Case Study: Kissimmee River Restoration

Stephen G. Bousquin
Applied Sciences Bureau
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
Development Activity Sequence

**Federal Interest Determined**

- **PROBLEM IDENTIFICATION**
  - 1 year

- **RECONNAISSANCE PHASE**
  - 1 year

- **FEASIBILITY PHASE**
  - 3 - 4 years

- **WASHINGTON LEVEL REVIEW**
  - .5 - 1 year

**Civil Works Project Development Sequence**

- **CONGRESS**
  - 1 - 2 years

- **PRE-CONSTRUCTION ENGINEERING & DESIGN**
  - 2 - 5 years

- **CONSTRUCTION/IMPLEMENTATION**
  - 2 - 5 years

- **OPERATION & MAINTENANCE**

**Cost Sharing**
Upper Kissimmee Basin
Kissimmee River Restoration Project
The Kissimmee River Prior to Channelization
Flooding and Humans in the Kissimmee Basin
Flooding Occurred on Regular Basis
City of Kissimmee Flooding ca. 1948
City of Kissimmee
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
Lake Kissimmee outlet, S-65 Construction (1965)
• 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
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 (SFWMMD) and federal studies
- Water Resources Development Act (WRDA 1992) – Authorized the Kissimmee River Restoration Project and the Headwaters Revitalization Project
  - USACE (construction and engineering)
  - SFWMD (land acquisition and restoration evaluation)
Restoration Investigations
1980 - 1995
Civil Works Project Development Sequence

Development Activity Sequence

1. PROBLEM IDENTIFICATION
   Cost Sharing

2. RECONNAISSANCE PHASE
   - 1 year

3. FEASIBILITY PHASE
   - 3 - 4 years

4. WASHINGTON LEVEL REVIEW
   - .5 - 1 year

5. CONGRESS
   - 1 - 2 years

6. PRE-CONSTRUCTION ENGINEERING & DESIGN
   - 2 - 5 years

7. CONSTRUCTION/IMPLEMENTATION
   - 2 - 5 years

8. OPERATION & MAINTENANCE

Federal Interest Determined
KRRP Restoration and Feasibility Studies

- 1971 - Governor’s Conference on Water Management in South Florida (formal acknowledgement of channelization problems)
- 1984-1990 – SFWMD Demonstration Project (Toth 1993)
- 1991– 2nd Federal Feasibility Study (IFR/EIS) (USACE 1991)
- 1994 – Test Fill 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
Kissimmee River Restoration 1000 foot Test Fill 1993
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.
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)
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

- **Reconnect, reconstruct physical form of the river**
- **Modify headwater inflows to mimic historical patterns**

- **Restoration of ecological integrity to central region of the Kissimmee River**
Operate the System to Mimic Natural Flow and Stage Patterns
Changes in S-65 Regulation Schedule

- **Zone A - Flood Control Releases when Stage is above Schedule**: ~3,000 - 4,000 cfs
- **No Releases**: 0 cfs
- **Zone C - No Releases, 0 cfs**:

### Original Regulation Schedule for the Upper Kissimmee Basin Chain of Lakes
- **Lake Stage (feet NGVD)**
- **No Releases**: 0 cfs
- **Zone A**: Flood Control Releases when Stage is above Schedule
  - ~3,000 - 4,000 cfs

### Revised Regulation and Operational Schedule for the Upper Kissimmee Basin Chain of Lakes
- **Lake Stage (feet NGVD)**
- **Zone A - Flood Control Releases when Stage is above Schedule**
  - >1.5 feet: 11,000 cfs
  - >1.0 feet: 6,000 cfs
  - >0.5 feet: 4,000 cfs
  - Zone C - No Releases, 0 cfs
  - 400 cfs
  - 150 cfs
  - 100 cfs
  - 800 cfs
  - 2,500 cfs
  - 1,600 cfs
  - 1,000 cfs
  - 400 cfs
## Phased Construction

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

- **Problem Identification**
  - 1 year

- **Reconnaissance Phase**
  - 3 - 4 years

- **Feasibility Phase**
  - .5 - 1 year

- **Congress**
  - 1 - 2 years

- **Pre-Construction Engineering & Design**
  - 2 - 5 years

- **Construction/Implementation**
  - 2 - 5 years

- **Washington Level Review**
  - .5 - 1 year

- **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
**Restoration of flow in river channels**

**Habitat effects**

- **Organic layer thickness** (-)
- **Dissolved oxygen** (+)
- **Vegetation mat width** (-)
- **Sand bars** (+)

**Effects on food web**

- **PF Macroinvertebrates** (+)
- **RA LMBA** (+)
- **Swimming fisheating birds** (+)

