Case Study: Kissimmee River Restoration

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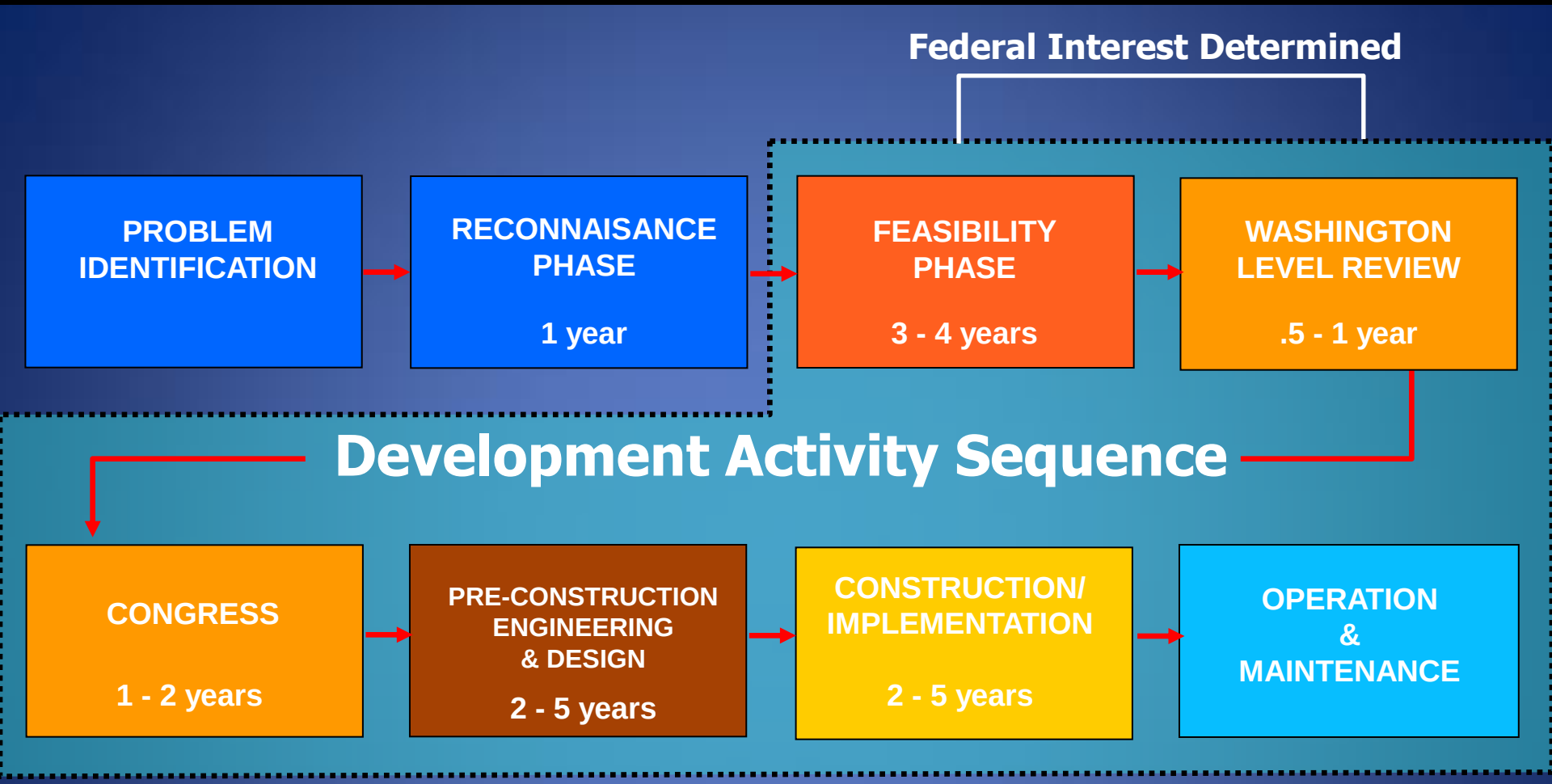
South Florida Water Management District

Alternativas para el Control de Inundaciones del río Piedras
El caso del Río Kissimmee, Estado de Florida
Teatro del Museo de Vida Silvestre
San Juan, Puerto Rico

4 de noviembre de 2013

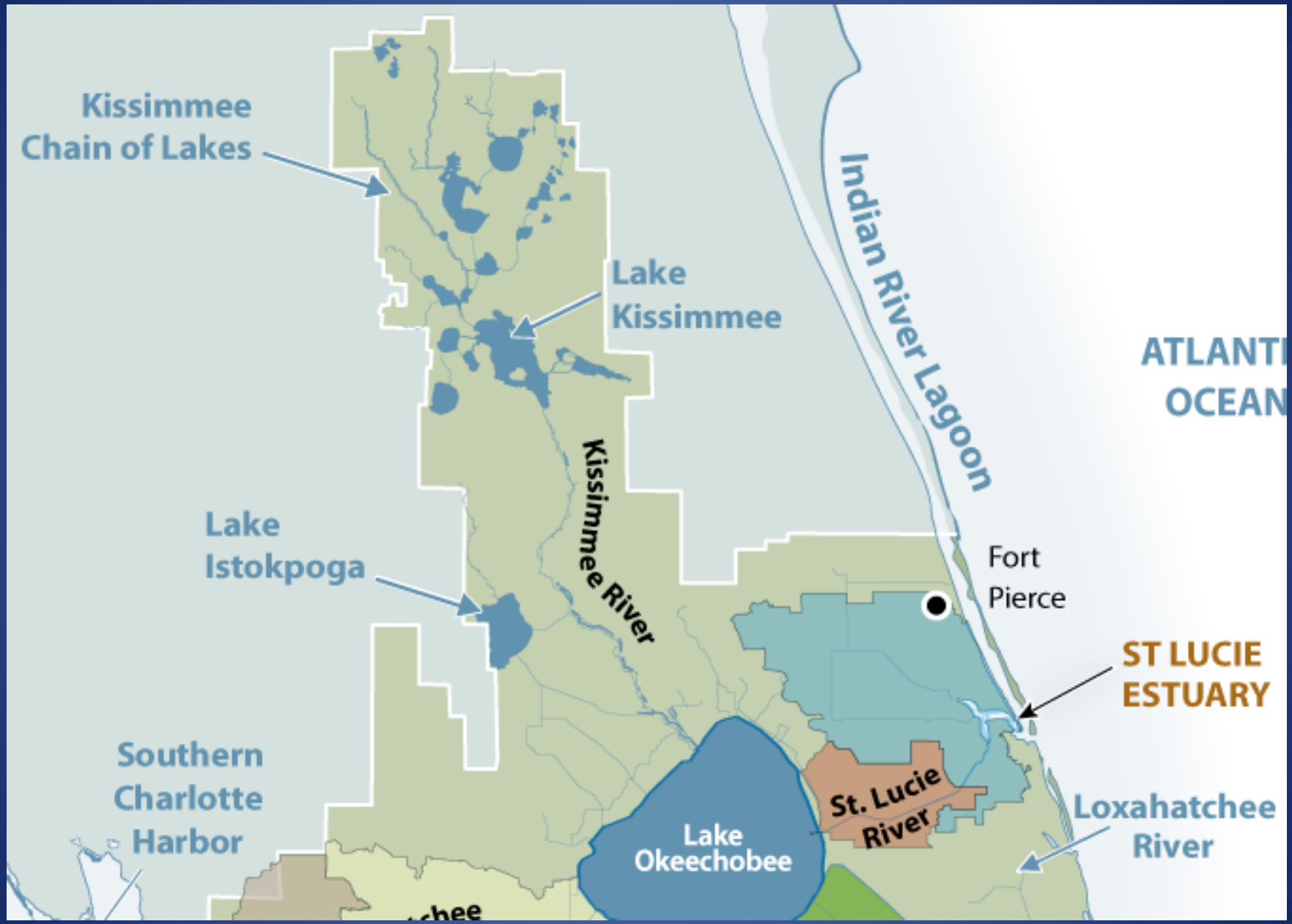
Overview

- Channelized in 1960s
- The Kissimmee River prior to channelization
- Flooding and channelization of the Kissimmee River
- Environmental effects of channelization
- Call for restoration
- Planning studies for restoration 1980-1993
- Project authorization
- Restoration construction: 1999-present
- Restoration progress and status
- Ecological responses
- Programmatic elements and process

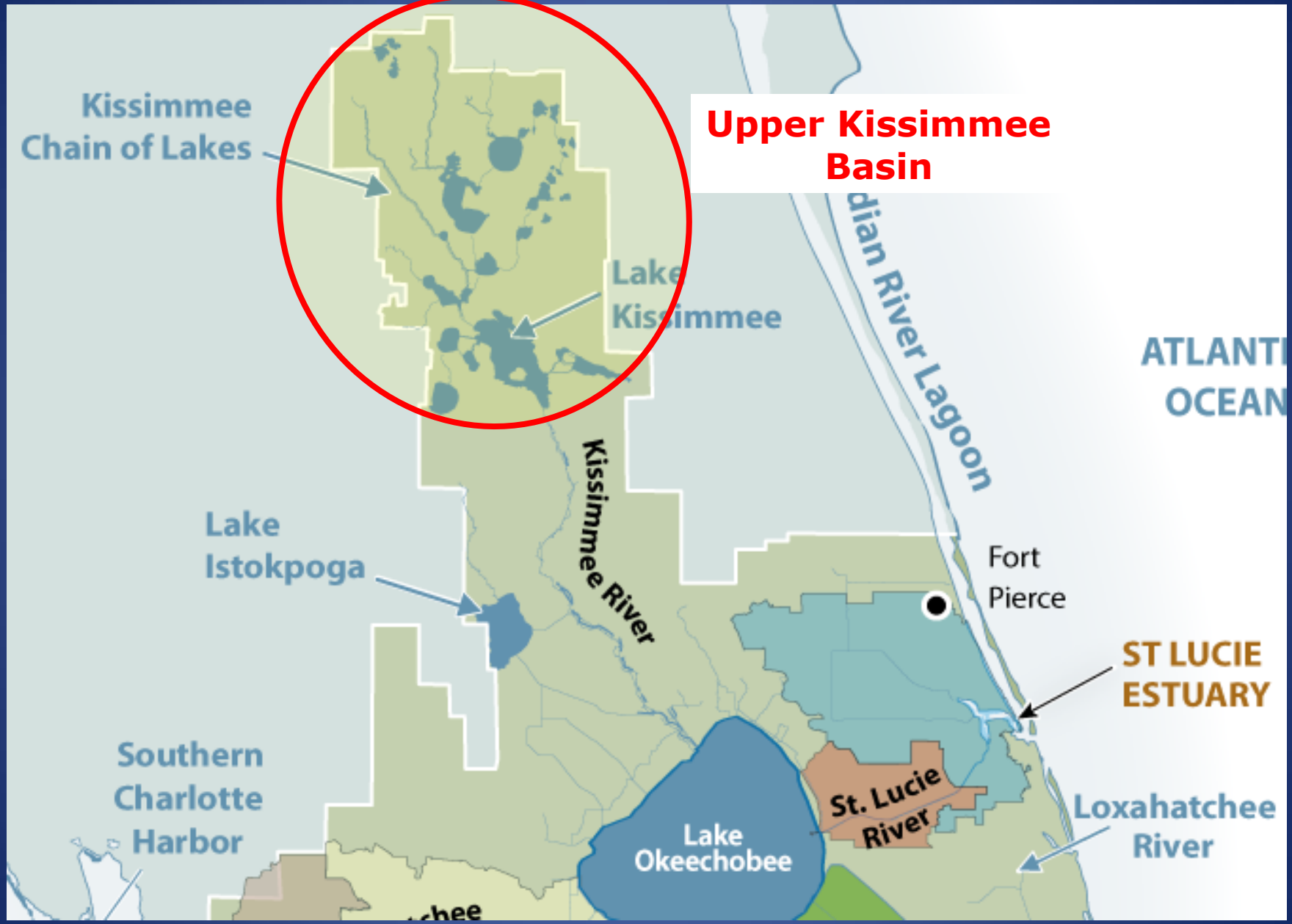


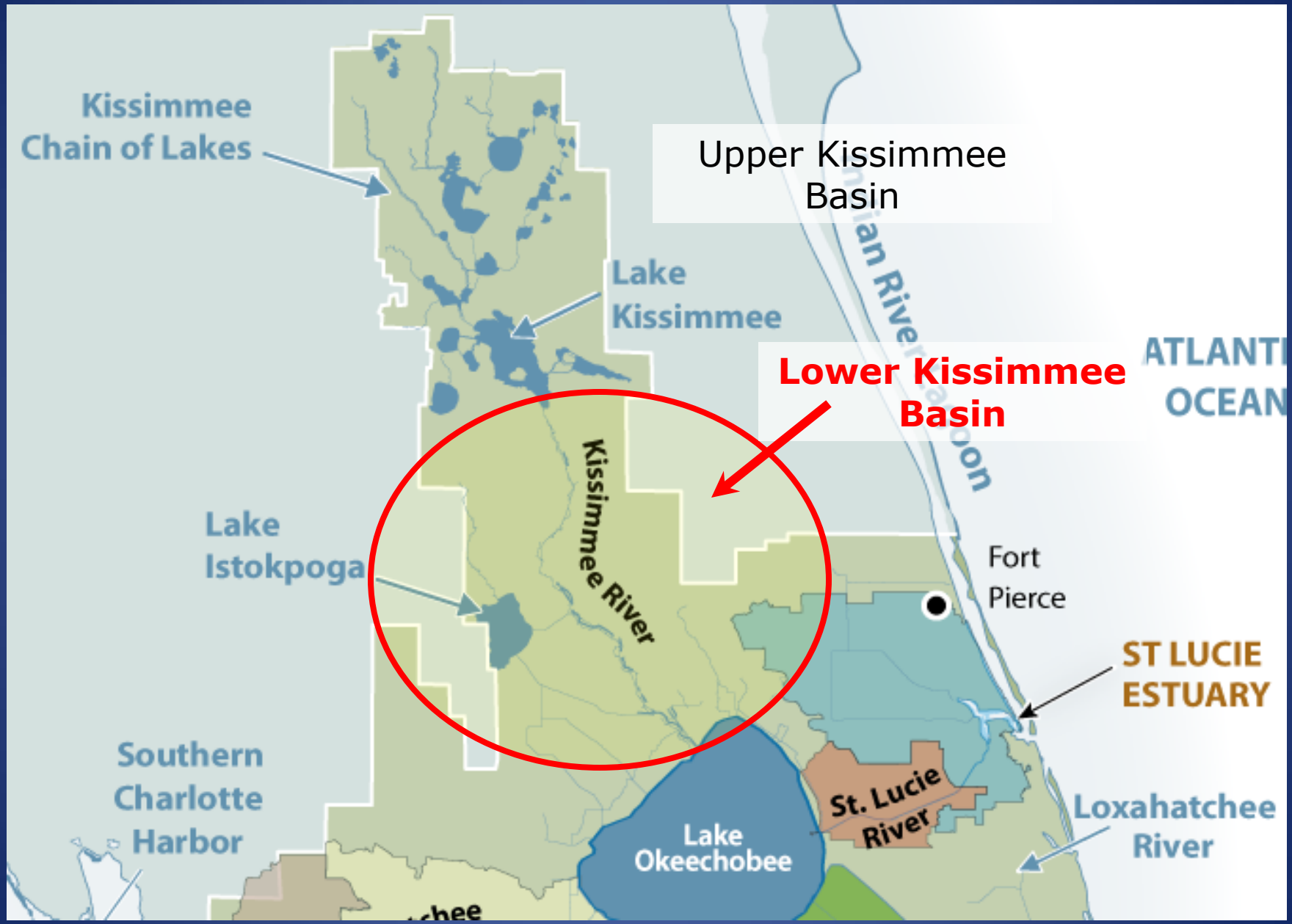
Civil Works Project Development Sequence

SO


Kissimmee
Chain of Lakes
Lake
Kissimmee
Kissimmee River
Indian River Lagoon
ATLANTI
OCEAN
Lake
Istokpoga
Fort
Pierce
ST LUCIE
ESTUARY
Southern
Charlotte
Harbor
St. Lucie
River
Loxahatchee
River
Lake
Okeechobee


Kissimmee Basin
Kissimmee Chain of Lakes
Lake Kissimmee
Kissimmee River
Indian River Lagoon
ATLANTI
OCEAN
Lake Istokpoga
Fort Pierce
ST LUCIE ESTUARY
Southern Charlotte Harbor
Lake Okeechobee
St. Lucie River
Loxahatchee River


Upper Kissimmee Basin
Kissimmee Chain of Lakes
Lake Kissimmee
Kissimmee River
Lake Istokpoga
Indian River Lagoon
ATLANTIC OCEAN
Fort Pierce
ST LUCIE ESTUARY
Southern Charlotte Harbor
Lake Okeechobee
St. Lucie River
Loxahatchee River


Kissimmee Chain of Lakes
Upper Kissimmee Basin
Lake Kissimmee
Lower Kissimmee Basin
Kissimmee River
Lake Istokpoga
Fort Pierce
ST LUCIE ESTUARY
Southern Charlotte Harbor
Lake Okeechobee
St. Lucie River
Loxahatchee River


Kissimmee Chain of Lakes
Lake Kissimmee
Kissimmee River
Kissimmee River Restoration Project
Indian River Lagoon
ATLANTIC OCEAN
Lake Istokpoga
Fort Pierce
ST LUCIE ESTUARY
Southern Charlotte Harbor
Lake Okeechobee
St. Lucie River
Loxahatchee River

