ARROYO COLORADO

HYDRAULIC ANALYSIS FOR REESTABLISHING DESIGN CAPACITY

Padinare Unnikrishna, Ph.D., P.E., CFM
Supervisory Civil Engineer

International Boundary and Water Commission
United States Section

Engineering Services Division

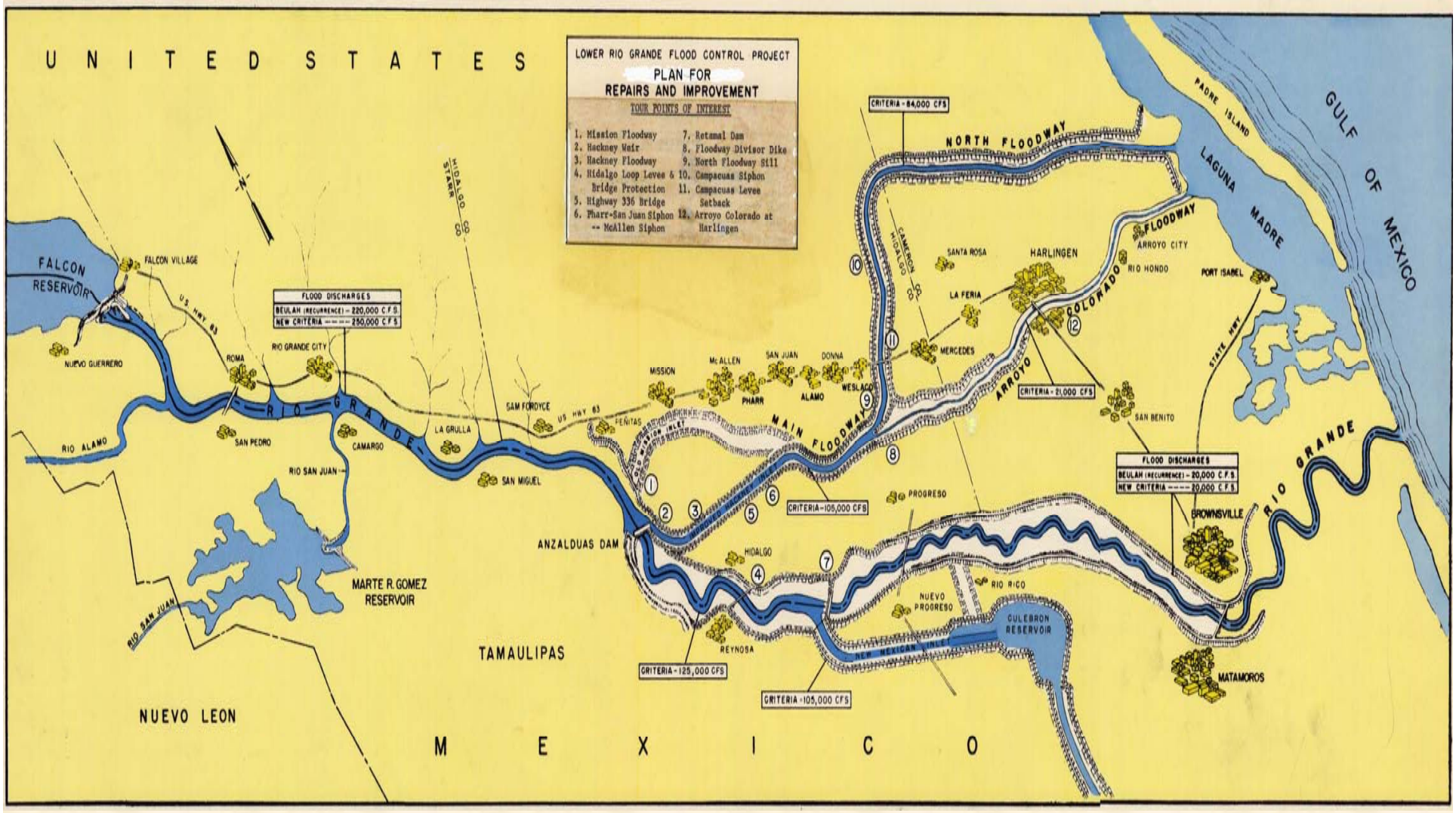
November 12, 2014

Lower Rio Grande Flood Control Project

- Design Flood estimates based on Hurricane Beulah of September 1967
- 250,000 cfs at Rio Grande City
- 105,000 cfs diverted to Main Floodway at Anzalduas Dam (Banker Weir)
- 105,000 cfs diverted to Mexican Floodway at Retamal Dam
- Remaining flow continues downstream along Rio Grande (20,000 cfs at Brownsville)

Lower Rio Grande Flood Control Project

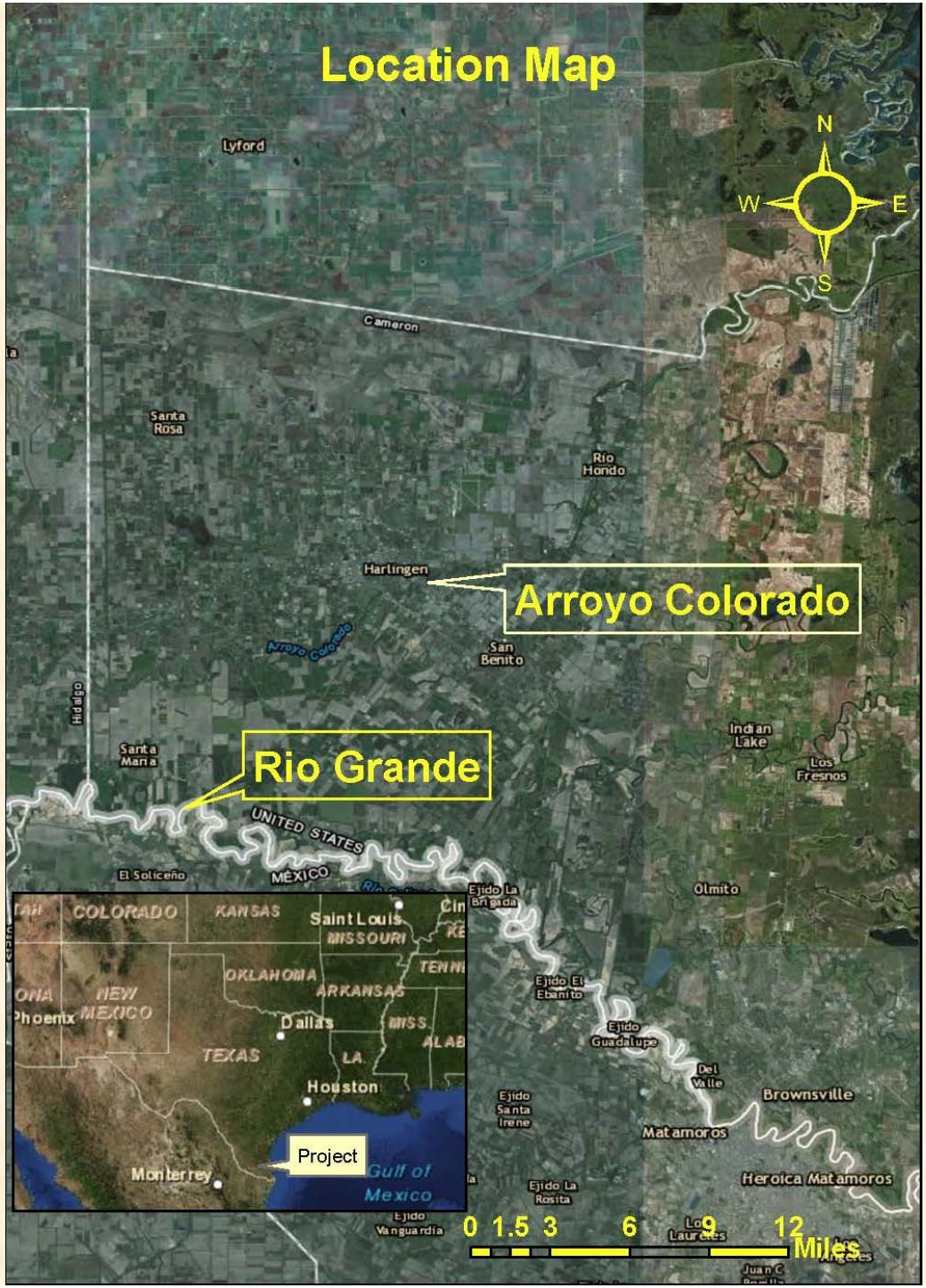
- **Main Floodway Design Flow = 105,000 cfs**
- **Divisor Dike at Mercedes (80%-20% Split)**
- **84,000 cfs diverted north into North Floodway**
- **21,000 cfs diverted east into Arroyo Colorado**
- **Arroyo Colorado is, therefore, an important component of regional flood control.**

