How much flow does the Everglades need to maintain ecosystem functions provided by ridge and slough landscape?
How will restored flow reconnect and restore deep-water sloughs that support dispersal pathways, nursery habitat, prey concentration/feeding areas

Pre-drainage ridge & slough landscape

Degraded ridge & slough landscape
Critical Issues for CERP/CEPP/Check-up:

What should be done with canals that are no longer needed for water conveyance?

Canals not backfilled may be sources of water quality problems and habitat for exotic fish. However, recreational fishermen want canals without backfill.

Presently there is little science to evaluate outcomes of full – partial – no backfill options.
The DPM Footprint – isolated from flow for 60 years

WCA-3A

S-152 – up to 450 cubic feet per second

2.5 km

Complete Fill

Partial Fill

No Fill

Levee Removal

WCA-3B
Three years of background and four years of flow
TESTING THE RESTORATION OF A FREE-FLOWING EVERGLADES:
The DPM High-Flow Experiments

Jud Harvey¹, Laurel Larsen²,¹, Colin Saunders³
Sue Newman³, Barry Rosen¹, David Ho⁴ and
Jay Choi¹

¹- U.S. Geological Survey-Reston, VA, ²- U.C.-Berkeley, ³- South Florida Water Management District, ⁴- U. Hawaii,
Questions:

1) How does restored high flow influence remaining deepwater sloughs in a degraded part of Everglades?

2) Is the observed “slough clearing” likely to be a self-reinforcing process that will cause sloughs to expand in the future?

3) What is the relative influence of ...
   • sediment transport? floc redistribution from sloughs to ridges
   • changes in periphyton and floc dynamics driven by ...
     - biochemical effects, e.g., greater phosphorus loading
     - flow effects on floc decomposition
Analysis for for southern flow path

- **S-152**

Directional flow speeds:
- **6 cm/s**
- **2 cm/s**
- **1 cm/s**
- **0.4 cm/s** background

**SF₆** (D. Ho)
Ridge flow speed
before flow release
during flow release

Slough flow speed
before flow release
during flow release
Flow pulses induce sediment movement

• Shear stress exceed bed floc entrainment threshold in slough during high flow, but only rarely in ridge

Data from L. Larsen
Low Flow

High Flow
## Sediment mobilized from Epiphyton

<table>
<thead>
<tr>
<th>Average Mass Epiphyton</th>
<th>Low-Flow</th>
<th>High-Flow</th>
</tr>
</thead>
<tbody>
<tr>
<td>per stem (grams)</td>
<td>0.090</td>
<td>0.003</td>
</tr>
<tr>
<td>per surface area</td>
<td>0.004</td>
<td>0.0001</td>
</tr>
<tr>
<td>(grams cm(^{-2}))</td>
<td>(0.011)</td>
<td>(0.0005)</td>
</tr>
</tbody>
</table>

data from A. Hurst and L. Larsen
Particles transported in big initial pulse and then later at lower concentrations

Entrainment of easily-mobilized particles from epiphyton and floating periphyton

Periphyton mat sinking and breakup

Depletion of easily mobilized particles
Slough clearing of floating periphyton within several weeks

Before Flow 2014

After Flow 2014
CONTROL - C2

Treatment - RS1D

Pre-flow
CONTROL - C2  
Treatment - RS1D

Flow Release  
10/17/16 12:30 PM
CONTROL - C2  
Treatment - RS1D  

1 Day Post Flow
CONTROL - C2

Treatment - RS1D

1 Week Post Flow
CONTROL - C2

Treatment - RS1D

2 Weeks Post Flow
CONTROL - C2

Treatment - RS1D

3 Weeks Post Flow
CONTROL - C2

Treatment - RS1D

4 Weeks Post Flow
CONTROL - C2  
Treatment - RS1D

8 Weeks Post Flow
Bed floc became more erodible with flow

S. Newman and C. Saunders (SFWMD)
Slough clearing increases velocity...more sediment transport...more slough clearing

2014

2015

Flow Speed

S152 Discharge, Q

Water Level

S152 Discharge, Q

Water Level
Physical-biological feedbacks increase slough clearing

Entrainment of easily-mobilized particles from epiphyton and floating periphyton

Depletion of easily mobilized particles

Floc physical and biochemical changes increase floc erodibility

Higher flow velocity due to less flow resistance increases sediment transport

Phosphorus Concentration (mg l$^{-1}$)

