River Engineering

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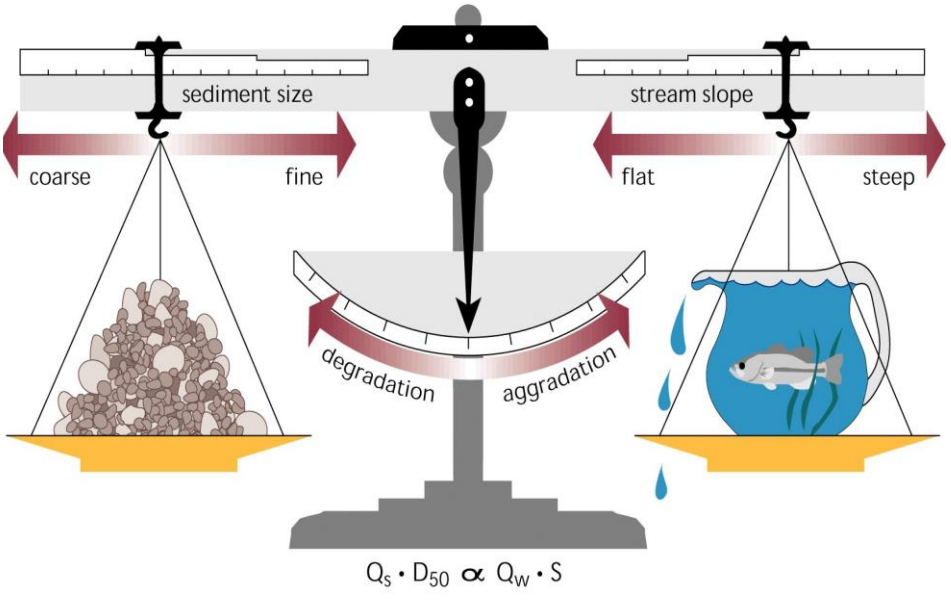
Short Course on
Restauracion Fluvial e Ingenieria de Rios
Lima Peru – September 27, 2016

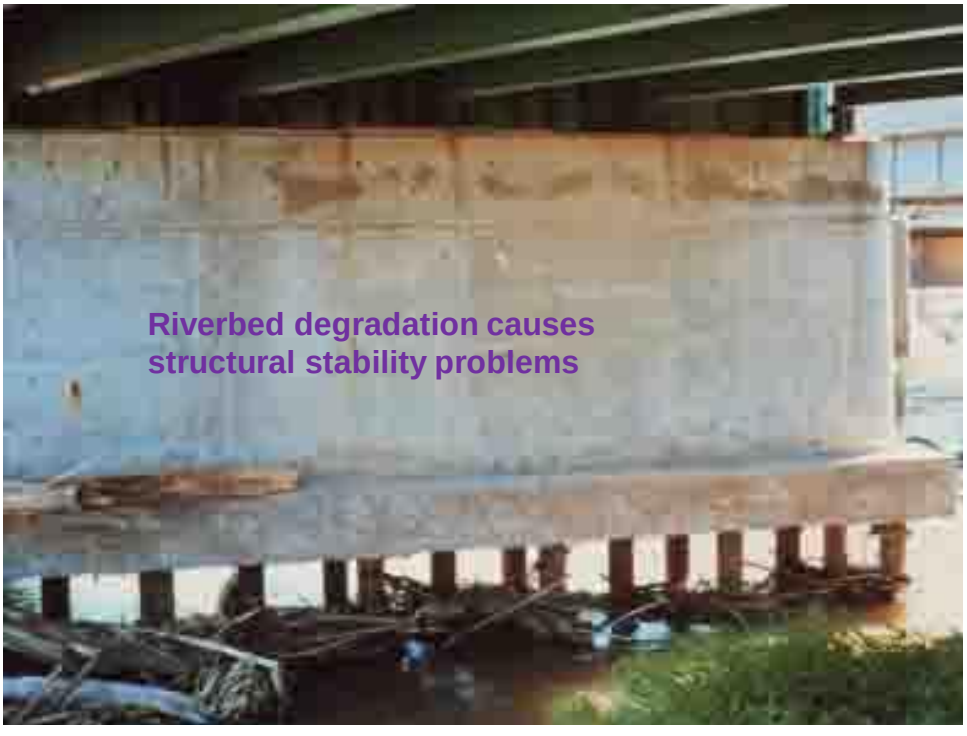
Objectives

Brief overview of methods and case studies for river engineering and modeling:

1. Degradation, Scour and Gravel Mining;
2. Aggradation, Sedimentation and Flushing;
3. Dredging and Sediment Management;
4. Disaster Prevention.

