HYDRAULIC ANALYSIS TECHNICAL ASSESSMENT

Workshop #2

April 16, 2015

Vegetation Maintenance

- Vegetation maintenance clearing is required on Soft Bottom Channels and levees

1. To provide flood protection for County residents
2. To comply with USACE Operation & Maintenance Manual
3. To comply with USACE Levee Safety Program
4. To comply with FEMA Levee Certification Program

Overview

- Purpose of the hydraulic study
- Design requirements for flood protection
- Hydraulic software and modeling
- Manning’s roughness coefficient
- Examples of hydraulic analysis

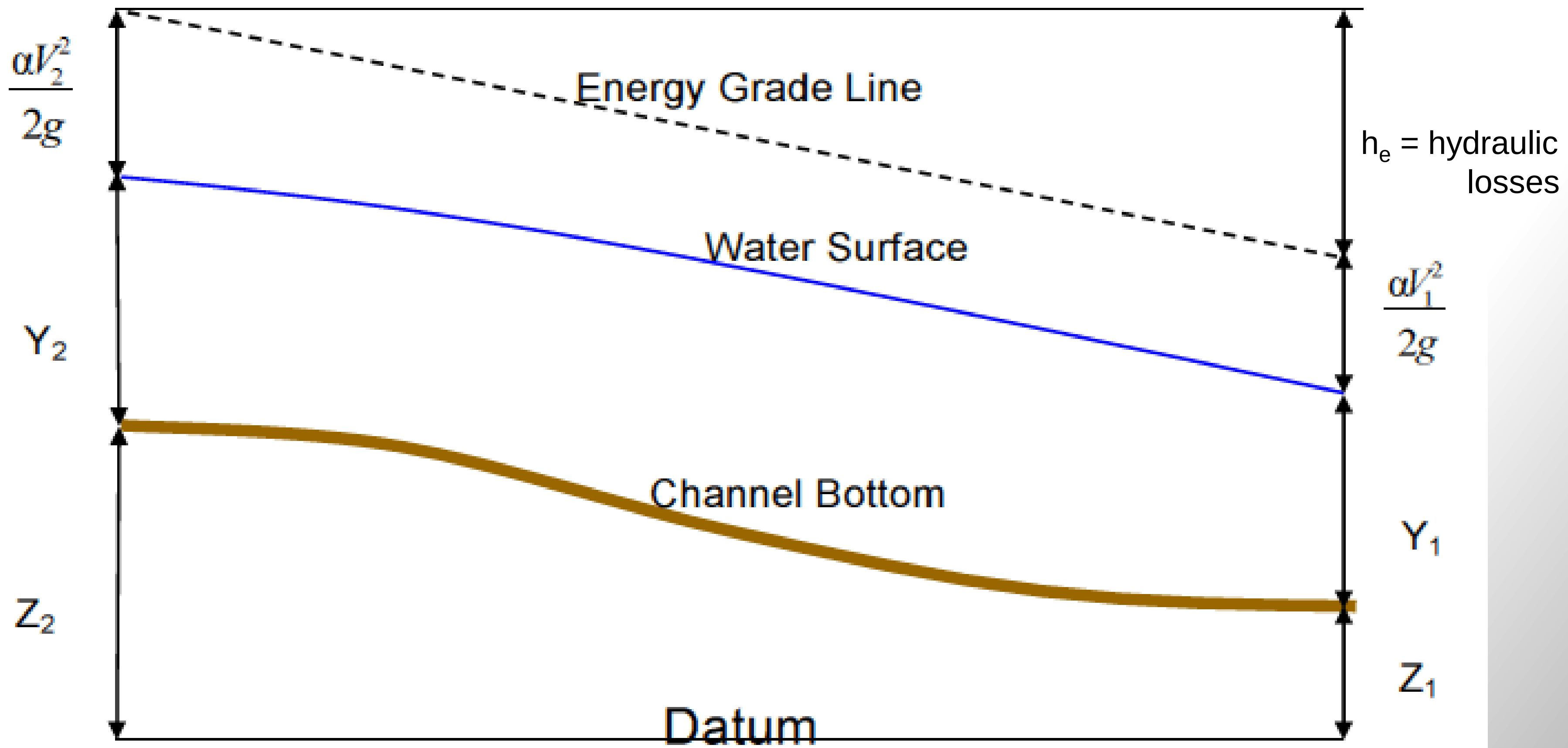
Hydraulic Software

- U.S. Army Corps of Engineers HEC-RAS software
- Developed by the Hydrologic Engineering Center
- Peer-reviewed
- Widely used and accepted
- Available free of charge

HEC-RAS

- User interacts through a graphical user interface (GUI)
- Compute water surface profiles
- Energy losses evaluated by friction (Manning's equation)

HEC-RAS



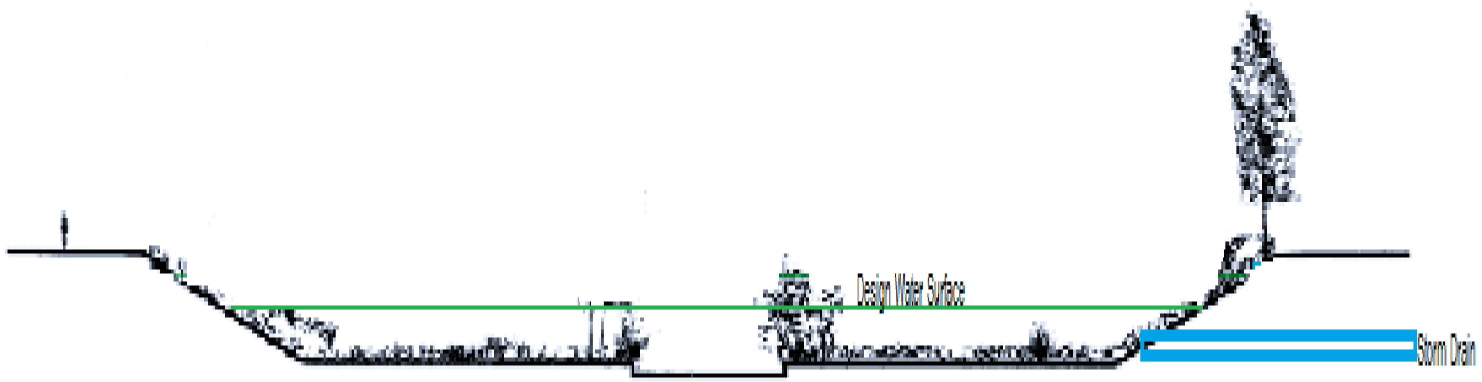
$\frac{\alpha V_2^2}{2g}$
Energy Grade Line
h_e = hydraulic losses
Water Surface
$\frac{\alpha V_1^2}{2g}$
Y_2
Channel Bottom
Y_1
Z_2
Z_1
Datum

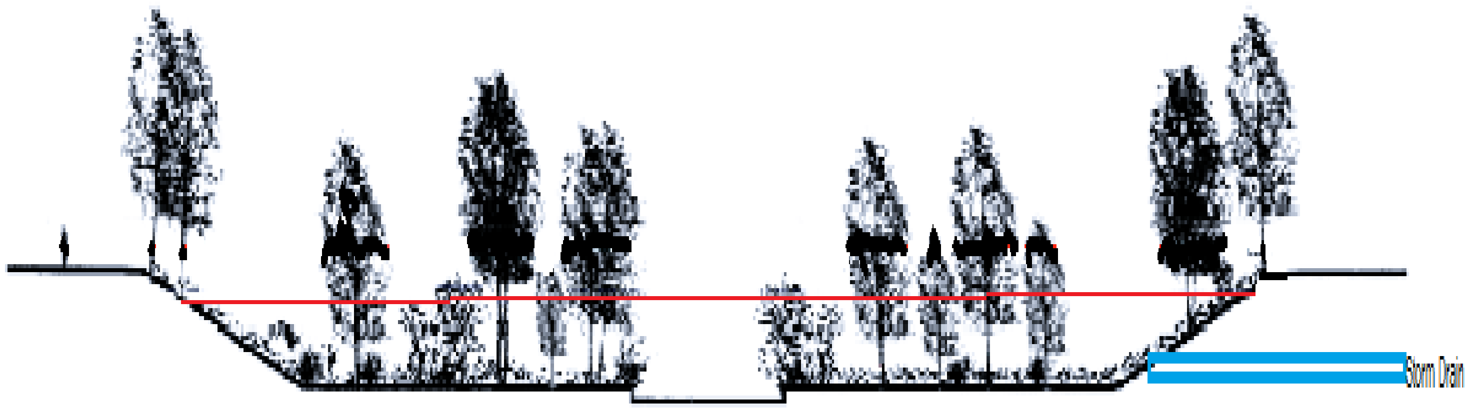
HEC-RAS

$$Z_2 + Y_2 + \frac{\alpha_2 V^2{}_2}{2g} = Z_1 + Y_1 + \frac{\alpha_1 V^2{}_1}{2g} + h_e$$

$$h_e = L\bar{S}_f + C\left|\frac{\alpha_2 V^2{}_2}{2g} - \frac{\alpha_1 V^2{}_1}{2g}\right|$$