The Kissimmee River Prior to Channelization


Kissimmee River pre-1960s

Flooding and Humans in the Kissimmee Basin

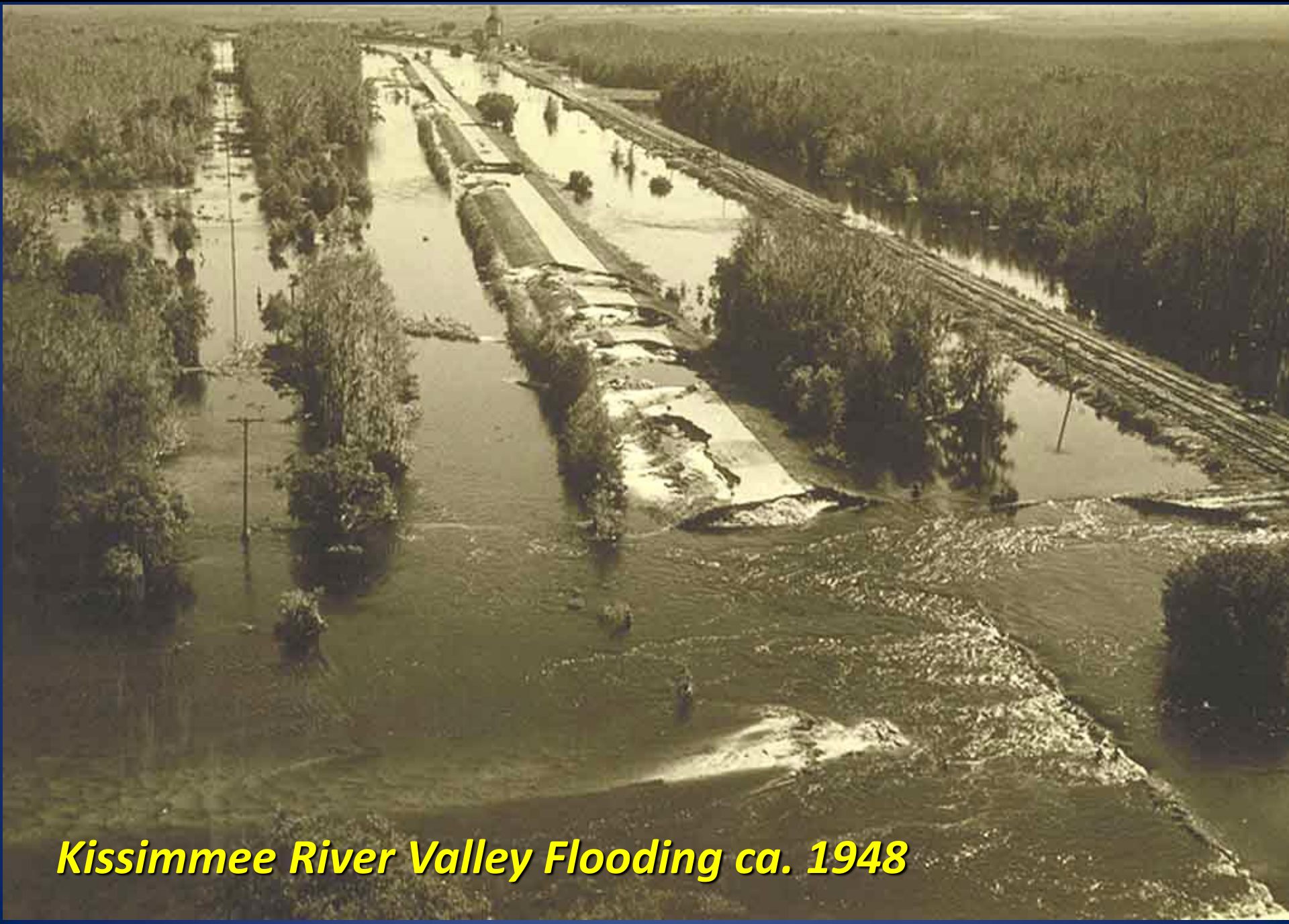
Flooding Occurred on Regular Basis

Kissimmee River Valley Flooding ca. 1948

City of Kissimmee Flooding ca. 1948


City of Kissimmee
Flooding ca. 1948

City of Kissimmee Flooding ca. 1948

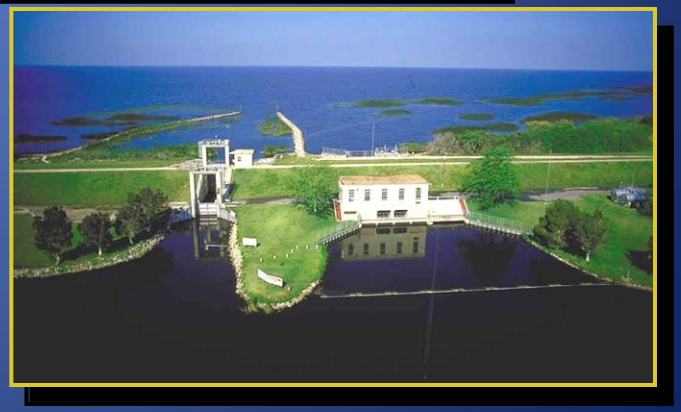


Kissimmee River Valley Flooding ca. 1948

Kissimmee River Valley Flooding ca. 1948

Flood Control in Central and South Florida

- Federal response to demand for flood protection
- Flood Control Act of 1948: congress approves the first phase of the Central and Southern Florida (C&SF) Project
  - 1,800 miles of canals and levees
  - Over 2,000 water control structures

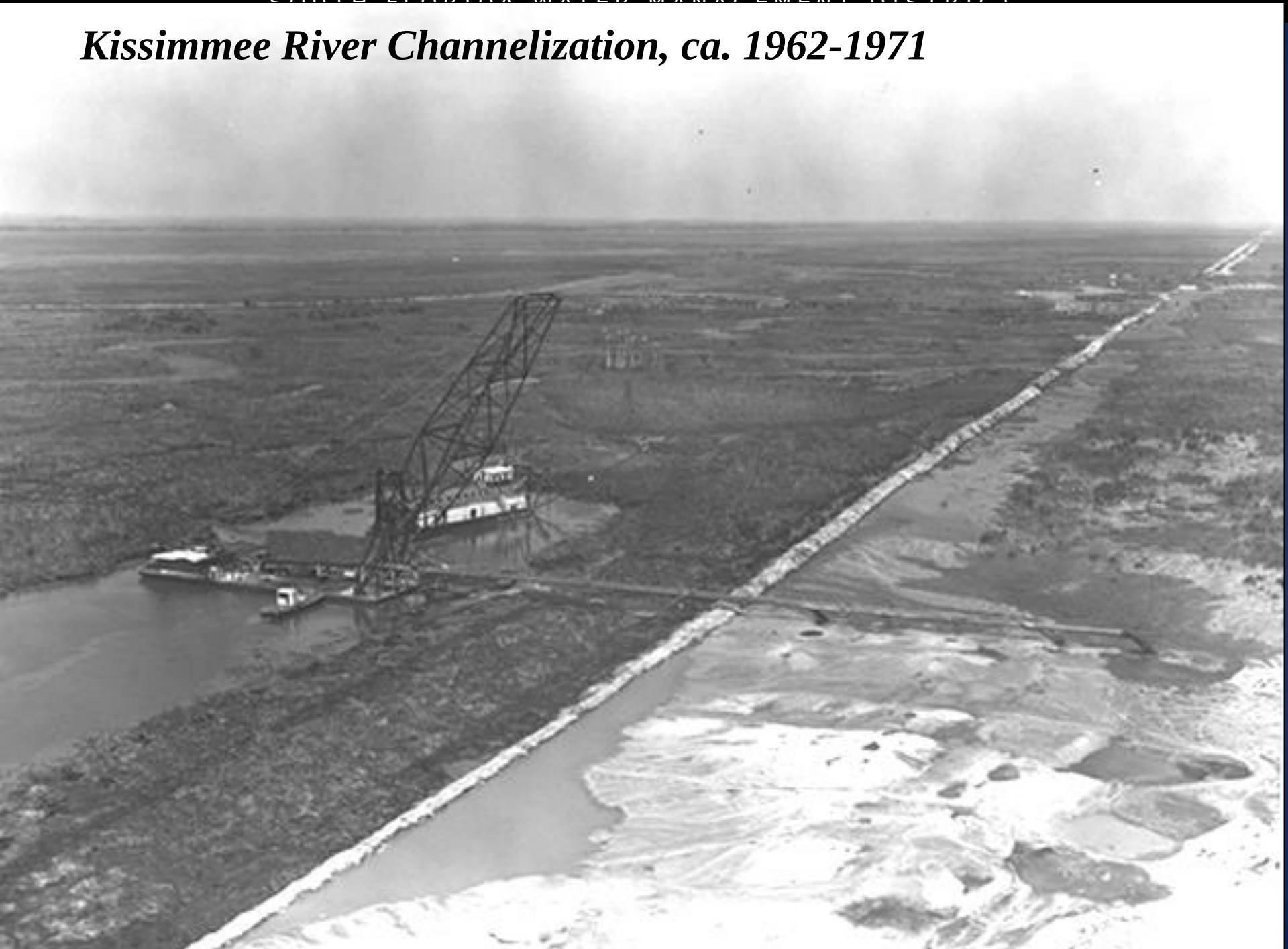


C&SF in the Kissimmee Basin

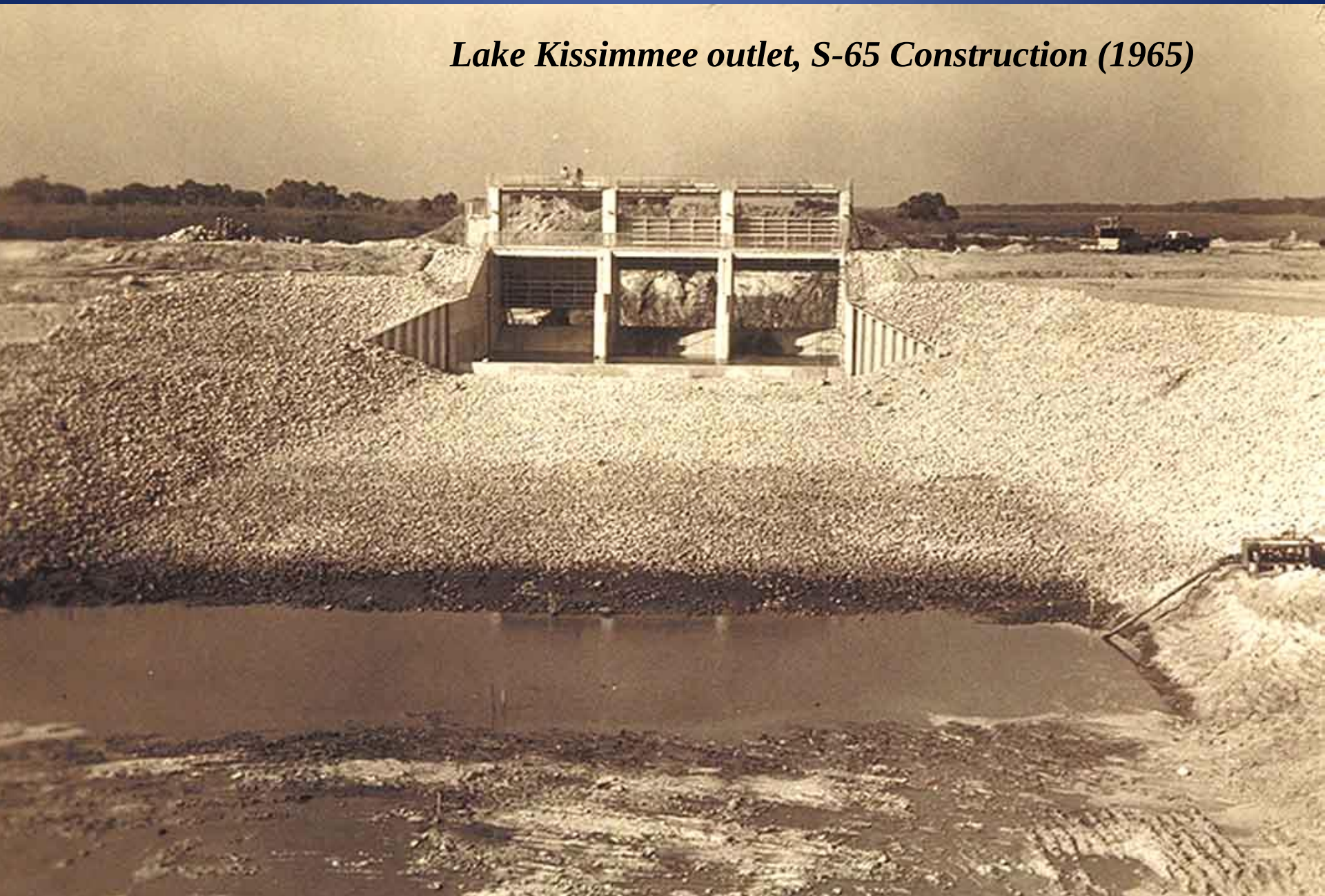
- Gates, structures, and canals constructed in the Upper Basin
- 1962-1971: C-38 canal constructed (channelization) by USACE

Kissimmee River Channelization, ca. 1962-1971

Kissimmee River Channelization, ca. 1962-1971

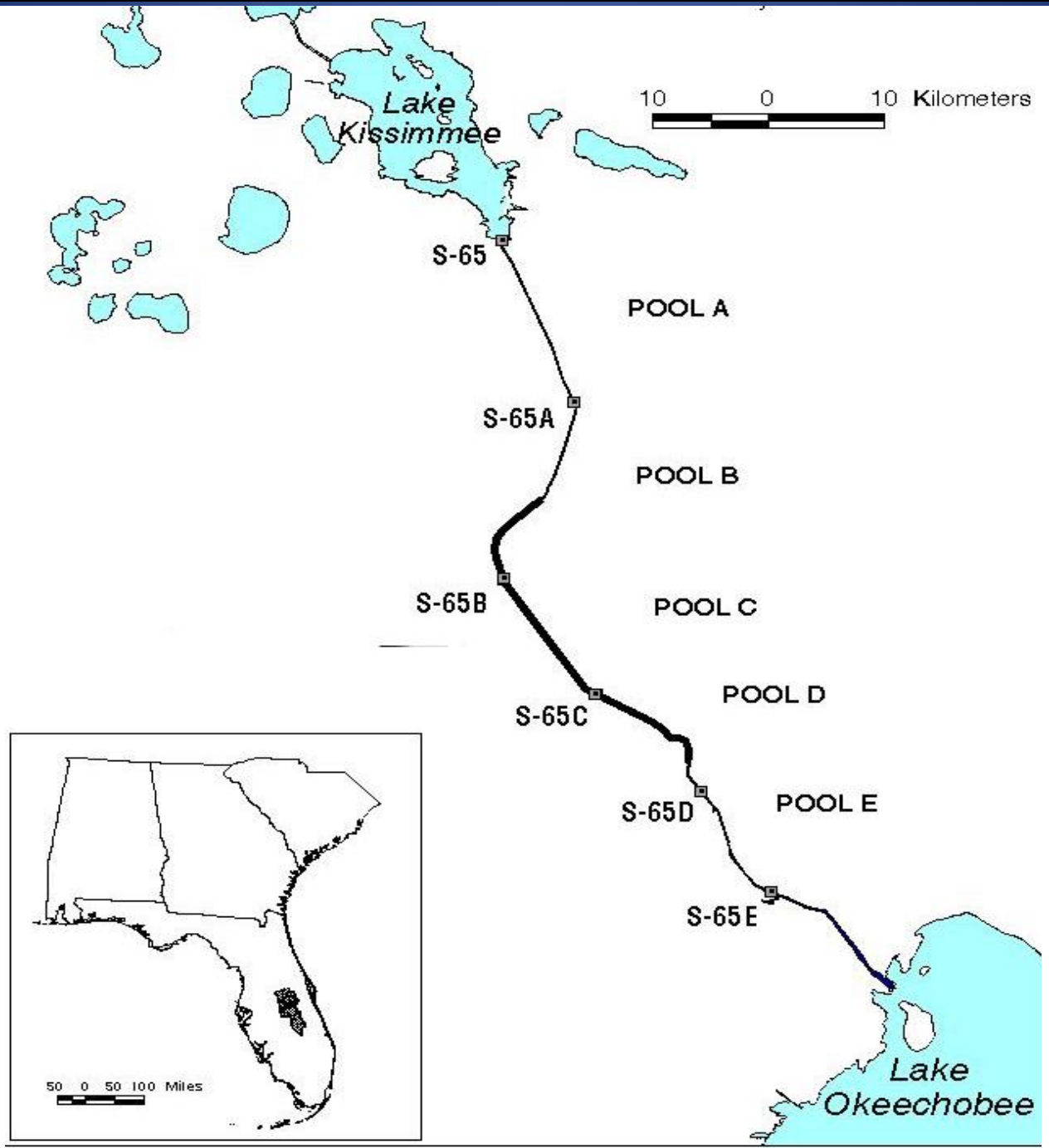


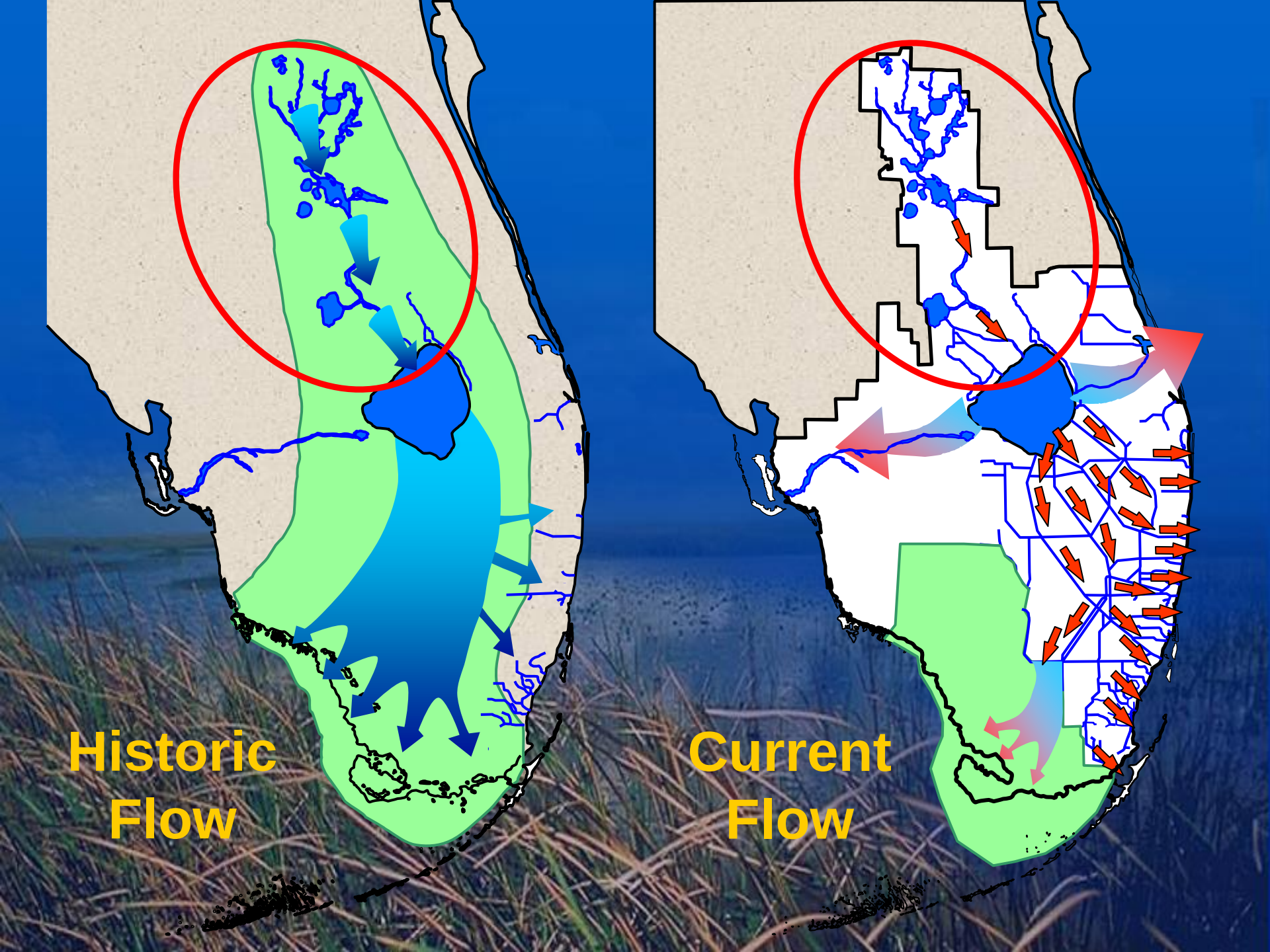
Kissimmee River Channelization, ca. 1962-1971