1. Degradation, Scour and Gravel Mining

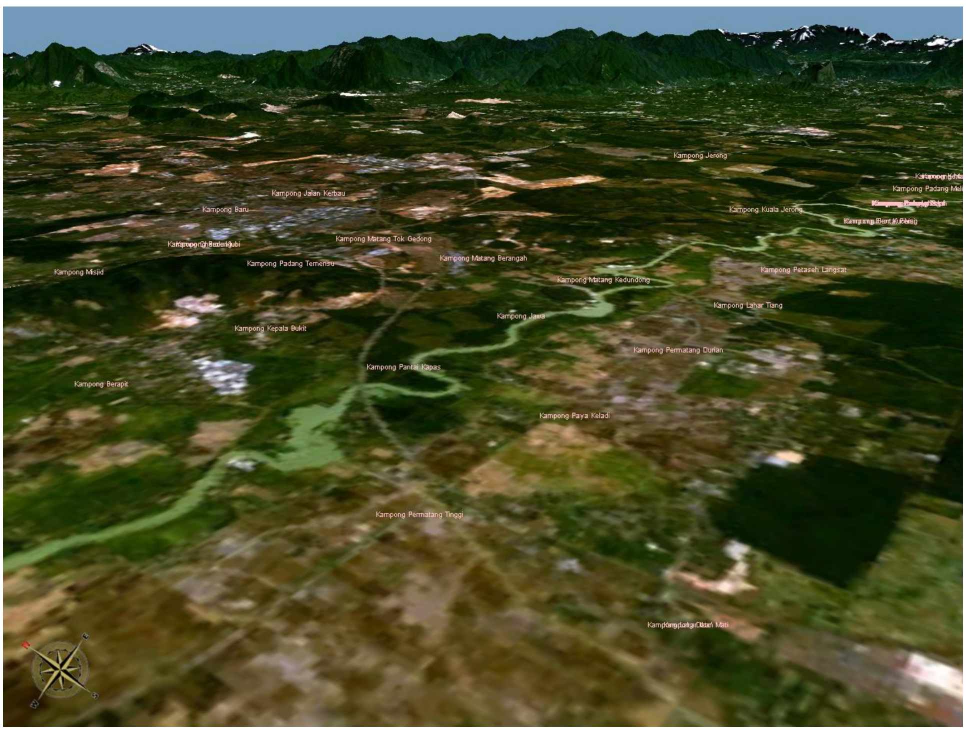



Riverbed degradation causes
structural stability problems

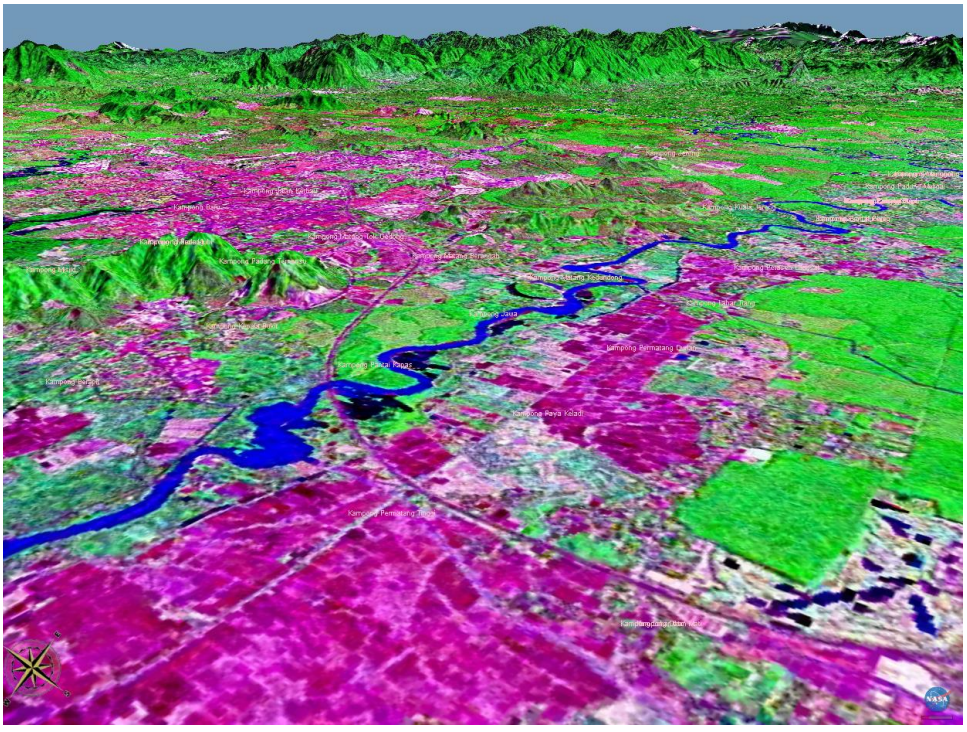
Bank Stabilization near Bridges
Sacramento River, CA


Grade-control Structures
Reduce Incision Problems

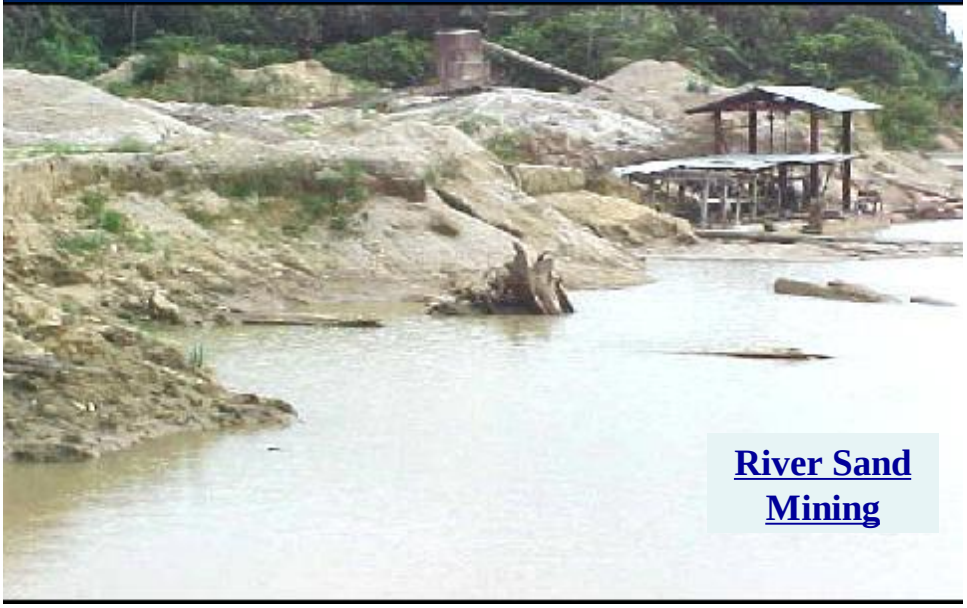
Tg. Perpat
Tg. Dawai
Pantai Merdeka
Sungai Merbok
SUNGAI PETANI
Kuala Muda
Kg. Tok Otek
North-South Highway
Golf Course



Kampong Jerong
Kampong Padang Meli
Kampong Jalan Kerbau
Kampong Baru
Kampong Kuala Jerong
Kampong Matang Tok Gedong
Kampong Padang Temensu
Kampong Matang Berangah
Kampong Misjid
Kampong Petaseh Langsat
Kampong Matang Kedundong
Kampong Lahar Tiang
Kampong Jawa
Kampong Kepala Bukit
Kampong Permatang Durian
Kampong Pantai Kapas
Kampong Berapit
Kampong Paya Keladi
Kampong Permatang Tinggi