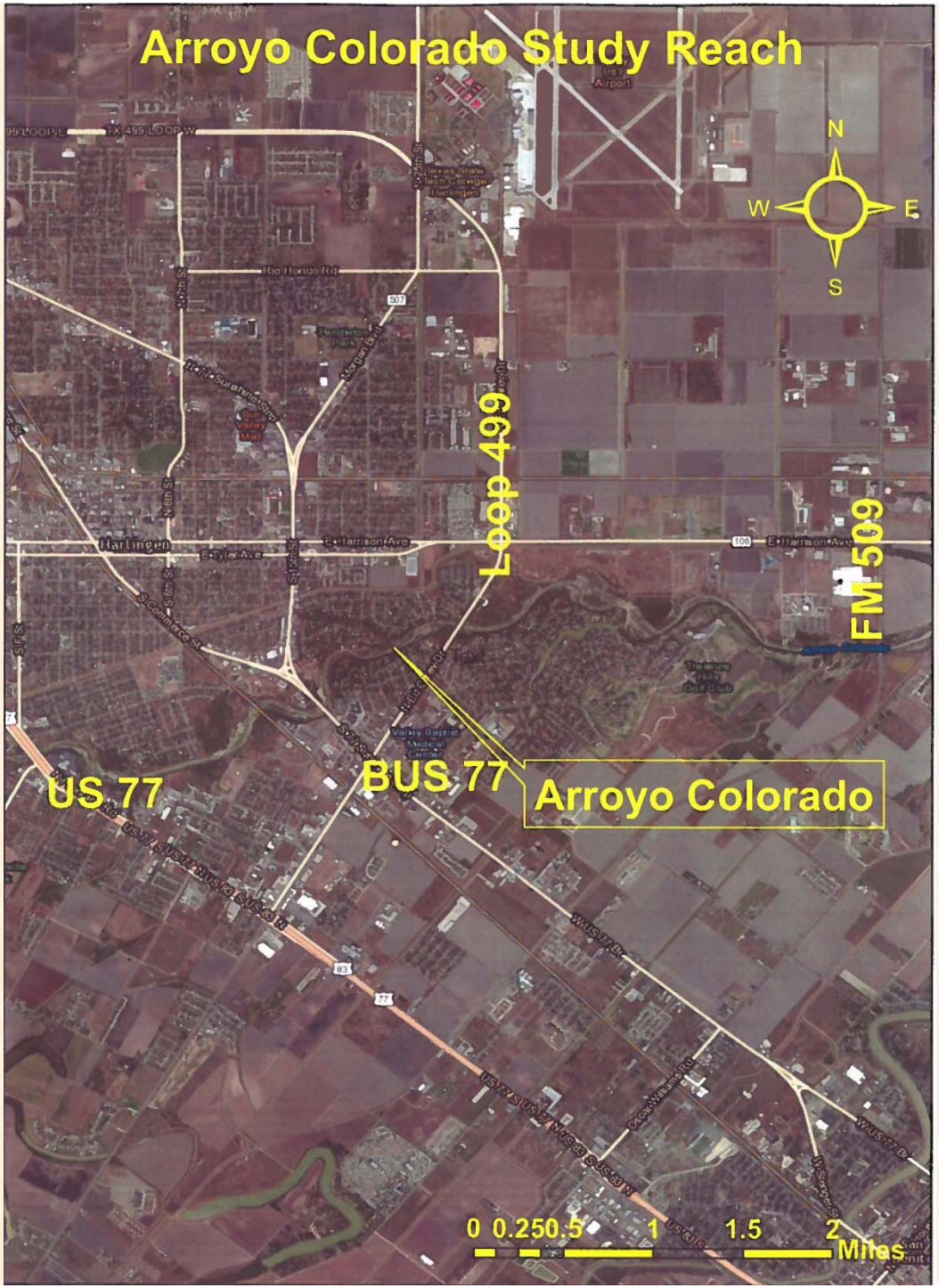

LOWER RIO GRANDE FLOOD CONTROL PROJECT
PLAN FOR
REPAIRS AND IMPROVEMENT
TOUR POINTS OF INTEREST
1. Mission Floodway
2. Hackney Weir
3. Hackney Floodway
4. Hidalgo Loop Levee & Bridge Protection
5. Highway 336 Bridge
6. Pharr-San Juan Siphon -- McAllen Siphon
7. Retamal Dam
8. Floodway Divisor Dike
9. North Floodway Sill
10. Campacuas Siphon
11. Campacuas Levee Setback
12. Arroyo Colorado at Harlingen
UNITED STATES
MEXICO
FALCON RESERVOIR
FALCON VILLAGE
NUEVO GUERRERO
ROMA
RIO GRANDE CITY
FLOOD DISCHARGES
BEULAH (RECURRENCE) - 220,000 C.F.S.
NEW CRITERIA ---- 250,000 C.F.S.
U.S. HWY 83
RIO ALAMO
SAN PEDRO
CAMARGO
RIO SAN JUAN
LA GRULLA
SAM FORDYCE
SAN MIGUEL
MARTE R. GOMEZ RESERVOIR
RIO SAN JUAN
NUEVO LEON
TAMAULIPAS
ANZALDUAS DAM
HIDALGO
REYNOSA
CRITERIA - 125,000 CFS
CRITERIA - 105,000 CFS
CRITERIA - 105,000 CFS
MISSION
McALLEN
PHARR
SAN JUAN
ALAMO
DONNA
WESLACO
FENITAS
MISSION INLET
HACKNEY WEIR INLET
MAIN FLOODWAY
NORTH FLOODWAY
CRITERIA - 84,000 CFS
HIDALGO CO.
CAMERON CO.
STARR CO.
SANTA ROSA
HARLINGEN
LA FERIA
MERCEDES
ARROYO COLORADO FLOODWAY
ARROYO CITY
RIO HONDO
CRITERIA - 21,000 CFS
SAN BENITO
PORT ISABEL
STATE HWY
PADRE ISLAND
LAGUNA MADRE
GULF OF MEXICO
PROGRESO
NUEVO PROGRESO
RIO RICO
CULEBRON RESERVOIR
NEW MEXICAN INLET
FLOOD DISCHARGES
BEULAH (RECURRENCE) - 20,000 C.F.S.
NEW CRITERIA ---- 20,000 C.F.S.
BROWNSVILLE
RIO GRANDE
MATAMOROS