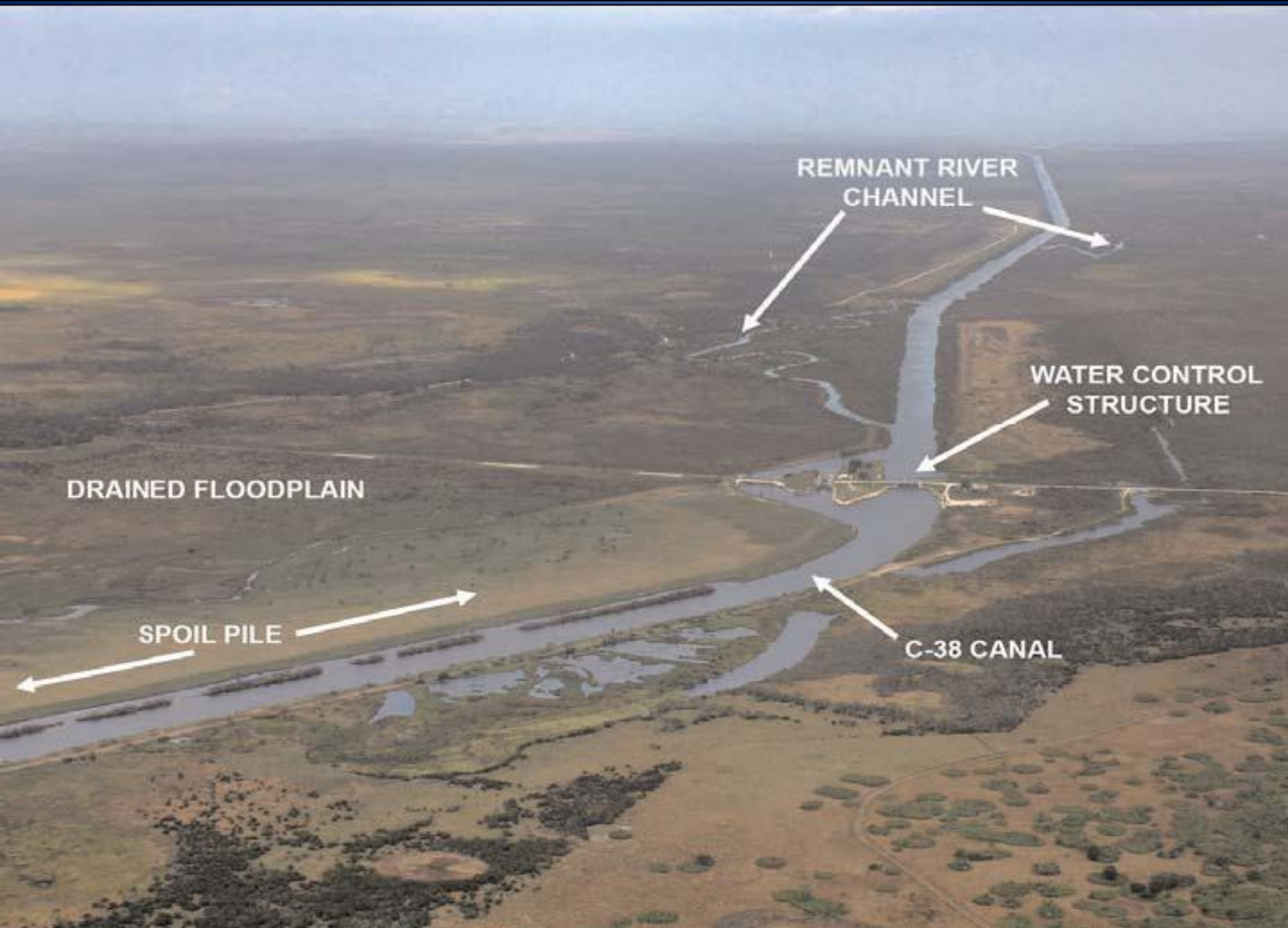


Lake Kissimmee outlet, S-65 Construction (1965)

Lake Kissimmee outlet, S-65 Gates and Navigation Lock (2001)

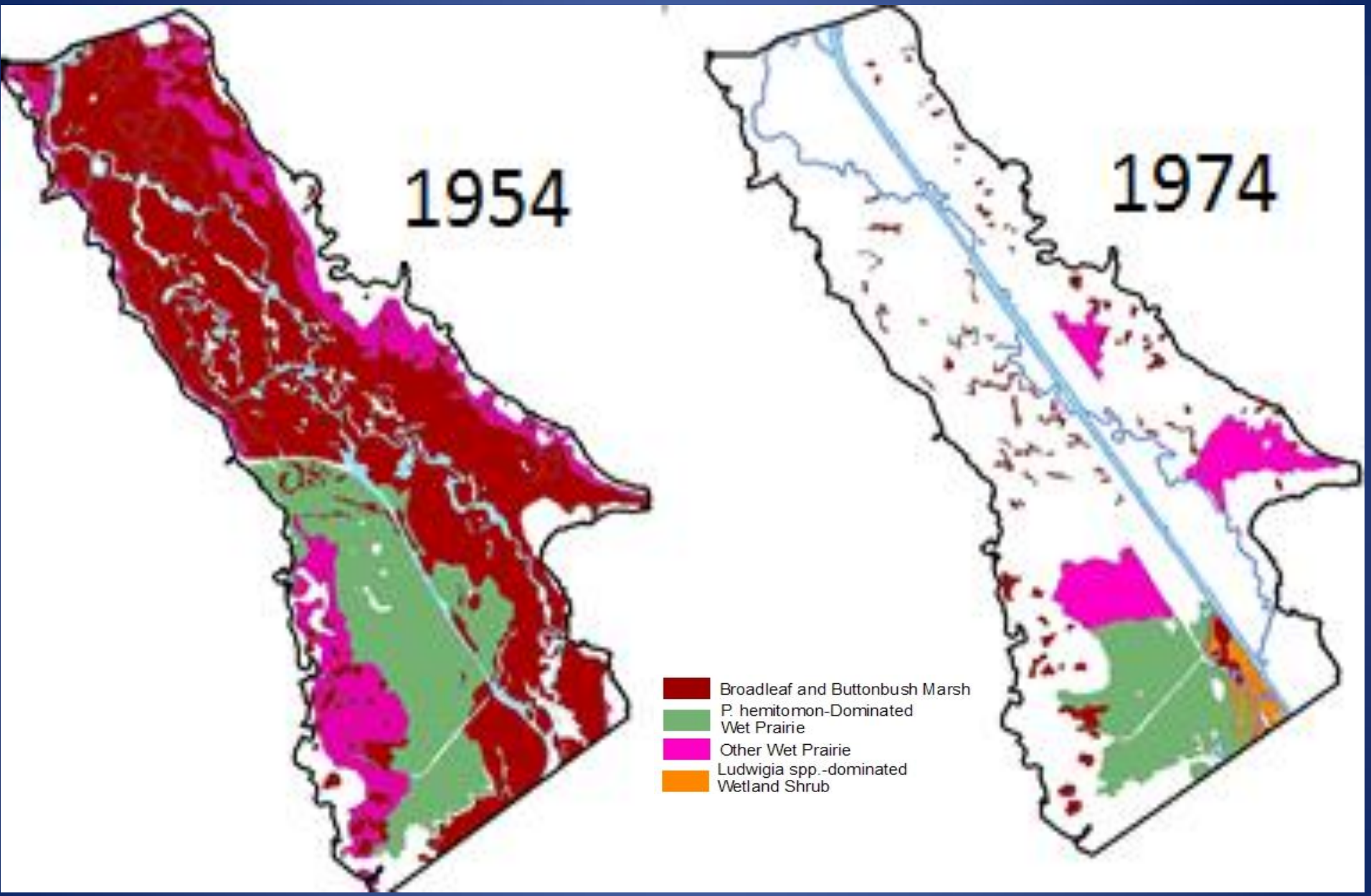

Lake Kissimmee
10 0 10 Kilometers
S-65
POOL A
S-65A
POOL B
S-65B
POOL C
POOL D
S-65C
S-65D
POOL E
S-65E
Lake Okeechobee
50 0 50 100 Miles


Historic
Flow
Current
Flow


REMNANT RIVER CHANNEL
WATER CONTROL STRUCTURE
DRAINED FLOODPLAIN
SPOIL PILE
C-38 CANAL

Impacts of Channelization

- Channelization of the Kissimmee River was highly successful at flood control . . . but had substantial hydrologic and environmental effects
  - Loss of flood pulse
    - Shift to terrestrial plants
    - Fewer wading birds, ducks
    - Loss of highly productive floodplain habitats
  - Loss of flow in river
    - Increases in floating vegetation
    - Increases in organic matter deposition
    - Lower dissolved oxygen
    - Shift in fish, invertebrate communities

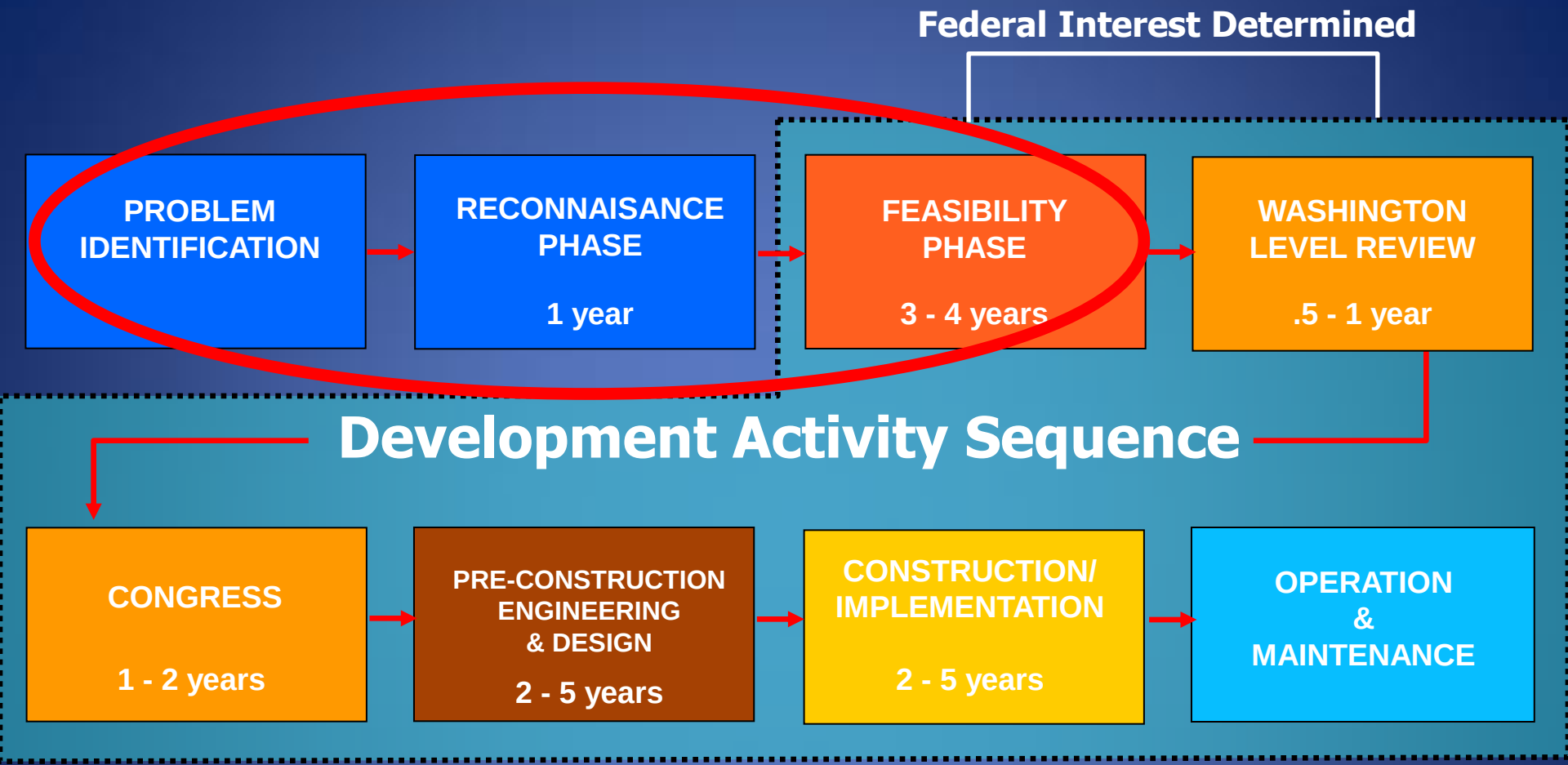

1954
1974
Broadleaf and Buttonbush Marsh
P. hemitomon-Dominated Wet Prairie
Other Wet Prairie
Ludwigia spp.-dominated Wetland Shrub

Kissimmee River Restoration Project: Impetus and Authorization

Restoration Impetus and Authorization

- 1970s - grassroots restoration movement
- 1976 - State legislation - Kissimmee River Restoration Act (Florida Statute 373.1965)
- State (SFWMD) and federal studies
- Water Resources Development Act (WRDA 1992)
  - Authorized the Kissimmee River Restoration Project and the Headwaters Revitalization Project
- Cooperative Agreement (1994)
  - 50:50 Cost share between
    - USACE (construction and engineering)
    - SFWMD (land acquisition and restoration evaluation)

Restoration Investigations 1980 - 1995



Civil Works Project Development Sequence

KRRP Restoration and Feasibility Studies

- 1971 - Governor's Conference on Water Management in South Florida (formal acknowledgement of channelization problems)
- 1978 -1985 – 1st Federal Feasibility Study (USACE 1985)
- 1988: Kissimmee River Restoration Symposium (Loftin et al. 1988)
- 1984-1990 – SFWMD Demonstration Project (Toth 1993)
- 1991– 2nd Federal Feasibility Study (IFR/EIS) (USACE 1991)
- 1994 – Test Fill Project (USACE 1996)
- 1996 – Project Modification Report (added Headwaters Revitalization Project (USACE 1996)

Project Goal

- Ecological integrity:
  - "The capability of supporting and maintaining a balanced, integrated, adaptive community of organisms having a species composition, diversity, and functional organization comparable to natural habitat of the region". (Frey 1975, Karr and Dudley 1981)

Five Hydrologic Criteria (KRRP) Needed to Reestablish Integrity

1. Continuous flow with duration and variability characteristics comparable to pre-channelization records.
2. Average flow velocities between 0.8 - 1.8 feet per second when flows are contained within channel banks.
3. A stage-discharge relationship that results in overbank flow along most of the flood plain when discharges exceed 1,400 - 2,000 cfs.
4. Stage recession rates on the flood plain that typically do not exceed 1 foot per month.
5. Stage hydrographs that result in floodplain inundation frequencies comparable to pre-channelization hydroperiods, including seasonal and long term variability characteristics.

Tools to Develop and Evaluate Alternatives

- Conceptual work and modeling
- Hydrologic modeling
- Physical modeling
- Experimental manipulations with data collection and analysis

- **All of these interact with**
  - Criteria or performance measures against which to gauge desired outcomes

Questions for Alternative Designs and Feasibility

1. Stability: is the alternative likely to be successful in an engineering sense?
2. What features are needed to maintain the current level of flood control?
   - What lands are likely to be affected and need to be acquired?
3. Will the alternative provide the desired environmental benefits?

1. Stability

- Hydrologic modeling:
  - River channel velocity and sediment erosion/deposition in the restored river channel
  - How high stages might go during floods
  - Backwater effects (include the headwater lakes and tributaries)
  - Needs for additional gates at structures
  - Enlargement of canals (increased conveyance)
  - Identify the upstream limit of backfilling
- Physical modeling
  - Stability of the backfill and reconnected river channel
- Experiments
  - Weirs and high flow test
  - Test fill – stability of backfilled canal

2. Flood Control

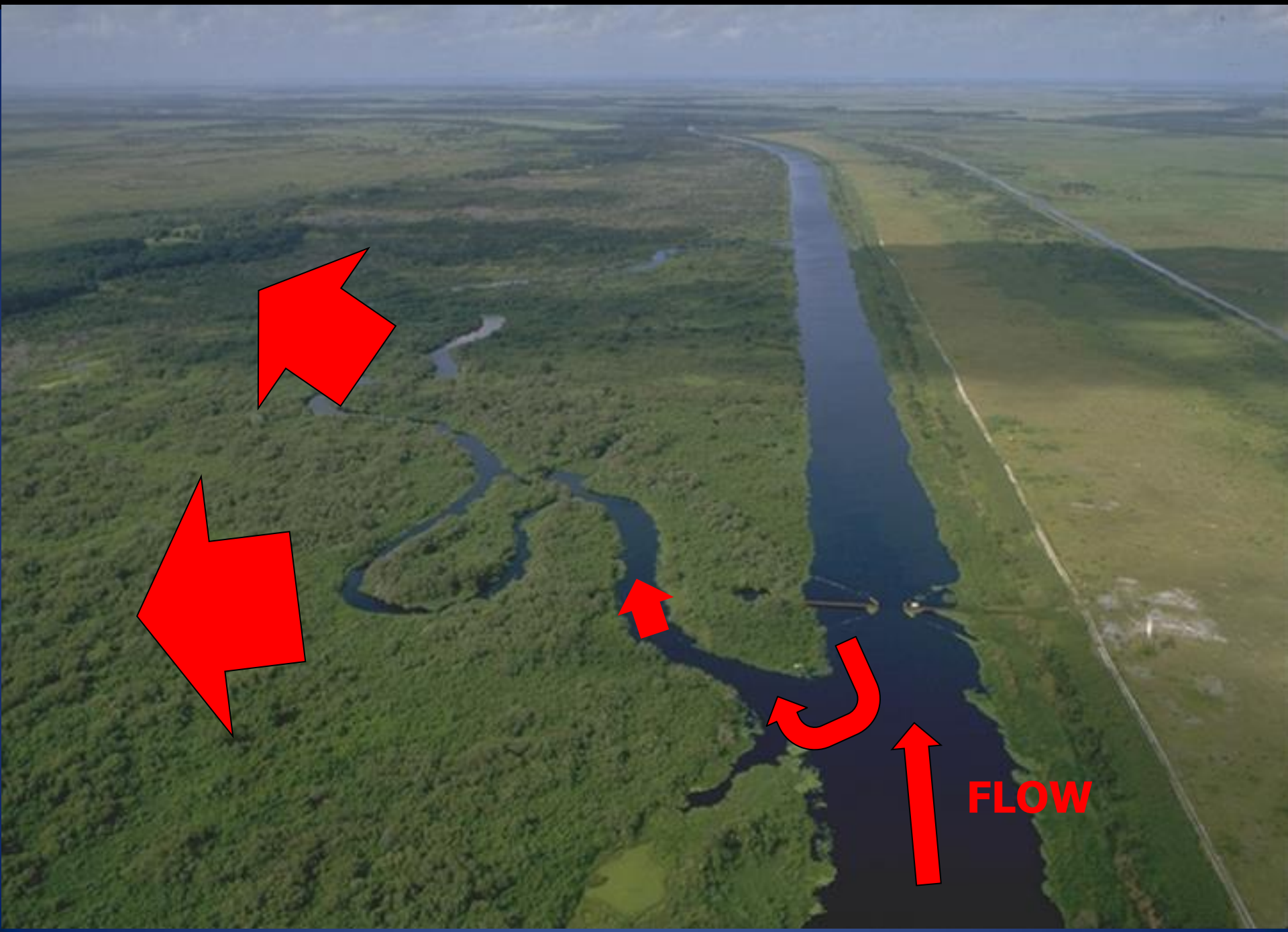
- Hydrologic modeling to identify the 5-year and 100-year flood lines