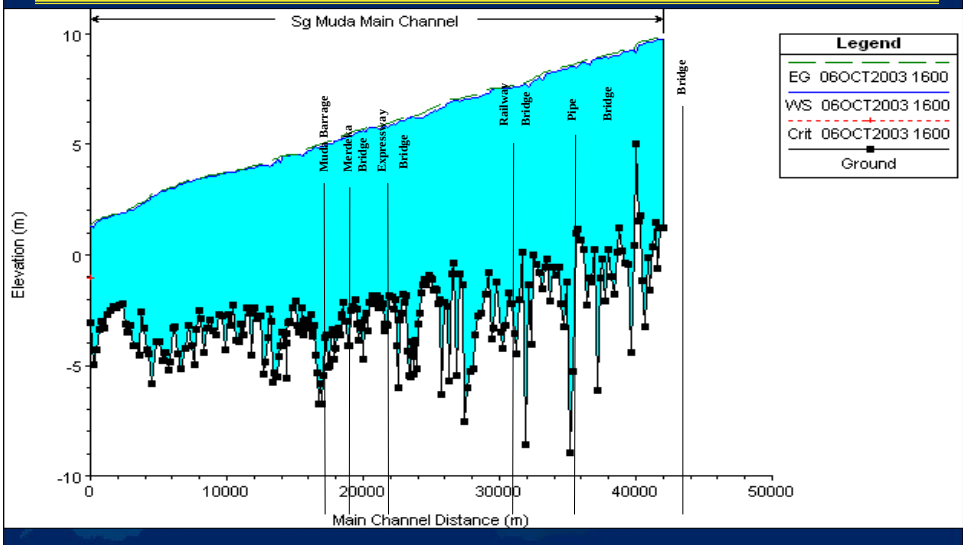
Sand and Gravel Mining



River Sand Mining

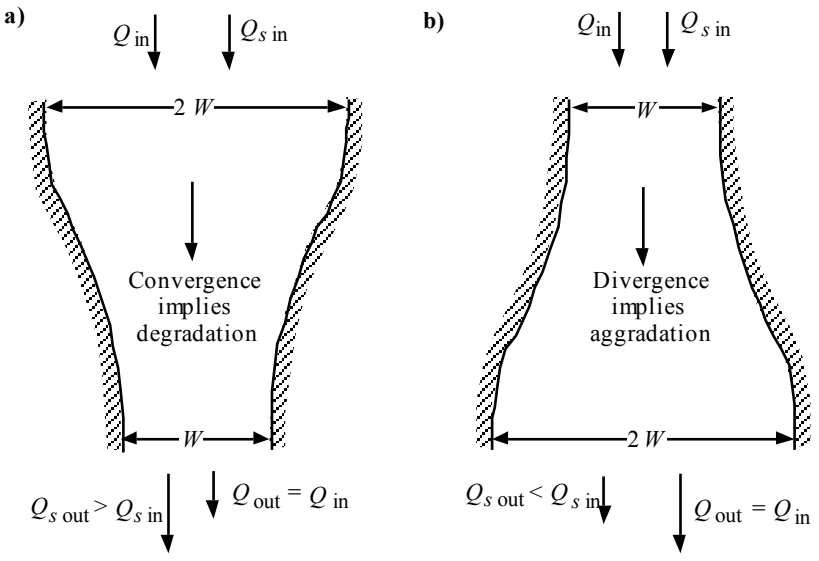
Channel realignment

Longitudinal Profile for Sg Muda (Q=1340m³/s)



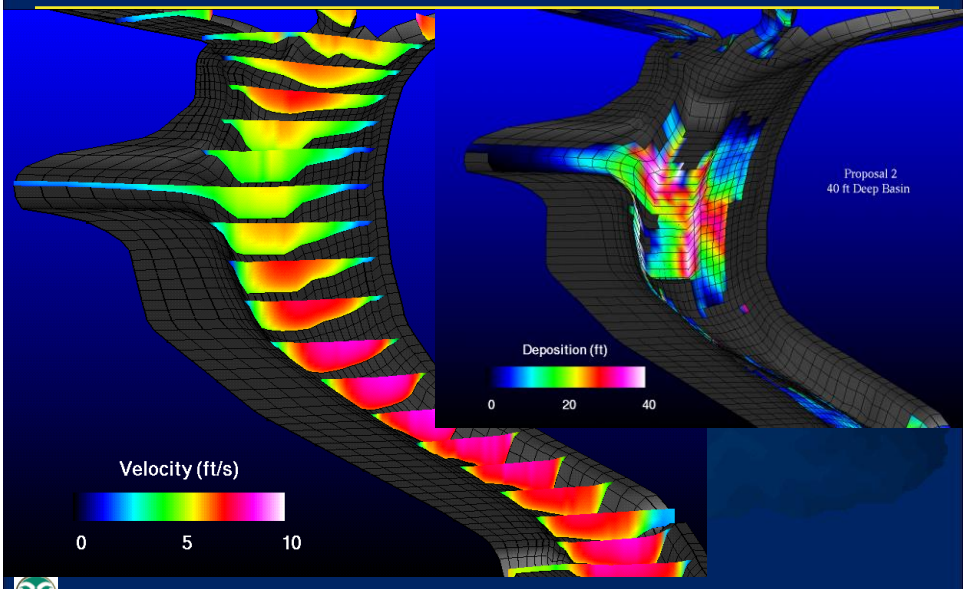
Off-stream Sand and Gravel Mining

2. Aggradation, Sedimentation and Flushing



Environmental Considerations

Example 3-D Model Mississippi



Dykes

FY06 Completed, Scheduled, Awarded, & Ongoing Cutterhead, Dustpan And Hopper Dredging Work for New Orleans

http://www.mvn.usace.army.mil/od/navigation.asp
Last Updated 01-Oct-06

Changes made since last update
Cutterheads
Hoppers
Dustpans

All scheduled information subject to change. Does not include contingency projects
Dredging Performed
Contract Period = Bid Date + (Award/NTP Estimated Period) + Construction Duration Allowed

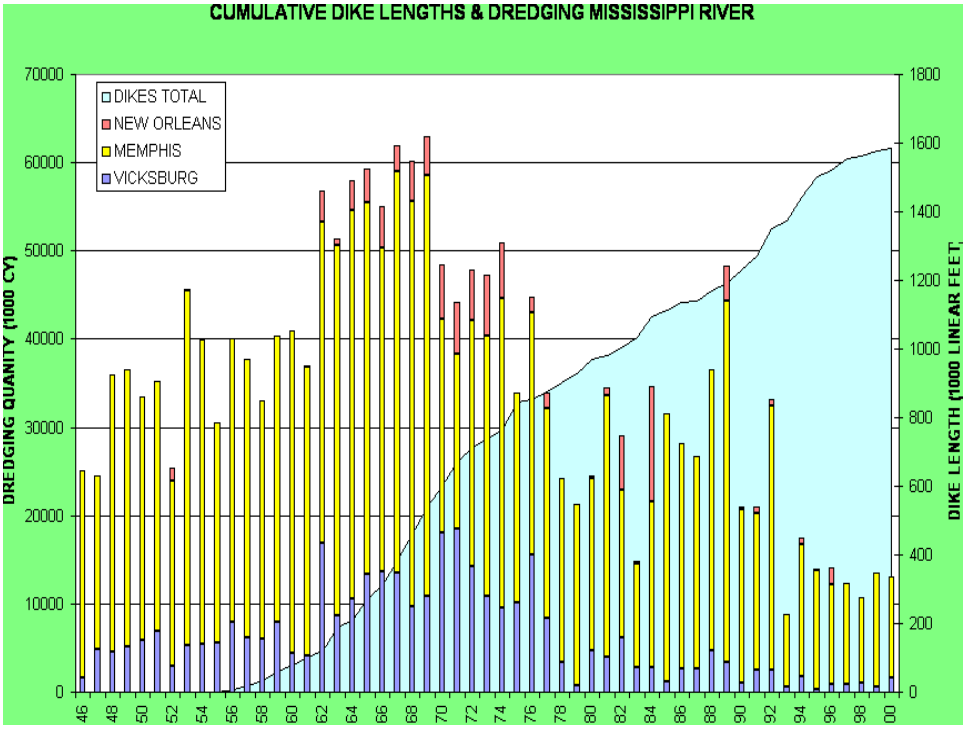
Project	Solicitation No.	Contract No.	OPS Manager	Dredge	Actuals Dredge Start	Actuals Dredge End	Actual Bid Date
CALC RIV AND PASS MI 17 TO 28.5 AND DEVIL'S EL.	05B0065	05C0045	Falk	"Mike Hooks"	08-11-05	02-27-06	7/7/2005
HOUMA NAV CANAL, TERREBONNE BAY, CAT IS PASS	05R0049	06D0001	Daigle	"Tom James"	11-29-05	02-01-06	11/16/2005
OUTLETS AT VENICE BAPTISTE COLLETTE	05R0049	06D0006	Daigle	"Ponchartrain"	01-23-06	03-31-06	10/30/2005
ATCH BAY & BAR CH C/L STA 4355+59 TO 650+00	05B0001	06C0098	Nord	"G. D. Williams"	03-08-06	04-30-06	2/6/2006
BARATARIA BAY WATERWAY & BAYOU RIGAUD	05B0028	05C0039	Daigle	"Dredge 32"	03-31-06	05-02-06	5/26/2005
PORT FOURCHON NAV CHANNEL	06B0003	06C0125	Daigle	"Tom James"	04-17-06	05-13-06	3/23/2006
MISS RIVER, NEW ORLEANS HARBOR CUTT 2-2005	05B0058	06C0144	Mujica/Um	"Meridian"	05-08-06	06-10-06	4/26/2006
ATCH BAR CHANNEL CY NO. 2-2004	05B0003	06C0126	Nord	"G. D. Williams"	05-03-06	07-05-06	3/31/2006
BERWICK BAY/3 RIVERS CDR 3-2005 & WAX LAKE XIN	05B0039	06C0142	Nord	"Venture"	05-03-06	07-10-06	4/20/2006
HOUMA NAV CANAL, C/L STA 16+90 TO 1250+00	06B0009	06C0138	Daigle	"Mike Hooks"	06-11-06	10-01-06	4/19/2006
OUTLETS AT VENICE TIGER PASS MI 7.3 TO MI 13.8	06B0005	06C0143	Daigle	"Dredge 32"	06-22-06	08-13-06	4/21/2006
BARATARIA BAR CHANNEL	06R0188	06C0169	Daigle	"G. D. Williams"	07-28-06	08-15-06	6/22/2006
GIWW BELOW BAYOU SORREL LOCK	06B0006	06C0145	Ulm	"Marion"	08-09-06	09-27-06	4/26/2006
ATCH BAY, BAR, HORSE, CHENE 1-2005	05B0061	06C0181	Nord	" Venture"	08-30-06		8/11/2006
CALC RIV MILE 29-35, COON & CLOONEY LOOPS	06B0008	06C0189	Falk				8/24/2006
ATCH BASIN, GIWW CDR #1-06 (3 RIVERS, ORL)	06B0042	06C0190	Nord/Ulm				8/30/2006
MISS RIV SOUTH PASS	06B0052	06C0191	Mujica	"Meridian"	09-12-06		8/30/2006
CALC RIVER MILE 5 TO 17 & DEVIL'S ELBOW	06B0059	06C0192	Falk				9/6/2006
FRESHWATER BAYOU & MERMENTAU RIV BAR CHAN	06B0056		Falk				9/12/2006
BAYOU SEGNETTE MI 0 TO 4.5 (06B0061)	06R0242		Daigle				9/20/2006
ATCH RIV BAR CY #1-2006	06B0054		Nord				9/21/2006
EAST & WEST CALUMET FLOODGATE	06B0105		Falk				9/28/2006
BAYOU LAFOURCHE W BELLE PASS MI 1.5 TO 2.2	06B0107		Daigle				9/29/2006