Study Area

Arroyo Colorado Reach in Cameron County, Texas

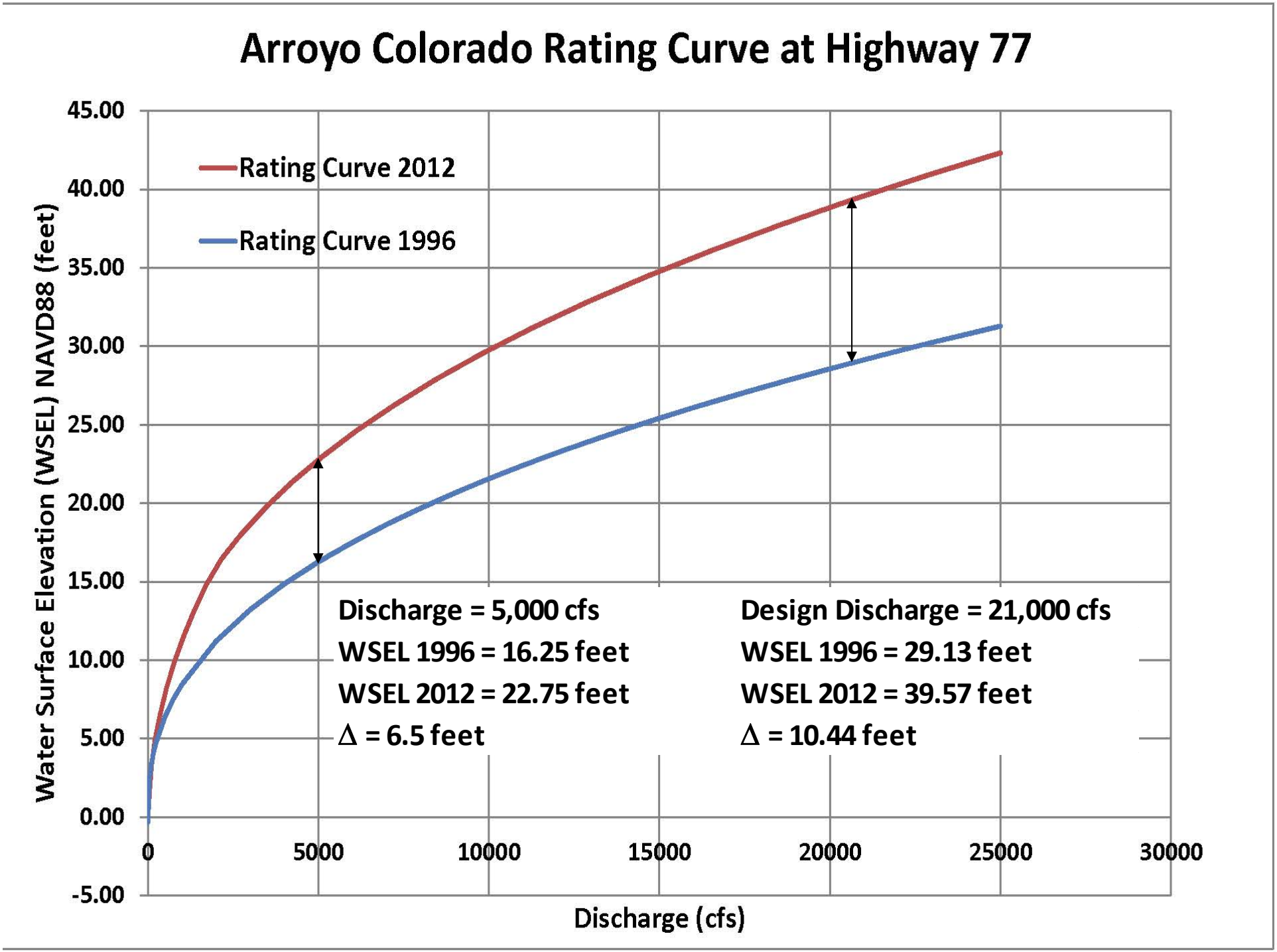
- **From US 77 to FM 509**
  - **USIBWC Gaging Station at US 77**
  - **Major Bridges: US 77, UPRR, BUS 77, Loop 499, FM 509**
- **City of Harlingen**
  - **Covers 34 square miles**
  - **Population Approx. 66,000**

