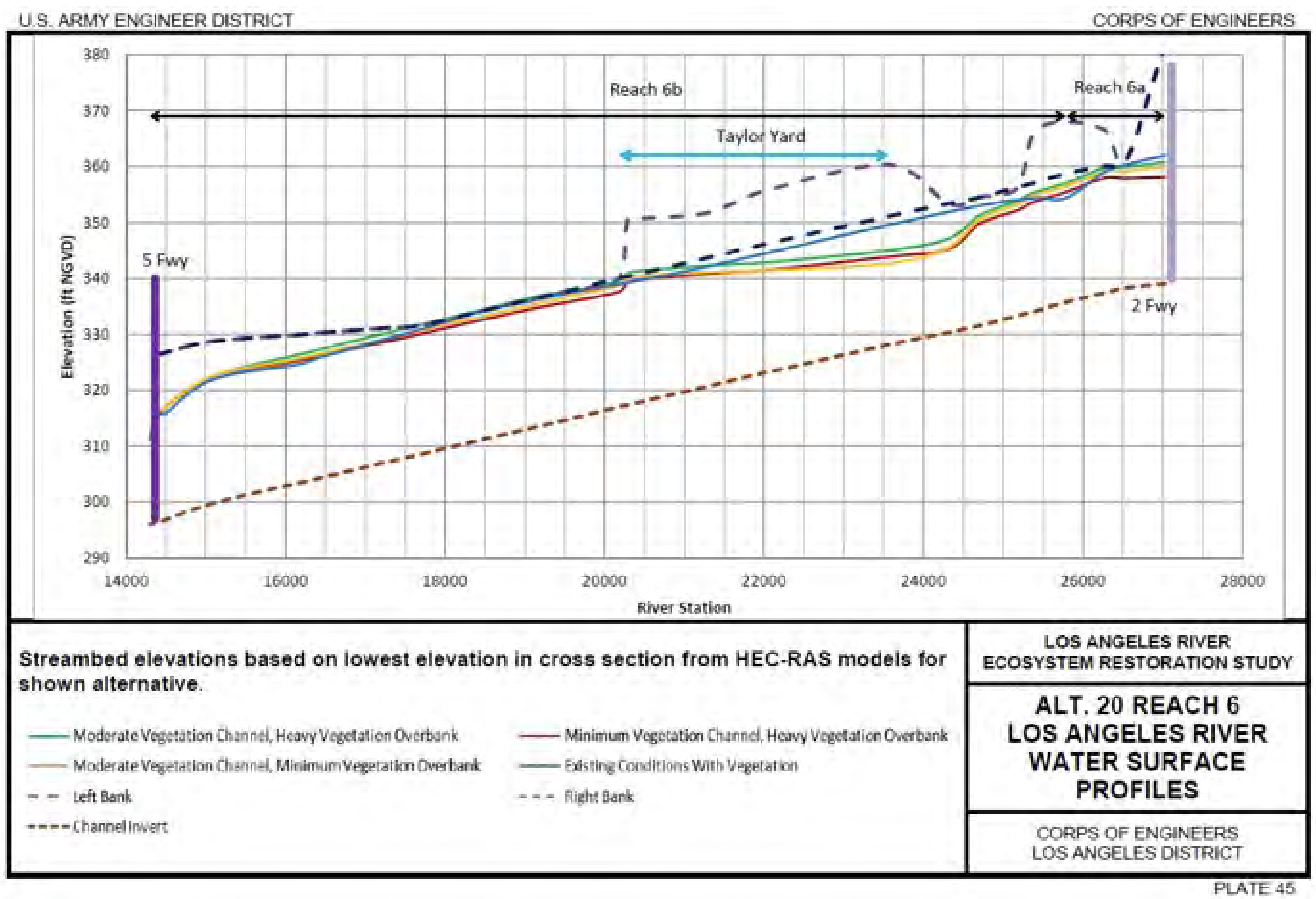
Notes:
(a) Letters a & b in Reach names denote a change in the river due to a confluence or change in channel dimensions.
(b) Original design discharge for clean prismatic channel.
(c) Freeboard from EM 1110-2-1601; 3 feet for leveed sections and 2.5 feet for trapezoidal entrenched sections.
(d) Existing channel capacity with vegetation, sedimentation and freeboard. The values shown are the minimum within the reach. Discharges above these listed do not necessarily cause damages.
(e) Return periods for Design Discharge and Existing Channel Capacity are based on discharge frequency analysis for the 1992 LACDA Feasibility Study.
(f) In some limited reaches the existing channel capacity is greater than the original design discharge because of more than adequate freeboard.
(g) Refer to Plates 21a through 24b to see the floodplains for various return frequency flows within the study limits.