$$\bar{S}_f = \left[\frac{Q \times n}{1.486 \times AR^{2/3}}\right]^2$$


Design Water Surface
Storm Drain

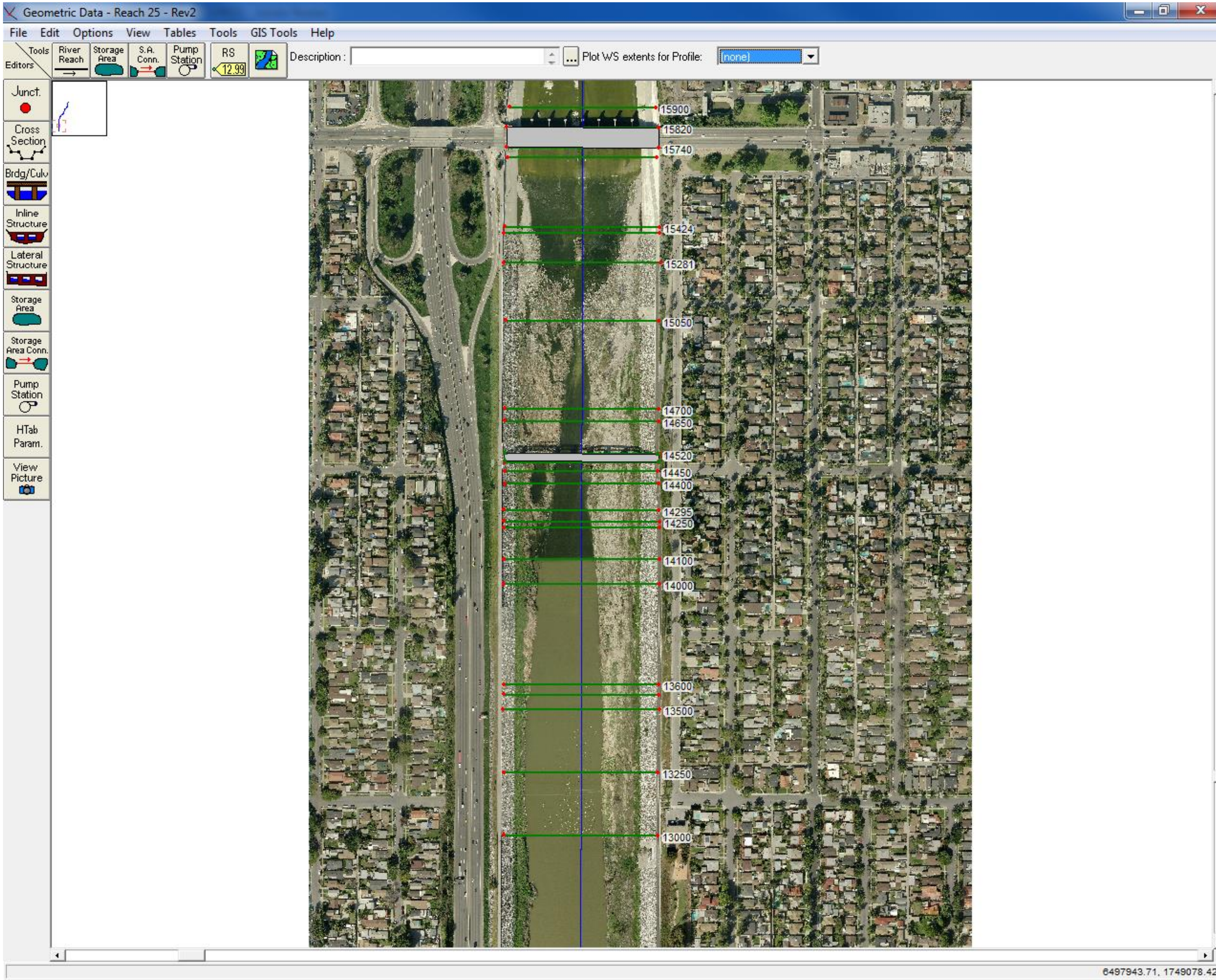

Storm Drain

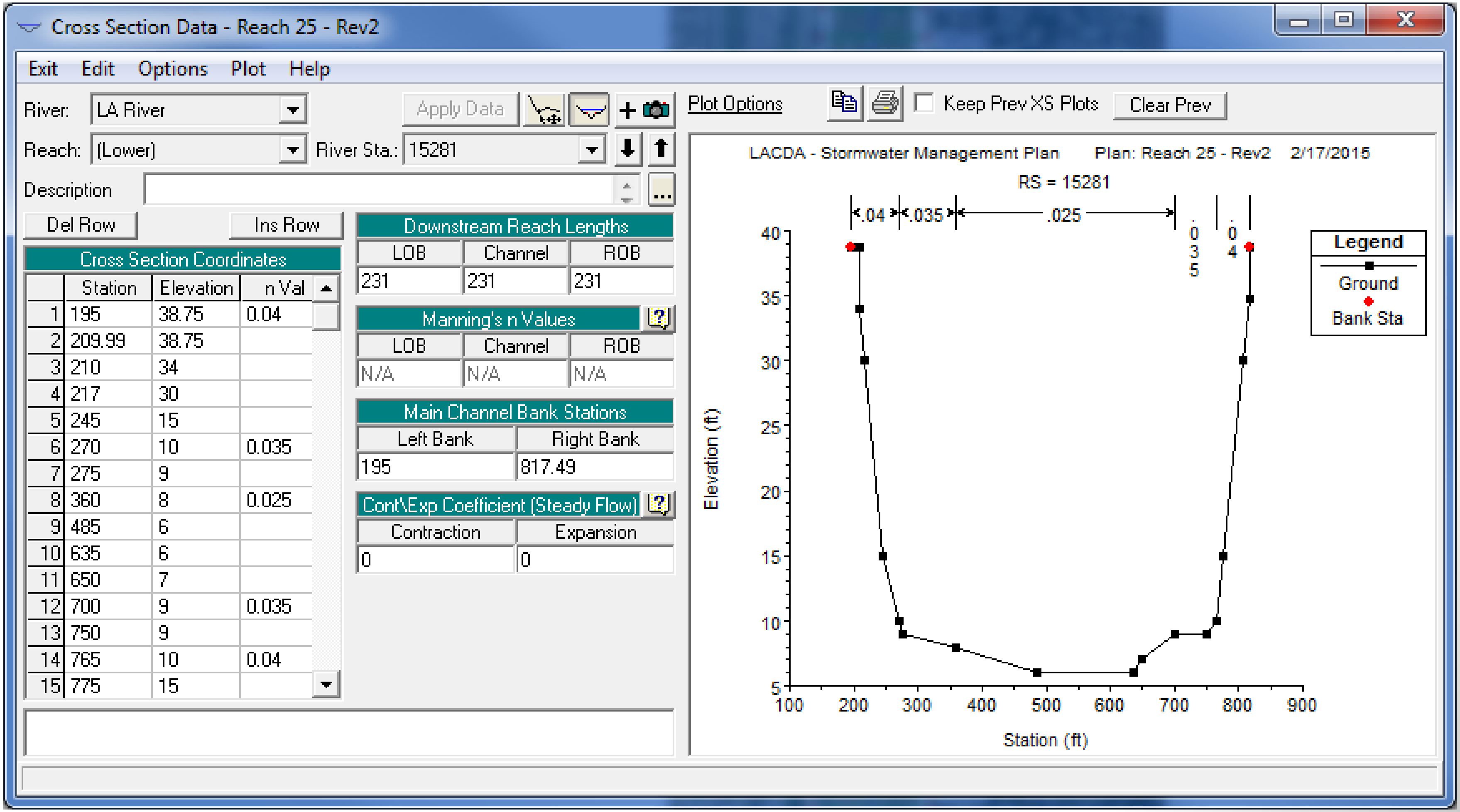
Developing A Hydraulic Model with HEC-RAS

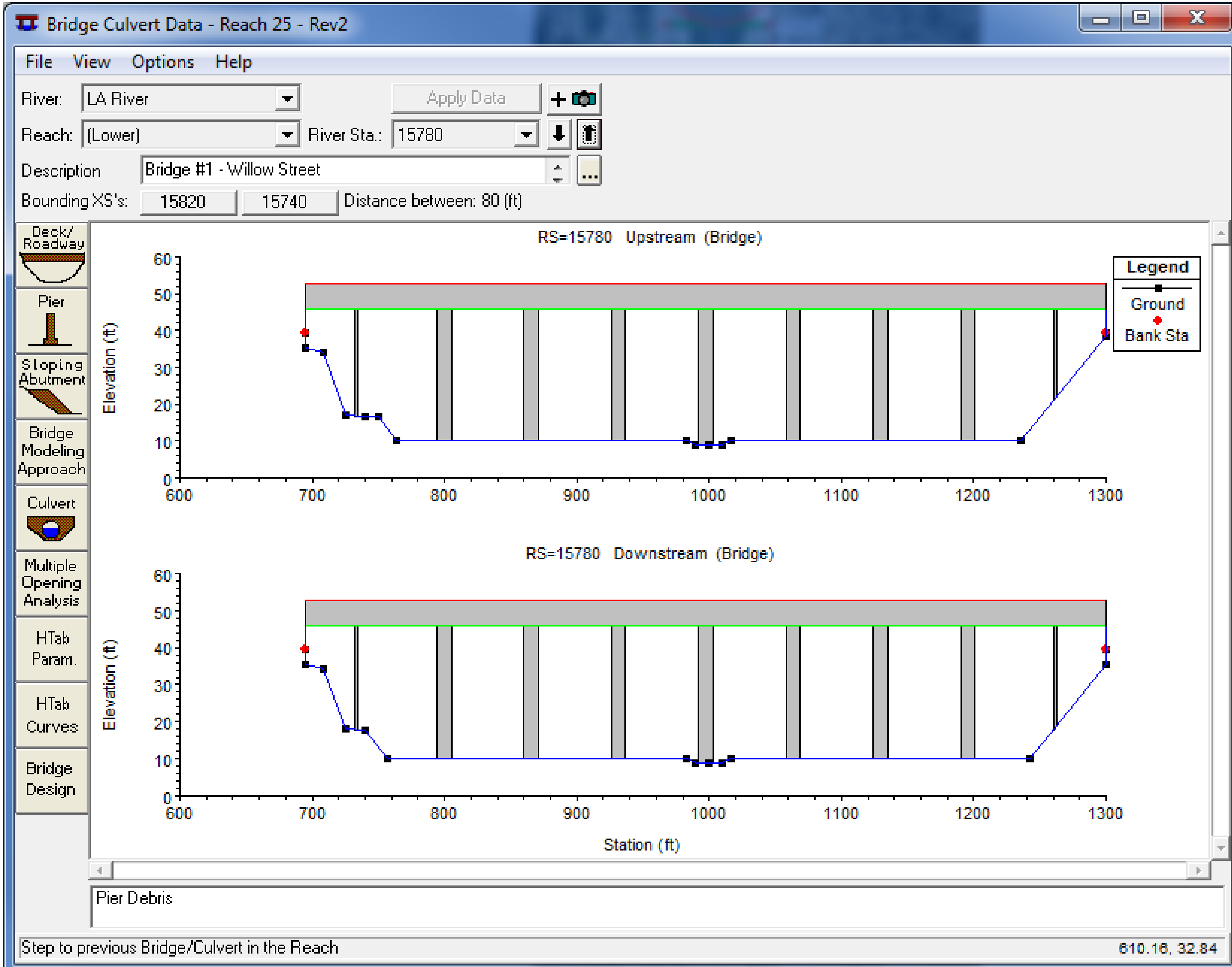
- Geometric data
  - As-built plans, field surveys, LiDAR
  - Defines channel shape
  - Bridges, culverts, etc.
  - Manning’s roughness coefficient (n-value)

