Using a Hydrologic Monitoring Network to Evaluate the Role of Enhanced Flow in Everglades Restoration

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Key Issues in the Everglades

The Everglades is a low-gradient, subtropical wetland vegetated by emergent macrophytes and submerged aquatic vegetation. Extensive development and drainage of the Everglades began in the early 20th century. In order to manage water conservation and flood control, levees enclose the water conservation areas (WCAs) in the central Everglades and a system of canals, pumps, and spillways redistributes water between these basins.

Predrainage　　Present Day

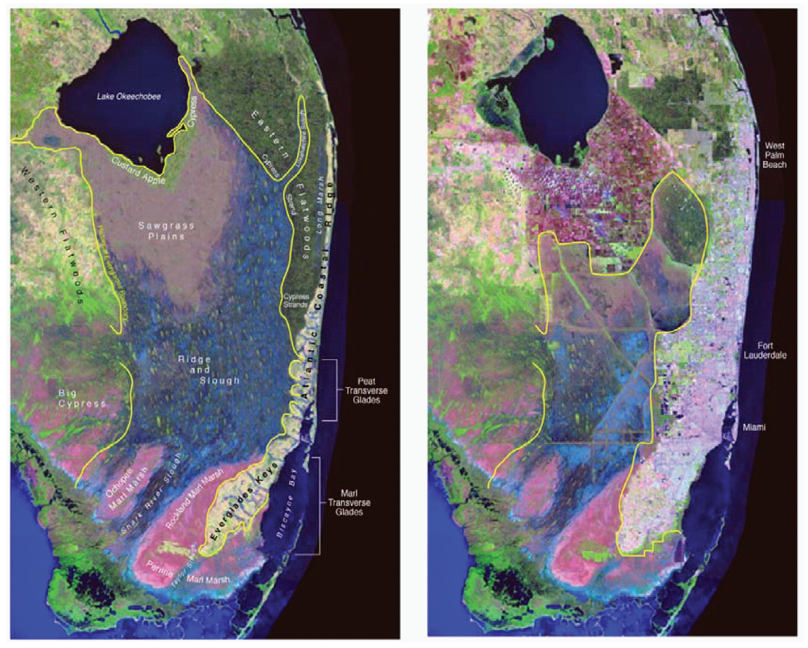
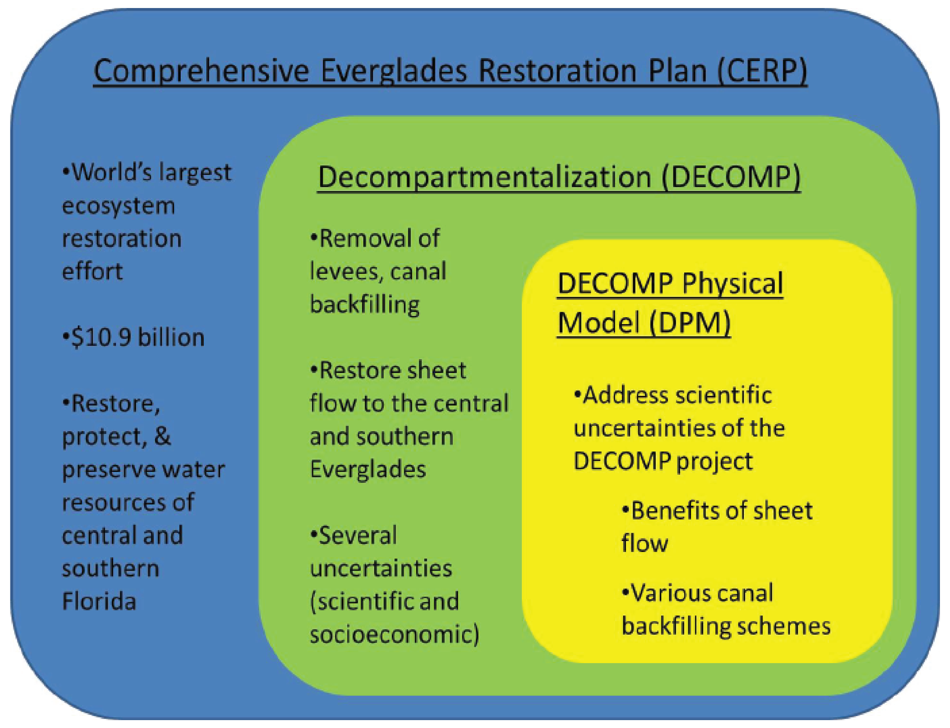


Figure 1. Map indicating both the historic and modified flow patterns in the Everglades.