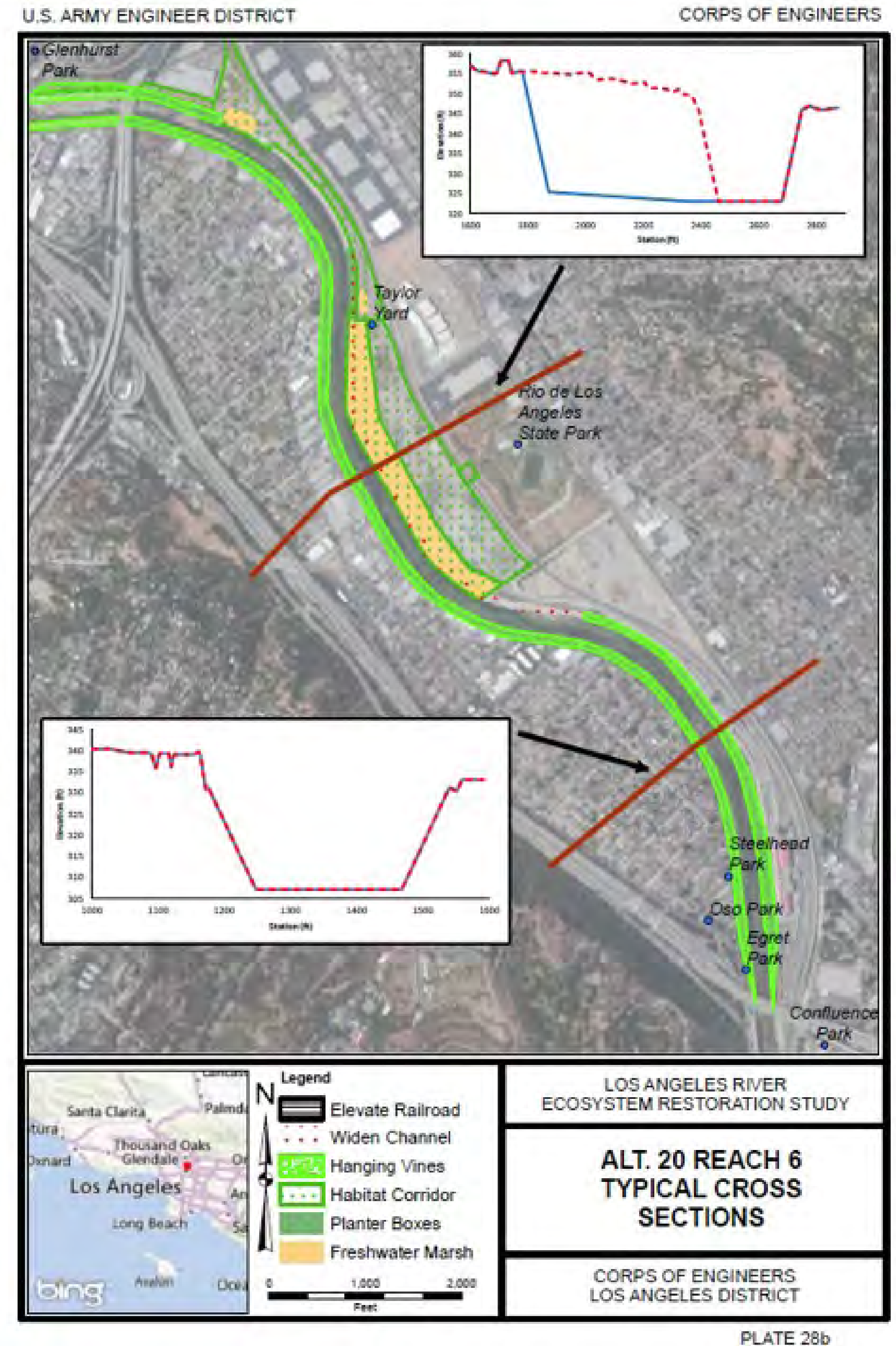
HH Appendix 61 September 2015

Source: U.S. Army Corps of Engineers, Los Angeles District. Los Angeles River Ecosystem Restoration Project, Volume III, Appendix E (HH Appendix). 2015.

INCREASE CHANNEL WIDTH

Width increase needs to be for extended distances





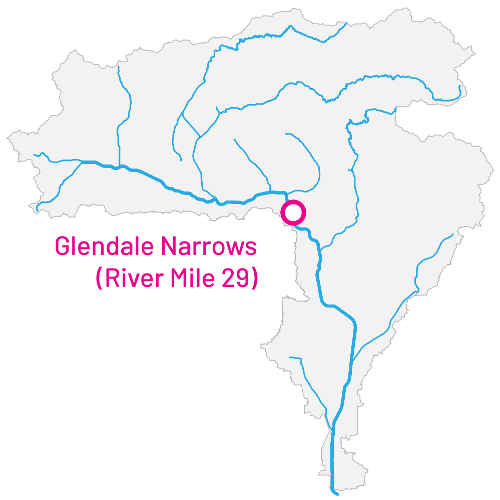
Source: Los Angles River Ecosystem Restoration Feasibility Study, Appendix E, Hydrology and Hydraulics, US Army Corps of Engineers, Los Angeles District, September 2015

INCREASE CHANNEL WIDTH