3. Environmental Benefits

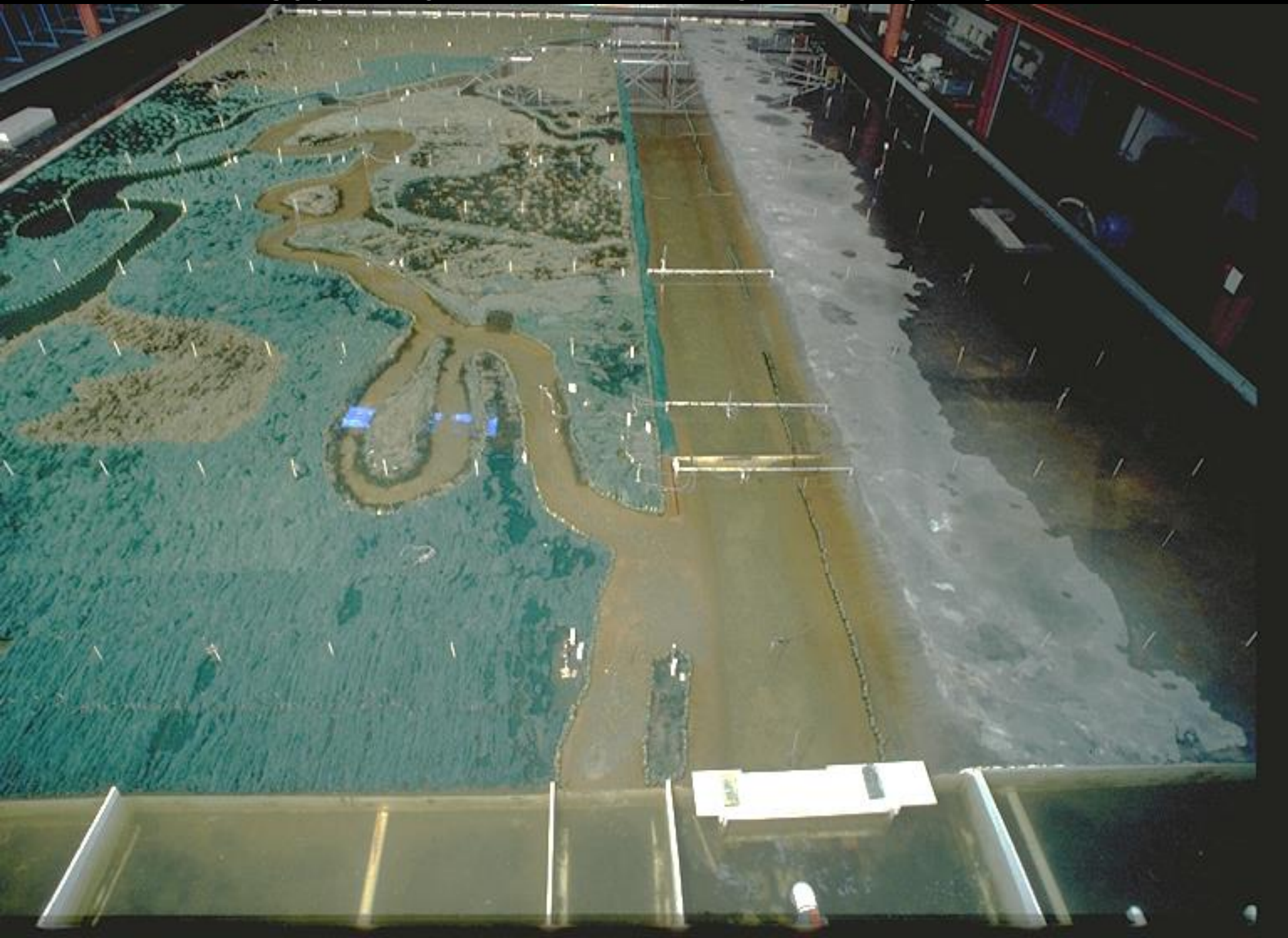
- Hydrologic modeling to determine discharge regimes
  - Comparisons of different regulation schedules.
  - Shen's modeling provided model output to evaluate the hydrologic criteria for several restoration alternatives
  - Hydrologic/hydraulic analysis of the Demonstration Project
- Monitoring during the Demonstration Project provided data on biological and environmental benefits
  - Flow-through marsh
  - River channel response

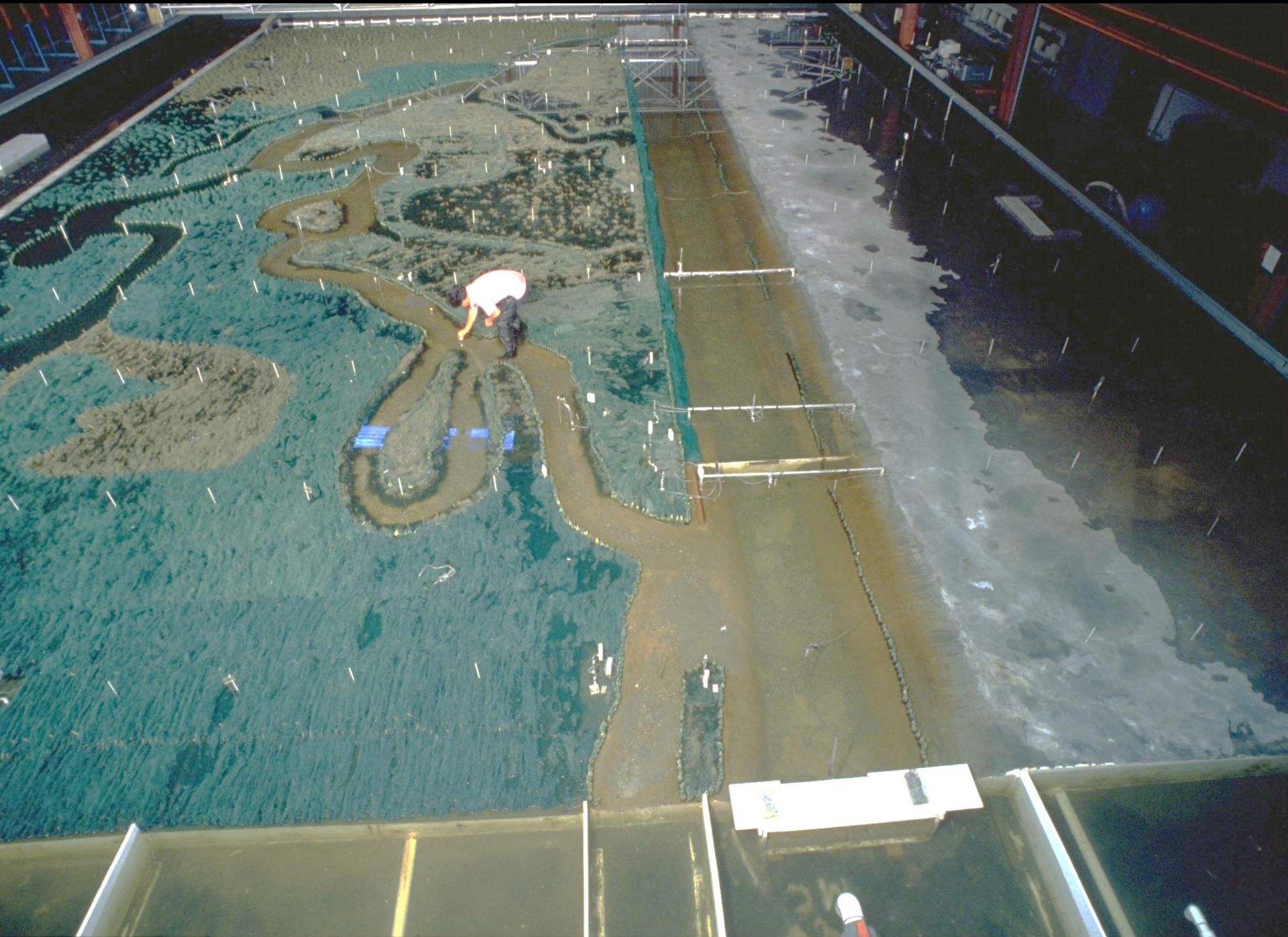
Kissimmee River Demonstration Project

- Wier alternative
- Monitoring documented effects of flow on river channel vegetation, dissolved oxygen
- Implementation of a stage fluctuation schedule
- Creation of a flow through marsh to test inundation effects


FLOW

Kissimmee River Restoration 1000 foot Test Fill 1993





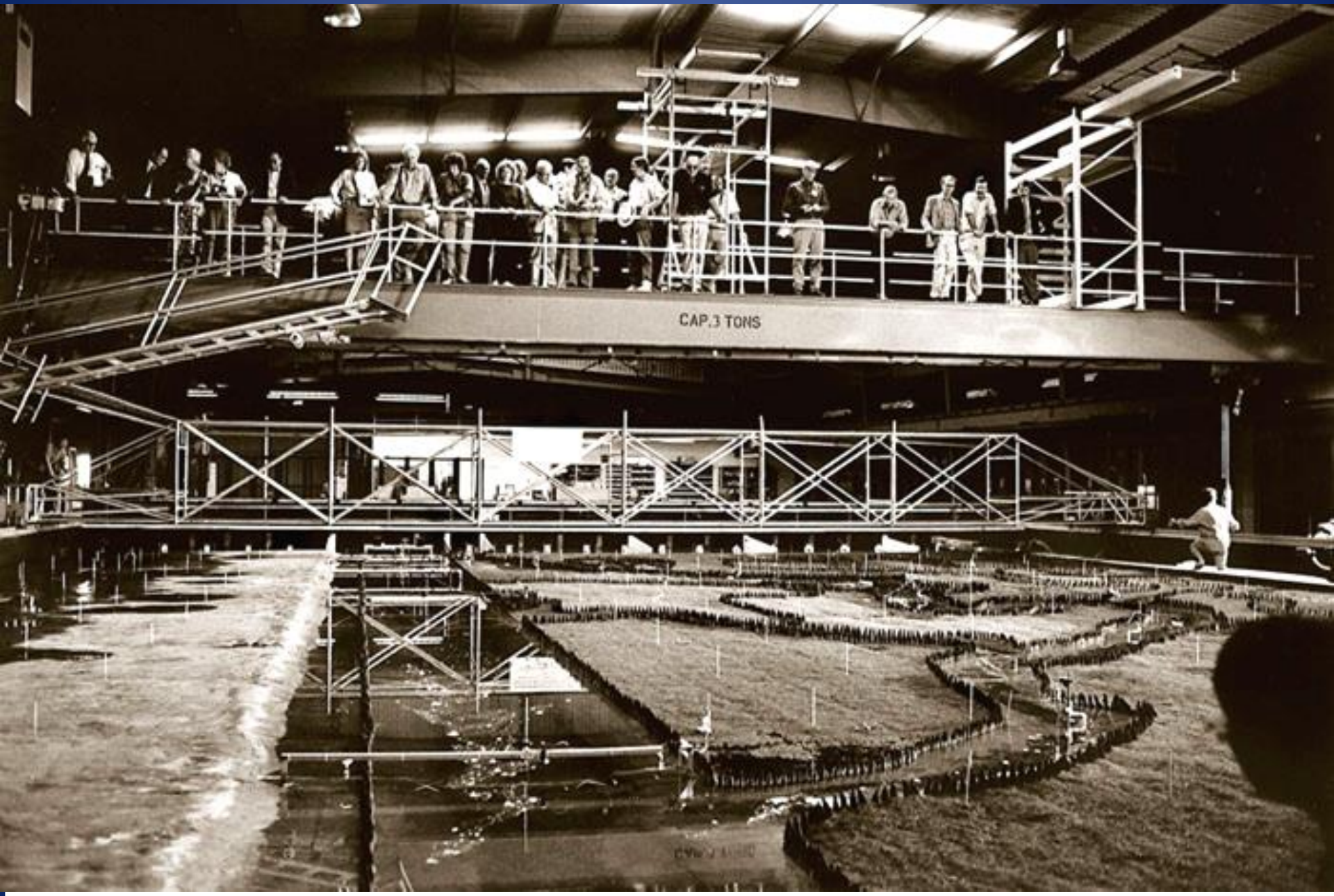
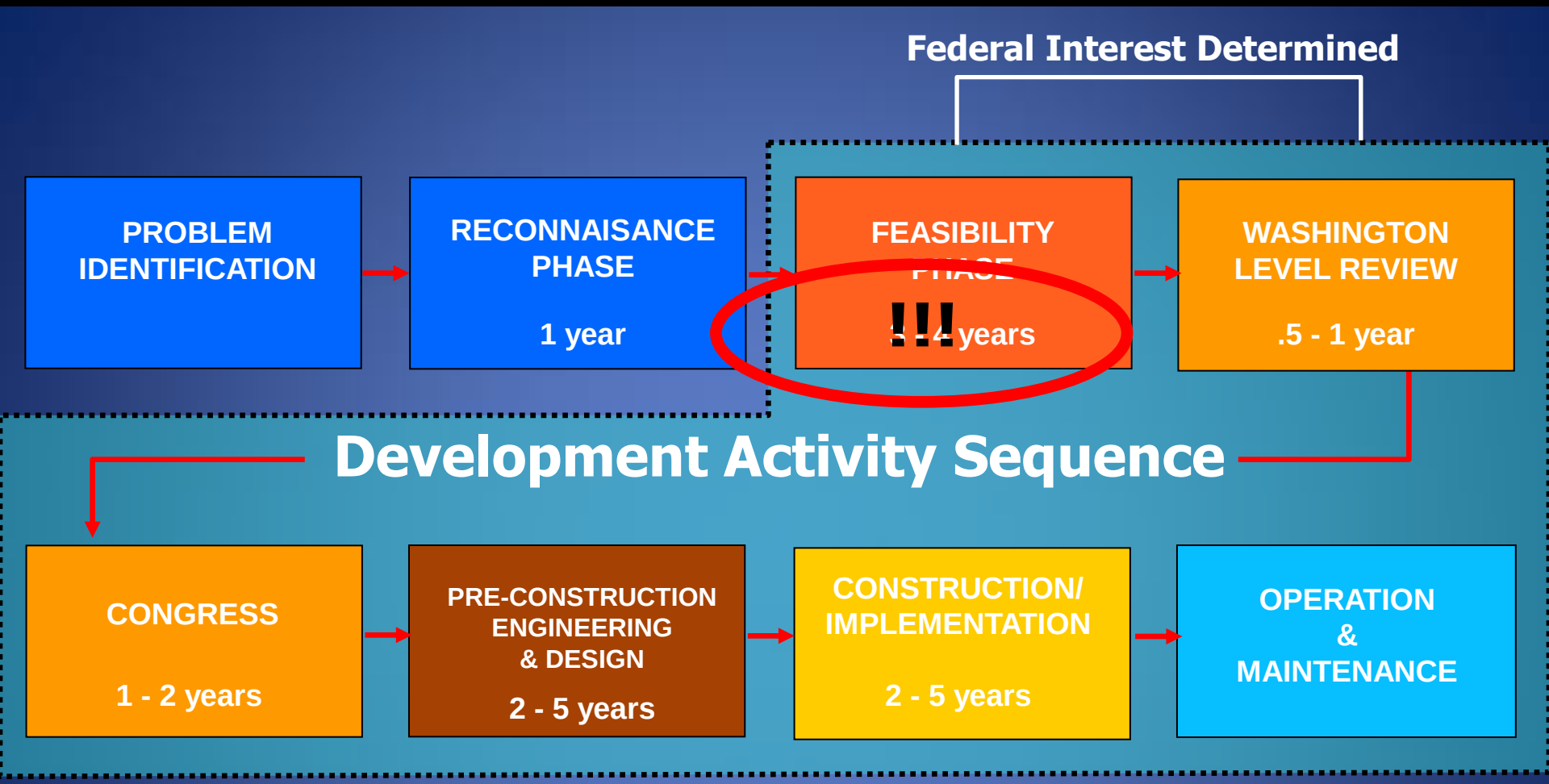

CAP.3 TONS

Figure 26-2b Physical Modeling. On the Kissimmee River restoration project, studies combined the use of physical and computer models. This photograph shows measurements being taken for an earth plug stability and scour test on a physical model constructed to a scale of 1:20.
(photograph by Pat Partington, SFWMD)

Summary of Feasibility Studies

- The various feasibility studies concluded that an opportunity existed
- This opportunity was to restore a portion of the channelized Kissimmee River and floodplain



Civil Works Project Development Sequence

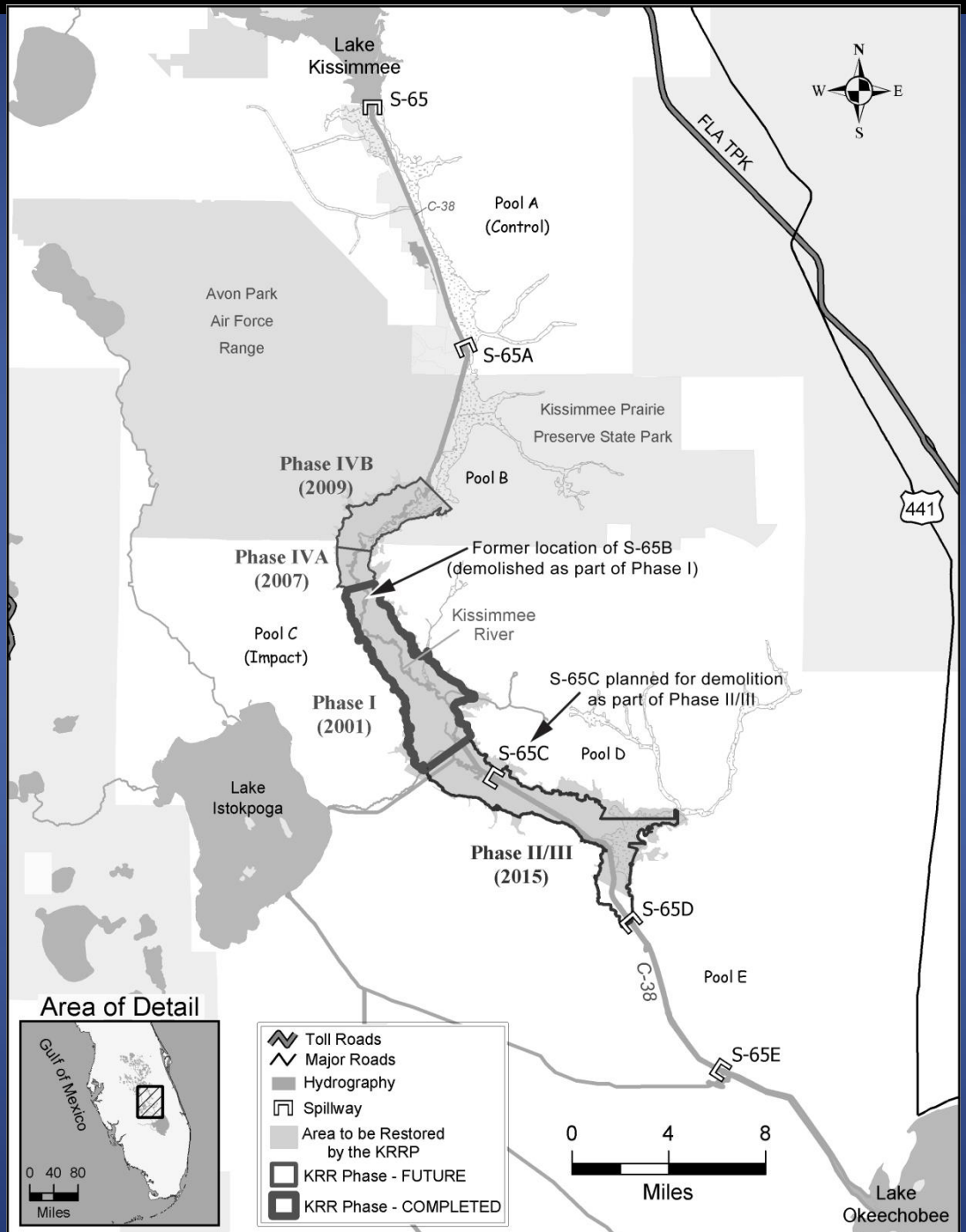
Intermission?