**Effects at higher trophic levels**

- **Hypothesized increases in aquatic invertebrates and shorebirds**
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
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
Development Activity Sequence

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
2 - 5 years

OPERATION & MAINTENANCE

Cost Sharing

Civil Works Project Development Sequence

See Planning Guidance Notebook
http://140.194.76.129/publications/eng-reggs/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

1. Identify Problems & Opportunities
2. Inventory & Forecast Conditions
3. Formulate Alternative Plans
4. Evaluate Effects of Alternative Plans
5. Compare Alternative Plans
6. Select Plan
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](http://140.194.76.129/publications/eng-regs/ER_1105-2-100/ER_1105-2-100.pdf)
Thank You!

www.sfwmd.gov

Steve Bousquin
sbousquu@sfwmd.gov
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.

<table>
<thead>
<tr>
<th>Date</th>
<th>Event</th>
<th>Purpose</th>
<th>Result</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>1962-1971</td>
<td>Channelization of the Kissimmee River under C&amp;SF Project for Flood Control and other Purposes</td>
<td>Provide flood control for central and southern Florida</td>
<td>Severe degradation of fish and wildlife values of the Kissimmee River</td>
<td>USACE 1956, Toth 1993, Koebel 1995</td>
</tr>
<tr>
<td>1976</td>
<td>Governor’s Conference on Water Management in South Florida</td>
<td>Focused on water quality issues in south Florida</td>
<td>Formed the Kissimmee River Coordinating Council</td>
<td>USACE 1991</td>
</tr>
<tr>
<td>1976</td>
<td>Kissimmee River Restoration Act (Florida Statute 373.1965)</td>
<td>Created Kissimmee River Coordinating Council</td>
<td>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</td>
<td>Koebel 1995</td>
</tr>
<tr>
<td>1978-1985</td>
<td>First Federal Feasibility Study</td>
<td>Evaluate feasibility of altering existing flood control system to improve water quality and enhance fish and wildlife resources</td>
<td>Did not recommend federal participation in project because initial plans projected no net economic benefit</td>
<td>USACE 1985, Koebel 1995</td>
</tr>
<tr>
<td>1984-1990</td>
<td>Kissimmee River Demonstration Project</td>
<td>Hydrologic and hydraulic monitoring studies to evaluate potential ecosystem responses to reestablished flow and floodplain hydroperiod</td>
<td>Responses indicated that restoration of ecosystem structure and function were feasible and sustainable</td>
<td>Toth 1993</td>
</tr>
<tr>
<td>1986</td>
<td>Water Resources Development Act (U.S. Public Law 99-662)</td>
<td>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</td>
<td>Removed barriers that prevented the First Feasibility Study from recommending federal participation</td>
<td>Woody 1993, USACE 1991</td>
</tr>
<tr>
<td>1990-1991</td>
<td>Second Federal Feasibility Study</td>
<td>Determine the extent of federal participation</td>
<td>Recommended backfilling plan as most appropriate method for reestablishing ecological integrity to the Kissimmee River ecosystem</td>
<td>USACE 1991</td>
</tr>
<tr>
<td>1992</td>
<td>Water Resources Development Act (U.S. Public Law 102-580) (Federal)</td>
<td>Reauthorized USACE civil works construction programs and provided for the “conservation and development of water and related resources”</td>
<td>Authorized restoration of the Kissimmee River</td>
<td>USACE 1996</td>
</tr>
<tr>
<td>1994</td>
<td>Test-fill construction</td>
<td>Assess construction methodology and potential environmental impacts of backfilling</td>
<td>Finalized construction methodology and concluded there were no long-term impacts to water quality resulting from backfilling plan</td>
<td>Koebel et al. 1999, Colangelo and Jones 2005</td>
</tr>
<tr>
<td>1994</td>
<td>Project Cooperation Agreement</td>
<td>Create partnership between USACE and SFWMD</td>
<td>Authorized 50/50 cost share between federal government and state of Florida; defined specific roles and responsibilities of partners</td>
<td>Koebel et al. 1999, Colangelo and Jones 2005</td>
</tr>
<tr>
<td>1994-1999</td>
<td>Baseline data collection in Phase I restoration construction area</td>
<td>Baseline data collection on physical, chemical and biological properties for Phase I restoration evaluation</td>
<td>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</td>
<td>Koebel et al. 1999, Colangelo and Jones 2005</td>
</tr>
<tr>
<td>1999-2001</td>
<td>Phase I restoration construction</td>
<td>Backfill 12.8 km of canal, recarve 1.6 km of river channel</td>
<td>Reestablished 22.4 km of river channel and increased wetlands by 2345 ha</td>
<td>Whalen et al. 2002</td>
</tr>
<tr>
<td>2005</td>
<td>Publication of results of baseline restoration evaluation studies and performance measures</td>
<td>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</td>
<td>Results of baseline research; analyses describing the effects of channelization; publication of restoration expectations</td>
<td>Bousquin et al. 2005, Anderson et al. 2005</td>
</tr>
<tr>
<td>2007-2009</td>
<td>Construction Phases IVA and IVB completed (Phase numbers are not sequential).</td>
<td>Smaller phases of construction upstream of Phase I.</td>
<td>Construction monitoring only.</td>
<td>Jones et al. 2010</td>
</tr>
<tr>
<td>2007</td>
<td>Baseline data collection initiated in Phase VII</td>
<td>Baseline data collection for physical, chemical, and biological properties</td>
<td>Federal permit issued, solicitation for Phase VII restoration</td>
<td>Bousquin et al. 2005, Jones et al. 2010</td>
</tr>
</tbody>
</table>
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),
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 berC 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 of Weir-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 of C-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.
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 possible.
Thanks to