May require bridge lengthening or re-design and increasing channel width impacts the right-of-way, private and public real estate, transportation, etc.

Source: Geosyntec, OLIN

INCREASE CHANNEL WIDTH



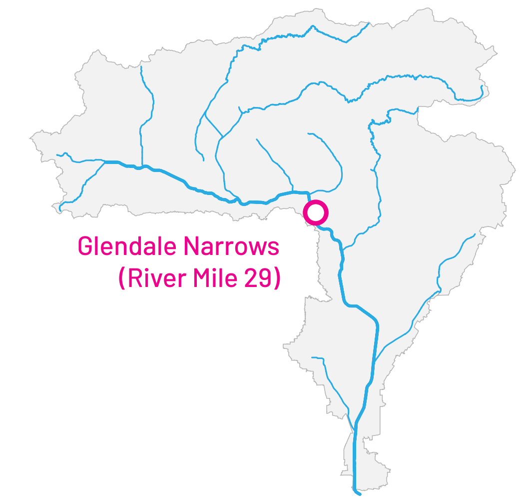
Existing Section: **34,700 cfs capacity**

Alternative Section: **95,000 cfs capacity**

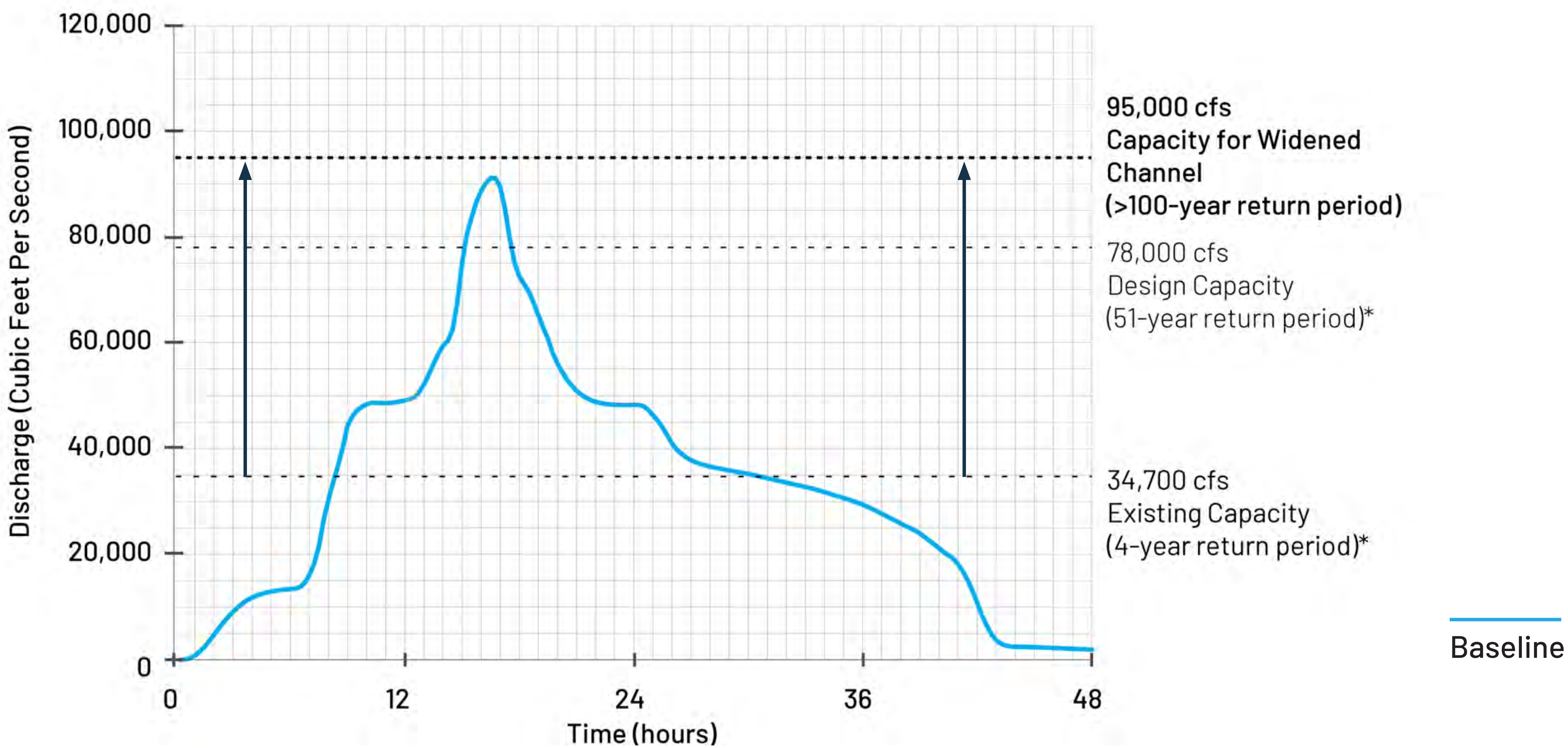
Source: Geosyntec, OLIN

MANNING'S

100-YEAR STORM WITH A WIDER CHANNEL



Hydrograph: Glendale Narrows, River Mile 29



MANNING'S

HEC-HMS

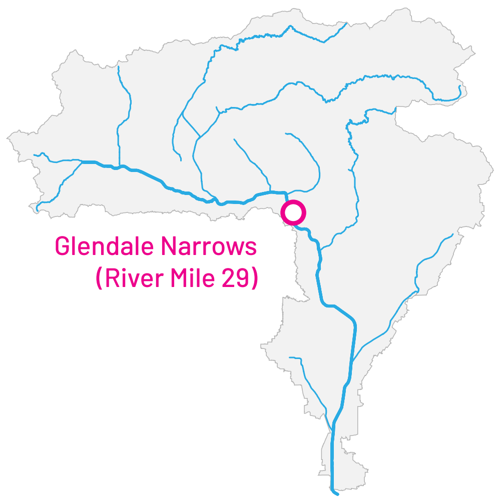
Source: Geosyntec, OLIN

* flow rates and return periods from Table 17 of HH Appendix E (USACE, 2015)