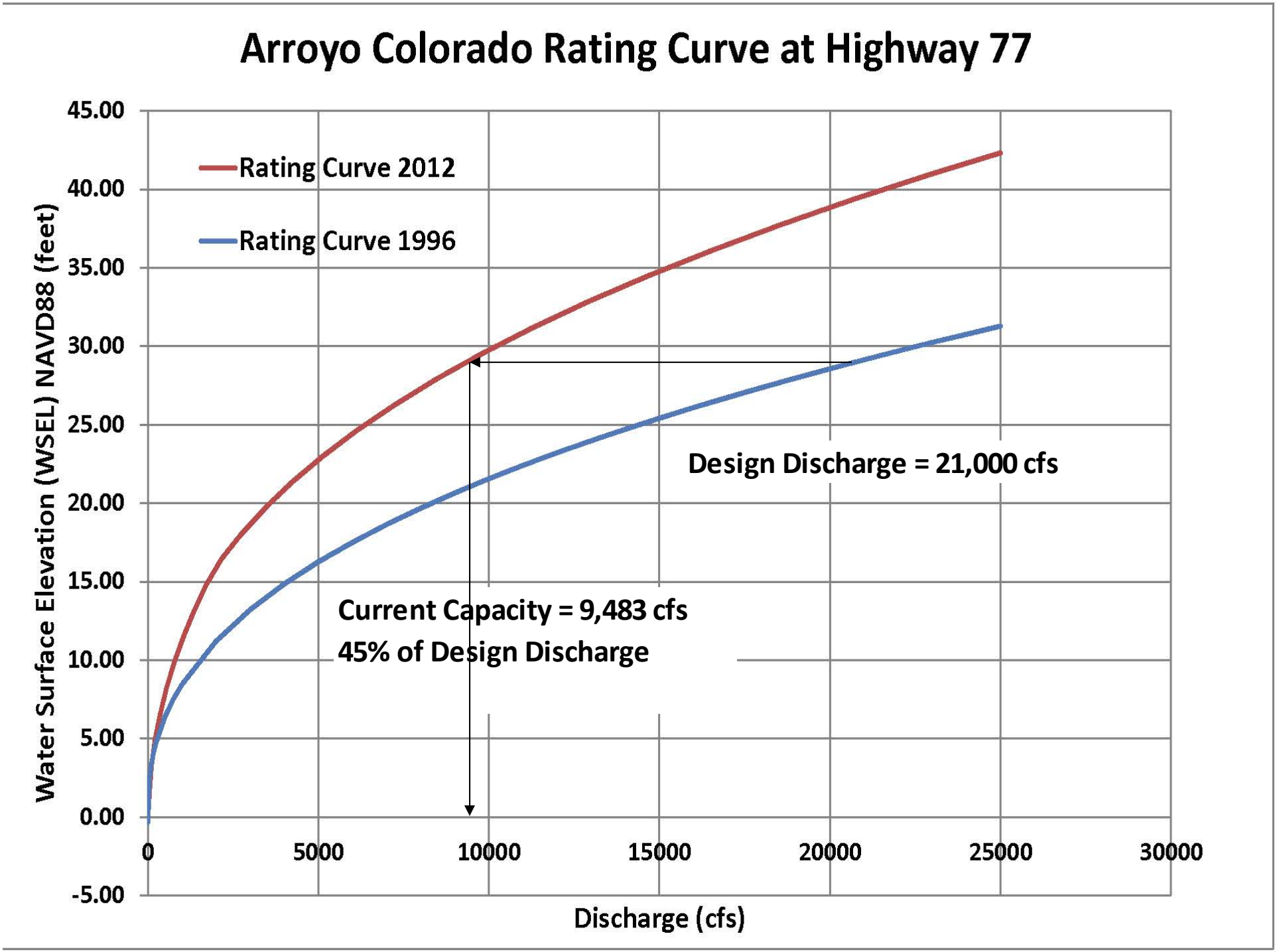

Location Map
N
W
E
S
Lyford
Cameron
Santa Rosa
Rio Hondo
Harlingen
Arroyo Colorado
San Benito
Hidalgo
Santa Maria
Rio Grande
Indian Lake
Los Fresnos
UNITED STATES
MÉXICO
El Soliceño
Olmito
Ejido La Brigada
Ejido El Ebanito
Ejido Guadalupe
Del Valle
Brownsville
Ejido Santa Irene
Matamoros
Heroica Matamoros
Ejido La Rosita
Ejido Vanguardia
COLORADO
KANSAS
Saint Louis
MISSOURI
OKLAHOMA
ARKANSAS
NEW MEXICO
Phoenix
Dallas
TEXAS
LA
Houston
Monterrey
Project
Gulf of Mexico
0 1.5 3 6 9 12
Miles


Arroyo Colorado Study Reach
N
W
E
S
Loop 499
FM 509
US 77
BUS 77
Arroyo Colorado
0 0.250.5 1 1.5 2
Miles

What is the Current Flood Risk?

How Much of the Design Flow of 21,000 cfs Can be Conveyed Now in Arroyo Colorado?


Arroyo Colorado Rating Curve at Highway 77
Rating Curve 2012
Rating Curve 1996
Water Surface Elevation (WSEL) NAVD88 (feet)
45.00
40.00
35.00
30.00
25.00
20.00
15.00
10.00
5.00
0.00
-5.00
0
5000
10000
15000
20000
25000
30000
Discharge (cfs)
Discharge = 5,000 cfs
WSEL 1996 = 16.25 feet
WSEL 2012 = 22.75 feet
Δ = 6.5 feet
Design Discharge = 21,000 cfs
WSEL 1996 = 29.13 feet
WSEL 2012 = 39.57 feet
Δ = 10.44 feet


Arroyo Colorado Rating Curve at Highway 77
Rating Curve 2012
Rating Curve 1996
Design Discharge = 21,000 cfs
Current Capacity = 9,483 cfs
45% of Design Discharge
Water Surface Elevation (WSEL) NAVD88 (feet)
Discharge (cfs)
45.00
40.00
35.00
30.00
25.00
20.00
15.00
10.00
5.00
0.00
-5.00
0
5000
10000
15000
20000
25000
30000

Reasons for the Decreased Flow Capacity

Objectives of the Study

- **Develop a New Hydraulic Model for Arroyo Colorado (US 77 to FM 509)**
- **Calibrate the Model to Replicate Elevated Water Surface Elevations (WSEL) at US 77 Rating Curve**
- **Explore Mitigation Scenarios to Improve/Reestablish Capacity to Convey the Design Flood**

Figure A-4A: Survey 2012 Cross Sections (Upstream)
Survey 2012 Cross Sections (Upstream)
Harlingen
W Jackson Ave
E Jackson Ave
W Van Buren Ave
E Van Buren Ave
W Tyler Ave
E Tyler Ave
E Harrison Ave
W Taylor Ave
E Taylor Ave
W Fillmore Ave
E Fillmore Ave
W Pierce Ave
E Pierce Ave
W Buchanan St
E Buchanan St
W Lincoln Ave
E Lincoln Ave
W Johnson Ave
W Grant Ave
E Grant Ave
W Hays St
Garfield Ave
W Cleveland Ave
E Mckinley Ave
E Roosevelt Ave
W Taft Ave
E Taft Ave
E Wilson Ave
E Harding Ave
E Coolidge Ave
F Arroyo Dr
Bush St
Carter St
Curtis St
Borls Park Dr
Sgt Cousse Dr
King Ave
W Lamb Ave
W Knox Ave
California St
Indiana St
Idaho St
Louisiana St
Frontage Rd
N Arroyo Pgt Ln
Arroyo Vista Dr
Bourbon St
Lime Oak Cir
Mississippi St
E New Hampshire St
Bonnet Dr
Falcon Dr
Fannin St
Sam Houston Dr
Oklahoma St
Franklin
Bell St
Peasey St
Bay Wood St
S 77 Sunshine Strip
Veterans Dr
Jones St
Runnels St
Murrah St
Lamar Ct
Clay Dr
Henderson St
Gilfred St
S Hall
S 25th St
N Parkwood St
Revere Dr
Laurel Dr
Ebony Dr
Genzo St
Little Creek Dr
E Greenway Dr
Greenway St
Southland Ave
S 16th St
S 17th St
S 19th St
S 21st St
S 22nd St
S 5th St
S 6th St
S 5-1/2 St
S West St
S Van Buren St
S Jackson St
S Fillmore St
S Pierce St
S Buchanan St
S Lincoln St
S Johnson St
S Grant St
S Hays St
S Garfield St
S Cleveland St
S McKinley St
S Roosevelt St
S Taft St
S Wilson St
S Harding St
S Coolidge St
S Arroyo Dr
S Bush St
S Carter St
S Curtis St
S Borls Park Dr
S Sgt Cousse Dr
S King Ave
S W Lamb Ave
S W Knox Ave
S California St
S Indiana St
S Idaho St
S Louisiana St
S Frontage Rd
S N Arroyo Pgt Ln
S Arroyo Vista Dr
S Bourbon St
S Lime Oak Cir
S Mississippi St
S E New Hampshire St
S Bonnet Dr
S Falcon Dr
S Fannin St
S Sam Houston Dr
S Oklahoma St
S Franklin
S Bell St
S Peasey St
S Bay Wood St
S 77 Sunshine Strip
S Veterans Dr
S Jones St
S Runnels St
S Murrah St
S Lamar Ct
S Clay Dr
S Henderson St
S Gilfred St
S Hall
S 25th St
S N Parkwood St
S Revere Dr
S Laurel Dr
S Ebony Dr
S Genzo St
S Little Creek Dr
S E Greenway Dr
S Greenway St
S Southland Ave
S 16th St
S 17th St
S 19th St
S 21st St
S 22nd St
SnBRS29
SnBRS31
SnBRS33
SnBRS34
SnBRS35
SnBRS36
SnBRS46
SnBRS48
SnBRS49
Gage_ArroyoCO
CSU1
CSU2
CSU3
CSU4
CSU5
CSU6
CSU7
CSU8
CSU9
CSU10
CSU11
CSU12
CSU13
CSU14
CSU15
CSU16
77
106
499
1479
83
© 2014 Google
© 2014 INEGI
Google Earth