FY06: OCT NOV DEC JAN FEB MAR APR MAY JUN JUL AUG SEP
FY07: OCT NOV DEC JAN FEB MAR
2005 2006 2007

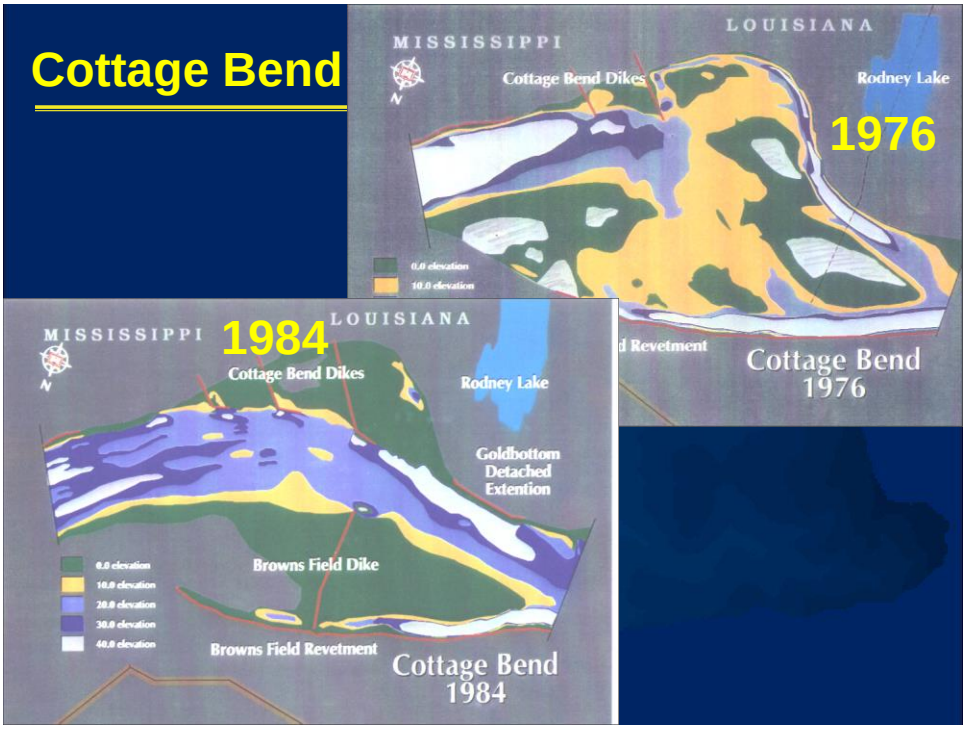
FOR FY06 ONGOING & FY07 UPDATES SEE THE FY07 SCHEDULE