INCREASE CHANNEL CAPACITY BY RAISING LEVEE HEIGHT

Source: OLIN

INCREASE LEVEE HEIGHT / PARAPET WALLS



Existing Section: **34,700 cfs capacity**

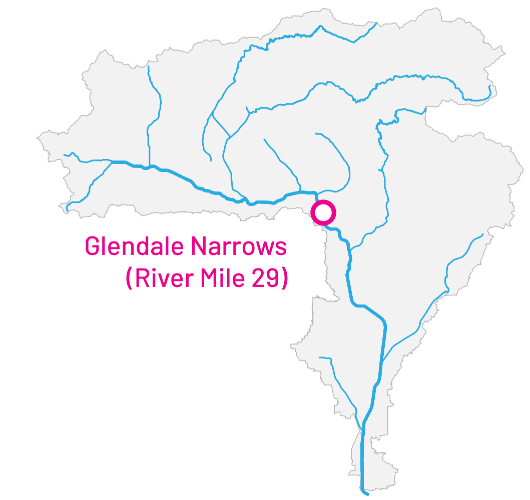
Alternative Section: **95,000 cfs capacity**

12' – 18' high parapet walls
Estimate based on Manning's equation

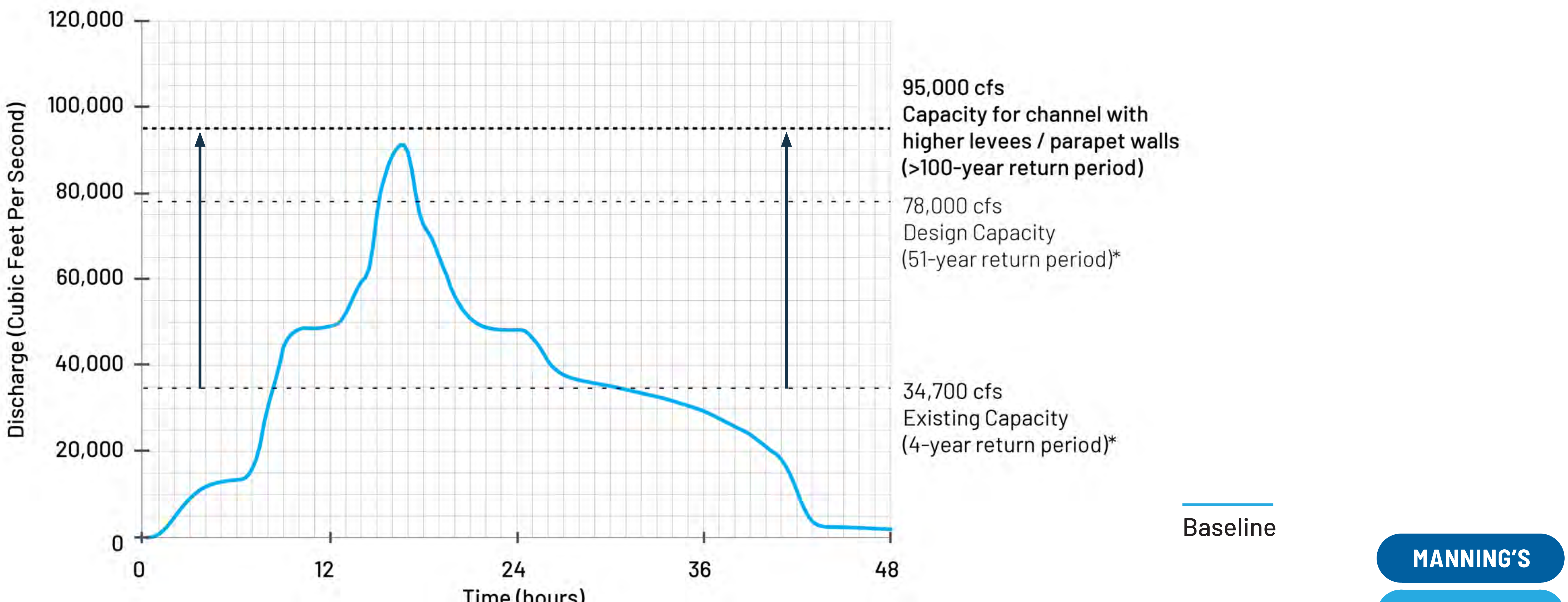
Source: Geosyntec, OLIN

MANNING'S

100-YEAR STORM WITH HIGHER LEVEES / PARAPET WALLS

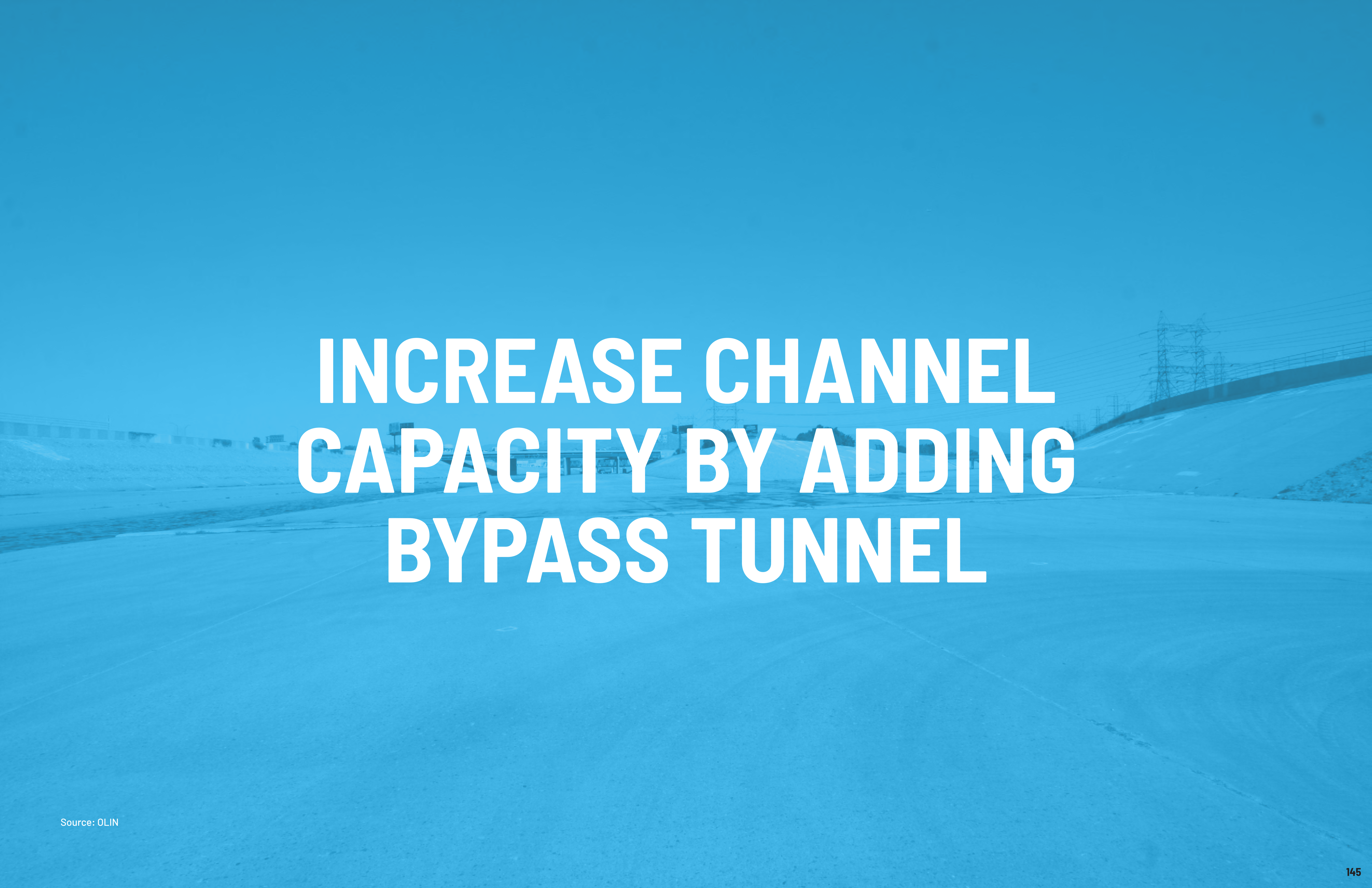


Hydrograph: Glendale Narrows, River Mile 29



Source: Geosyntec, OLIN

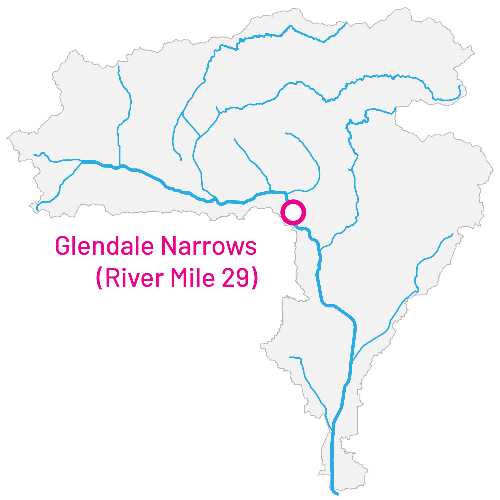
* flow rates and return periods from Table 17 of HH Appendix E (USACE, 2015)



INCREASE CHANNEL CAPACITY BY ADDING BYPASS TUNNEL

Source: OLIN

ADD A BYPASS TUNNEL



Existing Section: **34,700 cfs capacity**

Alternative Section: **54,700 cfs capacity**

Source: Geosyntec, OLIN

MANNING'S

BYPASS TUNNEL

- 40 foot diameter concrete tunnel
- 9 miles long
- 0.6% Slope
- Half full
- 20,000 cfs capacity
- Hydraulic challenges
- $2.5 Billion (scaled from Delta Tunnels estimate)

Source: Geosyntec, OLIN

TUNNEL EXAMPLES

TUNNELS	OWNER	DIAMETER (FT)	LENGTH (MI)
Delta Tunnels	CA DWR	2′ x 40′	35
Pawtucket Tunnel	Narragansett Bay Commission	28′	2.5
Euclid Creek Storage Tunnel	Northeast Ohio Regional Sewer District	24′	3.5
Anacostia River Tunnel	DC Water and Sewer Authority	23′	2.4
Lower & Middle River Des Peres Storage Tunnel	Metropolitan St. Louis Sewer District	30′	9