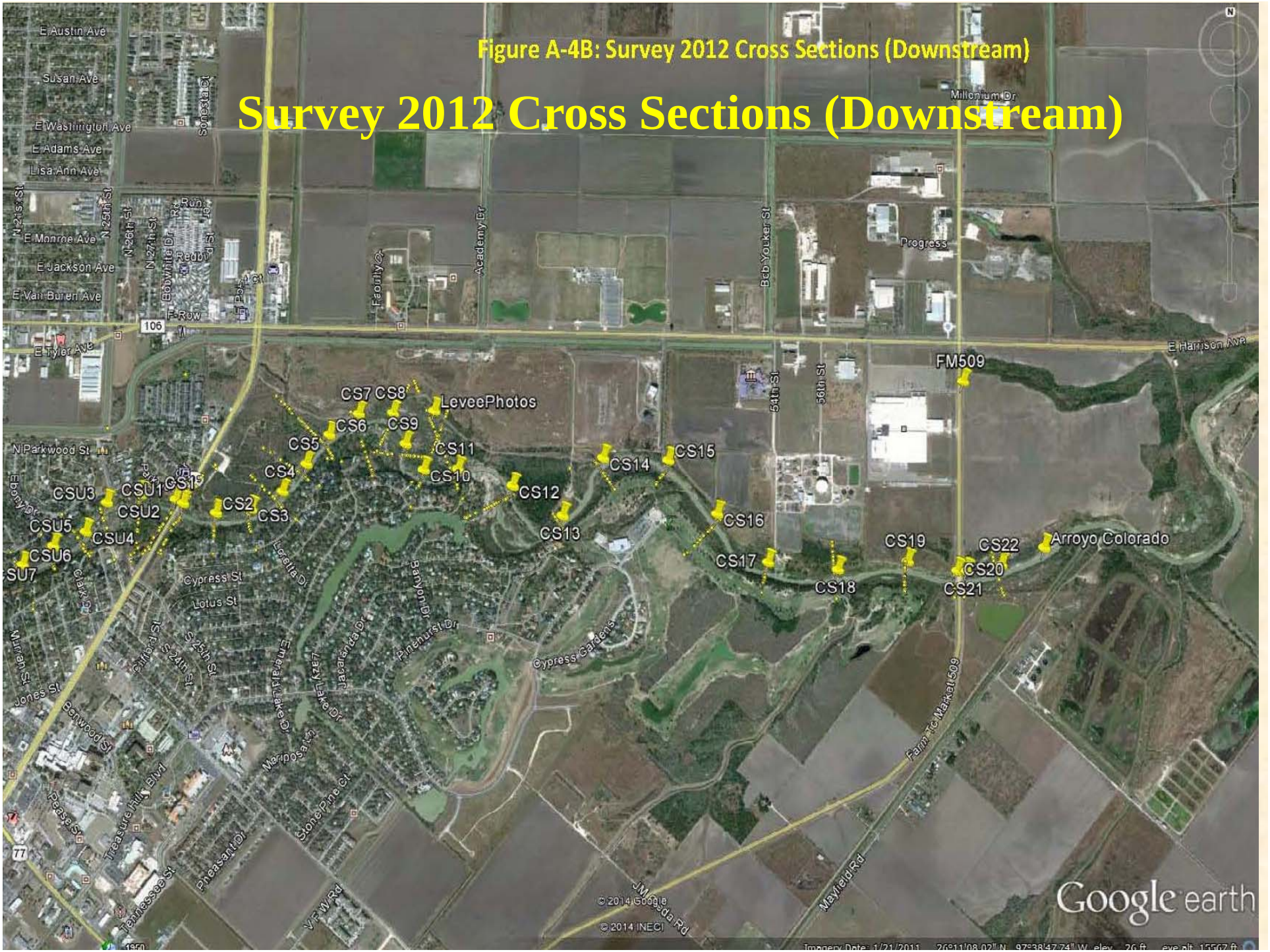


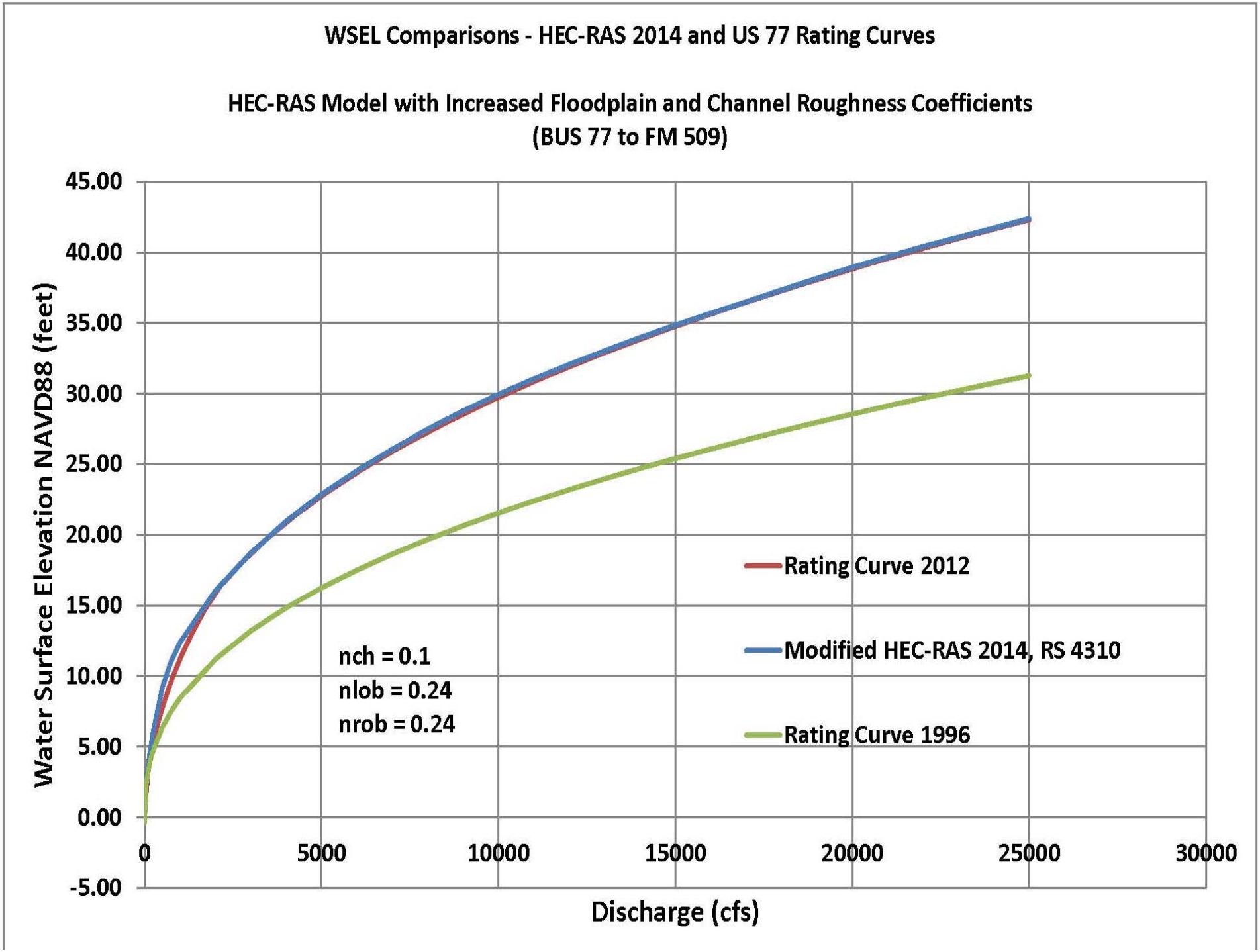
Figure A-4B: Survey 2012 Cross Sections (Downstream)
Survey 2012 Cross Sections (Downstream)
E Austin Ave
Susan Ave
E Washington Ave
E Adams Ave
Lisa Ann Ave
E Monroe Ave
E Jackson Ave
E Van Buren Ave
E Tyler Ave
E Harrison Ave
Millenium Dr
Progress
Academy Dr
Bob Younker St
54th St
56th St
106
FM509
N Parkwood St
CS1
CS2
CS3
CS4
CS5
CS6
CS7
CS8
CS9
CS10
CS11
CS12
CS13
CS14
CS15
CS16
CS17
CS18
CS19
CS20
CS21
CS22
LeveePhotos
CSU1
CSU2
CSU3
CSU4
CSU5
CSU6
CSU7
Arroyo Colorado
Cypress St
Lotus St
Cypress Gardens
Pinehurst Dr
Jacaranda Dr
Lazy Lake Dr
Mariposa Ln
Stone Pine Ct
Pheasant Dr
Treasure Hills Blvd
Tennessee St
Benwood St
Jones St
Marrah St
Clark Dr
Farm-To-Market 509
Mayfield Rd
V F W Rd
JM Cogdell Rd
© 2014 Google
© 2014 INEGI
Google earth