- Flow data
  - At least one flow rate
  - Can be changed at any cross-section

- Boundary conditions
  - Establishes starting water surface conditions
  - Required at open ends of the river system


Geometric Data - Reach 25 - Rev2
File Edit Options View Tables Tools GIS Tools Help
Tools
Editors
River Reach
Storage Area
S.A. Conn.
Pump Station
RS
12.99
Description :
Plot WS extents for Profile:
(none)
Junct.
Cross Section
Brdg/Culv
Inline Structure
Lateral Structure
Storage Area
Storage Area Conn.
Pump Station
HTab Param.
View Picture
15900
15820
15740
15424
15281
15050
14700
14650
14520
14450
14400
14295
14250
14100
14000
13600
13500
13250
13000
6497943.71, 1749078.42


Cross Section Data - Reach 25 - Rev2
Exit Edit Options Plot Help
River: LA River
Apply Data
Plot Options
Keep Prev XS Plots
Clear Prev
Reach: (Lower)
River Sta.: 15281
Description
Del Row
Ins Row
Cross Section Coordinates
Station Elevation n Val
1 195 38.75 0.04
2 209.99 38.75
3 210 34
4 217 30
5 245 15
6 270 10 0.035
7 275 9
8 360 8 0.025
9 485 6
10 635 6
11 650 7
12 700 9 0.035
13 750 9
14 765 10 0.04
15 775 15
Downstream Reach Lengths
LOB Channel ROB
231 231 231
Manning's n Values
LOB Channel ROB
N/A N/A N/A
Main Channel Bank Stations
Left Bank Right Bank
195 817.49
Cont\Exp Coefficient (Steady Flow)
Contraction Expansion
0 0
LACDA - Stormwater Management Plan
Plan: Reach 25 - Rev2
2/17/2015
RS = 15281
.04
.035
.025
Legend
Ground
Bank Sta
Elevation (ft)
Station (ft)


Bridge Culvert Data - Reach 25 - Rev2
File View Options Help
River: LA River
Apply Data
Reach: (Lower)
River Sta.: 15780
Description Bridge #1 - Willow Street
Bounding XS's: 15820 15740 Distance between: 80 (ft)
Deck/ Roadway
Pier
Sloping Abutment
Bridge Modeling Approach
Culvert
Multiple Opening Analysis
HTab Param.
HTab Curves
Bridge Design
RS=15780 Upstream (Bridge)
Legend
Ground
Bank Sta
Elevation (ft)
RS=15780 Downstream (Bridge)
Station (ft)
Pier Debris
Step to previous Bridge/Culvert in the Reach
610.16, 32.84

Manning's Roughness Coefficient

- Very significant in computing water surface profiles
- Estimated using formula developed by Cowan (1956)

$$n = (n_b + n_1 + n_2 + n_3 + n_4)m$$

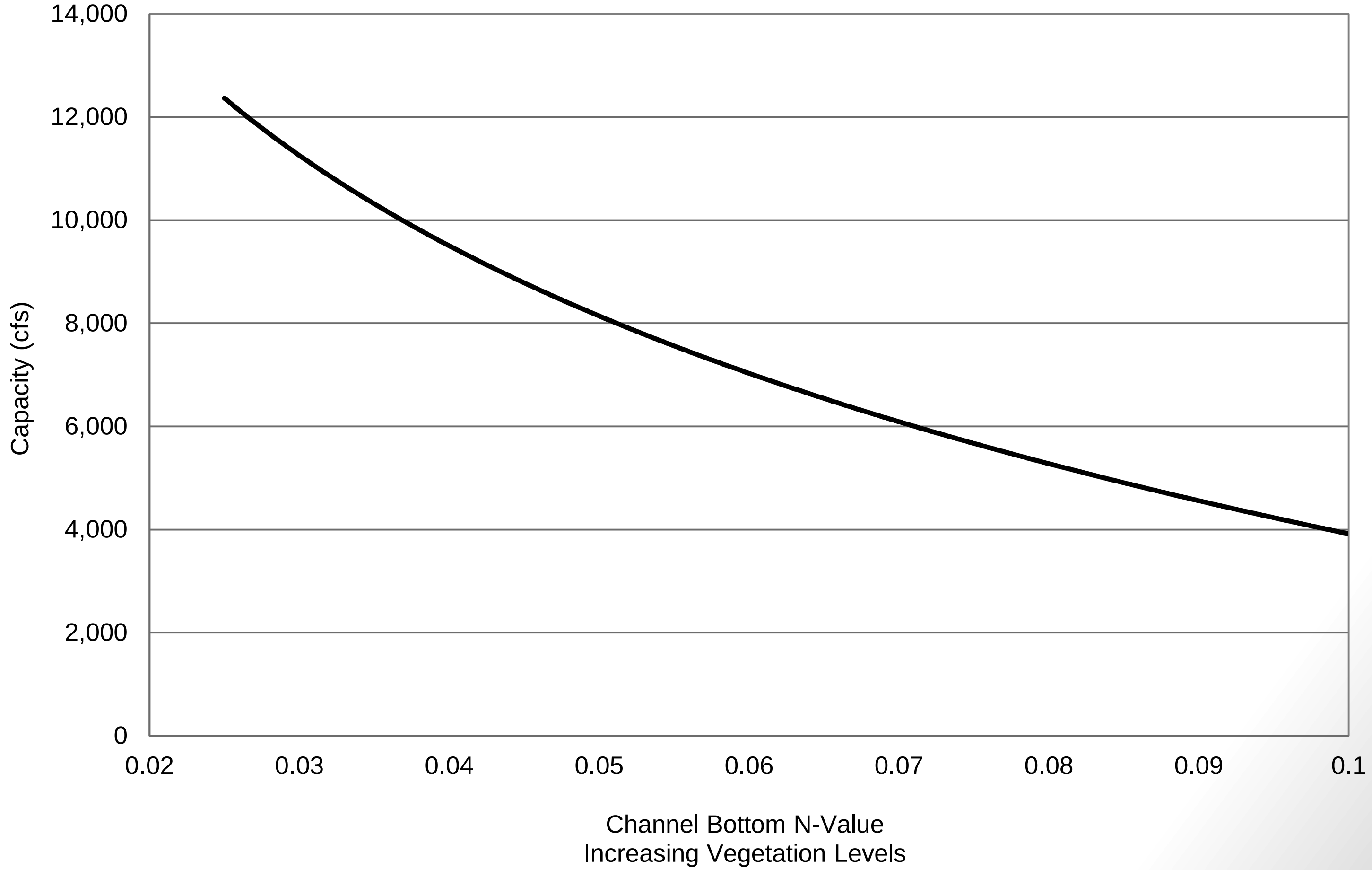
Where:

n_b = a base value of n for a straight, uniform, smooth channel in natural materials,
n_1 = a correction factor for the effect of surface irregularities,
n_2 = a value for variation in the shape and size of the channel cross section,
n_3 = a value for obstructions,
n_4 = a value for vegetation and flow conditions, and
m = a correction factor for meandering of the channel

- Adjustments based on field site observations

Source: Guide for Selecting Manning's Roughness Coefficients for Natural Channels and Flood Plains (USGS, 1984)

Effects of Roughness Coefficient on Channel Capacity



Guide for Selecting Manning's Roughness Coefficients for Natural Channels and Flood Plains

United States Geological Survey Water-Supply Paper 2339

Prepared in cooperation with the United States Department of Transportation, Federal Highway Administration

Table 1. Base values of Manning's *n*

[Modified from Aldridge and Garrett, 1973, table 1; —, no data]

Bed material	Median size of bed material (in millimeters)	Base *n* value: Straight uniform channel[1]	Base *n* value: Smooth channel[2]
Sand channels			
Sand[3]	0.2	0.012	—
	.3	.017	—
	.4	.020	—
	.5	.022	—
	.6	.023	—
	.8	.025	—
	1.0	.026	—
Stable channels and flood plains			
Concrete	—	0.012–0.018	0.011
Rock cut	—	—	.025
Firm soil	—	0.025–0.032	.020
Coarse sand	1–2	0.026–0.035	—
Fine gravel	—	—	.024
Gravel	2–64	0.028–0.035	—
Coarse gravel	—	—	.026
Cobble	64–256	0.030–0.050	—
Boulder	>256	0.040–0.070	—

[1] Benson and Dalrymple (1967).
[2] For indicated material; Chow (1959).
[3] Only for upper regime flow where grain roughness is predominant.

Table 2. Adjustment values for factors that affect the roughness of a channel

[Modified from Aldridge and Garrett, 1973, table 2]