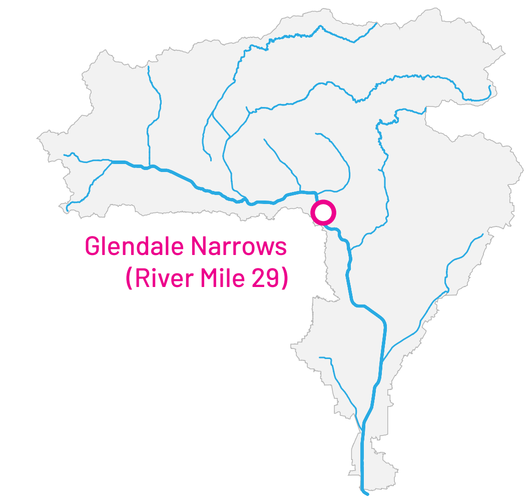
Source: DCWater.com, narrabay.com

TARP TUNNEL

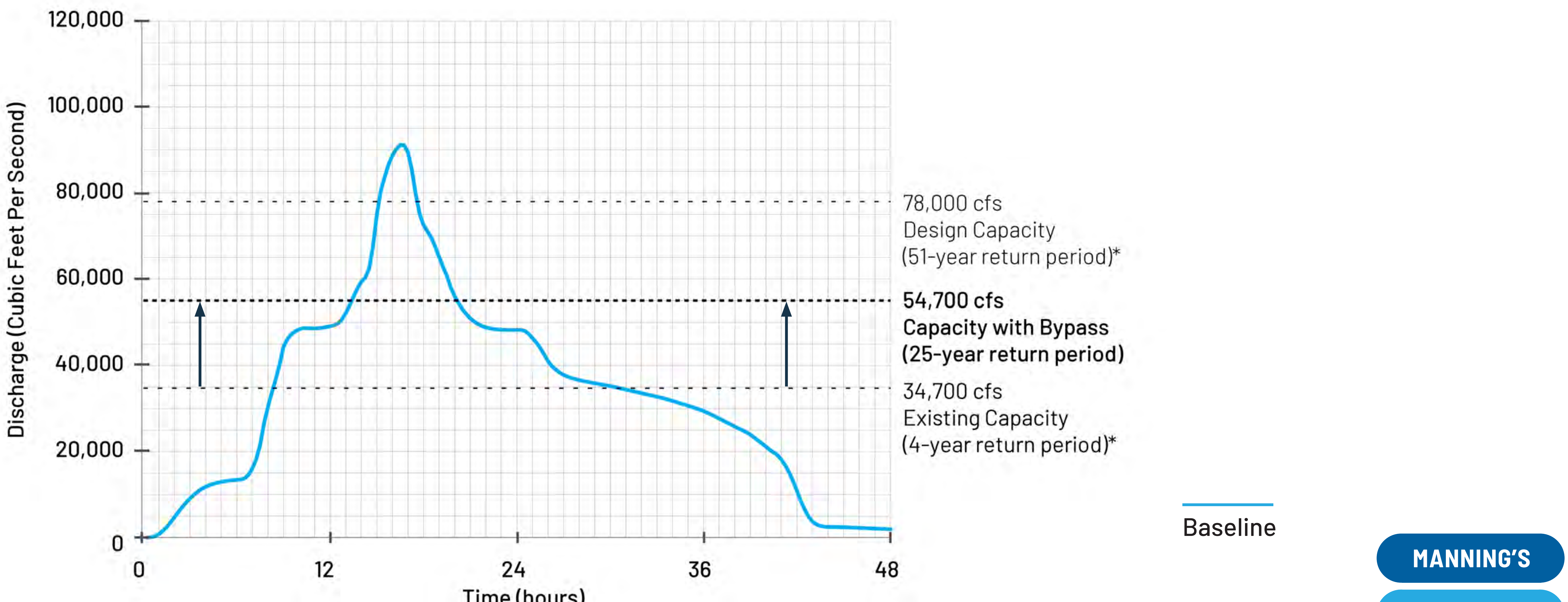
Chicago

Source: OLIN

100-YEAR STORM WITH BYPASS TUNNEL



Hydrograph: Glendale Narrows, River Mile 29

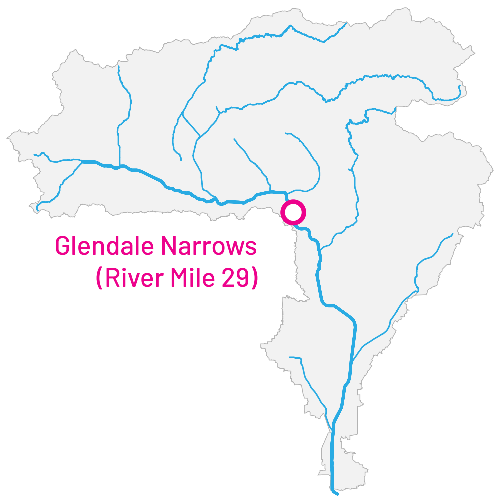


Source: Geosyntec, OLIN

* flow rates and return periods from Table 17 of HH Appendix E (USACE, 2015)

INCREASE CHANNEL CAPACITY BY REFURBISHING THE CHANNEL

Source: OLIN



REFURBISHMENT

To increase channel capacity: remove invasives, remove sediment, maintain channel, replace exotic with native grasses.

Existing Section: **34,700 cfs capacity**

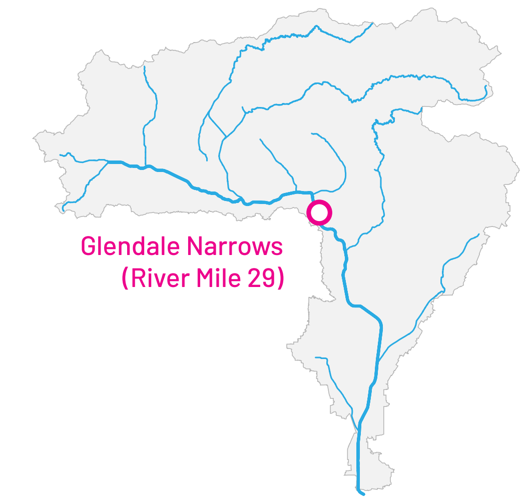
n = 0.06

Alternative Section: **78,000 cfs capacity**

n = 0.03

Source: Geosyntec, OLIN

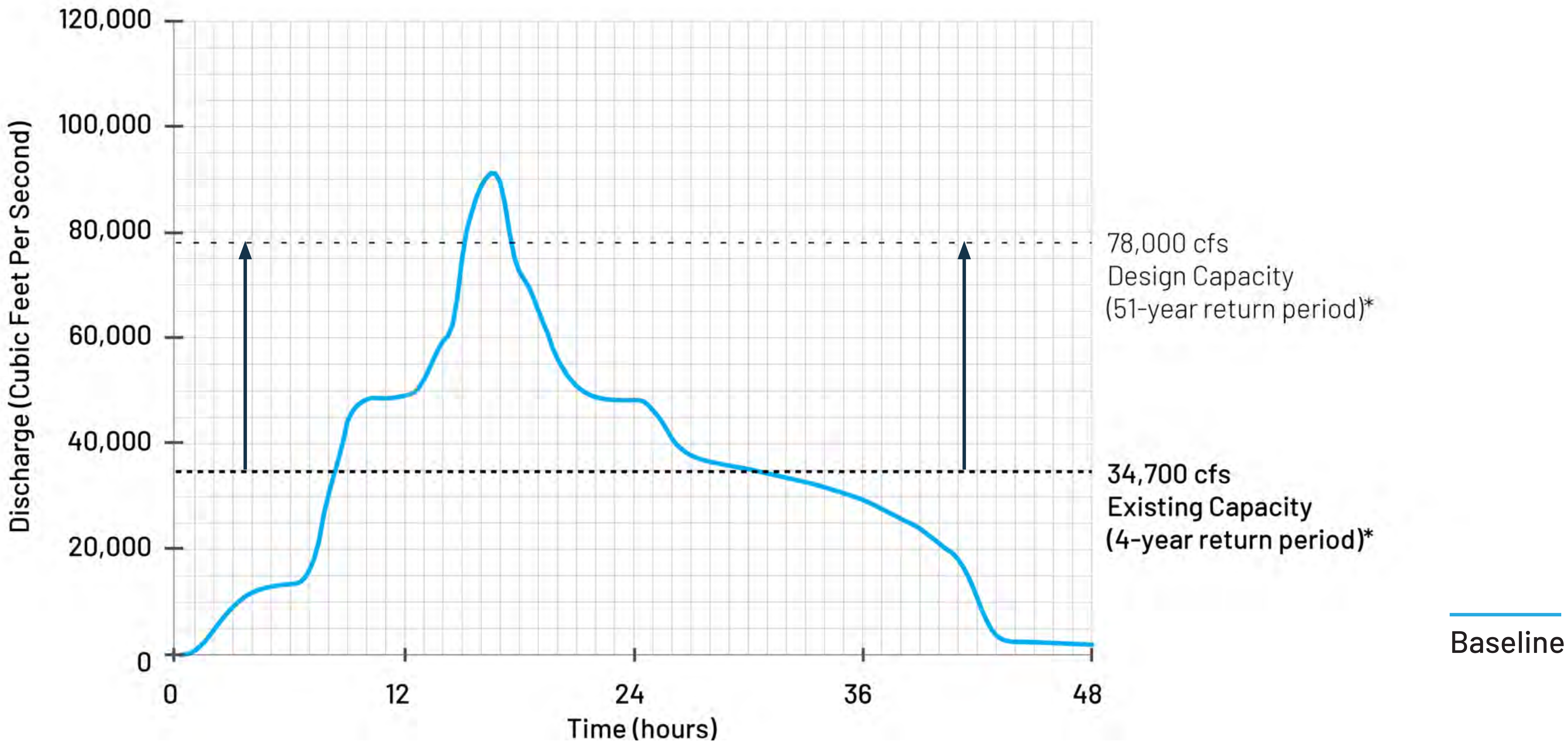
HEC-RAS



100-YEAR STORM WITH REFURBISHMENT

To increase channel capacity: remove invasives, remove sediment, maintain channel, replace exotic with native grasses.