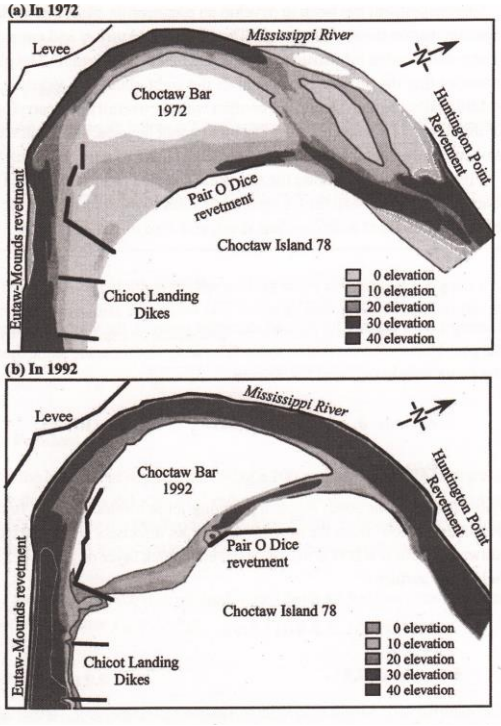
Page 1

CUMULATIVE DIKE LENGTHS & DREDGING MISSISSIPPI RIVER

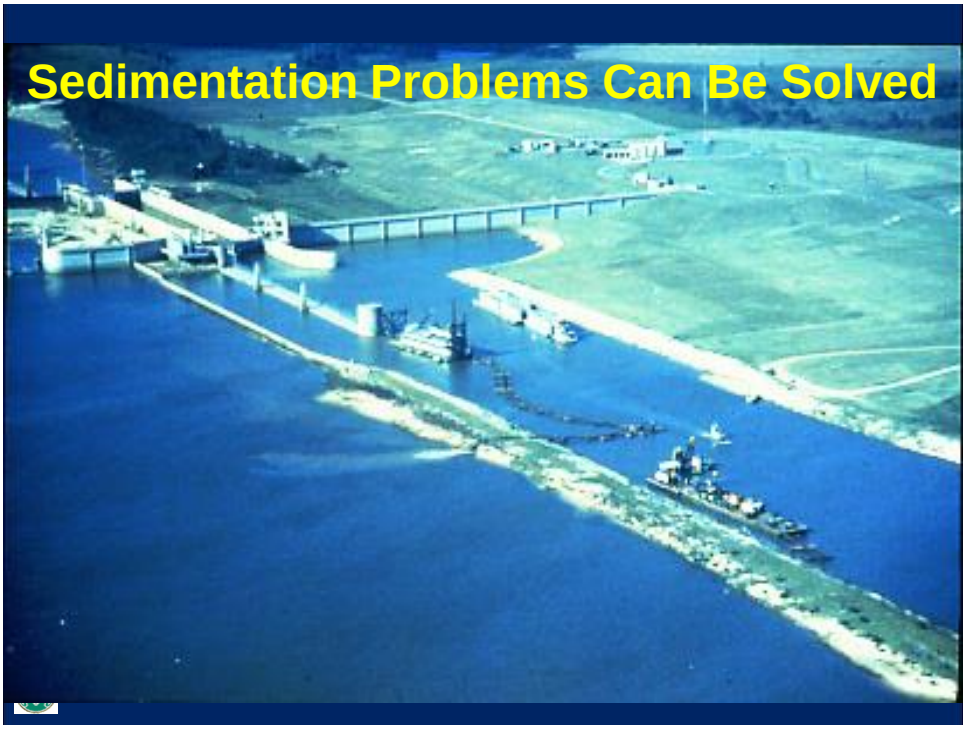


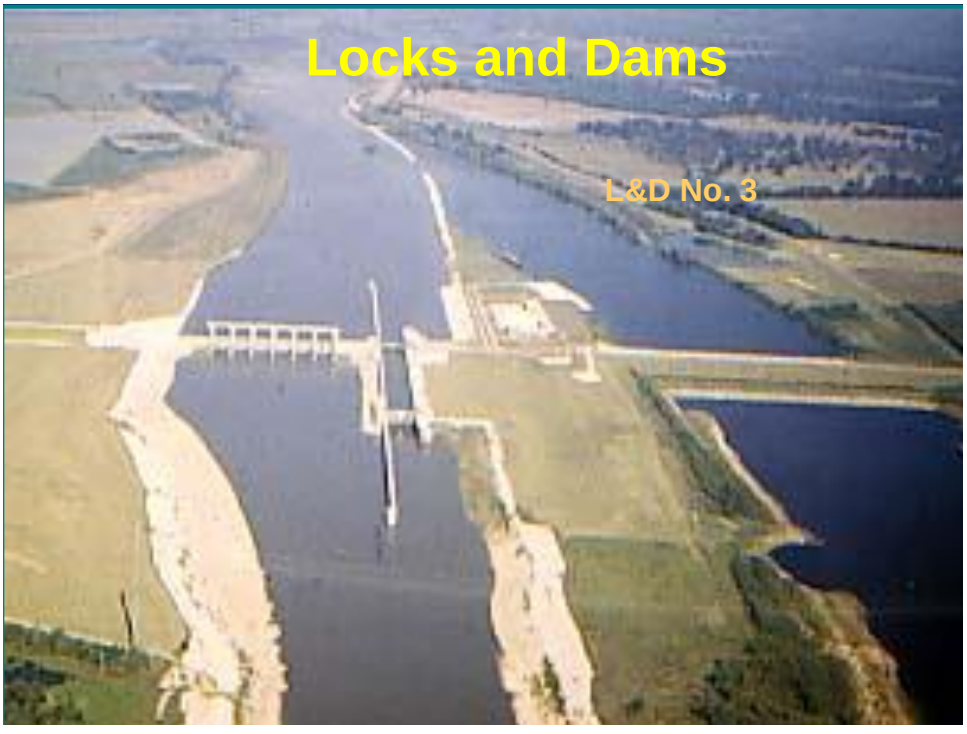
Cottage Bend



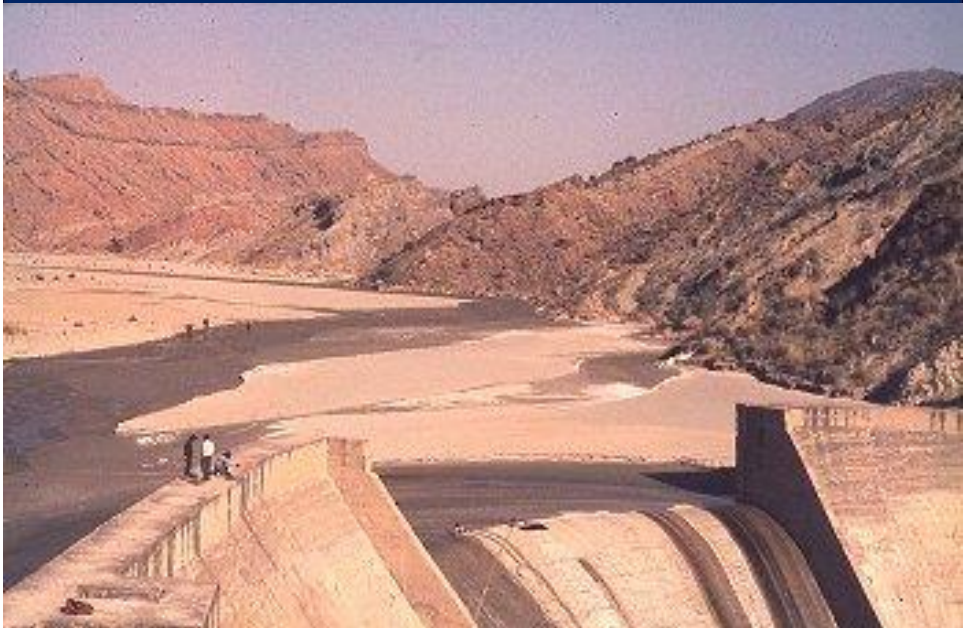


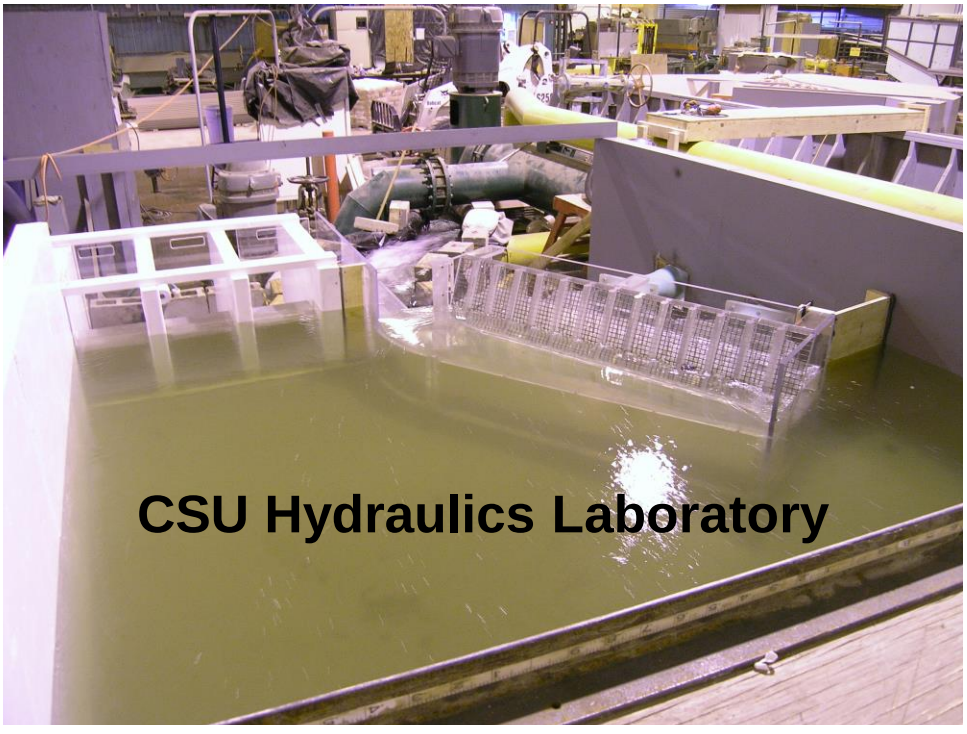
From Julien River Mechanics CUP 2002


Sedimentation Problems Can Be Solved


Locks and Dams
L&D No. 3

Bengal and Indus




CSU Hydraulics Laboratory

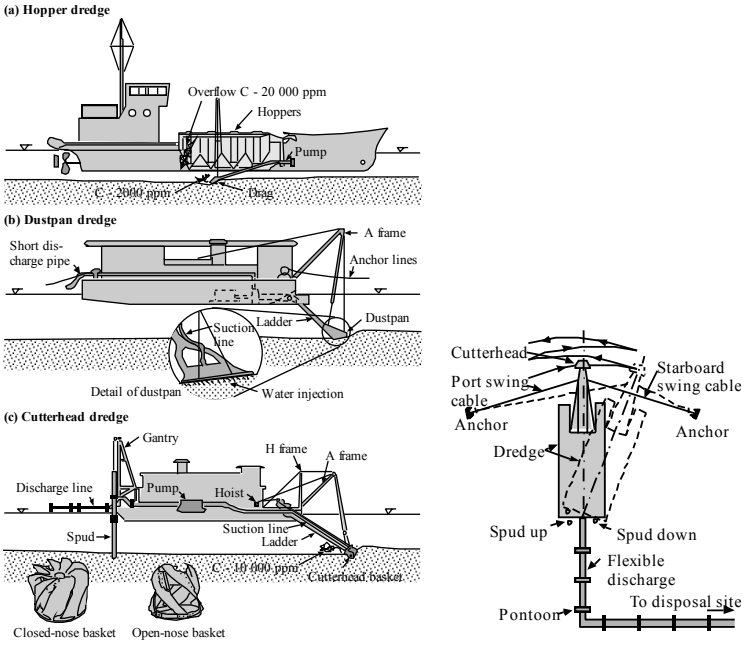
Sediment Flushing

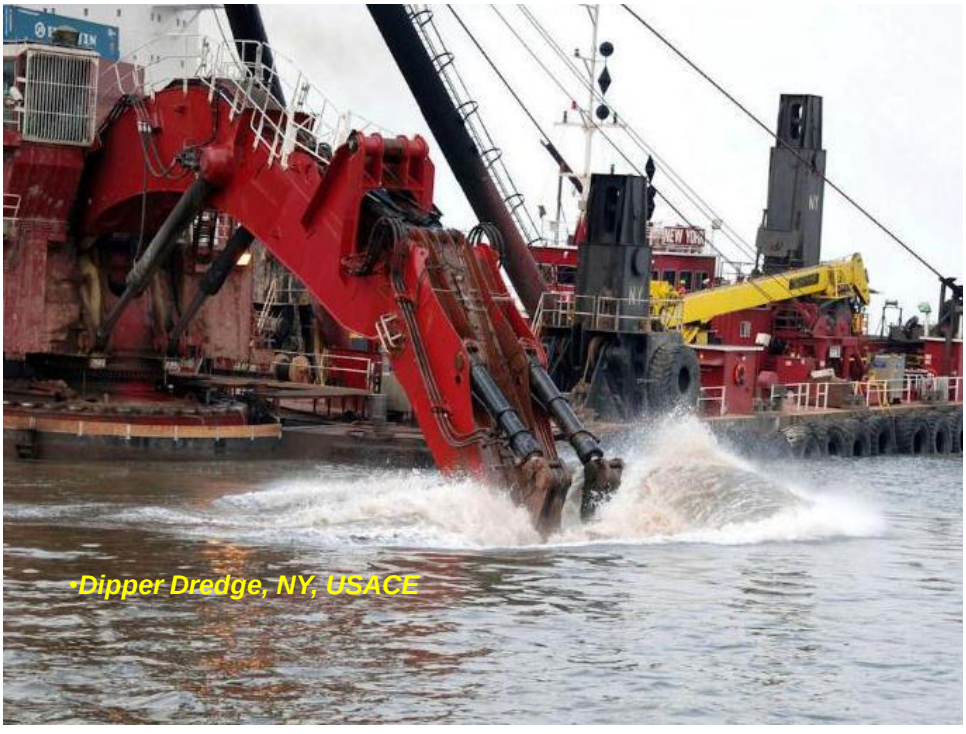
3. Dredging and Sediment Management

Sediment Plugs on the Rio Grande


•Middle Rio Grande, NM, USBR


•Middle Rio Grande, NM, USBR


(a) Hopper dredge
Overflow C - 20 000 ppm
Hoppers
Pump
C - 2000 ppm
Drag
(b) Dustpan dredge
A frame
Short discharge pipe
Anchor lines
Suction line
Ladder
Dustpan
Detail of dustpan
Water injection
(c) Cutterhead dredge
Gantry
H frame
A frame
Discharge line
Pump
Hoist
Suction line
Ladder
Spud
C - 10 000 ppm
Cutterhead basket
Closed-nose basket
Open-nose basket
Cutterhead
Port swing cable
Starboard swing cable
Anchor
Anchor
Dredge
Spud up
Spud down
Flexible discharge
To disposal site
Pontoon