Sediment Concentration ($\mu$g l$^{-1}$)

D$_{50}$ Particle Size (μm)

Turbidity

Decimal Time from Flow Release (h)

11/5/14 11/7/14 12/3/14 1/20/15 3/10/15
Particles Mobilized from Floc during Sustained High Flow are Deposited on Ridges

<table>
<thead>
<tr>
<th>Suspended Sediment</th>
<th>Areal rate (g/m²/s) x 10⁻⁴</th>
<th>Areal deposition (g/m²)</th>
</tr>
</thead>
</table>
| **Pulse High Flow (day 1):**  
  6-hr pulse repeated every 14-days for 3 months | Slough | 3 | 40 | Ridge | 1 | 10 |
| **Sustained High Flow**  
  lasting 3 months | Slough | 1 | 1000 | Ridge | 7 | 6000 |
Modeling flow velocity to understand controls and manage outcomes

Log (Velocity, m/s)

Log (Distance, m)

-3 -2.5 -2 -1.5 -1 -0.5 0 1 1.2 1.4 1.6 1.8 2 2.2 2.4 2.6 2.8 3 3.2 3.4 3.6

2015_Ridge
2014_Ridge
2013_Ridge
2015_Ridge
2014_Slough
2013_Slough

pre-flow velocity 0.004 m/s
Modeling flow velocity to understand controls and manage outcomes.

Log (Velocity, m/s) vs. Log (Distance, m)

No Flow Boundary

Point Source Q[m³/s]

2013
2015
2013_Slough
2015_Slough

2014
2014_Slough
2015_Slough
2015_Ridge
2014_Ridge
2013_Ridge

/pre-flow velocity 0.004 m/s

Log (Distance, m)
“Optimal” velocities that open sloughs achieved in only a very small area

Log (Velocity, m/s) vs. Log (Distance, m)

- Pre-flow velocity: 0.004 m/s

- Data points for 2013, 2014, and 2015

- Locations: Z51_USGS, Z53_NE, Z53_B, RS1, RS1SE, Z53_B, Z53_NE, RS2, UB2

- Graph showing the relationship between velocity and distance for different years and locations.
“Optimal” velocities that open sloughs achieved in only a very small area.

Erosion in Sloughs  
Deposition on Ridges

Bed Erosion  
Everywhere

No Bed  
Erosion

24 - 48 acres

pre-flow velocity 0.004 m/s

Optimal velocities that open sloughs achieved in only a very small area.
But…“optimal” conditions sensitive to $Q$, discharge at S-152 structure

Bed Erosion Everywhere

Erosion in Sloughs

Deposition on Ridges

No Bed Erosion

24 - 48 acres

614 acres

pre-flow velocity 0.004 m/s

2013
2015
2014
2015_4 x $K_f$
2015_4 x $Q$

2013_Slough
2014_Slough
2015_Slough

2013_Ridge
2014_Ridge
2015_Ridge

24 - 48 acres

614 acres

pre-flow velocity 0.004 m/s
Expanding sloughs where sediment is mobilized and redistributed to ridges

Choked sloughs
No sediment redistribution

Uniform sawgrass

DEGRADED

Early DPM Response

Well Functioning
Even more sensitive to % sawgrass
Slough connectivity is self-reinforcing

Bed Erosion
Everywhere

Erosion in Sloughs
Deposition on Ridges

No Bed
Erosion

pre-flow velocity 0.004 m/s

2013
2014
2015
2015_4 x Q
2015_4 x K_f

1,941 acres
614 acres
24 - 48 acres

2013_Ridge
2014_Ridge
2015_Ridge
2013_Slough
2014_Slough
2015_Slough
How will restored flow influence outcomes for ecosystem

- High flow is conducive to preserving and restoring ecologically important deepwater sloughs

- Hydraulic, sediment transport, and biochemical processes contribute to slough clearing

- Short, intense flow pulses momentarily mobilize more sediment but quickly become source depleted.

- Sustained high flow releases lasting several months are most effective in redistributing sediment from sloughs to ridges

- Areas of optimum flow in DPM currently limited, but modeling suggests that slough clearing could be a self-reinforcing process that could progressively reconnect historic sloughs