• Tiphanie Jinks, USACE
<table>
<thead>
<tr>
<th>Feature Account</th>
<th>Baseline¹</th>
<th>Full Funded²</th>
</tr>
</thead>
<tbody>
<tr>
<td>02-Relocations</td>
<td>$8,266,000</td>
<td>$10,302,000</td>
</tr>
<tr>
<td>09-Channel and Canals</td>
<td>229,794,000</td>
<td>396,510,000</td>
</tr>
<tr>
<td><strong>SUBTOTAL</strong></td>
<td><strong>$238,060,000</strong></td>
<td><strong>$406,812,000</strong></td>
</tr>
<tr>
<td>01-Lands and Damages</td>
<td>116,946,000</td>
<td>141,237,000</td>
</tr>
<tr>
<td>30-Planning, Engineering and Design, Monitoring and Test Fill</td>
<td>43,854,000</td>
<td>80,218,000</td>
</tr>
<tr>
<td>31-Construction Management</td>
<td>23,807,000</td>
<td>54,733,000</td>
</tr>
<tr>
<td><strong>TOTAL PROJECT COST</strong></td>
<td><strong>$422,667,000</strong></td>
<td><strong>$683,000,000</strong></td>
</tr>
</tbody>
</table>

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>
<thead>
<tr>
<th>ALTERNATIVE</th>
<th>OPERATION RULES</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>RS1</strong> (SFWMD 1990 AND 1991 FEASIBILITY STUDY SCHEDULE)</td>
<td>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 &lt; 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.</td>
</tr>
<tr>
<td><strong>RS1-A</strong></td>
<td>Same as RS1 with slight modifications to historic stage-discharge rating curve.</td>
</tr>
<tr>
<td><strong>RS1-B</strong></td>
<td>Same as RS1 without March no discharge zone.</td>
</tr>
<tr>
<td><strong>RS2</strong></td>
<td>Same discharge zones as RS1-B except upper flood control regulation zone is bounded by existing regulation schedule elevations.</td>
</tr>
<tr>
<td><strong>RS3</strong></td>
<td>Same as RS1-B with slightly higher flood control envelop during May.</td>
</tr>
<tr>
<td><strong>RS4</strong></td>
<td>Same as RS3 except 250 cfs zone changed to 400 cfs zone.</td>
</tr>
<tr>
<td><strong>RS5</strong></td>
<td>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 &lt; 51.68 ft or unregulated flow as lake stages overtop a weir with a fixed crest of 51.68 ft.</td>
</tr>
<tr>
<td><strong>RS6</strong></td>
<td>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 &lt; 49 ft or vary according to a new outlet rating curve (RC-A rating curve from Appendix F).</td>
</tr>
<tr>
<td><strong>RS7</strong></td>
<td>Same as RS6 with the addition of a 400 cfs discharge zone when lake stages fall within designated ranges during November-May.</td>
</tr>
<tr>
<td><strong>RS8</strong></td>
<td>Same as RS6 with a different stage-discharge rating curve (RC-B rating curve from Appendix F).</td>
</tr>
<tr>
<td><strong>RS9</strong></td>
<td>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</td>
</tr>
</tbody>
</table>
Floodplain Vegetation Response

Wetland vs. Upland

Legend

Wetland Communities
Upland Communities
Open Water

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


Legend
- Broadleaf and Buttonbush Marsh
- P. hemitomon-Dominated Wet Prairie
- Other Wet Prairie
- Ludwigia spp.-dominated Wetland Shrub
S-65C Structure Removal

Tieback Levee Removal

Canal Backfilling

Culvert Installation

Re-carved River Sections

U-Shaped Weir

CSX Railroad Bridge

Install Tieback Levee

River Acres Flood Reduction