Hydrograph: Glendale Narrows, River Mile 29



HEC-HMS

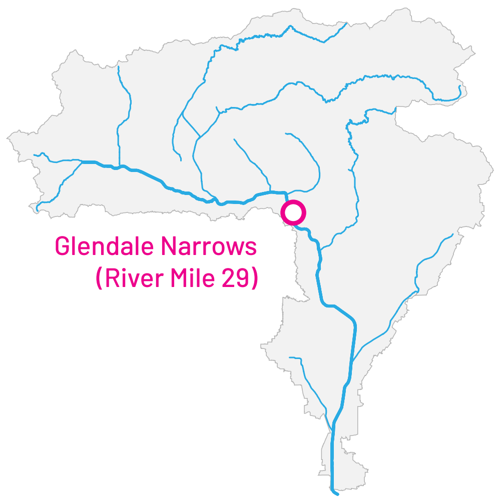
HEC-RAS

Source: Geosyntec, OLIN

* flow rates and return periods from Table 17 of HH Appendix E (USACE, 2015)

CONCRETE

To increase channel capacity: harden the channel bottom to reduce friction.



Existing Section: **34,700 cfs capacity**

n = 0.06

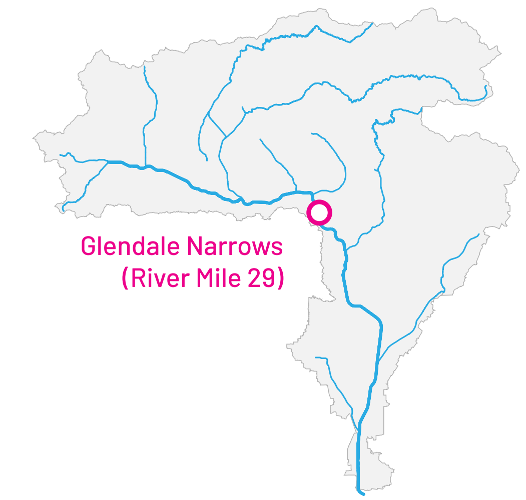
Alternative Section: **120,000 cfs capacity**

n = 0.016

Source: Geosyntec, OLIN

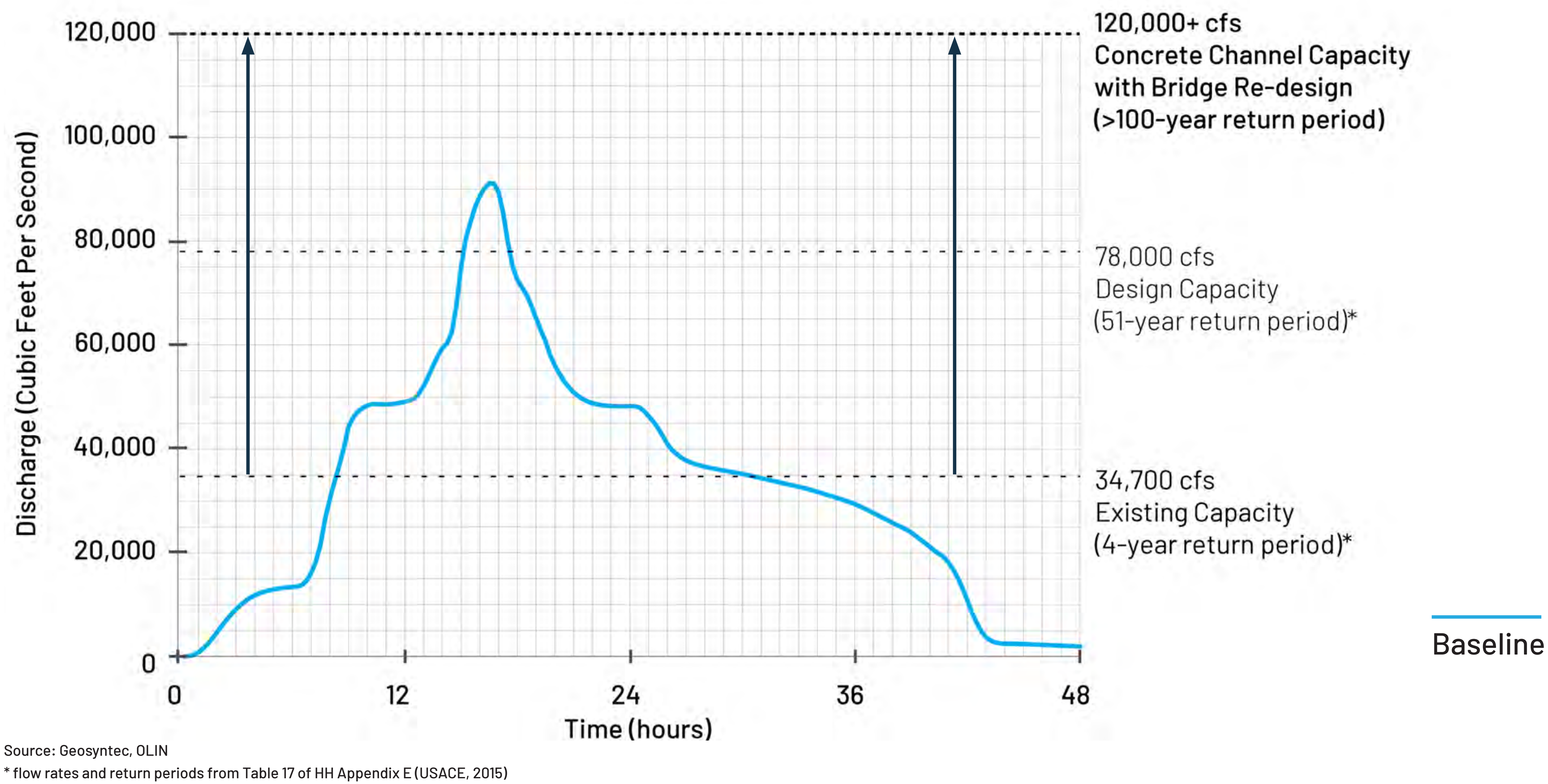
HEC-RAS

100-YEAR STORM WITH CONCRETE BOTTOM



To increase channel capacity: Harden the channel bottom to reduce friction.

Hydrograph: Glendale Narrows, River Mile 29

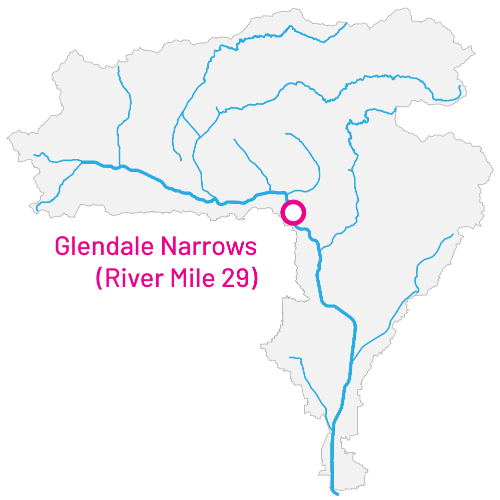


Source: Geosyntec, OLIN

* flow rates and return periods from Table 17 of HH Appendix E (USACE, 2015)

INCREASE CHANNEL CAPACITY BY COMBINING IDEAS

Source: OLIN



REFURBISHMENT + BYPASS TUNNEL

Remove invasives and sediment, maintain channel, optional native grasses, build bypass