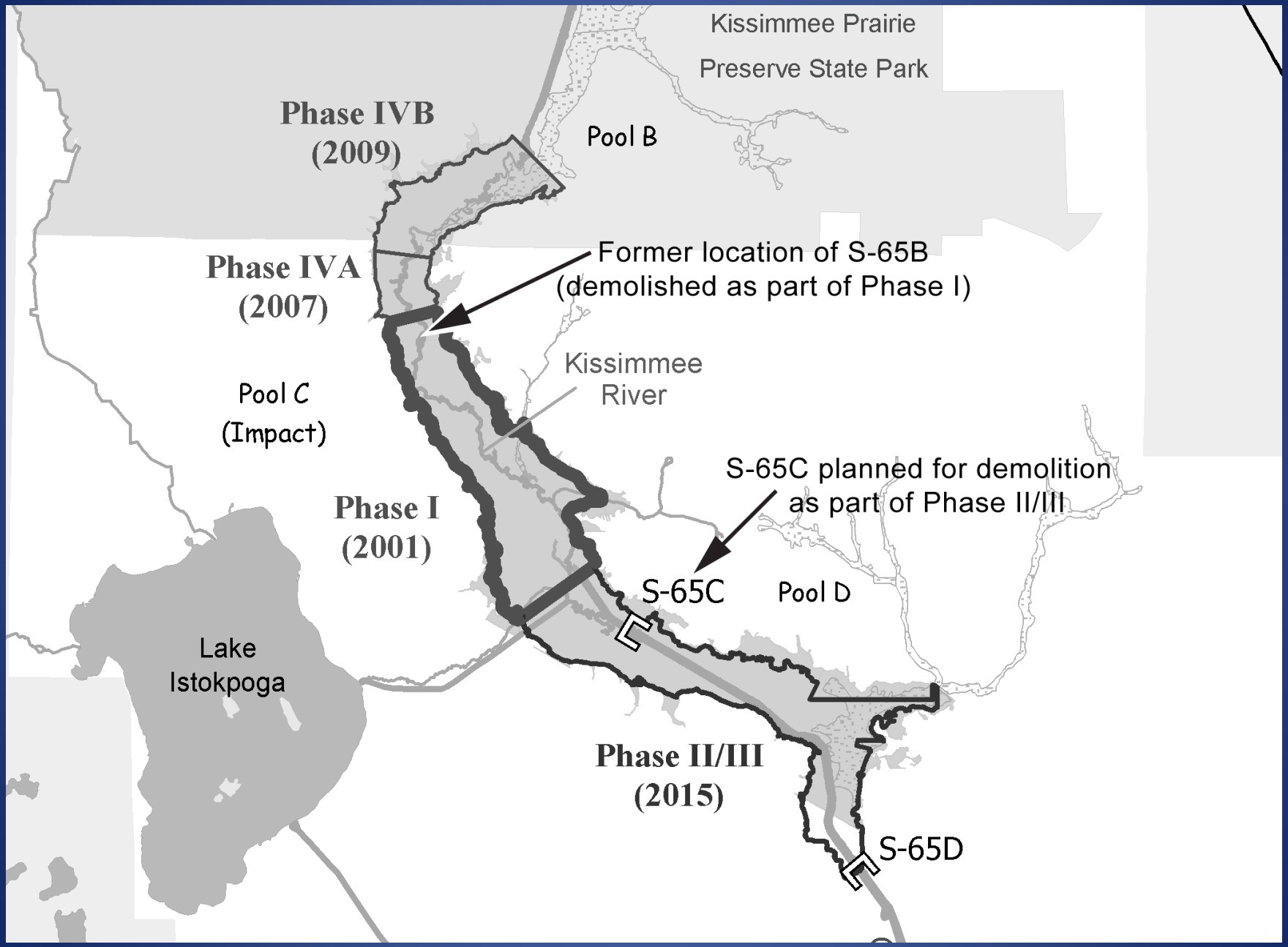
Kissimmee River Restoration Project Construction and Current Status

Recommended Plan

- Selected alternative:
  - Backfill about 1/3 of the canal's length,
  - Recarve obliterated river channels
  - Reconnect remnant channels
- This would restore flow to ~40 mi of continuous river channel and inundation to the floodplain in the central part of the Kissimmee Valley
  - While retaining existing levels of flood control
- Water volume and timing needed for restoration would be assured by changes in water regulation in the Upper Basin (the Headwaters Regulation Schedule)

SOUTH FLORIDA WATER MANAGEMENT DISTRICT

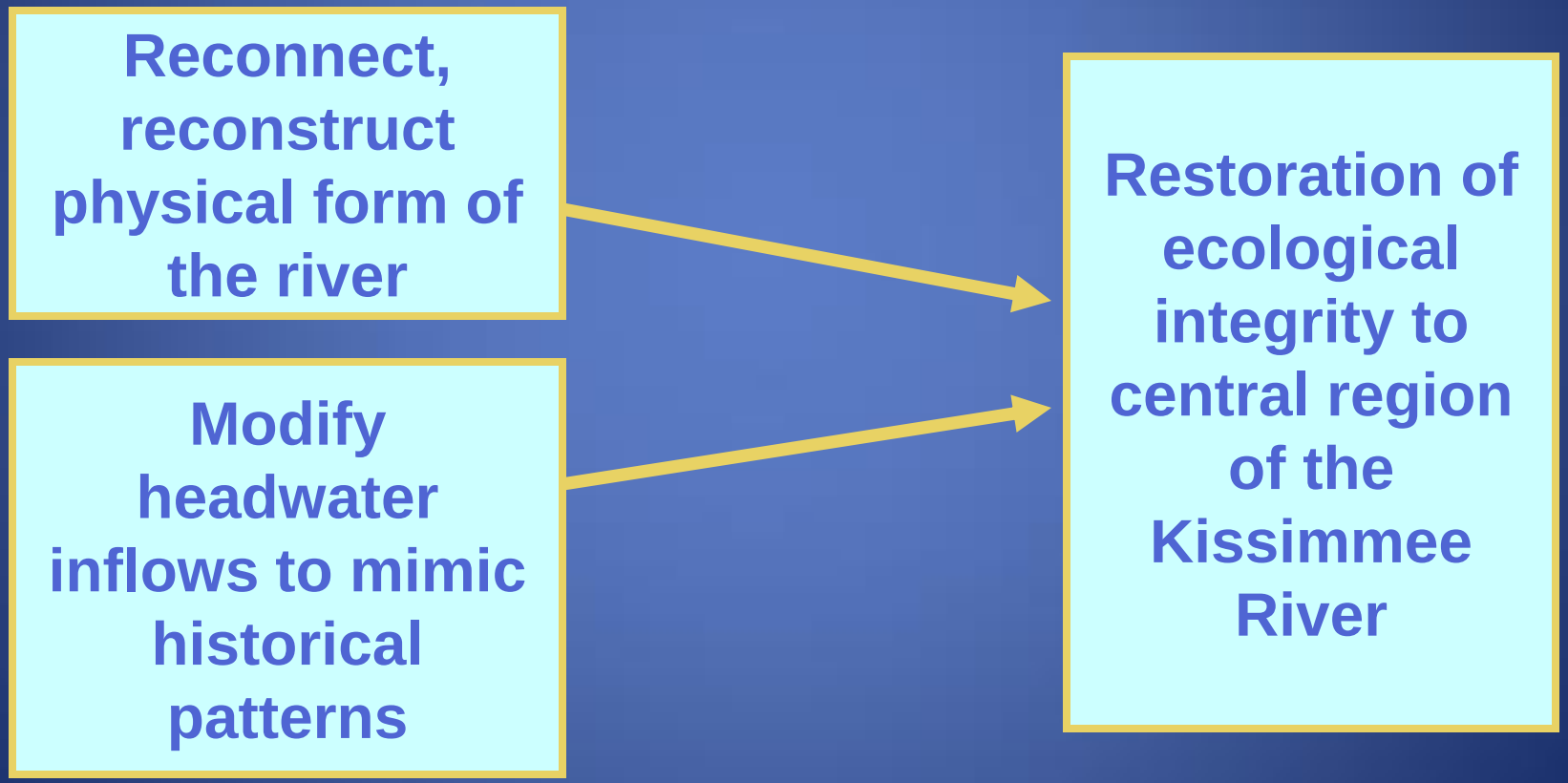



Kissimmee Prairie
Preserve State Park
Phase IVB
(2009)
Pool B
Phase IVA
(2007)
Former location of S-65B
(demolished as part of Phase I)
Kissimmee
River
Pool C
(Impact)
S-65C planned for demolition
as part of Phase II/III
Phase I
(2001)
S-65C
Pool D
Lake
Istokpoga
Phase II/III
(2015)
S-65D

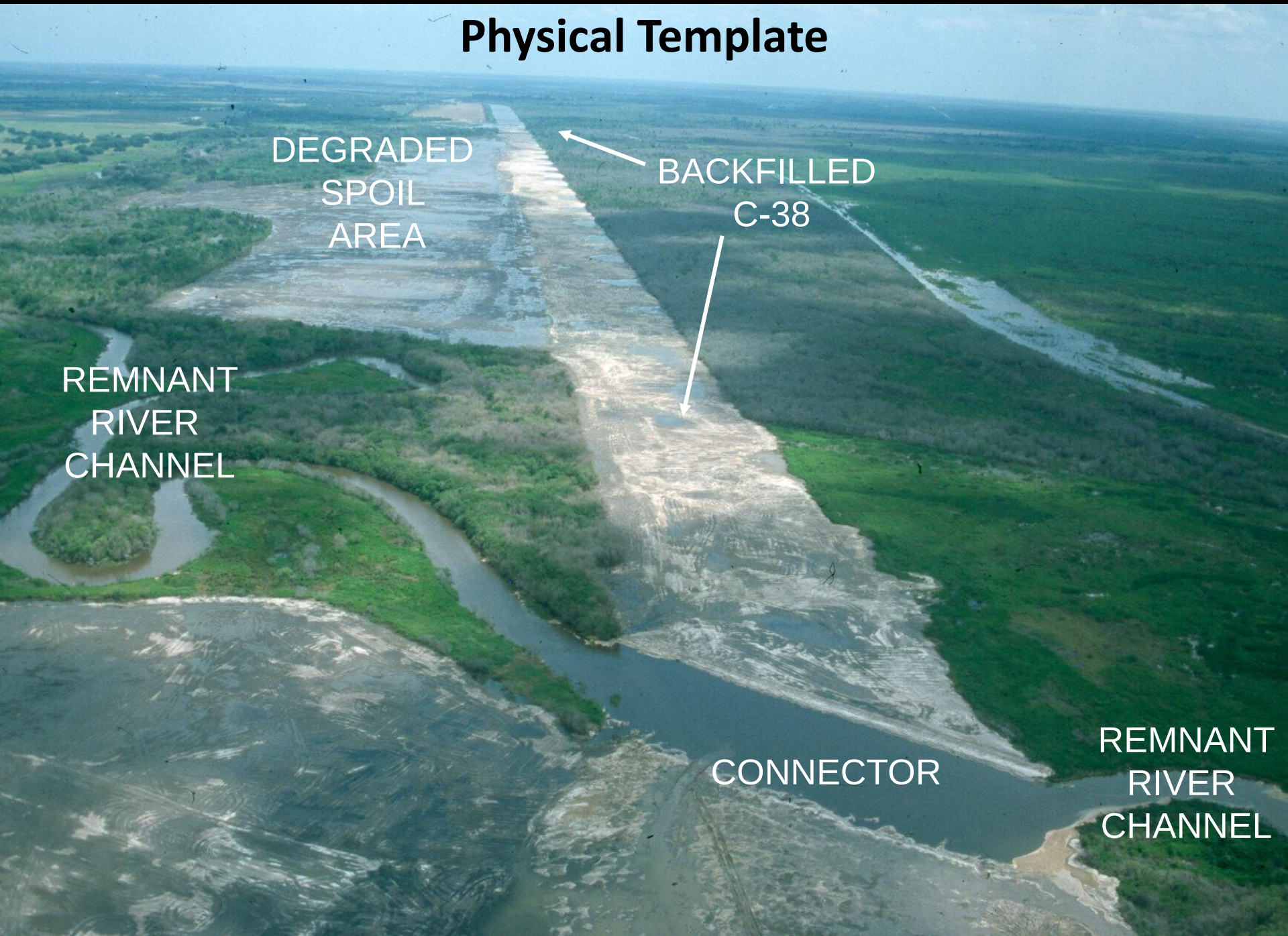
Restoration Approach

- Land acquisition in Lower and Upper Basin
- Reestablishment of the physical form of the river (backfilling, recarving, removal of structures) in four construction phases
- Canal and structure modifications in the Upper Basin to provide increased storage to provide volume and timing of water to the river
- Headwaters regulation schedule and adaptive operations to mimic historic hydrology
- Ecological monitoring for evaluation of the status and success of the project