- Prior to regulation, the ecosystem received nutrients and water through rainfall and the seasonal overflow of Lake Okeechobee.
- Pulsed sheetflow redistributed water, sediment, and nutrients and maintained geomorphic patterning and high biodiversity of the landscape.
- Water regulation has redirected flows through canals and slowed sheetflow to almost imperceptible velocities (< 0.5 cm/s).
- The conversion of wetlands to agriculture has resulted in increased phosphorus run-off leading to the replacement of vegetation communities with monospecific stands of cattail.

Everglades Restoration



The DECOMP Physical Model (DPM) is a colloborative experiment planned and conducted by the South Florida Water Managment District, USGS, The National Park Service, Florida International University and the University of Hawaii. In addition to social and economic considerations, the scientific goals will focus on the complex interaction between flow, vegetation, sediment, and phosphorus to determine the effectiveness of future restoration efforts.

Figure 2. Diagram illustrating the structure of key Everglades restoration projects.

DECOMP Physical Model

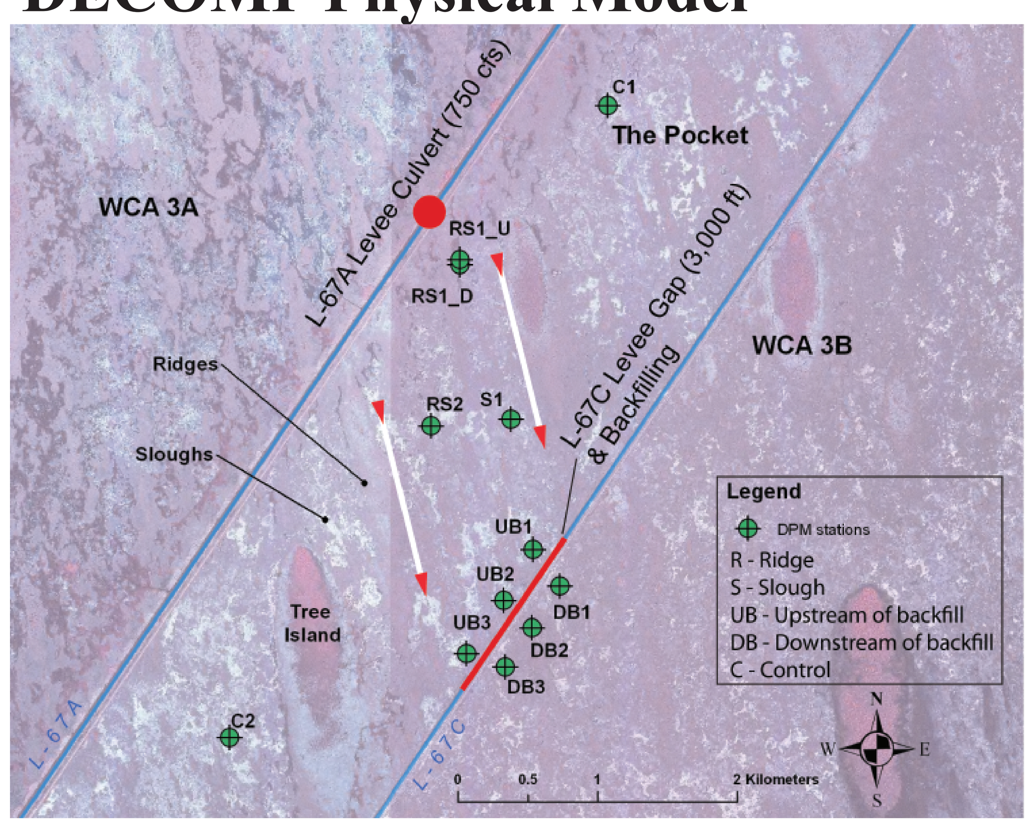


Figure 3. Site location map of the DPM indicating locations of the monitoring stations, management structures and geomoprhic features

- The culvert and levee gap will provide a controllable hydrologic connection between WCA-3A and WCA-3B
- Pulsed events will last 14 to 40 days
- Velocities will exceed 3 cm/s, allowing the redistribution of floculent organic particles which is thought to be essential for long-term maintenance of ridge and slough patterning (Larsen and Harvey, 2010).