Hydraulics

- **Hydraulic Model Development**
  - **USACE HEC-RAS (River Analysis System) Software (Ver. 4.1.0)**
  - **Cross Sections (Survey of 2012, LiDAR 2011)**
  - **Manning Roughness Coefficients and Parameters**
  - **Hydraulic Structures (Bridges: US 77, UPRR, BUS 77, Loop 499, FM 509)**

- **Hydraulic Analysis (Steady State Modeling)**
  - **2014 Model**
  - **Calibrated Model to Match Elevated WSEL in 2012 Rating Curve**

WSEL = Water Surface Elevations


WSEL Comparisons - HEC-RAS 2014 and US 77 Rating Curves
HEC-RAS Model with Increased Floodplain and Channel Roughness Coefficients
(BUS 77 to FM 509)
Water Surface Elevation NAVD88 (feet)
45.00
40.00
35.00
30.00
25.00
20.00
15.00
10.00
5.00
0.00
-5.00
0
5000
10000
15000
20000
25000
30000
Discharge (cfs)
nch = 0.1
nlob = 0.24
nrob = 0.24
Rating Curve 2012
Modified HEC-RAS 2014, RS 4310
Rating Curve 1996

MITIGATION SCENARIOS

Coordination

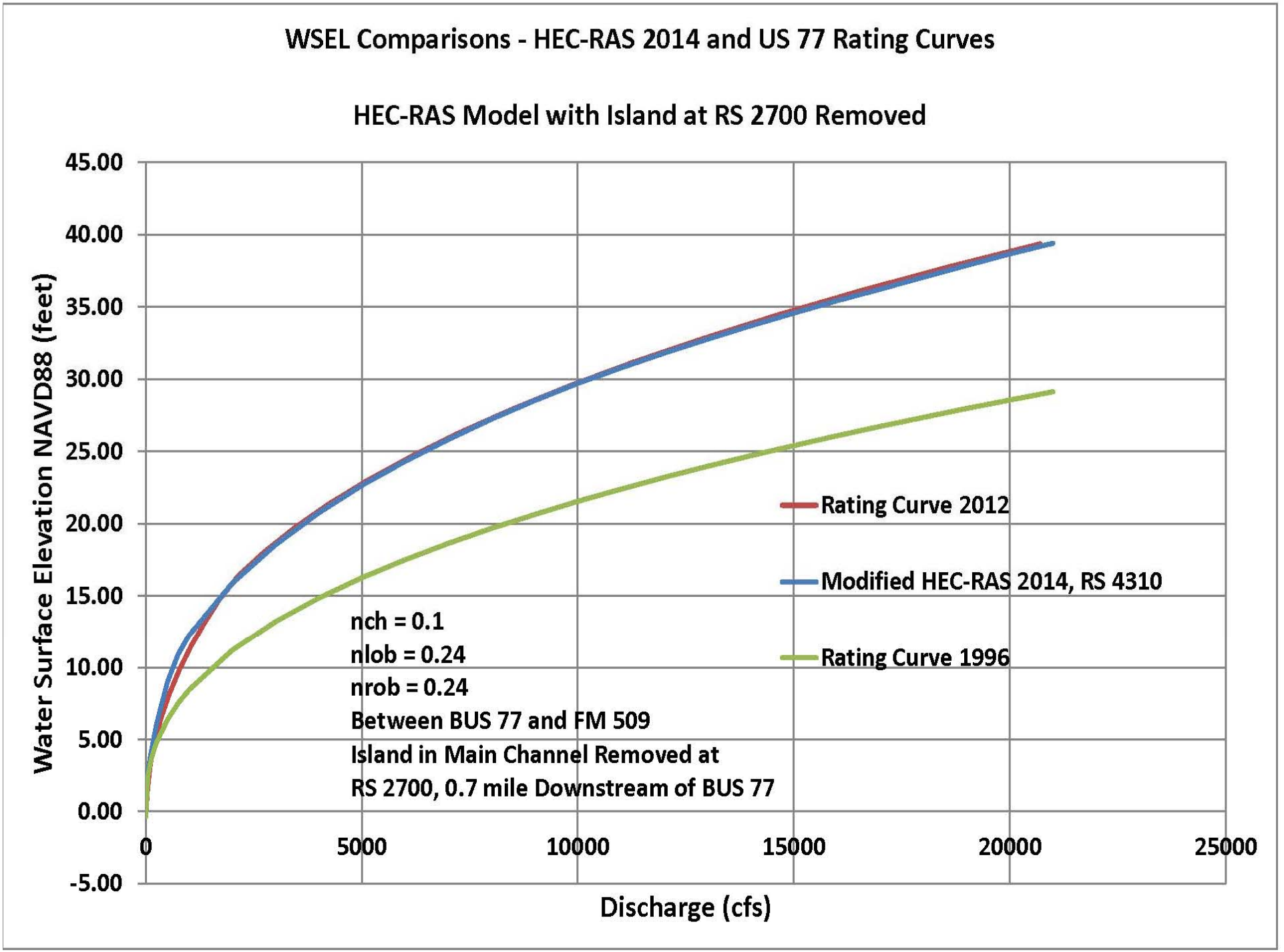
- **September 24, 2014:**
  Met with City of Harlingen to discuss decreased flow capacity and plans to improve/reestablish flow capacity.