Approach for the Kissimmee River Restoration Project

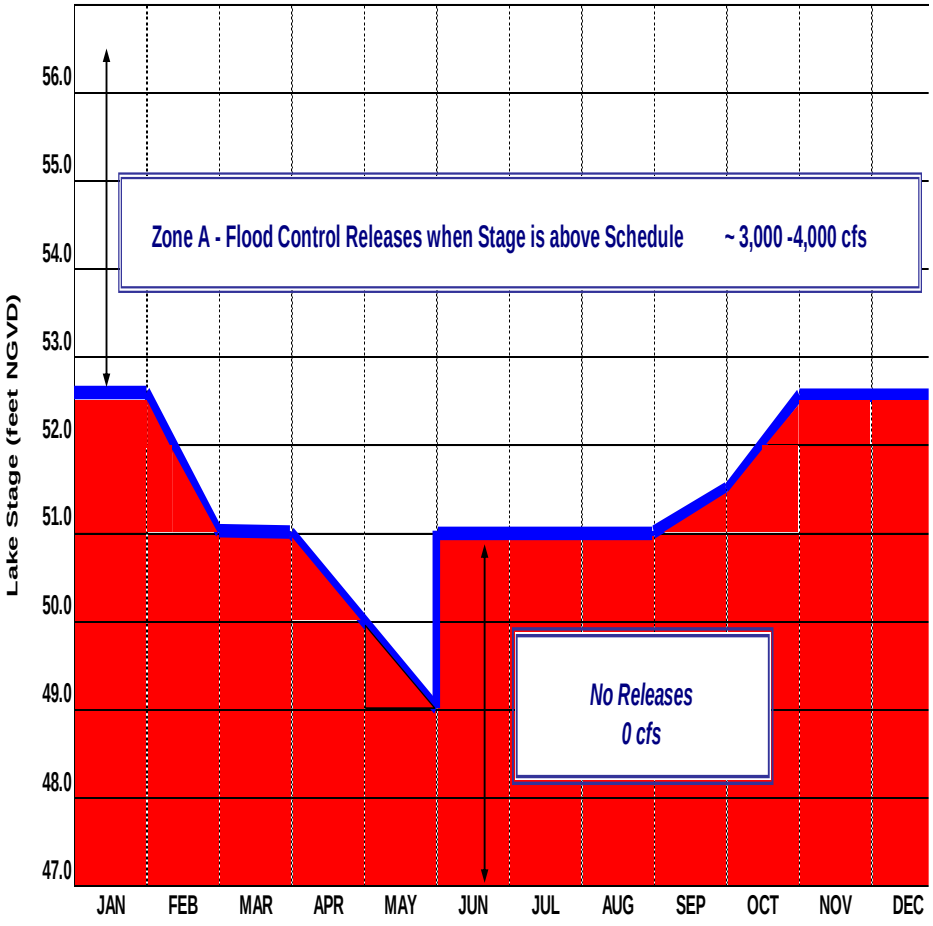


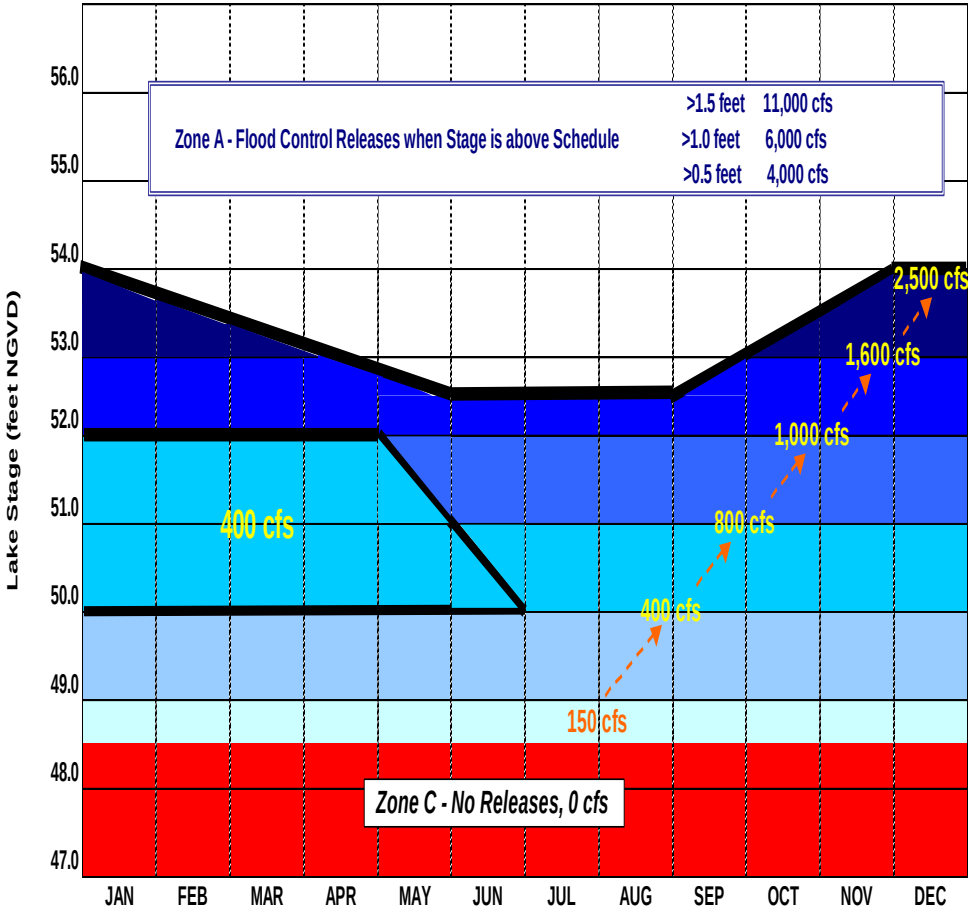
Physical Template



Operate the System to Mimic Natural Flow and Stage Patterns

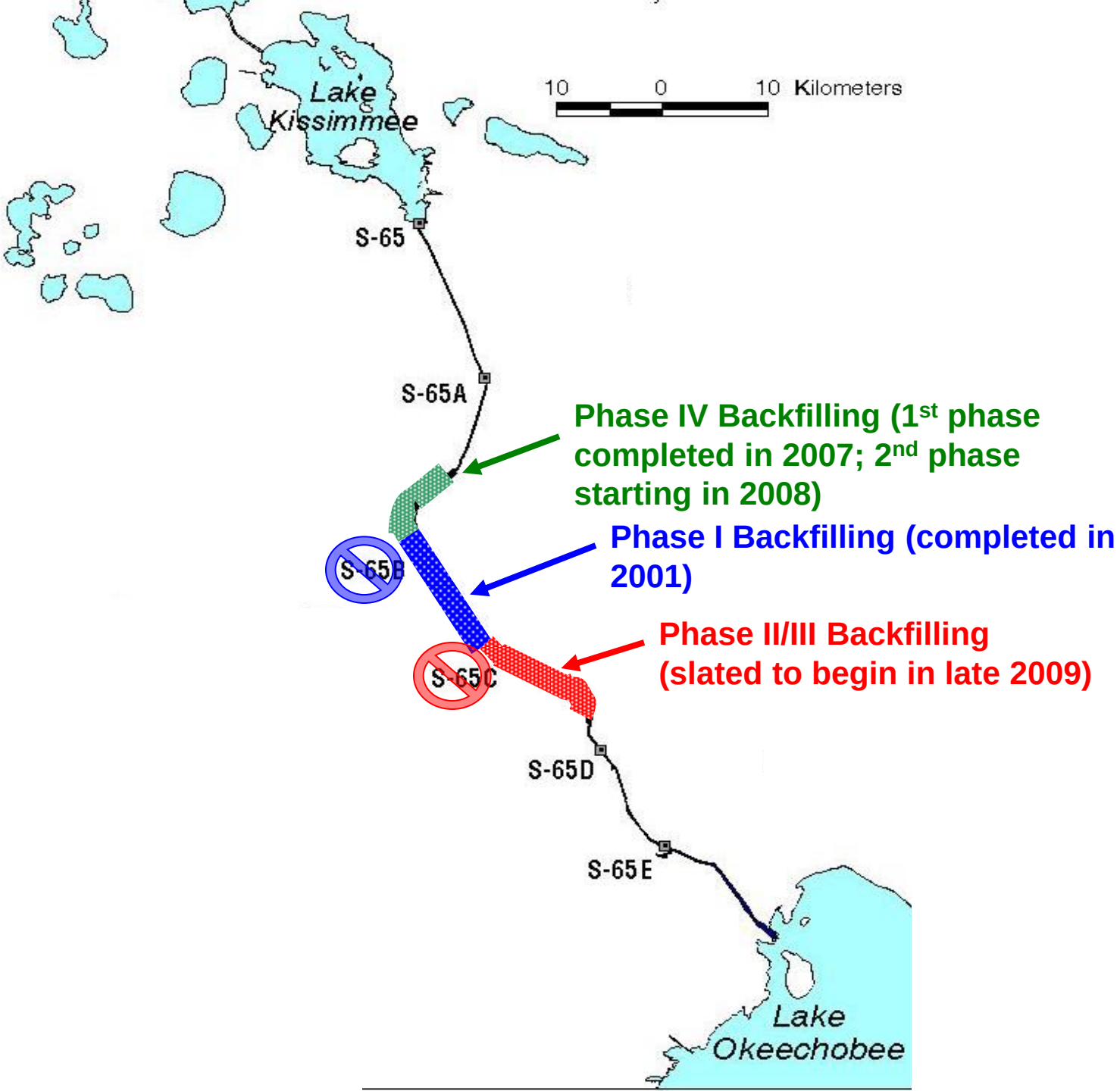
Changes in S-65 Regulation Schedule





Phased Construction

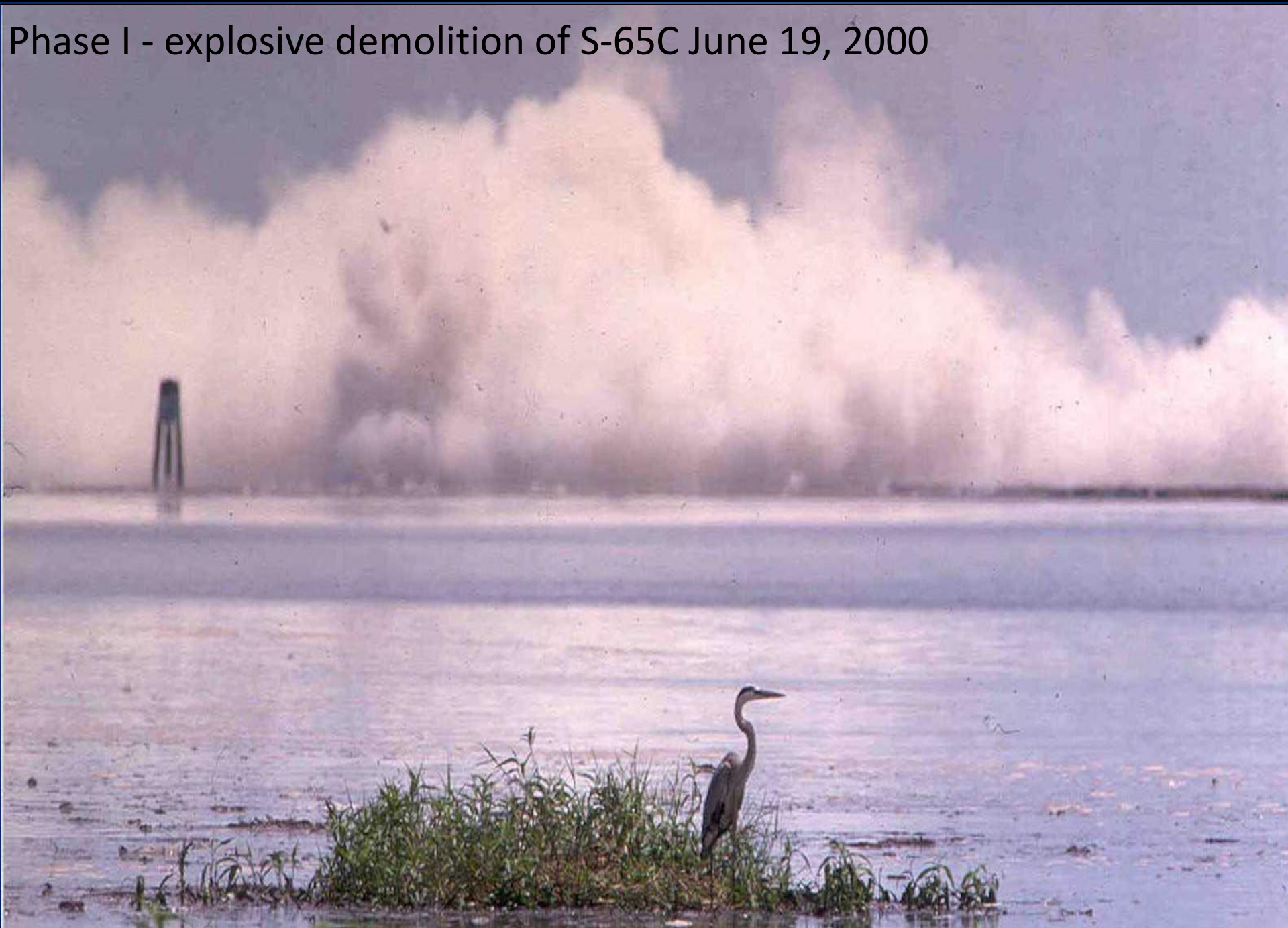
Construction Sequence	Name of Phase	Timeline	Miles of Backfilled Canal	Miles of River to Receive Reestablished Flow	Acres of Wetland to be Restored
1	Phase I	June 1999 - February 2001 (complete)	8	14	5793
2	Phase IVA	June 2006 - September 2007 (complete)	2	4	511
3	Phase IVB	June 2008 - December 2009 (projected)	4	6	1407
4	Phase II/III	October 2010 - September 2012 (projected)	9	16	4687
		Restoration Project Totals	**22**	**40**	**12398**

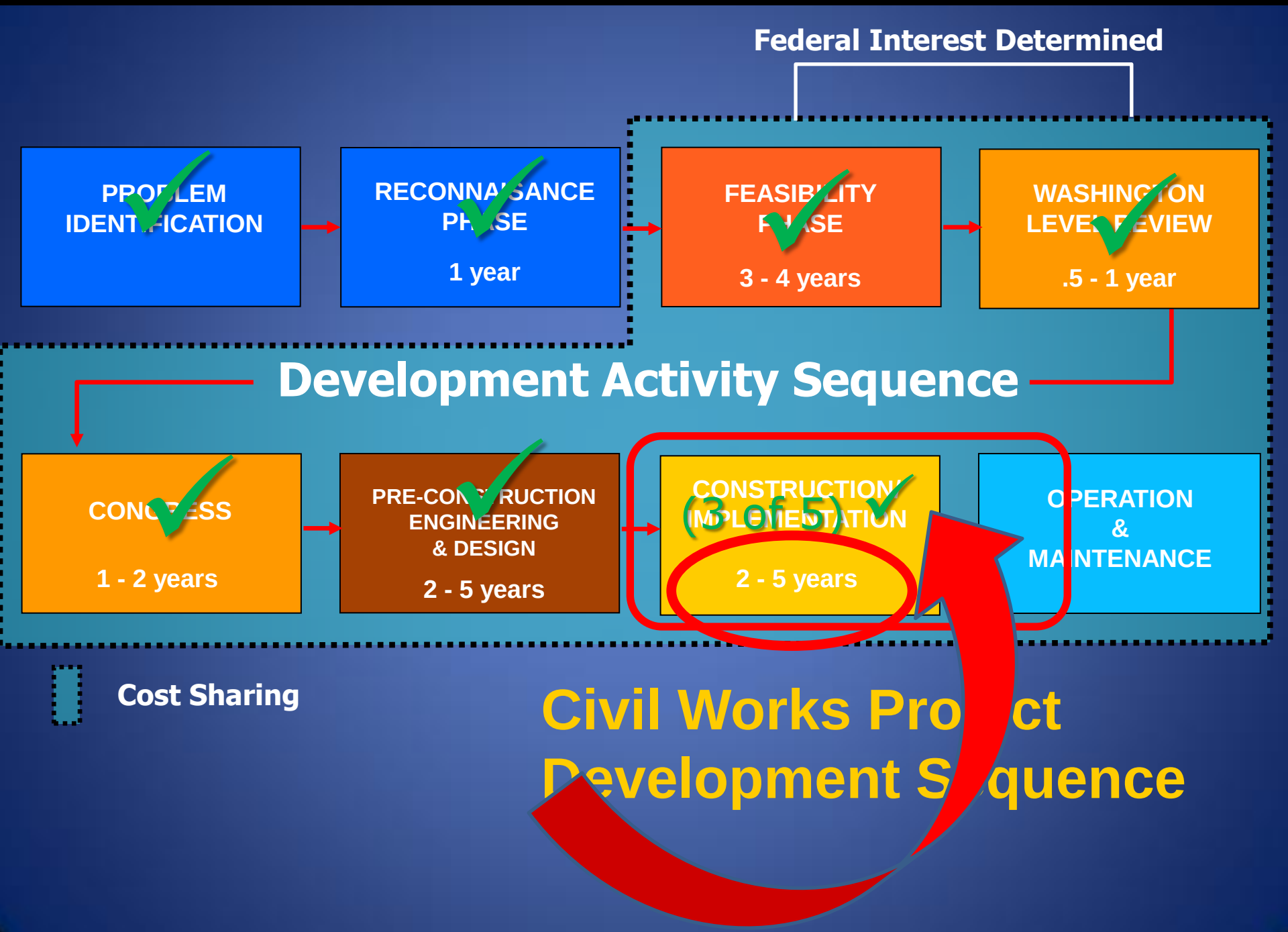

Lake Kissimmee
10 0 10 Kilometers
S-65
S-65A
S-65B
S-65C
S-65D
S-65E
Lake Okeechobee
Phase IV Backfilling (1st phase completed in 2007; 2nd phase starting in 2008)
Phase I Backfilling (completed in 2001)
Phase II/III Backfilling (slated to begin in late 2009)

Phase I Construction - backfilling of C-38

Phase I - hydraulic dredge carving new river channel

Phase I - explosive demolition of S-65C June 19, 2000




Federal Interest Determined
PROBLEM IDENTIFICATION
RECONNAISSANCE PHASE
1 year
FEASIBILITY PHASE
3 - 4 years
WASHINGTON LEVEL REVIEW
.5 - 1 year
Development Activity Sequence
CONGRESS
1 - 2 years
PRE-CONSTRUCTION ENGINEERING & DESIGN
2 - 5 years
CONSTRUCTION/ IMPLEMENTATION
(3 of 5)
2 - 5 years
OPERATION & MAINTENANCE
Cost Sharing
Civil Works Project Development Sequence

Kissimmee River Restoration Evaluation Program

Phase I Interim Response

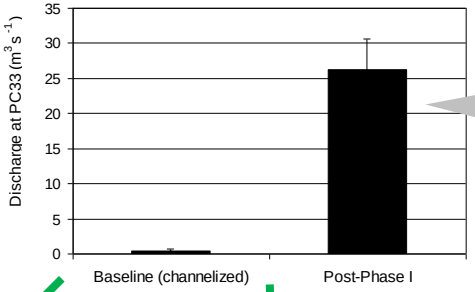
Kissimmee River Restoration Project (Lower Basin)

- Our mission: evaluation of the success of the project in meeting this goal
- . . . and the ongoing status of ecological response

Brief Timeline - Kissimmee River Restoration Evaluation Program (KRREP)

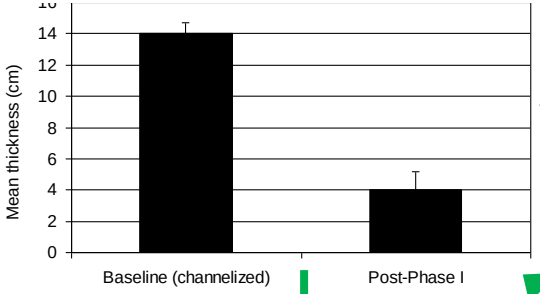
- 1995-1999: Baseline studies conducted in Phase I area
- 1995-1999: Development of restoration expectations
- 2001-2012: Ongoing monitoring of Phase I area
- 2005: Publication of two volumes of baseline (channelized-system) research and expectations
- 2007: Planning for Phase II/III evaluations starts
- 2012: Revised *KRRP Restoration Evaluation Plan*
- 2014: Special Section of *Restoration Ecology* on interim responses

In-channel flow (+)



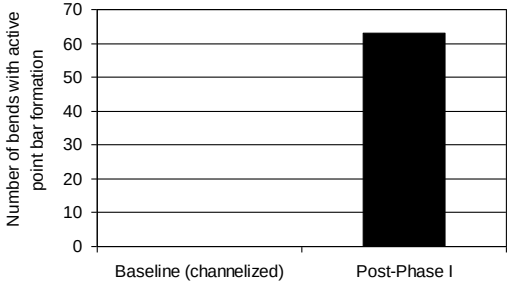
Restoration of flow in river channels

Organic layer thickness (-)

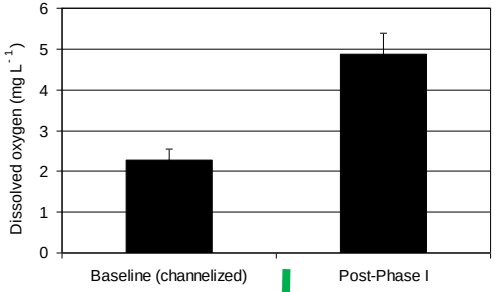


Habitat effects

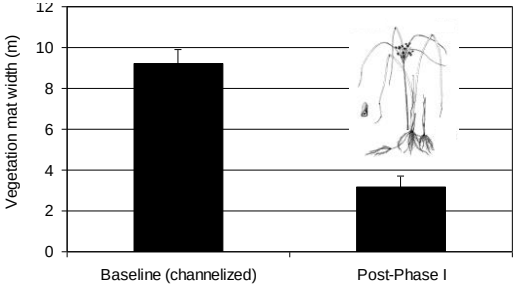
Sand bars (+)



Dissolved oxygen (+)



Vegetation mat width (-)

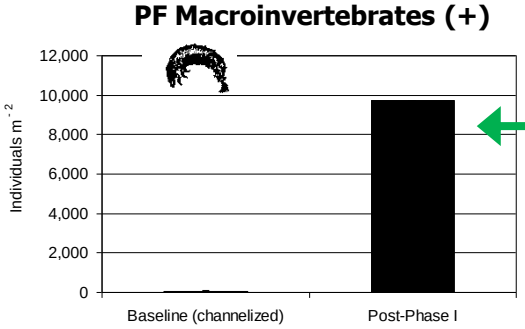


Hypothesized increases in aquatic invertebrates and shorebirds

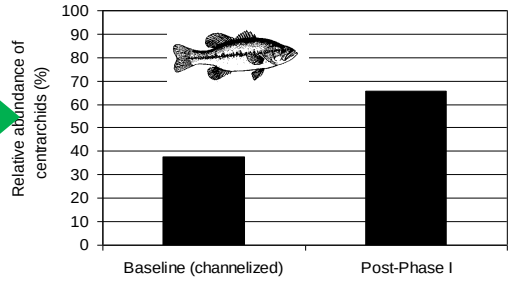
Effects on food web

Effects at higher trophic levels

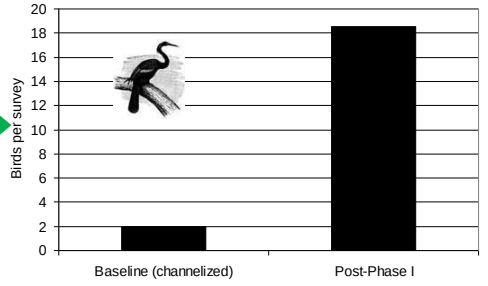
PF Macroinvertebrates (+)

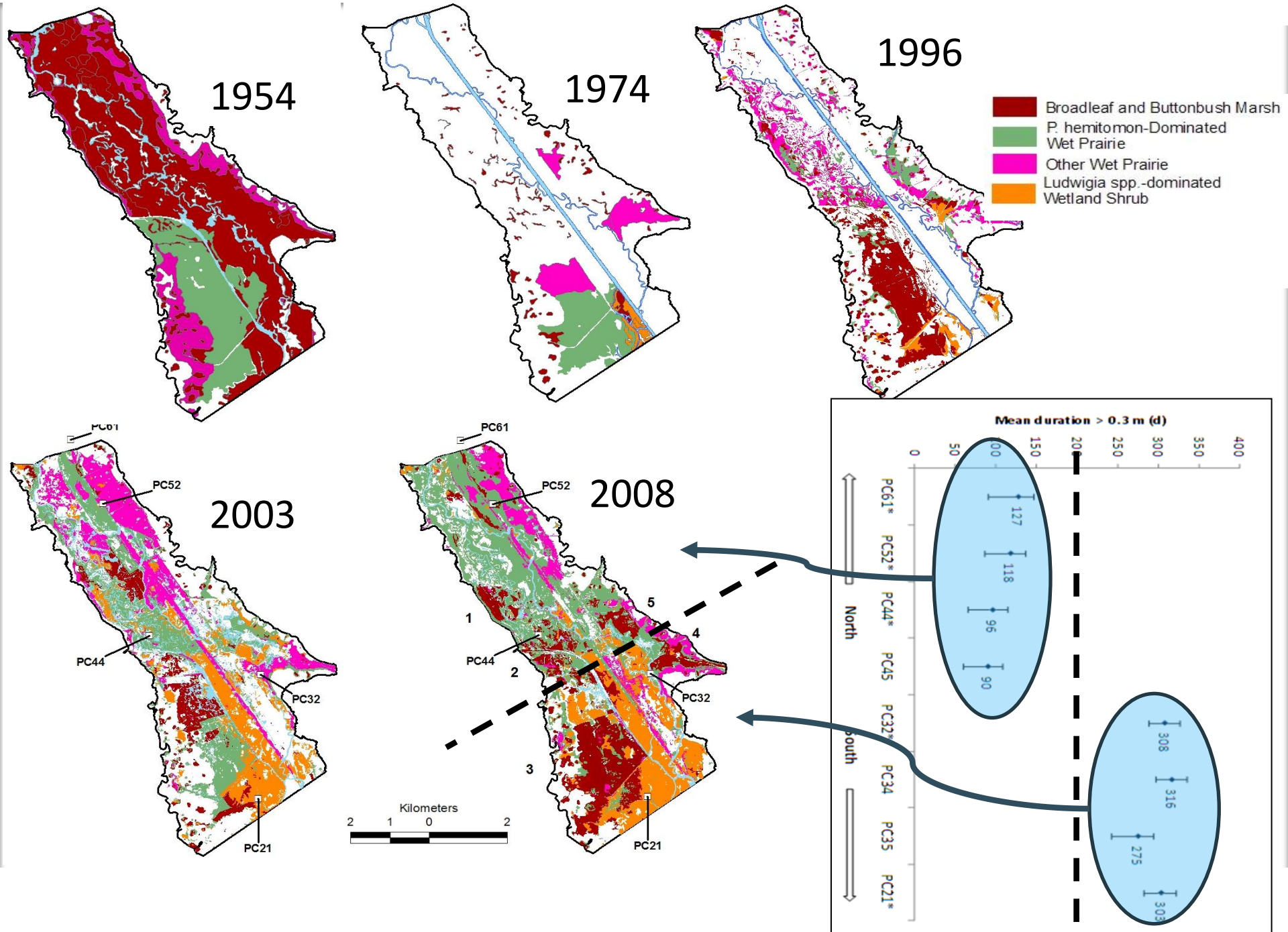


RA LMBA (+)