•Dipper Dredge, NY, USACE

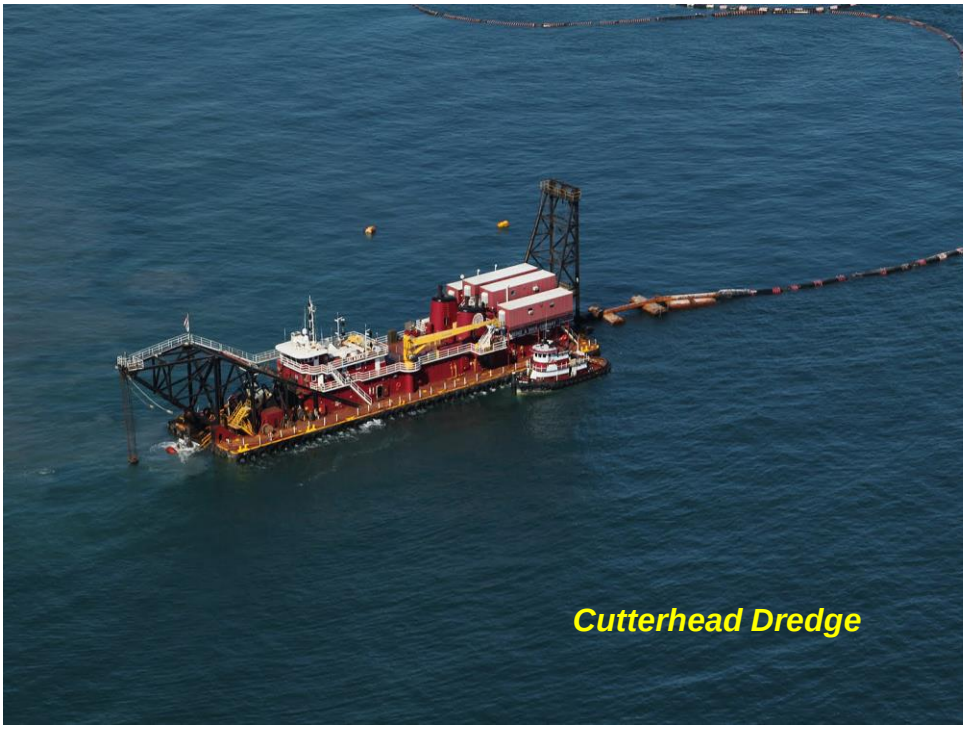
Clamshell Dredge

•Mystic River Clamshell Dredge, New England District, USACE


Hopper Dredge

Dustpan Dredge

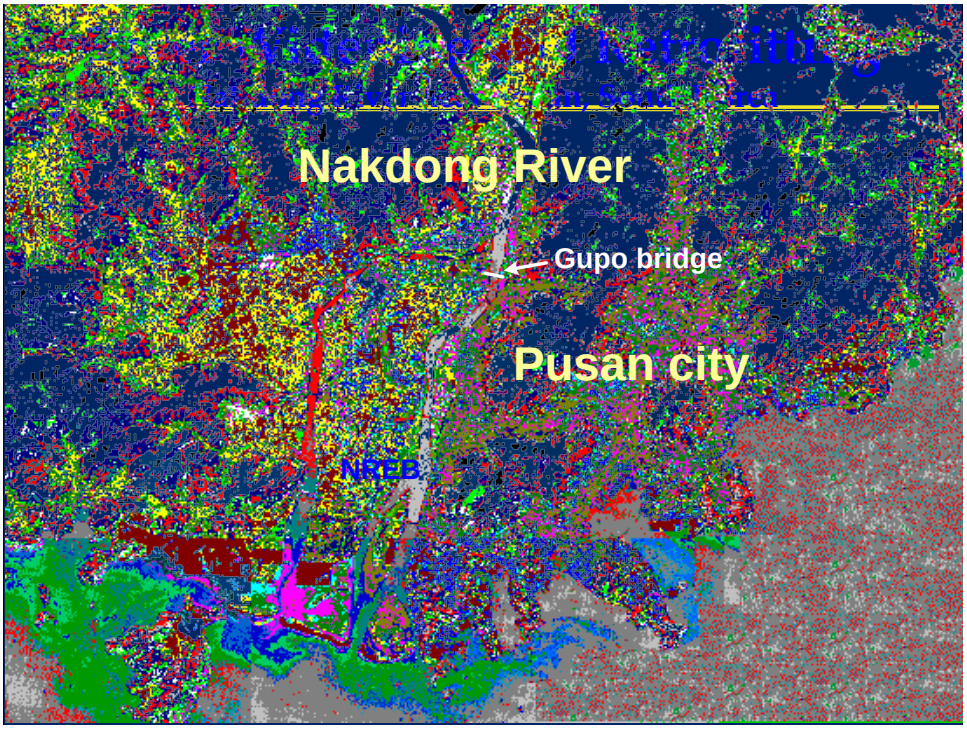
Cutterhead Dredge



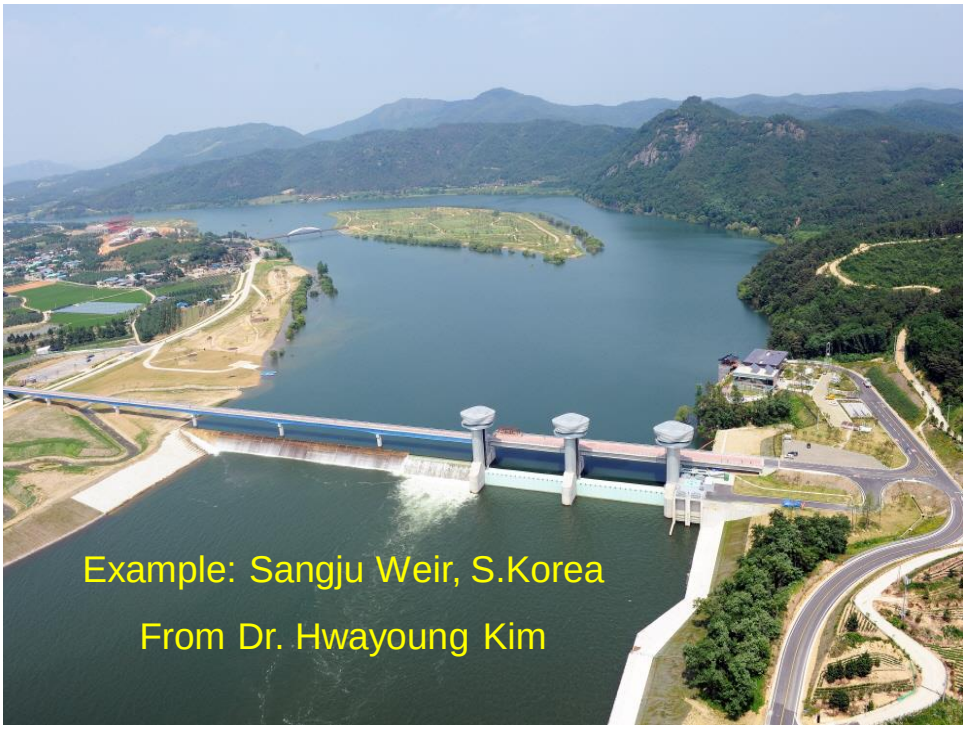
•Closed-nose Basket Cutterhead Dredge, Delaware River, USACE

•Open-nose Basket Cutterhead Dredge, Savannah River , USACE

Disposal site for dredged material


Nakdong River
Gupo bridge
Pusan city
NREB


Nakdong River Estuary Barrage
•from Ji et al. ASCE-JHE, Nov. 2011



Hydropower Revenues

Capacity: 1,500 kW * 2 units

$$P = 9.81 \times \eta \times Q_a \times H_a$$

Unit cost of sales = 0.13 USD/kWh

Weir	Production and benefit			Unit cost of sales	
	MWh	Benefit(10^6 KRW)	benefit(10^3USD)	KRW/kWh	USD/kWh
Sangju	8,004	1,179	1,072	147.32	0.13

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Excavation Costs

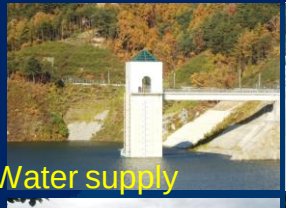
- Nakdong River Estuary Barrage (1990 – 2010)
- V = 13,678,000 m^3 (43.2 million dollars)
- Unit cost = 6.31 USD/m^3

Nakdong River Estuary Barrage

Photos of excavation

Other Issues besides sedimentation

- It is hard to change reservoir operation rules for sedimentation problems only because we have other issues to deal with.