Channel conditions		*n* value adjustment[1]	Example
Degree of irregularity (n_1)	Smooth	0.000	Compares to the smoothest channel attainable in a given bed material.
	Minor	0.001–0.005	Compares to carefully dredged channels in good condition but having slightly eroded or scoured side slopes.
	Moderate	0.006–0.010	Compares to dredged channels having moderate to considerable bed roughness and moderately sloughed or eroded side slopes.
	Severe	0.011–0.020	Badly sloughed or scalloped banks of natural streams; badly eroded or sloughed sides of canals or drainage channels; unshaped, jagged, and irregular surfaces of channels in rock.
Variation in channel cross section (n_2)	Gradual	0.000	Size and shape of channel cross sections change gradually.
	Alternating occasionally	0.001–0.005	Large and small cross sections alternate occasionally, or the main flow occasionally shifts from side to side owing to changes in cross-sectional shape.
	Alternating frequently	0.010–0.015	Large and small cross sections alternate frequently, or the main flow frequently shifts from side to side owing to changes in cross-sectional shape.
Effect of obstruction (n_3)	Negligible	0.000–0.004	A few scattered obstructions, which include debris deposits, stumps, exposed roots, logs, piers, or isolated boulders, that occupy less than 5 percent of the cross-sectional area.
	Minor	0.005–0.015	Obstructions occupy less than 15 percent of the cross-sectional area, and the spacing between obstructions is such that the sphere of influence around one obstruction does not extend to the sphere of influence around another obstruction. Smaller adjustments are used for curved smooth-surfaced objects than are used for sharp-edged angular objects.
	Appreciable	0.020–0.030	Obstructions occupy from 15 to 50 percent of the cross-sectional area, or the space between obstructions is small enough to cause the effects of several obstructions to be additive, thereby blocking an equivalent part of a cross section.
	Severe	0.040–0.050	Obstructions occupy more than 50 percent of the cross-sectional area, or the space between obstructions is small enough to cause turbulence across most of the cross section.
Amount of vegetation (n_4)	Small	0.002–0.010	Dense growths of flexible turf grass, such as Bermuda, or weeds growing where the average depth of flow is at least two times the height of the vegetation; supple tree seedlings such as willow, cottonwood, arrowweed, or saltcedar growing where the average depth of flow is at least three times the height of the vegetation.
	Medium	0.010–0.025	Turf grass growing where the average depth of flow is from one to two times the height of the vegetation; moderately dense stemmy grass, weeds, or tree seedlings growing where the average depth of flow is from two to three times the height of the vegetation; brushy, moderately dense vegetation, similar to 1- to 2-year-old willow trees in the dormant season, growing along the banks, and no significant vegetation is evident along the channel bottoms where the hydraulic radius exceeds 2 ft.
	Large	0.025–0.050	Turf grass growing where the average depth of flow is about equal to the height of the vegetation; 8- to 10-year-old willow or cottonwood trees intergrown with some weeds and brush (none of the vegetation in foliage) where the hydraulic radius exceeds 2 ft; bushy willows about 1 year old intergrown with some weeds along side slopes (all vegetation in full foliage), and no significant vegetation exists along channel bottoms where the hydraulic radius is greater than 2 ft.
	Very large	0.050–0.100	Turf grass growing where the average depth of flow is less than half the height of the vegetation; bushy willow trees about 1 year old intergrown with weeds along side slopes (all vegetation in full foliage), or dense cattails growing along channel bottom; trees intergrown with weeds and brush (all vegetation in full foliage).
Degree of meandering[2] (m)	Minor	1.00	Ratio of the channel length to valley length is 1.0 to 1.2.
	Appreciable	1.15	Ratio of the channel length to valley length is 1.2 to 1.5.
	Severe	1.30	Ratio of the channel length to valley length is greater than 1.5.

[1] Adjustments for degree of irregularity, variations in cross section, effect of obstructions, and vegetation are added to the base *n* value (table 1) before multiplying by the adjustment for meander.
[2] Adjustment values apply to flow confined in the channel and do not apply where downvalley flow crosses meanders.

Source: Guide for Selecting Manning's Roughness Coefficients for Natural Channels and Flood Plains (USGS, 1984)

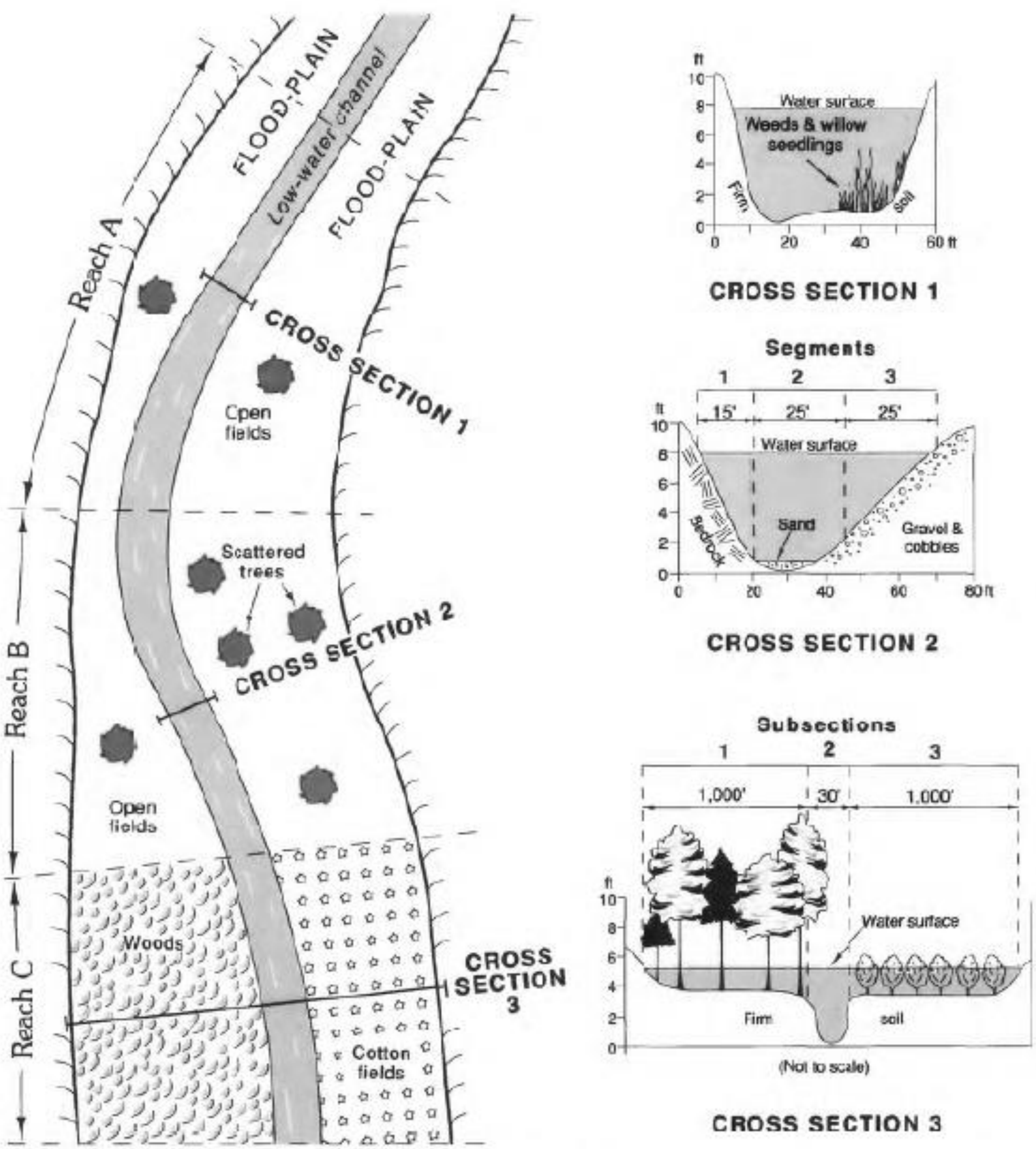


Figure 1. A schematic anc cross sections of a hypothetical reach of a channel and flood plain showing subdivisions used in assigning *n* values.

Source: Guide for Selecting Manning's Roughness Coefficients for Natural Channels and Flood Plains (USGS, 1984)

Summary of Modeling Procedures

- Develop HEC-RAS model
- Estimate Manning's roughness coefficients
- Calculate water surface elevations
- Compare results to design conditions
- Determine if channel has capacity
- Show examples

Modeled Scenarios

- Existing Vegetation Scenario
  - Developed for every reach
  - Based on existing vegetation levels prior to maintenance activities
  - If no excess capacity, looked at a clear channel scenario
  - If excess capacity, further modeling done using recommendation scenario

- Clear Channel Scenario
  - Developed for reaches found to have insufficient capacity under existing vegetation levels
  - Assumed no vegetation located within the channel (design condition)
  - If still insufficient capacity, no further modeling performed
  - If excess capacity available, further modeling done assuming vegetation condition less than existing

- Recommendation Scenario
  - Developed if reach had sufficient channel capacity under existing vegetation or clear channel scenario
  - Vegetation levels based on recommendations by biologist
  - Manning's n-values adjusted accordingly to account for additional vegetation
  - Hydraulics checked to ensure sufficient capacity maintained along the reach

Reach 25 – Lower LA River

- Willow Street to Pacific Coast Highway
- Constructed by U.S. Army Corps of Engineers in 1955
- Improved by Corps in 1998 as part of the LACDA Project
- Designed for 133-year flood protection (182,000 cfs)
- HEC-RAS model developed by Corps in 2004

LOS ANGELES COUNTY DRAINAGE AREA
RIO HONDO CHANNEL AND LOS ANGELES RIVER
WHITTIER NARROWS DAM TO PACIFIC OCEAN

STORMWATER MANAGEMENT PLAN

PHASE I

HEC-RAS HYDRAULIC MODELS

RIO HONDO CHANNEL REACH 4
AND
LOWER LOS ANGELES RIVER REACHES 3B, 3A, AND 2

Department of the Army
Los Angeles District, Corps of Engineers
Los Angeles, California

July 2004

LOS ANGELES COUNTY DRAINAGE AREA
RIO HONDO CHANNEL AND LOS ANGELES RIVER
WHITTIER NARROWS DAM TO PACIFIC OCEAN

STORMWATER MANAGEMENT PLAN

PHASE 1

HEC-RAS HYDRAULIC MODELS

RIO HONDO CHANNEL REACH 4 AND LOWER LOS ANGELES RIVER REACHES 3B, 3A, and 2

1. INTRODUCTION

Purpose

1.1 The purpose of this report is to present the hydraulic analyses for Phase I of the Stormwater Management Plan. In addition, the report establishes the regulatory water surface elevations that will be used as the basis against which all hydraulic impacts to the Phase I channels are evaluated.

Scope

1.2 Phase I of the plan encompasses the development of hydraulic models for the Rio Hondo Channel and lower Los Angeles River. Additional phases for modeling the remaining portion of the Los Angeles River and other major tributaries may follow at a later date.