Swimming fisheating birds (+)




1954
1974
1996
Broadleaf and Buttonbush Marsh
P. hemitomon-Dominated Wet Prairie
Other Wet Prairie
Ludwigia spp.-dominated Wetland Shrub
2003
2008
PC61
PC52
PC44
PC32
PC21
1
2
3
4
5
Kilometers
2 1 0 2
Mean duration > 0.3 m (d)
0 50 100 150 200 250 300 350 400
PC61*
PC52*
PC44*
PC45
PC32*
PC34
PC35
PC21*
North
South
127
118
96
90
308
316
275
303

Summary of Phase I Responses

- KRRP is not complete yet, physically or hydrologically
- Phase I of the KRRP is showing good response to physical and partial hydrologic restoration, especially in the river channel
- “Interim” monitoring is a valuable tool to guide adaptive management, particularly under hydrologically incomplete conditions


Before


After


Before again

USACE Development Process

Jacksonville District Mission

Navigation

Shore Protection

Ecosystem Restoration

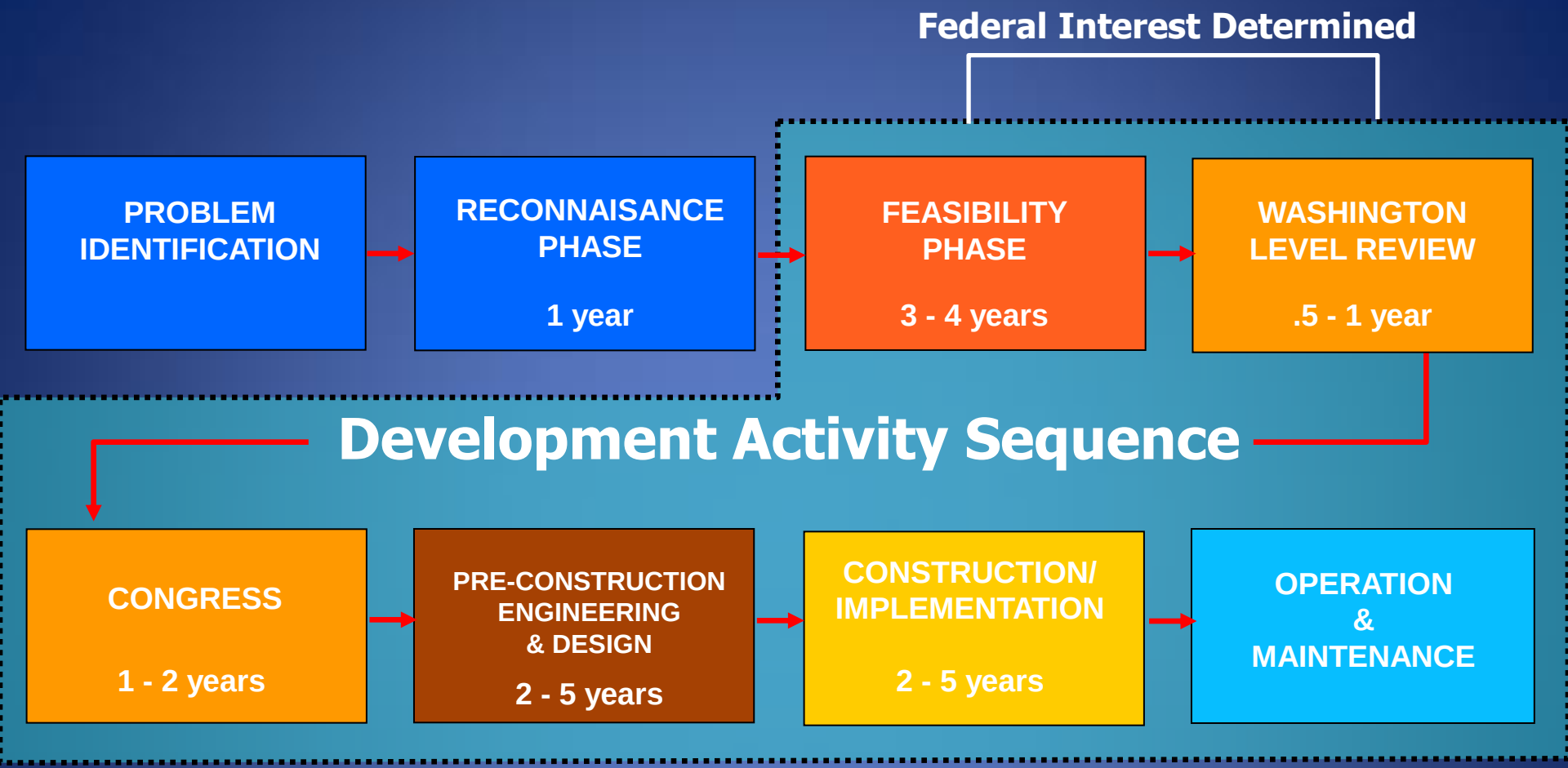
Regulatory

Flood Damage Reduction

Interagency and International Services (IIS)

Emergency Management

War on Terrorism



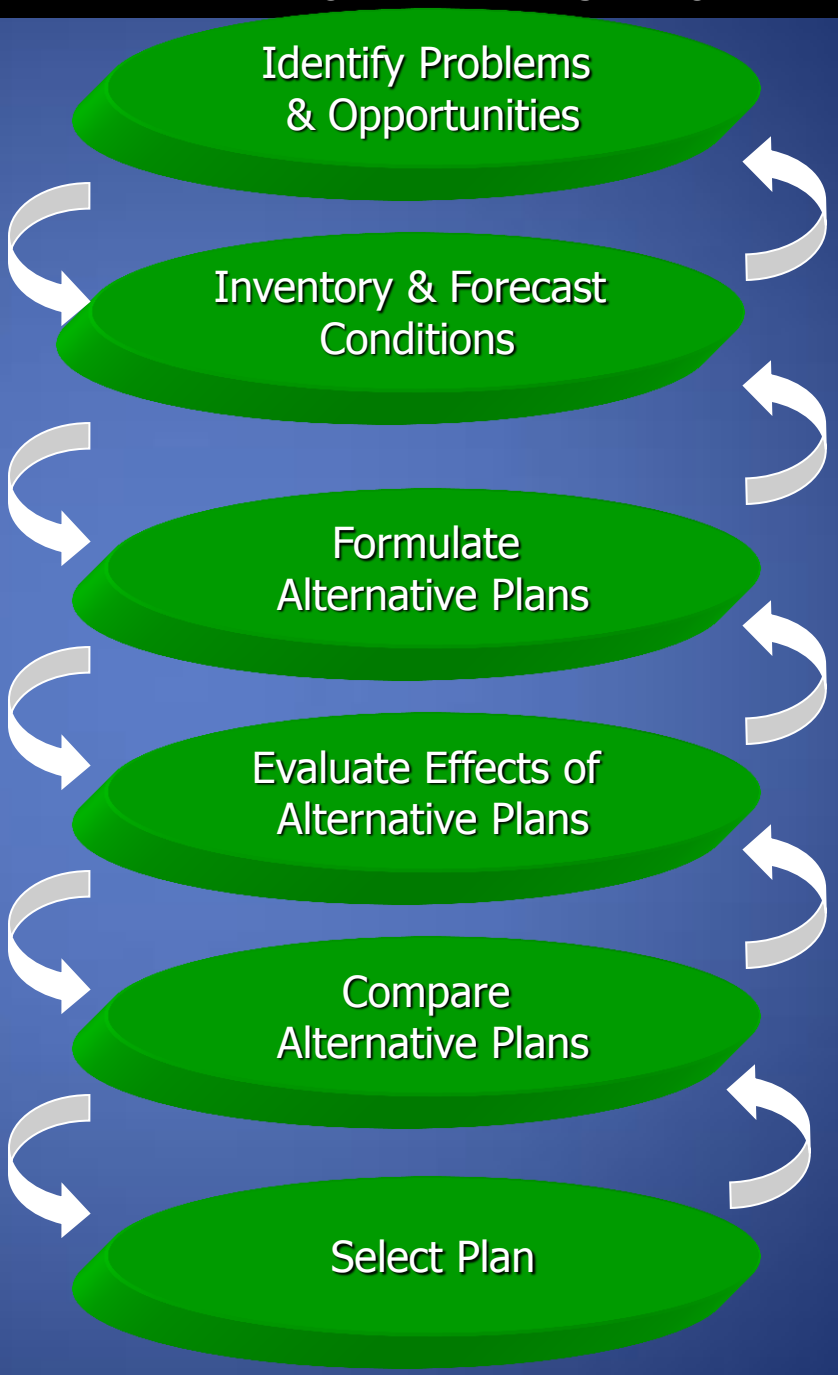
Civil Works Project Development Sequence

See *Planning Guidance Notebook*
http://140.194.76.129/publications/eng-regs/ER_1105-2-100/ER_1105-2-100.pdf

Feasibility Study Purposes

- Describe and evaluate alternative plans and fully describe the recommended plan
- Develop a fully-funded baseline cost of the project
- Feasibility Report serves as a Decision Document to convince the Office of Management and Budget (OMB) of project viability
- Feasibility Report is an Authorization Document and is submitted to Congress for project authorization

Feasibility Phase Planning Steps



Discussion Topics

- Project similarities
  - Balancing flood control and natural values
- Project differences
  - Urban/developed vs. rural
- What opportunities exist?

Resources

- CD of KRRP and KRREP documents
- SFWMD Web Page
- USACE Jacksonville web page
  - *Planning Guidance Notebook* http://140.194.76.129/publications/eng-regs/ER_1105-2-100/ER_1105-2-100.pdf

Thank You!

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Backup Slides

- 12 years since construction began
- Almost 40 years since first glimmers of restoration

Table 2. Timeline of legislation, planning studies, and other significant events related to the Kissimmee River Restoration Project.

Date	Event	Purpose	Result	Reference
1962-1971	Channelization of the Kissimmee River under C&SF Project for Flood Control and other Purposes	Provide flood control for central and southern Florida	Severe degradation of fish and wildlife values of the Kissimmee River	USACE 1956, Toth 1993, Koebel 1995
1971	Governor's Conference on Water Management in South Florida	Focused on water quality issues in south Florida	Formal recognition of environment concerns associated with the C-38 canal; provided consensus to restore fish and wildlife values of the Kissimmee River	USACE 1991
1976	Kissimmee River Restoration Act (Florida Statute 373.1965)	Created Kissimmee River Coordinating Council	Achieved consensus to restore hydrology and floodplain wetlands and create conditions favorable to increase production of wildlife, vegetation and aquatic life; stated broad goals for restoration that were later synthesized in the concept of ecological integrity	Koebel 1995
1978-1985	First Federal Feasibility Study	Evaluate feasibility of altering existing flood control system to improve water quality and enhance fish and wildlife resources	Did not recommend federal participation in project because initial plans projected no net economic benefit	USACE 1985, Koebel 1995
1984-1990	Kissimmee River Demonstration Project	Hydrologic and hydraulic monitoring studies to evaluate potential ecosystem responses to reestablished flow and floodplain hydroperiod	Responses indicated that restoration of ecosystem structure and function were feasible and sustainable	Toth 1993
1986	Water Resources Development Act (U.S. Public Law 99-662)	Authorized USACE to modify existing Corps projects to enhance environmental quality in the public interest and calculate the benefits of such enhancements as being equal to other costs	Removed barriers that prevented the First Feasibility Study from recommending federal participation	Woody 1993, USACE 1991
1990-1991	Second Federal Feasibility Study	Determine the extent of federal participation	Recommended backfilling plan as most appropriate method for reestablishing ecological integrity to the Kissimmee River ecosystem	USACE 1991
1992	Water Resources Development Act (U.S. Public Law 102-580) (Federal)	Reauthorized USACE civil works construction programs and provided for the "conservation and development of water and related resources"	Authorized restoration of the Kissimmee River	USACE 1996
1994	Test-fill construction	Assess construction methodology and potential environmental impacts of backfilling	Finalized construction methodology and concluded there were no long-term impacts to water quality resulting from backfilling plan	Koebel et al. 1999, Colangelo and Jones 2005
1994	Project Cooperation Agreement	Create partnership between USACE and SFWMD	Authorized 50/50 cost share between federal government and state of Florida; defined specific roles and responsibilities of partners	
199x-1999	Baseline data collection in Phase I restoration construction area	Baseline data collection on physical, chemical and biological properties for Phase I restoration evaluation	Implementation of detailed studies designed to collect baseline data to monitor status and evaluate physical, chemical and biological responses to the Kissimmee River Restoration Project	
1999-2001	Phase I restoration construction	Backfill 12.8 km of canal, recarve 1.6 km of river channel	Reestablished 22.4 km of river channel and increased wetlands by 2345 ha	Whalen et al. 2002
2005	Publication of results of baseline restoration evaluation studies and performance measures	Described and compared physical, chemical and biological characteristics of the channelized Kissimmee River and floodplain with pre-channelized condition; predicted outcomes of restoration based on formal restoration expectations.	Results of baseline research; analyses describing the effects of channelization; publication of restoration expectations	Bousquin et al. 2005, Anderson et al. 2005
2007, 2009	Construction Phases IVA and IVB completed (Phase numbers are not sequential).	Smaller phases of construction upstream of Phase I.	Construction monitoring only.	Jones et al. 2010
		Baseline data collection for physical, chemical, and		

5 Hydrologic Criteria

- Continuous flow with duration and variability comparable to pre-channelization periods
- Average flow velocities between 0.8-1.8 ft per second, when flow within bank
- Stage discharge relationship resulting in overbank flow >1400 ft^2/sec and >2000 ft^2/sec
- Stage recession rates on floodplain <1 ft/month
- Floodplain inundation comparable to historic hydrographs

5 Hydrologic Expectations

1. The number of days that discharge is equal to 0 m^3/s in a water year will be zero.
2. Intra-annual monthly flows will reflect historic seasonal patterns and have intra-annual variability (coefficient of variation) < 1.0.
3. River channel stage will exceed the average ground elevation for 180 days per water year and stages will fluctuate by at least 1.14 m.
4. An annual prolonged recession event will be reestablished with an average duration of >173 days and with peak stages in the wet season (June-October) receding to low stage in the dry season (November-May) at a rate that will not exceed 0.30 m per 30 days.
5. Mean velocities within the main river channel will range from 0.2 m/s to 0.6 m/s a minimum of 85% of the year (Chamberlain 2005c).

New and Revised Slides

Public Concerns

- As a result of the study's extensive public involvement efforts, and the findings and conclusions of numerous previous studies and reports, a list of public concerns about the Kissimmee River Basin was developed. These concerns were:
  - Loss of naturally fluctuating water levels.
  - Loss of large areas of wetlands.
  - Deterioration of water quality in Lake Okeechobee and its tributaries.
  - Changes in land use resulting in increased drainage.
  - Loss of the natural meandering and braided river.
  - Lower groundwater levels and degraded groundwater quality.
  - Potential need for increased flood protection.
  - Potential reduction in frost protection.
  - Potential increases in mosquito populations.
  - Reduced recreational navigation opportunities.

Public Concerns => Planning Objectives (1991 IFR)

- These concerns were subsequently evaluated and restated as the study's planning objectives, and provided the basis for identifying management measures that could help to achieve their intents. Some public concerns, such as frost protection, were impact evaluation criteria rather than bases for planning objectives, and were therefore included in later evaluation activities.
- The resulting planning objectives focusing on restoring lost environmental values of the Kissimmee River were:
  - Restore wetland areas.
  - Improve water quality.
  - Restore river meanders and oxbows.
  - Improve groundwater recharge.
  - Maintain flood protection.
  - Restore fluctuating water levels.
  - Provide surface water supply.
  - Maintain navigation.
  - Meet recreational demands.

Evaluation of State's Preferred Alternative (Backfilling)

- In response to the Governor's Executive Order 83-178 and the Seven Point Plan, the SFWMD undertook a series of activities designed to test and evaluate the State's preferred alternative of backfilling C-38.
- The SFWMD work drew from data and findings of the first Corps' feasibility study, and was the next step in developing a recommended plan for restoration of the Kissimmee River. The principal study efforts and milestones during this period were:
  - Demonstration Project (1984-1989),
  - Model Study (1986-1989),
  - Kissimmee River Restoration Symposium (1988),
  - Restoration Report (1990).

Demonstration Project Description

- Weirs
- Three sheet pile weirs located in C-38 were installed to divert some of the canal flow through three abandoned river channels. Under normal and low flow conditions the navigation notch will carry some canal flow whereas for high flows the weirs function under completely submerged (both notch and the crest) conditions. Both headwater and tailwater elevations are monitored continuously.

- Flow Through Marsh Features
- Several structural features are designed to re-create sheet flow in the floodplain. The installation of a two-barrel, 72 inch slide gate structure in the tieback levee east of S-65A (Culvert No.5 in Figure I) is designed to discharge water from Pool A (above Pool B) into the northeast section of the floodplain in Pool B. An 8000 foot separation ber¢ constructed along the east edge of C-38 prevents the flow from short-circuiting back to C-38. The sheetflow combined with local inflow will enter C-38 via the east oxbow upstream ofWeir-3.
- A second feature in the form of a culvert installed at the north end of Air l"orce spoil pile (Culvert immediately above Weir-3) will provide a hydraulic connection and introduce flow in to the Avon Park Bombing range (U.S. Air Force) in the western half of Pool B. Similar improvements to sheet flow were made in the Boney marsh area in the southwest corner of Pool B.

- Pool Stage Manipulation
- Another component in the Phase-I Demonstration Project is the fluctuation of water levels to more closely mimic natural wet and dry cycles typical of the pre-project Kissimmee floodplain hydroperiod. The original flood control project called for holding water levels in Pool B at 40 feet m.s.l throughout the year, Under pool stage manipulation, initiated in September of 1985, the water levels are fluctuated in the range 39-42 feet NGVD (with a drawdown to 38 feet every 3 to 5 years). The
- higher water levels induced an estimated 1300 acres of wetlands integrated in to the riverine system.

Demonstration Project - Wiers

- Weirs
- However, the weirs appear to divert a larger fraction of the C-38 flow to the oxbows and floodplain during high C-38 flow than for low C-38 flow. This behavior is not desirable from environmental or flood protection perspectives.
- It is desirable for the oxbows to receive the majority of the average and low flows in order to restore their environmental function. But it is also desirable for the C-38 canal to carry the majority of the high flows in order to preserve the flood protection for the upper basins.
- For a two year period during the Phase I Demonstration Project, the median daily flow in the original river was restored to 600 cfs, 350 cfs, and 350 cfs for the river segments near Weirs-1, 2, and 3, respectively, This restored flow was less than the average daily flow experienced in the river before the construction of C-38; however, it was a significant improvement over the near-zero flow that resulted after the construction ofC-38.