Water supply

Stream ecology

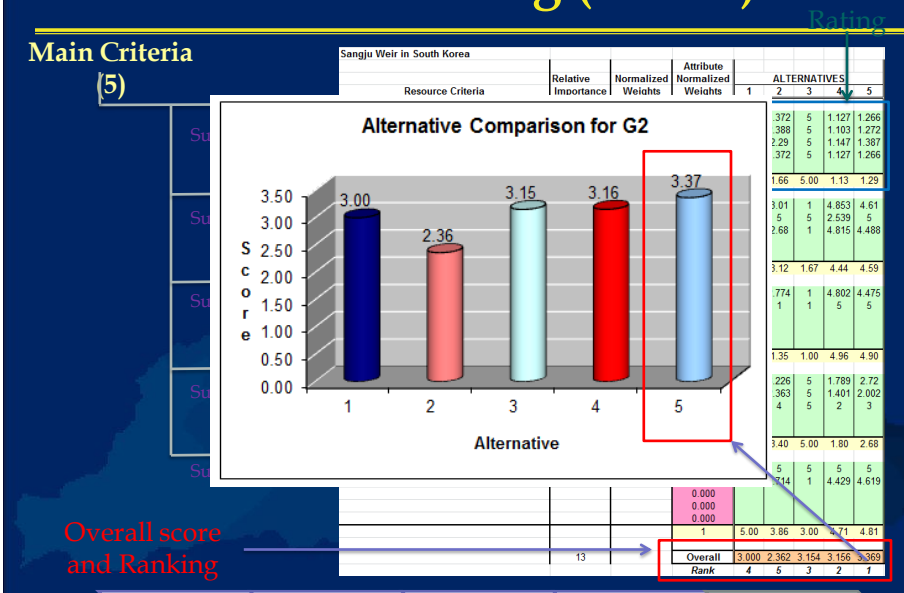
Hydropower

Flood control

Riverside environment

Turbidity

MCDA Rating (WAM)



Step 1 Criteria Identification | Step 2 RIF Definition | Step 3 Constraints Analysis | Step 4 Alternatives development | Step 5 MCDA Modeling

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4. Disaster Prevention

Classification and Rheology

Total shear stress :

$$\tau = \tau_y + \tau_v + \tau_t + \tau_d$$

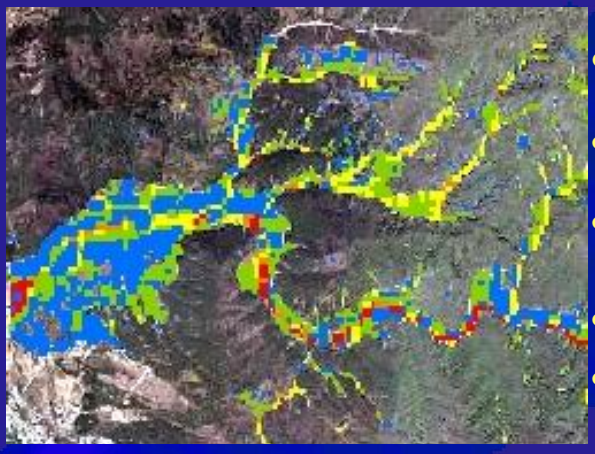
Landslides ⟺ Yield stress

Mudflows ⟺ Viscous stress

Mudfloods ⟺ Turbulent stress

Debris flows ⟺ Dispersive stress

Landslides



Duksan Creek modeling with TREX
from Dr. Jaehoon Kim, CSU and KFRI

- Yield strength
- Steep hillslopes
- High rainfall precipitation
- High Infiltration
- Saturated yield strength ~ 1kPa

Landslide Countermeasures

Effective Solution → **Slope reduction, drain, vegetation**

- **Terraces**
- **Drainage**

Mudflows

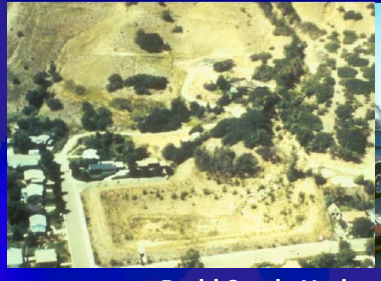
- Viscous
- High concentration of silts and clays
- 45% < Cv < 55%
- Low velocity and Froude number
- Large flow depth and pressure
- No abrasion

Mudflow Countermeasures

Effective Solution ➡ **Store, Deflect, Spread**

- **Storage basins**
- **Deflection walls**

Storage Basin



Deflection Wall

Rudd Creek, Utah
from Dr. Jim O'Brien

Mud Floods

- Turbulent
- Non-cohesive particles
- Sands and silts
- Cv as high as 40%
- High velocity and Froude Number
- Abrasive

Mudflood Countermeasures

Effective Solution ➡ **Increased conveyance**

- **Straight channel**
- **Lined canal**
- **Berm and levee**
- **Drop structure**

Straight Channel

Lined canal with drop structures

Debris Flows – Los Corales, Venezuela

Los Corales

Debris Flow

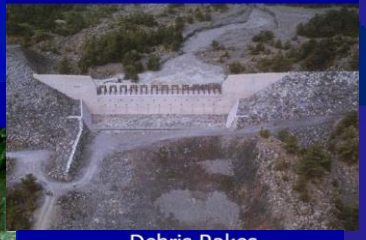
- Dispersive
- Large rocks
- Non cohesive
- Low viscosity
- High velocity
- Destructive impact force

Debris flow Countermeasures

Effective Solution ➡ **Retain large rocks**
Drain water

- **Concrete sabo dams**
- **Steel Frames**
- **Debris Racks**

Sabo Dam and Steel Frames



Sabo Dam Construction

Debris Rakes

5. Example Mt Umyeon

- Mitigation structures for mudflows
  - » Detention basins
  - » Deflection walls
- Mitigation structures for mud floods
  - » Straight channels
  - » Lined canals, berm and levee channels
  - » Drop structures, energy dissipators
- Mitigation structures for debris flows
  - » Concrete Sabo dams
  - » Steel frames and debris rakes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Dr. Tom Pokrefke, ERDC
... so many others ...
•Photo of Sangju Weir in South Korea from Hwayoung Kim


Muchas
Gracias!
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University U.S.A