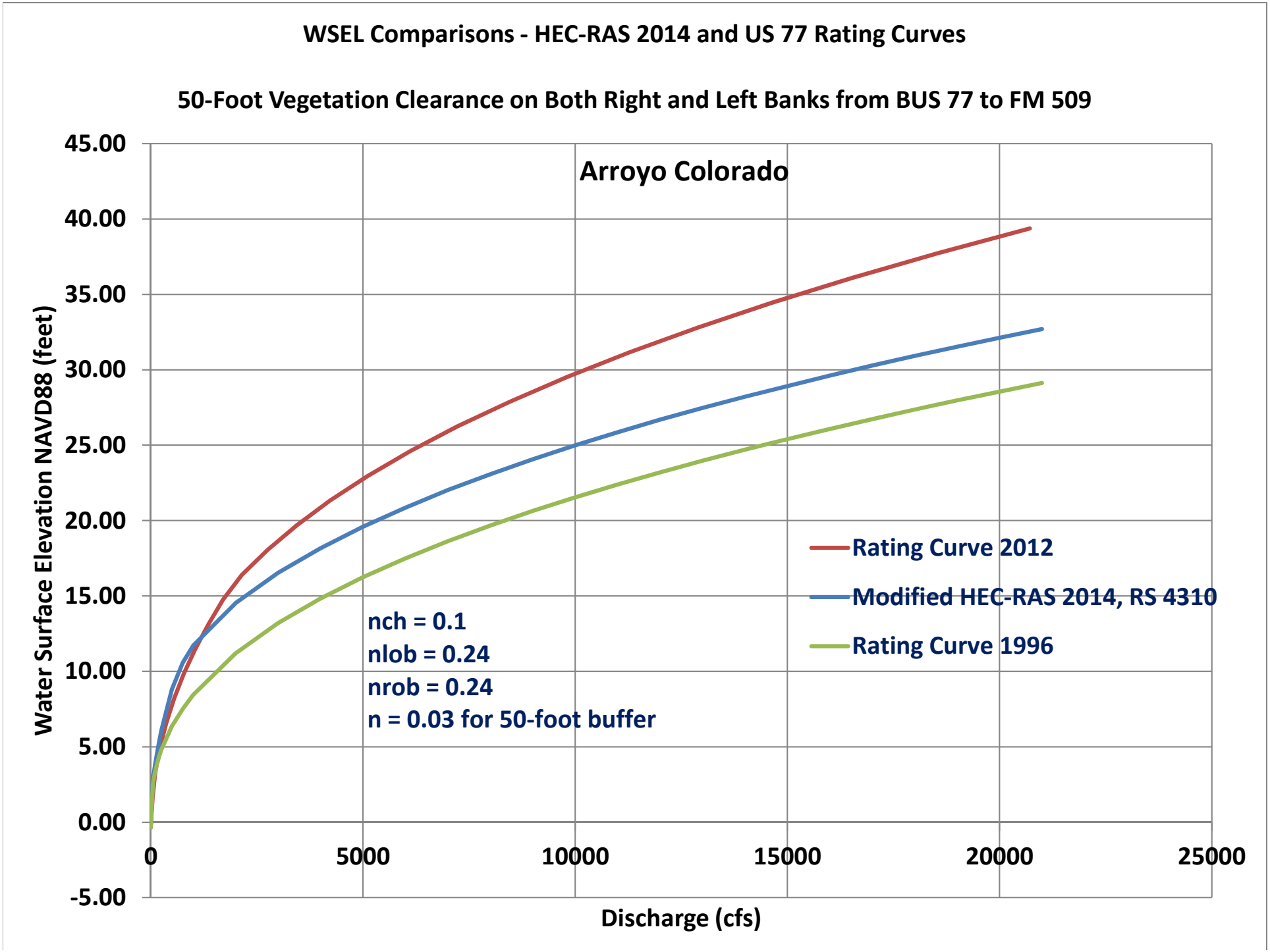
- **September 25, 2014:**
  Met with U.S. Fish & Wildlife Service and discussed type of vegetation that can be removed and locations.