Existing Section: **34,700 cfs capacity**

Alternative Section: **98,000 cfs capacity**

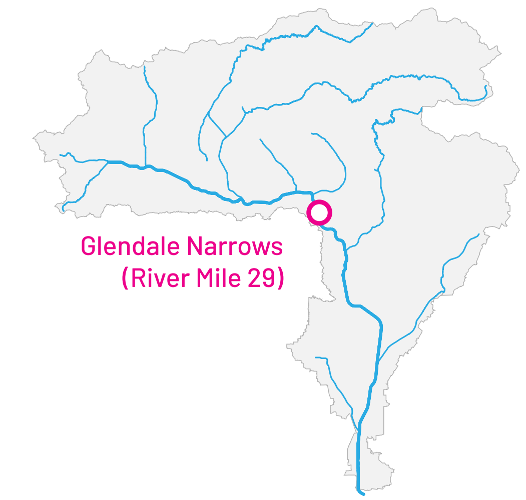
Source: Geosyntec, OLIN

MANNING'S

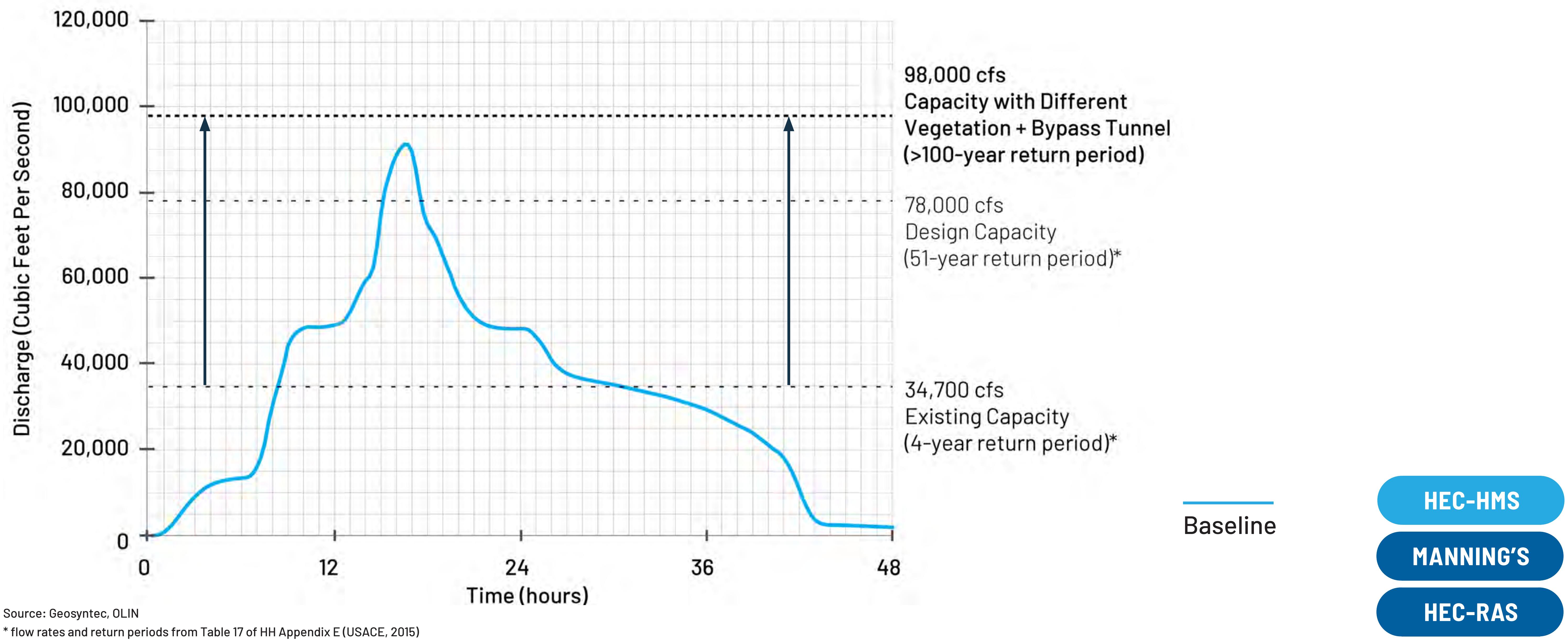
HEC-RAS

REFURBISHMENT + BYPASS TUNNEL

Remove invasives and sediment, maintain channel, optional native grasses, build bypass



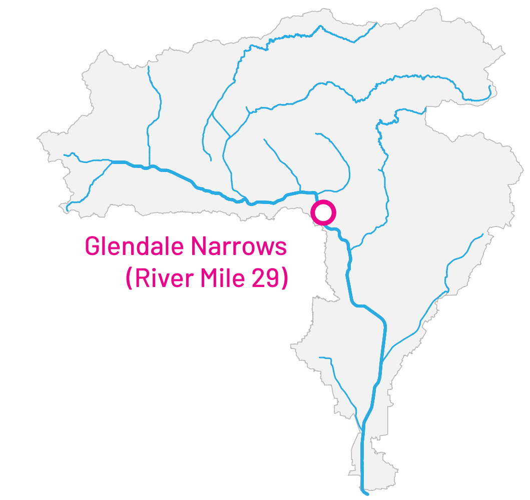
Hydrograph: Glendale Narrows, River Mile 29



Source: Geosyntec, OLIN

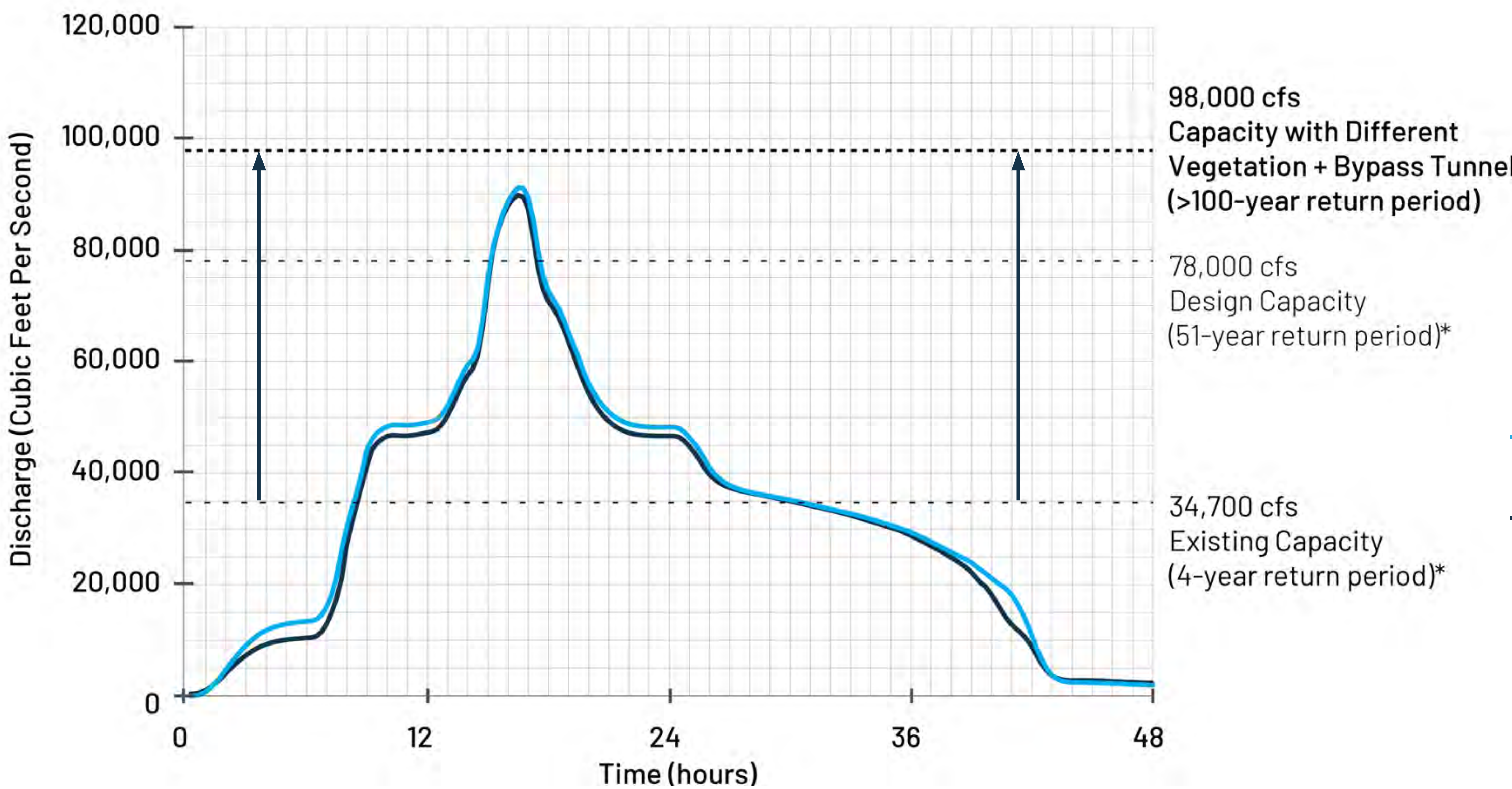
* flow rates and return periods from Table 17 of HH Appendix E (USACE, 2015)