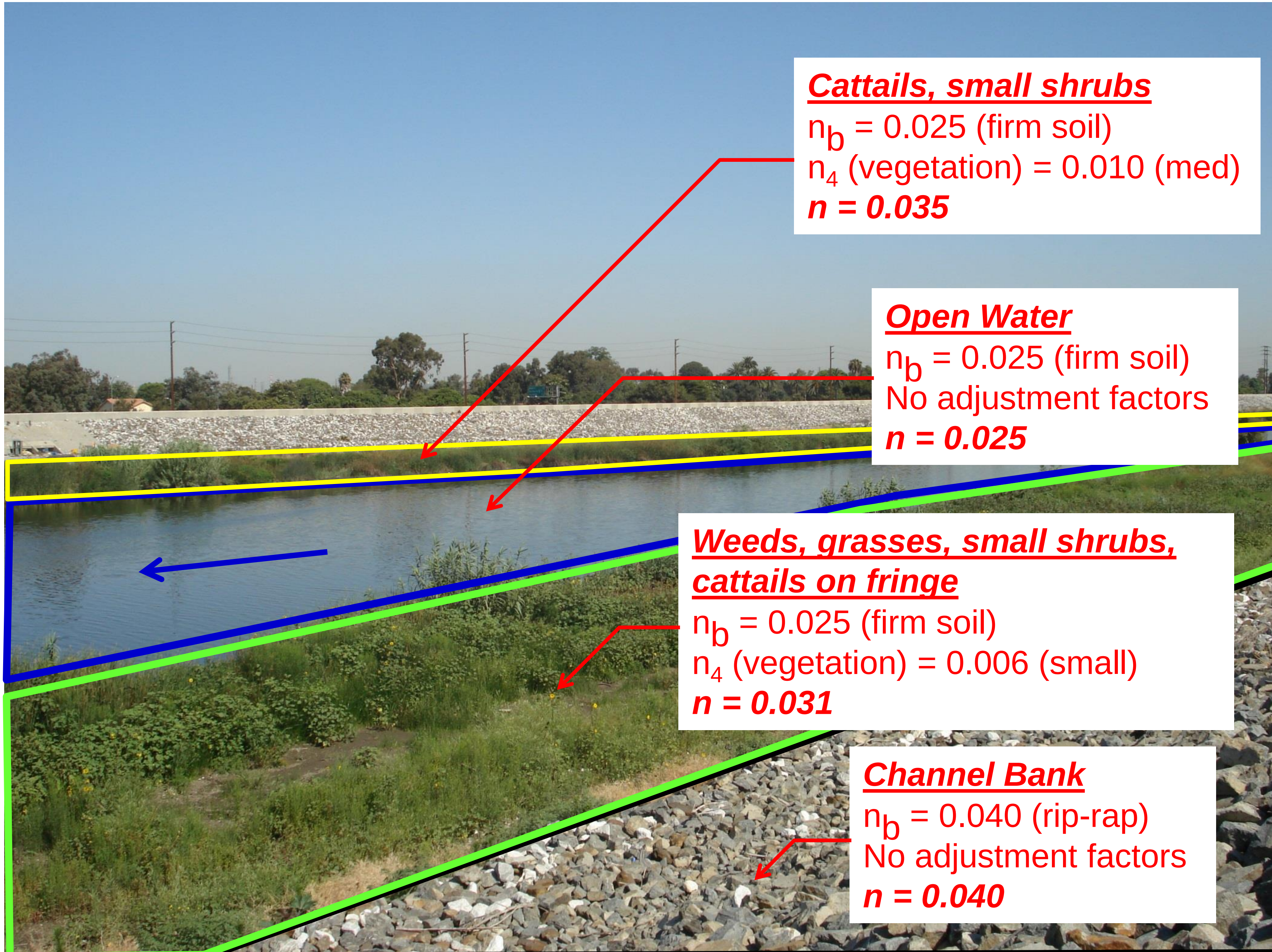
Project Authorization

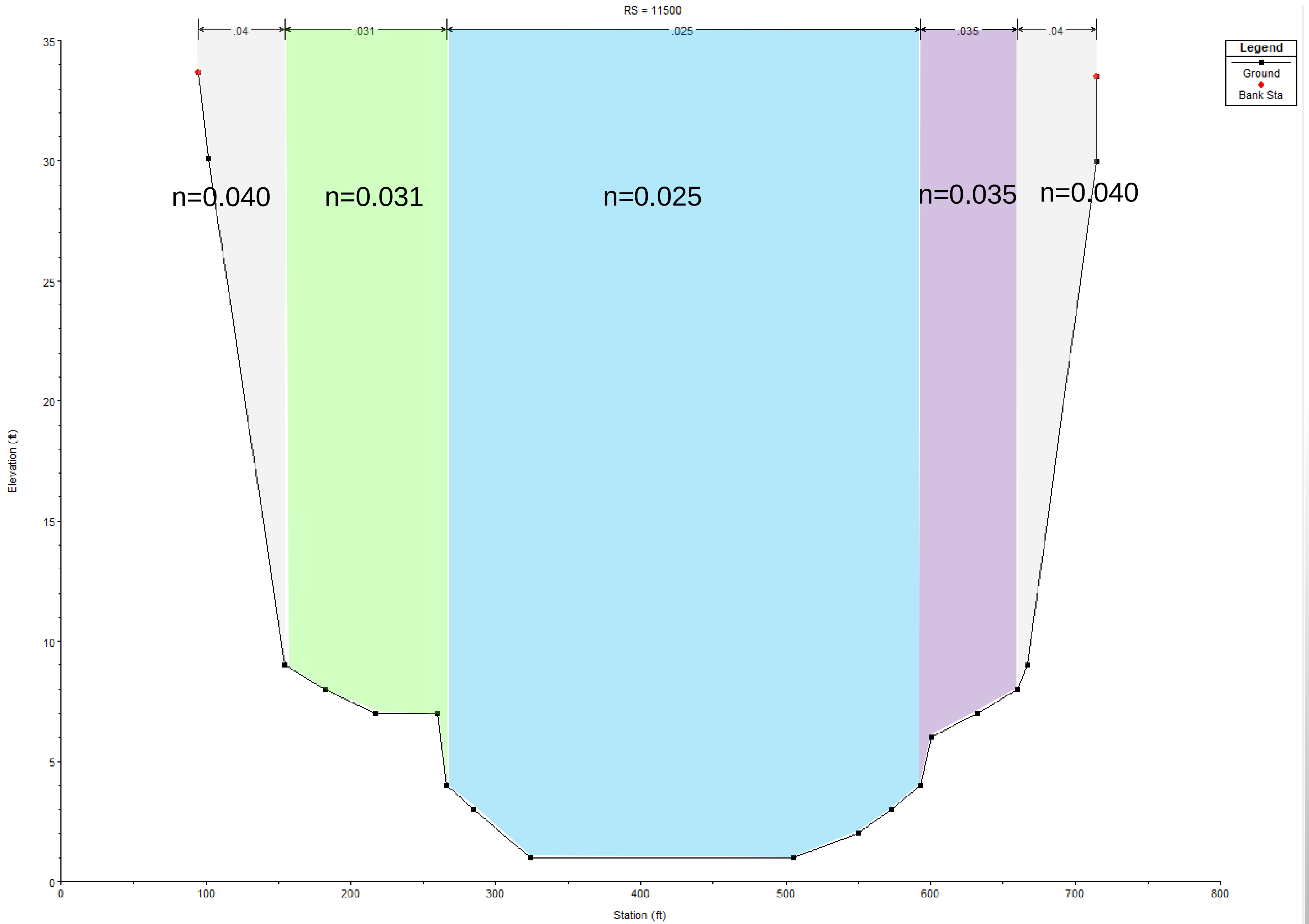
1.3 The Project Cooperation Agreement (Appendix A) between the Department of the Army and the Los Angeles County Flood Control District for Construction of the Los Angeles County Drainage Area, California Flood Control Project, states under Article II.Q that:

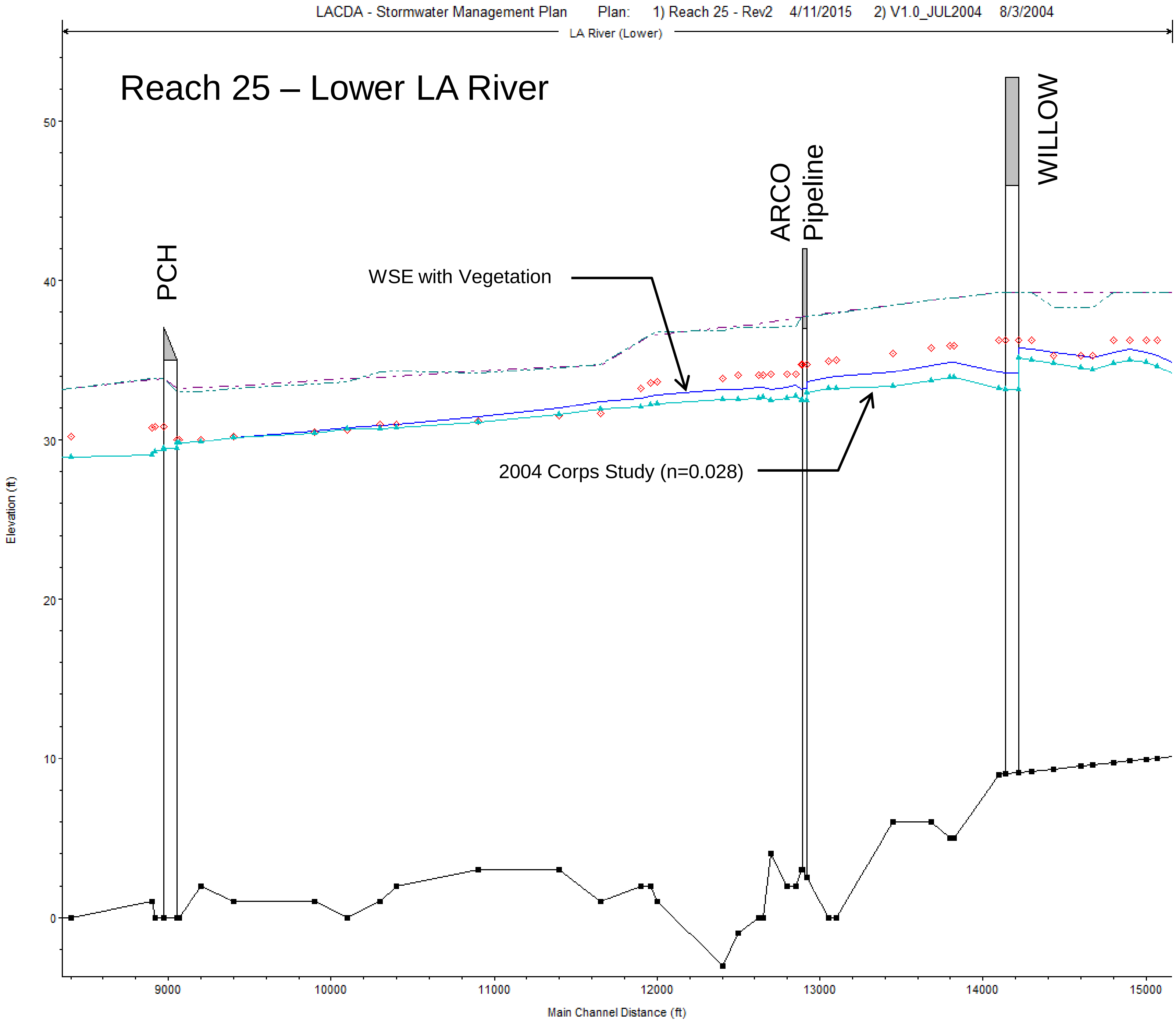
> "The Non-Federal Sponsor shall prescribe and enforce regulations, or undertake other actions, managing stormwater runoff (hereinafter the "stormwater management plan") from within Los Angeles County to ensure that the quantity or concentration of stormwater inflow does not reduce the authorized level of flood protection."