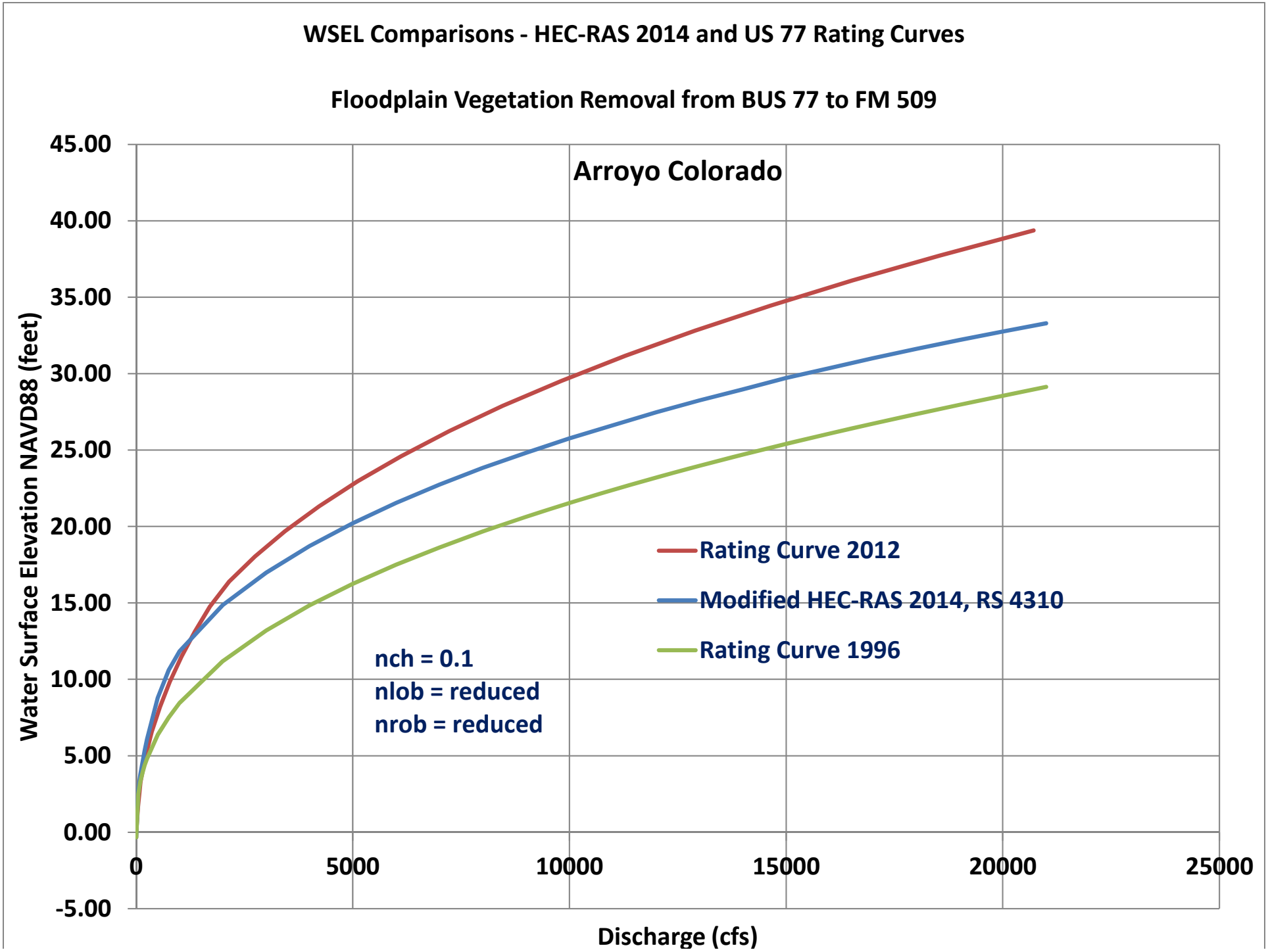
Mitigation Scenarios

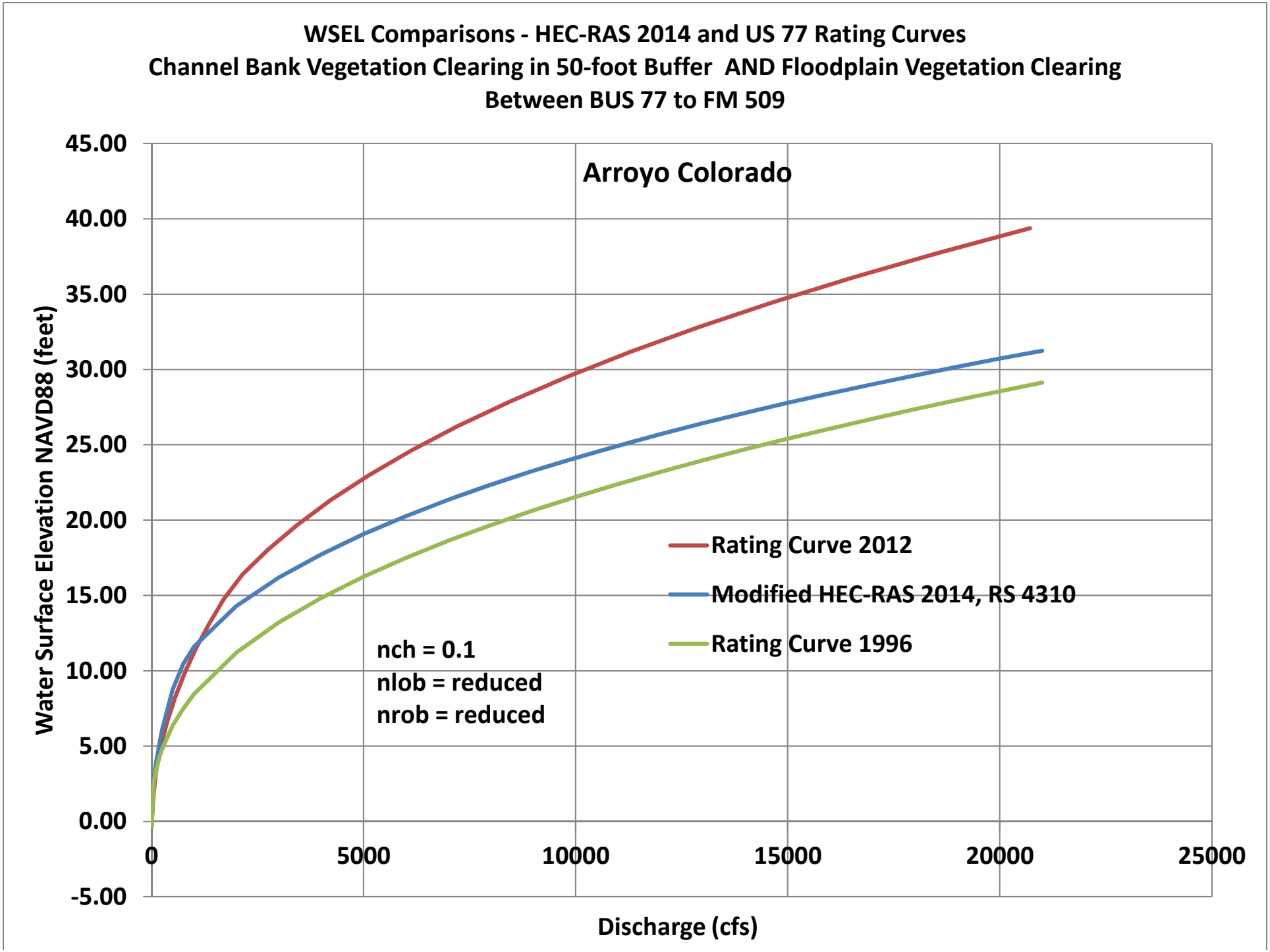
- (1) Removal of Island
- (2) 50-Foot Vegetation Free Buffer
- (3) Removal of Floodplain Vegetation
- (4) Scenario (2) + (3)

Note: Vegetation removal is from BUS 77 to FM 509. Along steep slopes, only partial vegetation removal


WSEL Comparisons - HEC-RAS 2014 and US 77 Rating Curves
HEC-RAS Model with Island at RS 2700 Removed
Water Surface Elevation NAVD88 (feet)
45.00
40.00
35.00
30.00
25.00
20.00
15.00
10.00
5.00
0.00
-5.00
0
5000
10000
15000
20000
25000
Discharge (cfs)
Rating Curve 2012
Modified HEC-RAS 2014, RS 4310
Rating Curve 1996
nch = 0.1
nlob = 0.24
nrob = 0.24
Between BUS 77 and FM 509
Island in Main Channel Removed at
RS 2700, 0.7 mile Downstream of BUS 77


WSEL Comparisons - HEC-RAS 2014 and US 77 Rating Curves
50-Foot Vegetation Clearance on Both Right and Left Banks from BUS 77 to FM 509
Arroyo Colorado
Water Surface Elevation NAVD88 (feet)
45.00
40.00
35.00
30.00
25.00
20.00
15.00
10.00
5.00
0.00
-5.00
0
5000
10000
15000
20000
25000
Discharge (cfs)
nch = 0.1
nlob = 0.24
nrob = 0.24
n = 0.03 for 50-foot buffer
Rating Curve 2012
Modified HEC-RAS 2014, RS 4310
Rating Curve 1996


WSEL Comparisons - HEC-RAS 2014 and US 77 Rating Curves
Floodplain Vegetation Removal from BUS 77 to FM 509
Arroyo Colorado
Water Surface Elevation NAVD88 (feet)
45.00
40.00
35.00
30.00
25.00
20.00
15.00
10.00
5.00
0.00
-5.00
0
5000
10000
15000
20000
25000
Discharge (cfs)
Rating Curve 2012
Modified HEC-RAS 2014, RS 4310
Rating Curve 1996
nch = 0.1
nlob = reduced
nrob = reduced


WSEL Comparisons - HEC-RAS 2014 and US 77 Rating Curves
Channel Bank Vegetation Clearing in 50-foot Buffer AND Floodplain Vegetation Clearing
Between BUS 77 to FM 509
Arroyo Colorado
Water Surface Elevation NAVD88 (feet)
45.00
40.00
35.00
30.00
25.00
20.00
15.00
10.00
5.00
0.00
-5.00
0
5000
10000
15000
20000
25000
Discharge (cfs)
Rating Curve 2012
Modified HEC-RAS 2014, RS 4310
Rating Curve 1996
nch = 0.1
nlob = reduced
nrob = reduced

Comparison of Mitigation Scenarios

No.	Description	A		B		C	
		Q (cfs)	% of 1996	Q (cfs)	% of 1996	Q (cfs)	% of 1996
1	Year 1996 Rating	5000	100.00%	8000	100.00%	21000	100.00%
2	Year 2012 Rating	2107	42.13%	3430	42.87%	9483	45.16%
3	No Island	2146	42.91%	3511	43.89%	9513	45.30%
4	50-Foot Veg Buffer	2860	57.20%	5063	63.29%	15304	72.88%
5	Floodplain Vegetation Removal	2657	53.15%	4633	57.92%	14216	67.70%
6	(4) + (5)	3039	60.78%	5504	68.80%	17190	81.86%

Water Surface Elevations (WSEL) from 1996 Rating Curve

Q = 5000 cfs, WSEL = 16.25 feet
Q = 8000 cfs, WSEL = 19.67 feet
Q = 21,000 cfs, WSEL = 29.13 feet

QUESTIONS