REFURBISHMENT + BYPASS + EWMP 2037



Remove invasives, remove sediment, maintain channel, optional native grasses, build bypass, 28% impervious surface reduction

Hydrograph: Glendale Narrows, River Mile 29



Baseline

28% Reduction in Imperviousness

Source: Geosyntec, OLIN

* flow rates and return periods from Table 17 of HH Appendix E (USACE, 2015)

HEC-HMS

MANNING'S

HEC-RAS

INCREASING CAPACITY: 100-YEAR STORM EVENT

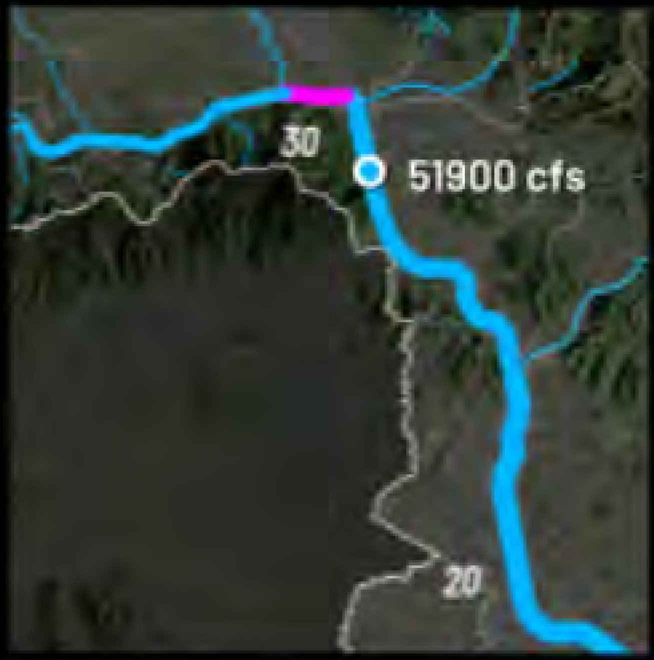
HEC-HMS Model:
Glendale Narrows (River Mile 29)

Hydrograph: 28% Impervious Reduction

Baseline Imperviousness

28% Imperviousness Reduction

28% Imperviousness Reduction + Refurbishment



28% Imperviousness Reduction + Refurbishment + Bypass Tunnel

Geosyntec, OLIN

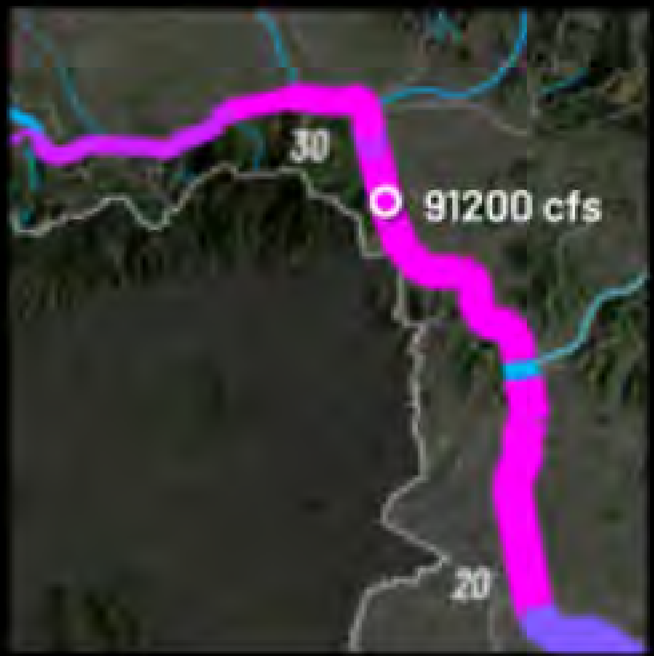
Note: Width of river represents flow, not floodway width

INCREASING CAPACITY: 100-YEAR STORM EVENT

HEC-HMS Model:
Glendale Narrows (River Mile 29)

Hydrograph: 28% Impervious Reduction

Baseline Imperviousness



28% Imperviousness Reduction

28% Imperviousness Reduction + Refurbishment

28% Imperviousness Reduction + Refurbishment + Bypass Tunnel

Geosyntec, OLIN

Note: Width of river represents flow, not floodway width

IDEAS TO...

REDUCE FLOWS TO THE CHANNEL

- Low Impact Development
- Best Management Practices
- Distributed Storage
- Increase Sepulveda and Hansen Flood Control Basins
- Additional Flood Control Basins

INCREASE CHANNEL CAPACITY

- Increase Channel Width
- Increase Levee Height
- Bypass Tunnel
- Sediment Removal/Vegetation Conversion
- Concrete

DISCUSSION AND WRAP UP

Source: OLIN

Q & A AND DISCUSSION

PARTICIPANTS

- **Iraj Nasseri, Ph.D., P.E.** (Los Angeles County Flood Control District)
- **Keith Lilley, P.E.** (Los Angeles County Flood Control District)
- **Nami Tanaka, P.E.** (Geosyntec)
- **Al Preston, Ph.D., P.E.** (Geosyntec)
- **Mark Hanna, Ph.D., P.E.** (Geosyntec)

WRAP UP

What have we learned?

What needs more study/analysis?

Web Resources:

- County real-time precipitation gages
  https://dpw.lacounty.gov/wrd/precip/alert_rain/index.cfm
- USACE real-time precipitation gages
  http://resreg.spl.usace.army.mil/cgi-bin/gMap.cgi?larP
- USACE real-time flow rates
  http://resreg.spl.usace.army.mil/cgi-bin/gMap.cgi?larF
- County HydroCalc
  http://dpw.lacounty.gov/wrd/publication/Engineering/hydrology/HydroCalc.zip
- USACE HEC-HMS
  https://www.hec.usace.army.mil/software/hec-hms/
- USACE HEC-RAS
  https://www.hec.usace.army.mil/software/hec-ras/
- Manning's calculator
  http://onlinecalc.sdsu.edu/onlinechannel01.php

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