1.4 In December 2002, the U.S. Army Corps of Engineers (USACE) and Los Angeles County Department of Public Works (LACDPW) agreed to develop a detailed HEC-RAS hydraulic model of the Los Angeles County Drainage Area (LACDA) system to assess the

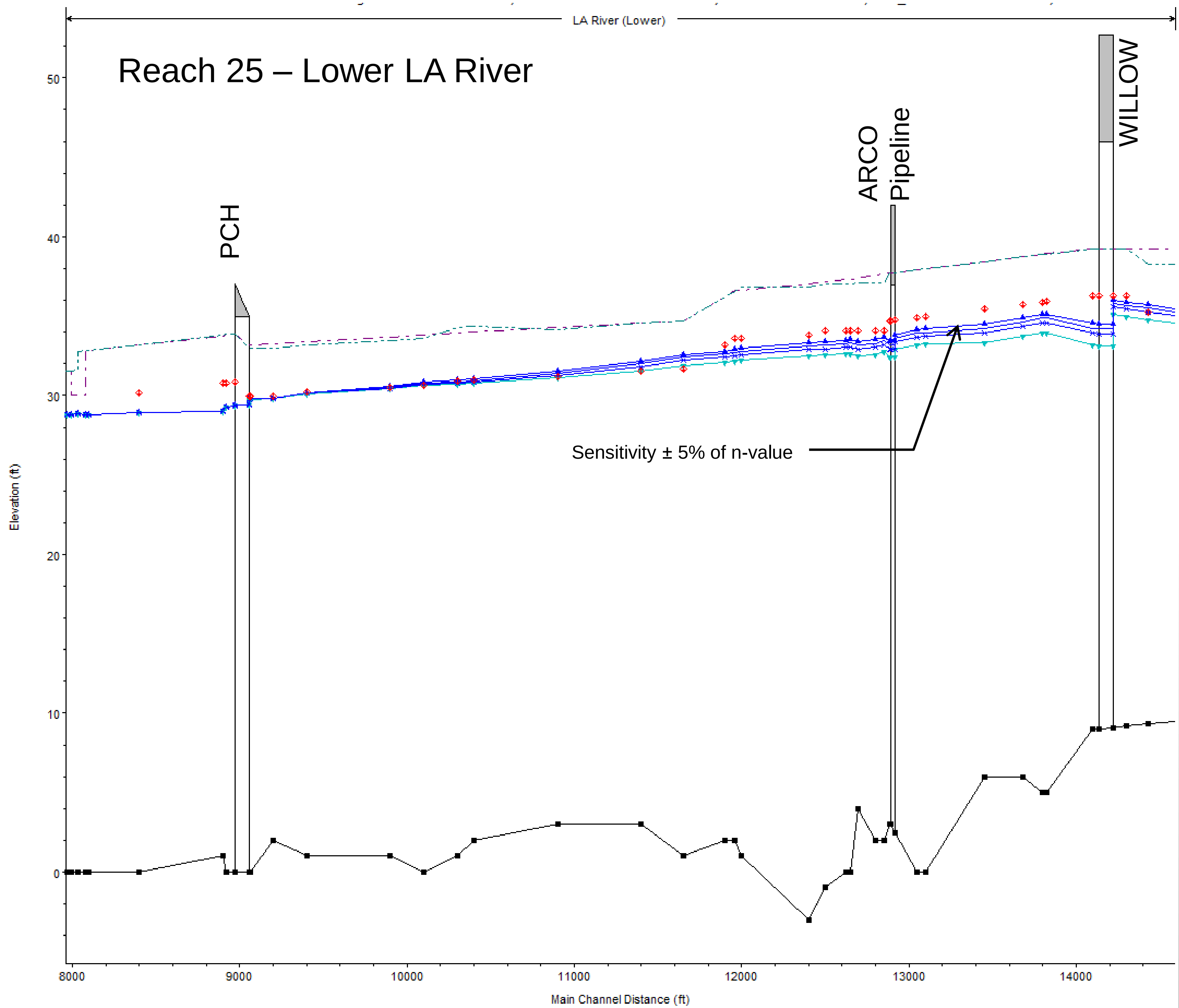

11900
11700
11500
11000
10800
10653
10571
LONG BEACH FRWY
LONG BEACH FRWY
DE FOREST AV
SAN FRANCISCO AV
W PACIFIC COAST HWY
Open Water
Cattails, small bushes
Some grasses, small shrubs
Some grasses, small shrubs, trees
Rip-rap
Concrete


Cattails, small shrubs
n_b = 0.025 (firm soil)
n_4 (vegetation) = 0.010 (med)
n = 0.035
Open Water
n_b = 0.025 (firm soil)
No adjustment factors
n = 0.025
Weeds, grasses, small shrubs, cattails on fringe
n_b = 0.025 (firm soil)
n_4 (vegetation) = 0.006 (small)
n = 0.031
Channel Bank
n_b = 0.040 (rip-rap)
No adjustment factors
n = 0.040


RS = 11500
.04
.031
.025
.035
.04
Legend
Ground
Bank Sta
n=0.040
n=0.031
n=0.025
n=0.035
n=0.040
Elevation (ft)
Station (ft)
0
5
10
15
20
25
30
35
0
100
200
300
400
500
600
700
800



LACDA - Stormwater Management Plan Plan: 1) Reach 25 - Rev2 4/11/2015 2) V1.0_JUL2004 8/3/2004
LA River (Lower)
Reach 25 – Lower LA River
PCH
ARCO Pipeline
WILLOW
WSE with Vegetation
2004 Corps Study (n=0.028)
Elevation (ft)
Main Channel Distance (ft)



LA River (Lower)
Reach 25 – Lower LA River
PCH
ARCO
Pipeline
WILLOW
Sensitivity ± 5% of n-value
Elevation (ft)
Main Channel Distance (ft)
50
40
30
20
10
0
8000
9000
10000
11000
12000
13000
14000

Reach 24 – Compton Creek

- Alameda Street to LA River confluence
- Constructed by U.S. Army Corps of Engineers in 1955
- Improved by Corps in 1998 as part of the LACDA Project (710 Fwy to LA River confluence)
- Increased capacity to 17,300 cfs by addition of parapet walls
- Upstream capacity is 13,750 cfs
- 100-Year Flood is 16,500 cfs
- HEC-RAS model developed by Corps in 2011

US Army Corps
of Engineers
Los Angeles District

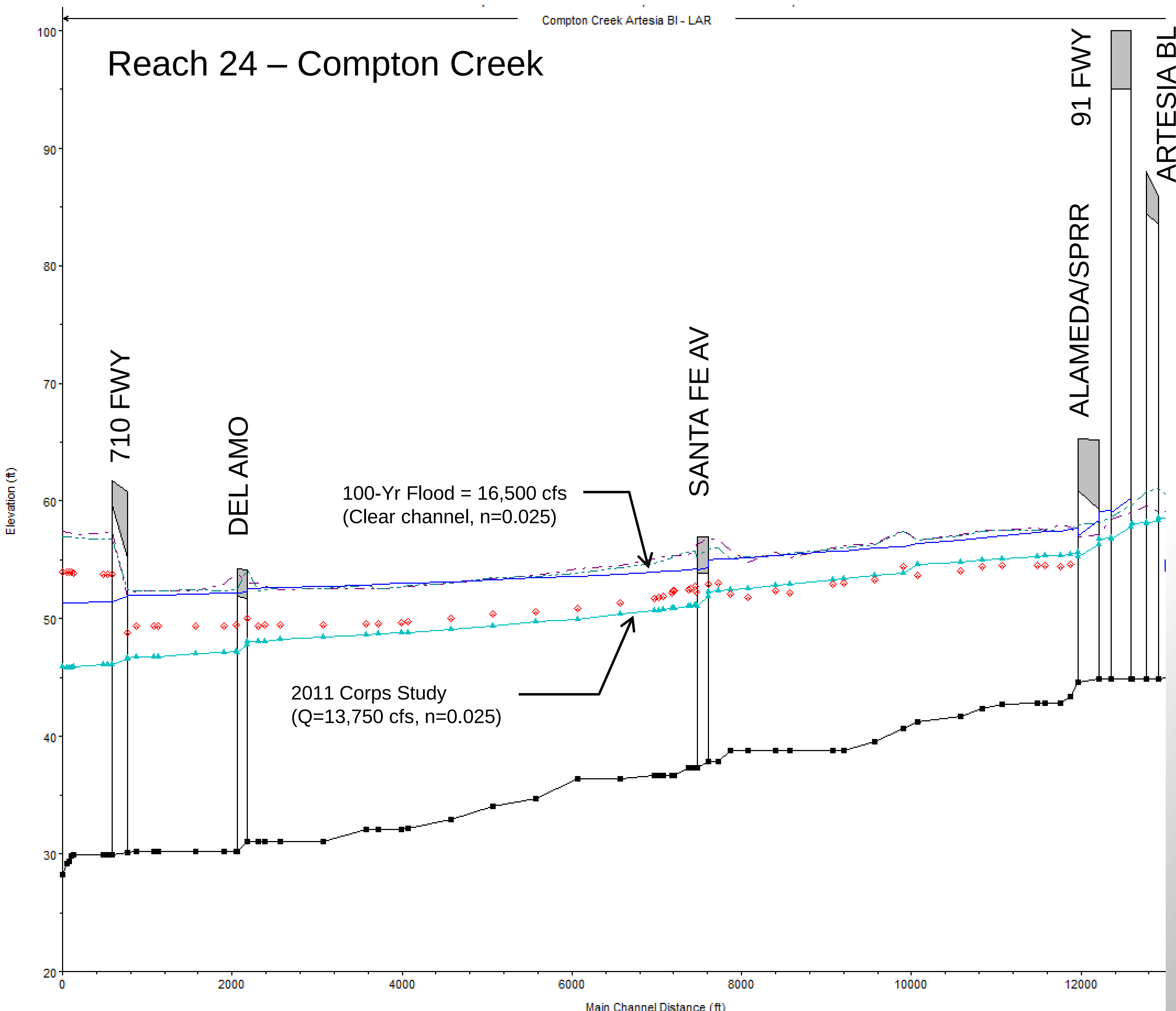
Los Angeles County Drainage Area
San Gabriel River, San Jose Creek
Compton Creek, Upper Rio Hondo
Coyote Creek, Verdugo Wash
Arroyo Seco
HEC-RAS Hydraulic Models