Demonstration Project: Conclusions

- In summary, the Demonstration Project clearly showed that restoration of the ecological integrity of the Kissimmee River ecosystem can be accomplished, but only if certain physical, chemical and hydrologic characteristics are reestablished in the river and flood plain.
- The studies established that a successful restoration plan must include measures that will restore the following characteristics of the pre-channelization system which were altered by the flood control project:
  - inundation frequencies,
  - spatial and temporal patterns of inundation,
  - stage recession rates
  - water depths on the floodplain,
  - river channel velocities,
  - dissolved oxygen regimes,
  - temporal discharge characteristics and variability
  - Hydraulic connectivity between the river and floodplain and continuity of river and floodplain habitat.

Physical Model Findings

- Kissimmee River sedimentation and river mechanics questions were addressed by a three-year physical and mathematical modeling study by the University of California at Berkeley.
- The model drew from the Demonstration Project, and helped in developing and evaluating an array of alternative restoration plans. A major study finding was that soil backfill placed in C-38 can be stabilized to resist erosion by major flood flows.
- Other findings indicated
  - that mass transport of sediment to Lake Okeechobee would not occur,
  - that remnant canal sections can severely limit restoration efforts by causing
    - high velocities in original river channels, rapid recession of flood plain
    - water levels, and inadequate flood plain inundation.

Restoration Symposium

- 8.3 **KISSIMMEE RIVER RESTORATION SYMPOSIUM**
- The State's Kissimmee River environmental restoration goals and objectives were formulated at the Kissimmee River Restoration Symposium conducted by the SFWMD in October 1988. Over 150 participants gathered in Orlando to consolidate knowledge developed since the early 1970's, with a focus on work conducted since 1983.
- The symposium emphasized that lost Kissimmee River values were dependent upon complex environmental attributes, including numerous physical, chemical and biological processes, dynamics of intricate food webs, and an array of river and flood plain habitat characteristics and interactions. The symposium's ecological review panel concurred with participating scientists that reestablishment of lost ecological values would be achieved only with a holistic, ecosystem restoration perspective.
- As an outcome of the symposium, Kissimmee River restoration became focused on the ecosystem and its emergent properties, rather than individual or discrete biological components. Based upon these guidelines and the impacts of channelization on the form and functioning of the Kissimmee River ecosystem (Le., habitat and hydrologic determinants of ecological integrity), the primary restoration objective became to reestablish pre-channelization physical form and hydrologic characteristics in as much of the river and flood plain ecosystem as

Thanks to

- Tiphanie Jinks, USACE

TABLE 34
BASELINE AND FULL FUNDED PROJECT COST ESTIMATES

Feature Account	Baseline[1]	Full Funded[2]
02-Relocations	$8,266,000	$10,302,000
09-Channel and Canals	229,794,000	396,510,000
SUBTOTAL	$238,060,000	$406,812,000
01-Lands and Damages	116,946,000	141,237,000
30-Planning, Engineering and Design, Monitoring and Test Fill	43,854,000	80,218,000
31-Construction Management	23,807,000	54,733,000
TOTAL PROJECT COST	$422,667,000	$683,000,000

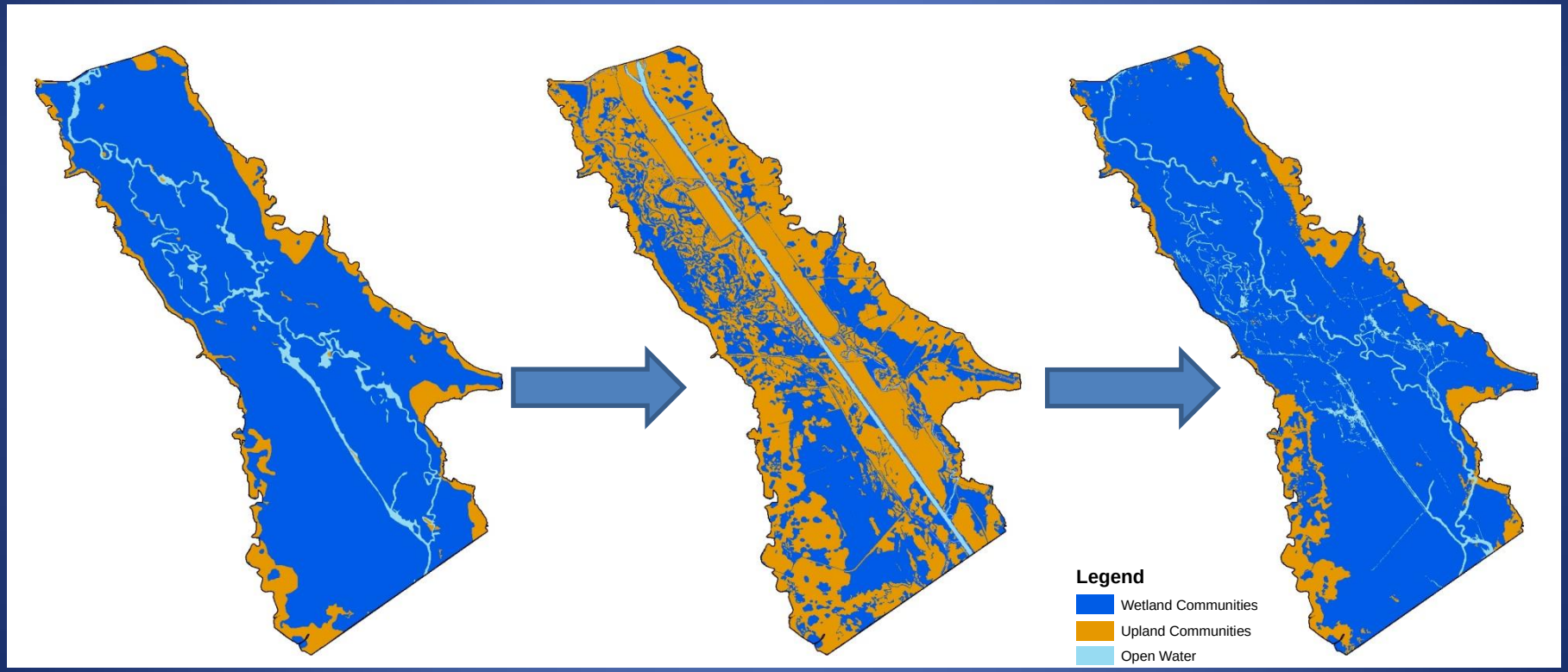
1/ Baseline construction cost estimate prepared using Corps of Engineers M-CACES system.
2/ Full funding estimate, assuming unconstrained Federal and non-Federal spending.

TABLE 7-1
REGULATION SCHEDULE ALTERNATIVES
(See Figures in Appendix F.)

ALTERNATIVE	OPERATION RULES
RS1 (SFWMD 1990 AND 1991 FEASIBILITY STUDY SCHEDULE)	Three discharge zones bounded by an upper flood control regulation zone when lake stages exceed 52.5-54 ft and a lower no discharge zone when lake stages are < 48.5 ft. Within this envelop no discharges are made during March; during other months discharges either vary according to the historic (pre-regulation) stage-discharge relationship or are maintained at 250 cfs, depending upon lake stages.
RS1-A	Same as RS1 with slight modifications to historic stage-discharge rating curve.
RS1-B	Same as RS1 without March no discharge zone.
RS2	Same discharge zones as RS1-B except upper flood control regulation zone is bounded by existing regulation schedule elevations.
RS3	Same as RS1-B with slightly higher flood control envelop during May.
RS4	Same as RS3 except 250 cfs zone changed to 400 cfs zone.
RS5	Two discharge zones bounded by the same flood control and lower no discharge zones as RS4. Within this envelop discharges are maintained at 250 cfs when lake stages are < 51.68 ft or unregulated flow as lake stages overtop a weir with a fixed crest of 51.68 ft.
RS6	Two discharge zones bounded by the same flood control and lower no discharge zones as RS4. Within this envelop discharges are maintained at 150 cfs when lake stages are < 49 ft or vary according to a new outlet rating curve (RC-A rating curve from Appendix F).
RS7	Same as RS6 with the addition of a 400 cfs discharge zone when lake stages fall within designated ranges during November-May.
RS8	Same as RS6 with a different stage-discharge rating curve (RC-B rating curve from Appendix F).
RS9	Same as RS6 with the addition of a 400 cfs discharge zone that occurs at different lake stages than the RS7 400 cfs discharge zone

Floodplain Vegetation Response

Wetland vs. Upland



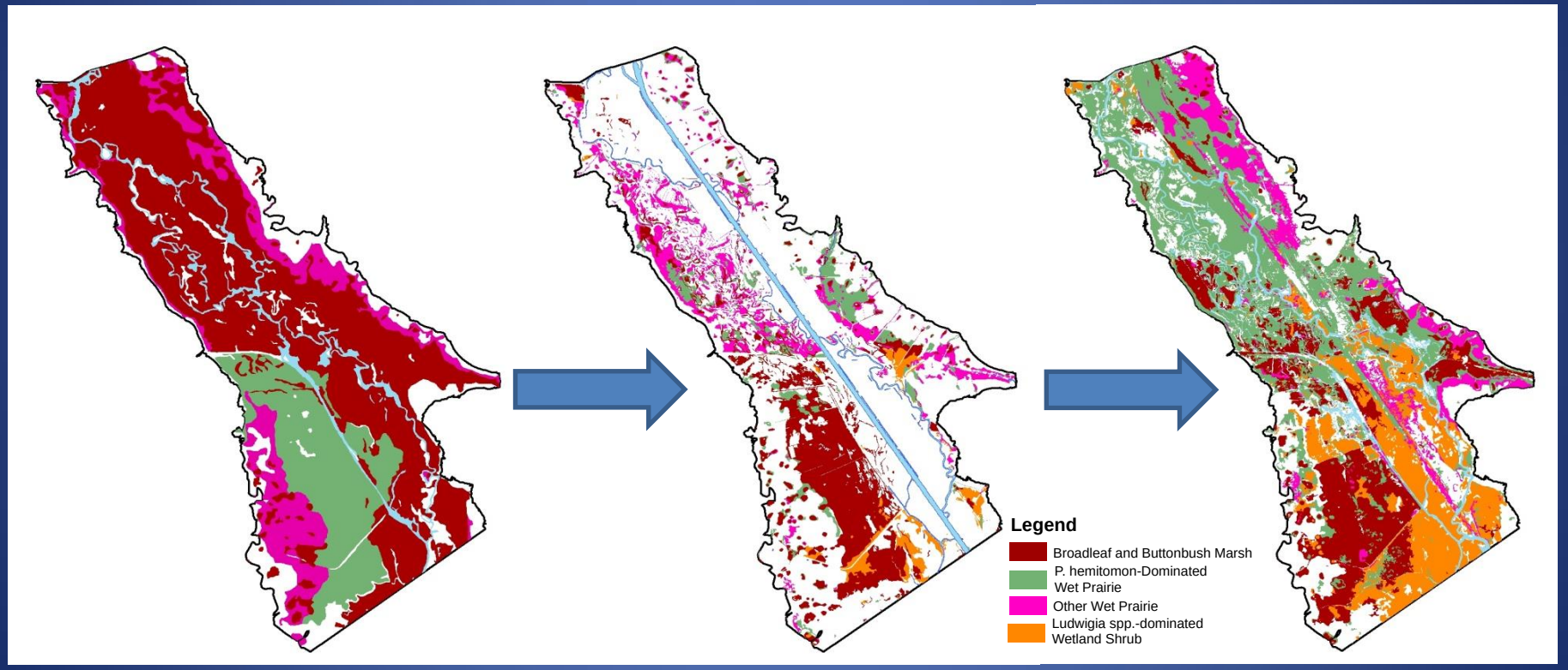
Pre-channelization (1952-1954)

Channelized (1996)

Post-Construction (2008)

Floodplain Vegetation Response

Relative Abundances of Wetland Community Types



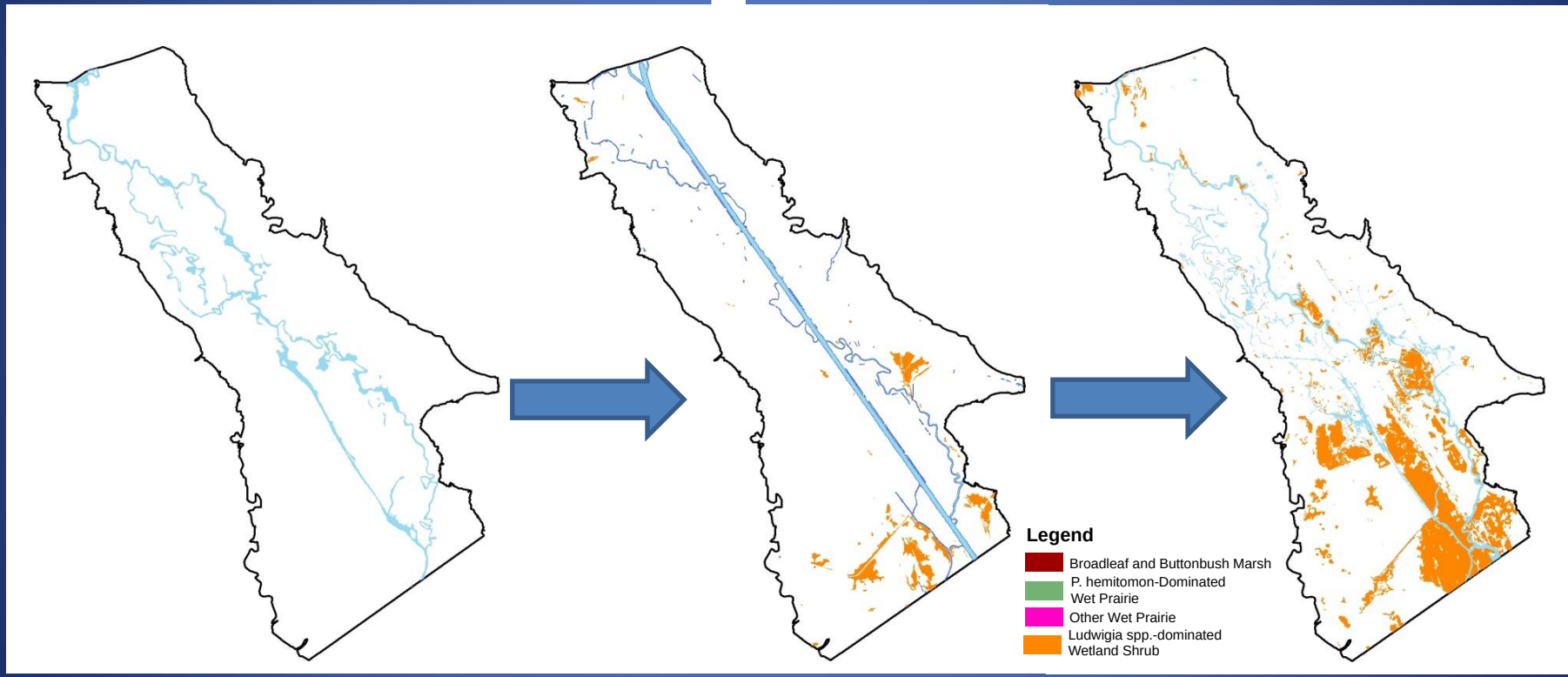
Pre-channelization (1952-1954)

Channelized (1996)

Post-Construction (2008)

Floodplain Vegetation Response

Increased Invasive Shrub Community



Pre-channelization (1952-1954)

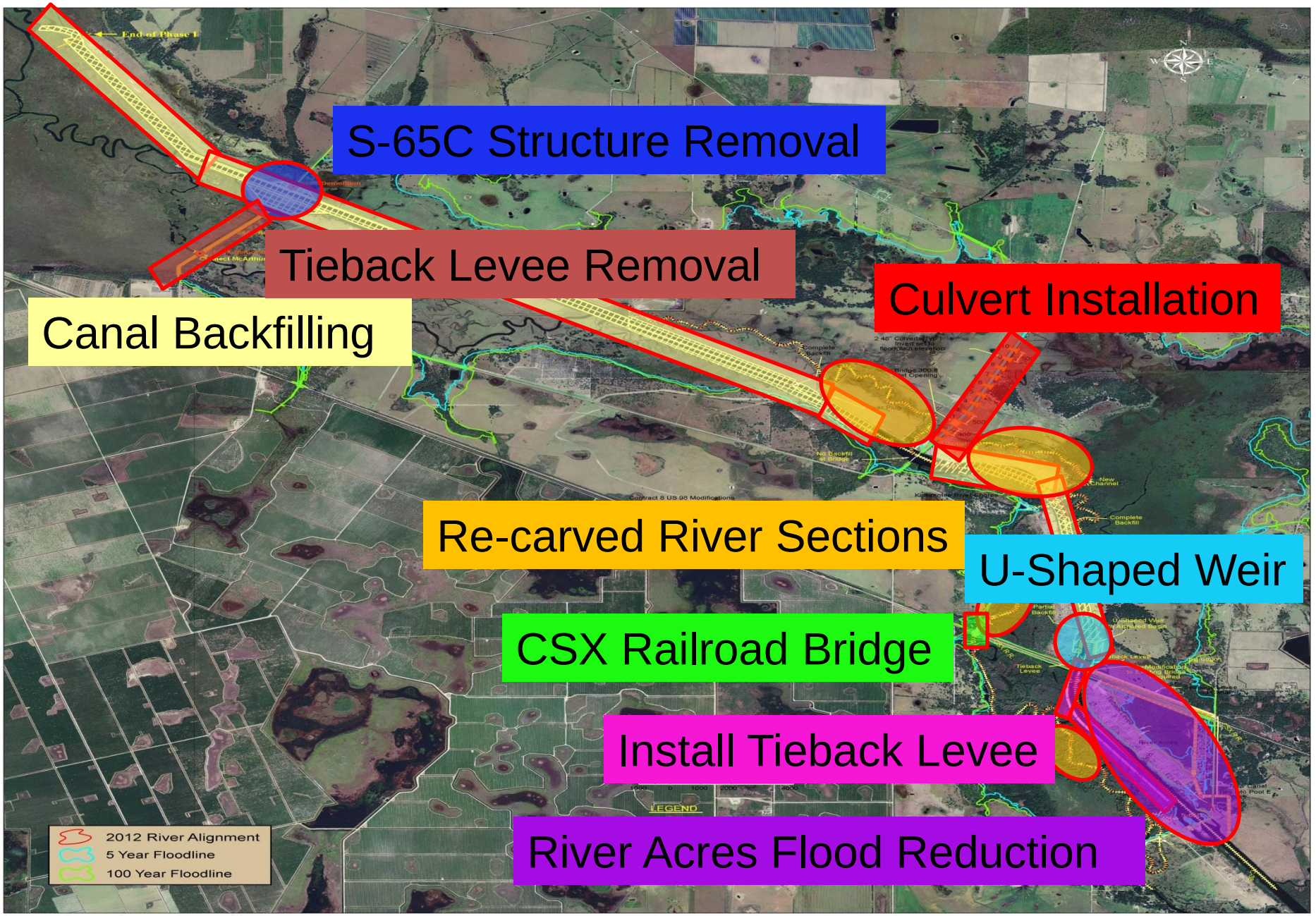
Channelized (1996)

Post-Construction (2008)

DRAFT

Phase II/III ~ Pool C and D Construction Features

DRAFT



0 0.5 1 Miles

N

0 0.5 1 Kilometers

The Pool D Construction Features were provided by the U.S. Army Corps of Engineers. Imagery data provided by the South Florida Water Management District (SFWMD). Map compiled by the Kissimmee Division, Watershed Management Department, SFWMD. The SFWMD makes no representation as to the suitability or accuracy of these data for any other purpose and disclaims any liability for errors that the data may contain. \\ad.sfwmd.gov\DFSRoot\data\fa_bus\arcgis\mxd\projmgmt\Construction\Phase2-3_PoolC-D_ConstructionFeatures.mxd. May 2007 bmr.

NOTE: Construction features last updated in February 2005.

http://www.sfwmd.gov/site/index.php?id=15#sites