DPM Key Questions:

Ridge and Slough Hydrodynamics

1. What flow regime is required to entrain and redistribute particles? How does this vary according to particle source?
2. How does vegetation density regulate flow velocity and impact the fate of entrained particles?
3. Do rates of sediment transport balance in-place peat accretion processes to maintain ridge and slough elevation differences?

Canal Backfilling Treatments

1. How do the different canal treatments (complete, partial, and no backfill) alter stage, sheetflow, and groundwater seepage?
2. How does the degree of backfilling impact sediment transport? water quality? habitat quality?

Hydrologic Monitoring Network

The USGS' role has been to install the extensive hydrologic monitoring network in the DPM study area, which consists of 20 stations outfitted with acoustic Doppler instrumentation, pressure transducers, particle size analyzers (LISSTs), and staff gauges. This network is used to characterize flow before, during, and after planned pulsed-flow releases.

Continuous Data Collection

Instrument	Parameter
ADVs, Argonauts	Velocity
SBE MicroCAT	Temperature, Conductivity
KPSI pressure transducers	Depth, Temperature

On-Site Data Collection

Instrument	Parameter
ADVs, Argonauts, Vectrinos	Velocity profiles
LISST instruments	Particle size distributions
Staff gauges, reference makers, floc/peat depth probes	Depth of water, floc layer, peat, and bedrock

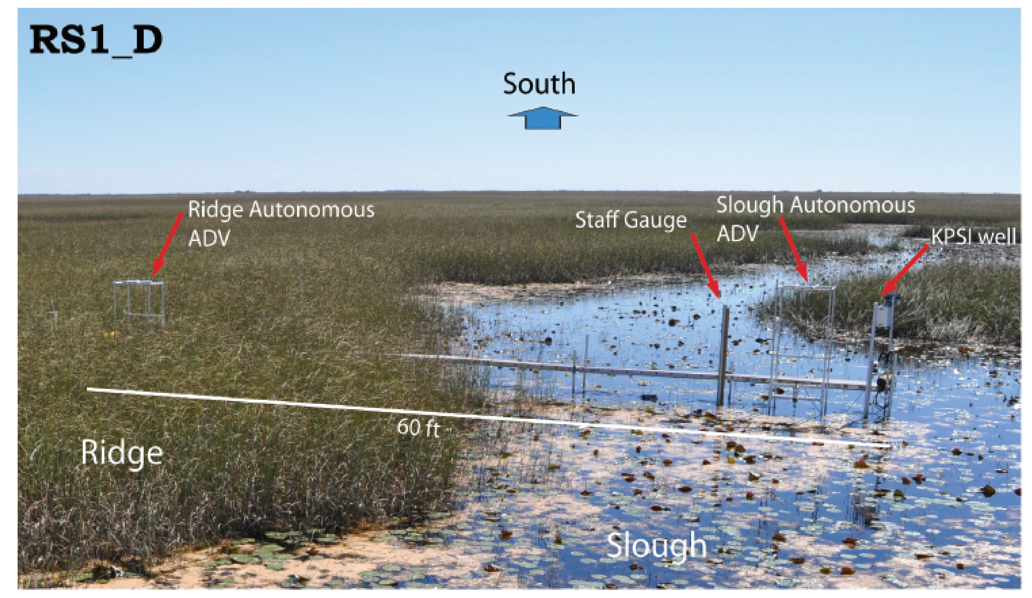


Figure 4. An example of a paired ridge-slough site. Access for all sites is from the south via airboat. Instruments are situated on the upstream (northern) side of the platform which remains relatively undistrubed.

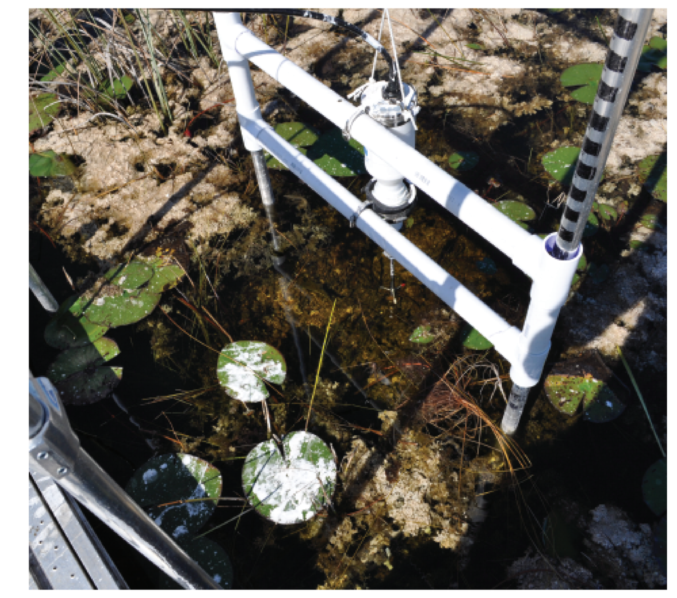


Figure 5. ADV deployed in the slough. The PVC frame allows the instrument to be raised and lowered by pulley during velocity profiles.