FINAL REPORT

Prepared By:

HDR CDM

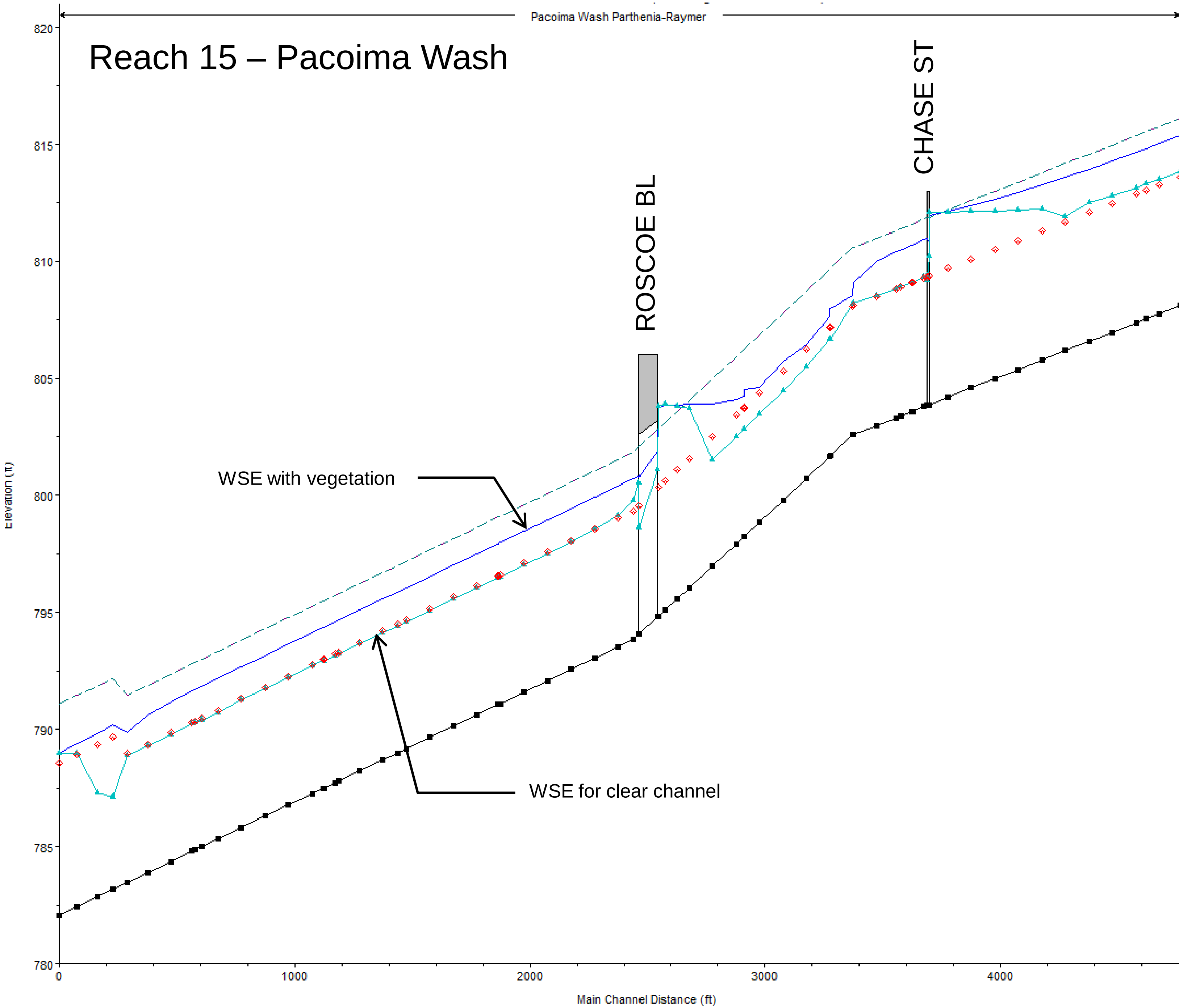
February 2011


Compton Creek Artesia Bl - LAR
Reach 24 – Compton Creek
710 FWY
DEL AMO
SANTA FE AV
ALAMEDA/SPRR
91 FWY
ARTESIA BL
100-Yr Flood = 16,500 cfs
(Clear channel, n=0.025)
2011 Corps Study
(Q=13,750 cfs, n=0.025)
Elevation (ft)
Main Channel Distance (ft)
100
90
80
70
60
50
40
30
20
0
2000
4000
6000
8000
10000
12000

Reach 24 – Compton Creek

Reach 15 – Pacoima Wash

- Parthenia Street to Marson Street
- Built by LACFCD in 1956
- HEC-RAS model developed from as-built plans
- Design Flow is 4,460 cfs

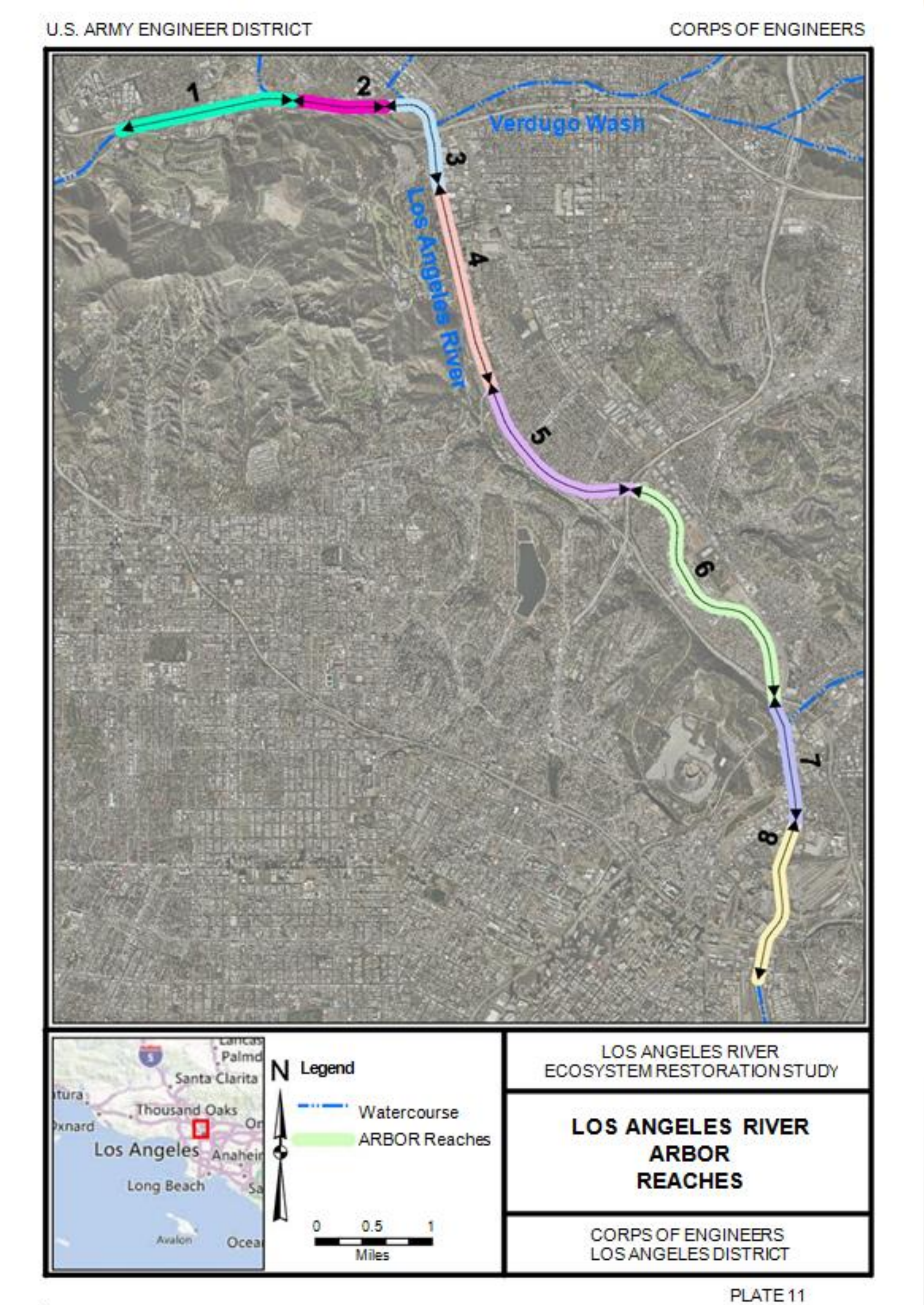


Pacoima Wash Parthenia-Raymer
Reach 15 – Pacoima Wash
CHASE ST
ROSCOE BL
WSE with vegetation
WSE for clear channel
820
815
810
805
800
795
790
785
780
Elevation (ft)
0
1000
2000
3000
4000
Main Channel Distance (ft)

Reach 15 – Pacoima Wash

US Army Corps
of Engineers
Los Angeles District

USACE

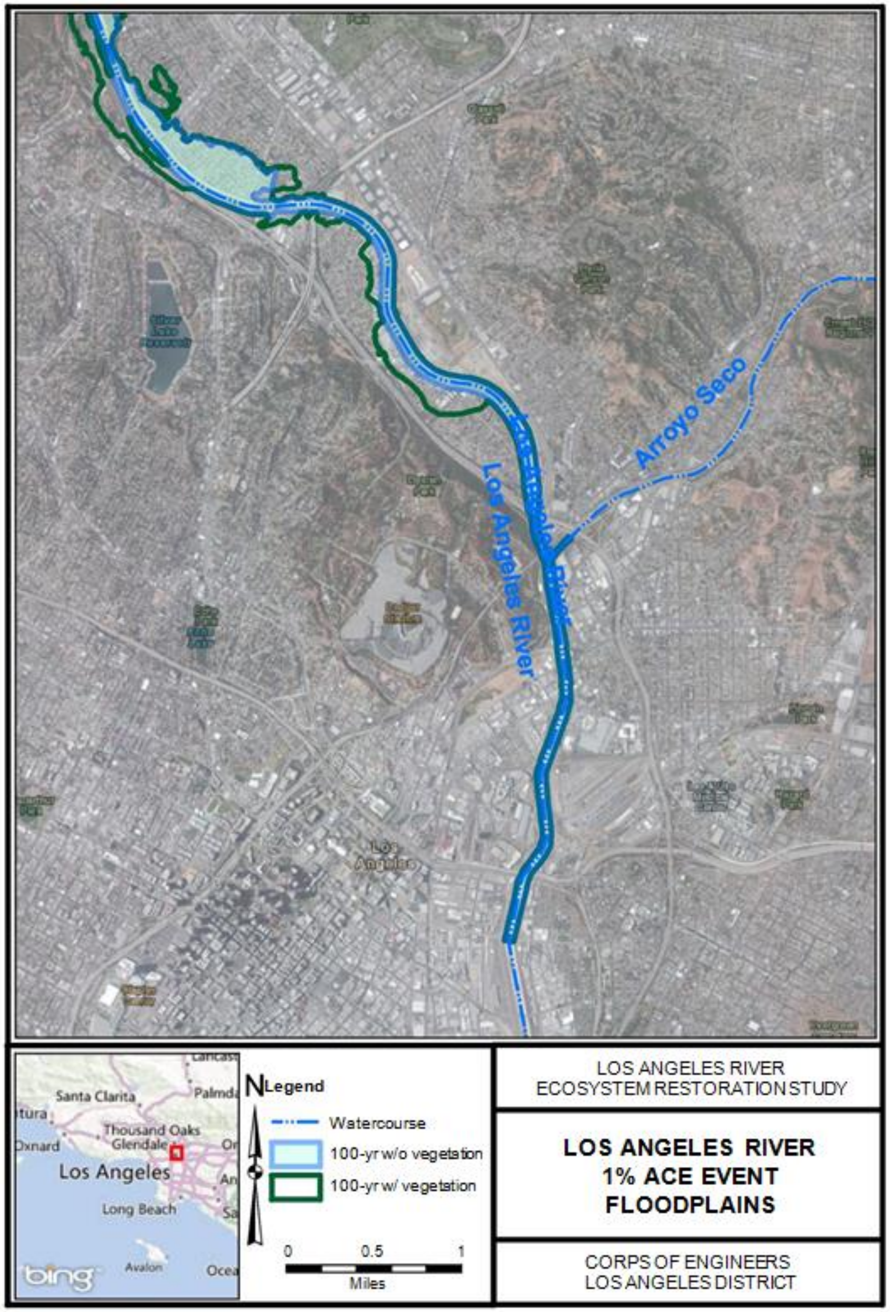


U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
1
2
3
4
5
6
7
8
Verdugo Wash
Los Angeles River
Santa Clarita
Thousand Oaks
Los Angeles
Long Beach
N
Legend
Watercourse
ARBOR Reaches
0
0.5
1
Miles
LOS ANGELES RIVER
ECOSYSTEM RESTORATION STUDY
LOS ANGELES RIVER
ARBOR
REACHES
CORPS OF ENGINEERS
LOS ANGELES DISTRICT
PLATE 11

Table 17: Revised Channel Capacity and Bankfull Discharge

Reach[a]	River Stations	Design[b] Discharge ft^3/s	Bankfull[c] Discharge ft^3/s	Freeboard[d] ft	Revised[e] Channel Capacity ft^3/s	Return Period[f] (yrs)
Reach 1	625+77 to 547+45	40,000	NA	3	29,300	10
Reach 2	546+45 to 510+05	40,000	35,100	3	25,800	5
Reach 3a	504+93 to 477+85	40,000	NA	3	40,000	10
Reach 3b	475+68 to 452+58	78,000	NA	3	78,000	30
Reach 4	432+16 to 359+75	78,000	45,200	3	34,700	5
Reach 5	358+63 to 271+89	78,000	48,200	3	34,000	5
Reach 6a	270+28 to 262+73	78,000	78,000	2.5	64,500	15
Reach 6b	257+85 to 144+23	83,700	66,800	2.5	50,500	10
Reach 7a	142+91 to 131+22	83,700	NA	2.5	83,700	30
Reach 7b	128+71 to 86+61	104,000	98,900	3	83,700	30
Reach 8	86+07 to 10+31	104,000	89,700	3	89,600	30

Notes:
(a) letters a & b in Reach names denote a break due to a confluence or flow change.
(b) Original design discharge for clean prismatic channel.
(c) Bankfull discharge with vegetation and sedimentation. The values shown are the minimum discharge within the reach. Bankfull discharges were only calculated for soft-bottom sections; NA denotes not applicable in all-concrete sections.
(d) Freeboard from EM 1110-2-1601; 3 feet for leveed sections and 2.5 feet for trapezoidal entrenched sections.
(e) Channel capacity with vegetation and sedimentation and freeboard. The values shown are the minimum within the reach.
(f) Return period for Revised Channel Capacity based on discharge frequency results from 1992 LACDA Feasibility Study.



LOS ANGELES RIVER
ECOSYSTEM RESTORATION STUDY

LOS ANGELES RIVER
1% ACE EVENT
FLOODPLAINS

CORPS OF ENGINEERS
LOS ANGELES DISTRICT

PLATE 23b

N

Legend

- Watercourse
- 100-yr w/o vegetation
- 100-yr w/ vegetation

0 0.5 1
Miles

LOS ANGELES RIVER
ECOSYSTEM RESTORATION STUDY

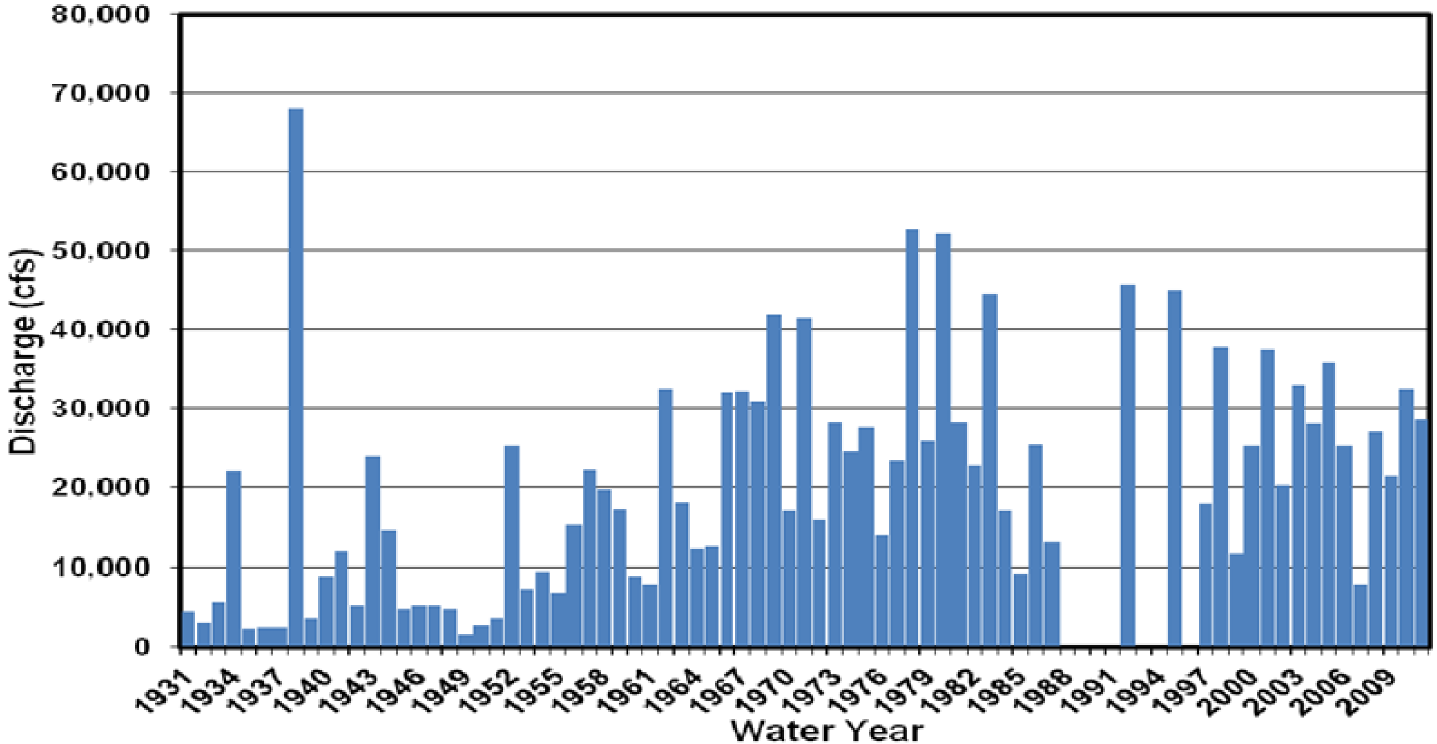
LOS ANGELES RIVER
1% ACE EVENT
FLOODPLAINS

CORPS OF ENGINEERS
LOS ANGELES DISTRICT

PLATE 23a

U.S. ARMY ENGINEER DISTRICT

CORPS OF ENGINEERS



Peak annual flows for period of record.

Ref: Los Angeles County Department of Public Works (LACDPW) Gage F57C-R; Los Angles River above Arroyo Seco.

LOS ANGELES RIVER
ECOSYSTEM RESTORATION STUDY

LOS ANGELES RIVER
ABOVE ARROYO SECO
PERIOD OF RECORD FLOWS

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LOS ANGELES DISTRICT