Initial Results

Two years of pre-release characterization show ambient flow velocities that are consistent with the reported average (< 1 cm/s), which is far too low for sediment entrainment (Harvey et al. 2011). Spatial variability in flow velocity is primarily attributable to variability in vegetation density. Water management operations drive many of the temporal changes in flow magnitude and direction, which is often transverse to the orientation of landscape features. A wildfire occurring in summer 2011 substantially thinned the vegetation canopy, resulting in higher mean flow velocities during the second year of pre-release characterization. Though daily-average velocity trends are relatively smooth, high instantaneous velocity variability reflects wind-driven movement of vegetation stems through the water column and the nightly occurrence of thermal overturn.

Continuous ADV and Discrete Velocity Data

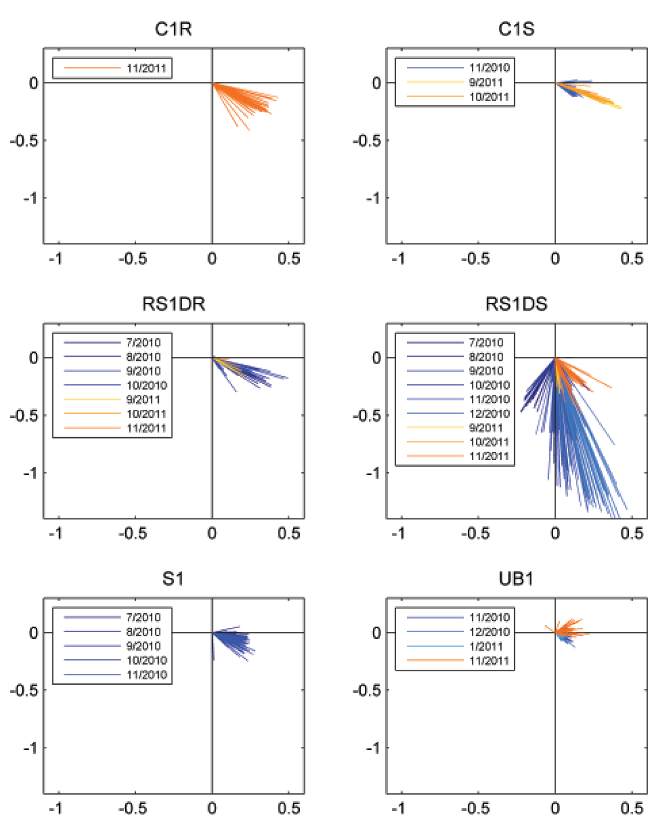


Figure 6. Autonomous velocity data collected by ADV at several DPM sites. Data show variability in direction and magnitude of flow.

	Site	Average Speed (cm/s) (STD in parenthesis)		Average Direction (STD in parenthesis)	
		2010	2011	2010	2011
CONTINUOUS ADV DATA	C1 Ridge		0.40 (0.25)		126.2 (44.4)
	C1 Slough	0.25 (0.15)	0.43 (0.20)	116.7 (65.8)	116.2 (32.3)
	RS1 Ridge	0.29 (0.20)	0.30 (0.16)	122.4 (46.5)	128.5 (41.5)
	RS1 Slough	0.74 (0.30)	0.31 (0.21)	177.1 (28.6)	164.5 (46.2)
	S1	0.20 (0.18)		114.5 (56.3)	
	UB1	0.08 (0.27)	0.15 (0.18)	125.8 (89.6)	60.3 (76.7)
	UB2	0.07 (0.28)	0.11 (0.24)	83.2 (92.7)	114.5 (86.4)
	UB3	0.06 (0.45)	0.13 (0.22)	76.7 (95.9)	118.4 (78.3)
DISCRETE VECTRINO DATA	C2 Ridge	0.11 (0.19)	0.42 (0.49)	89.6 (86.7)	253.6 (86.1)
	C2 Slough	0.44 (0.19)	0.22 (0.30)	233.5 (88.1)	238.6 (62.6)
	RS2 Ridge	0.31 (0.25)	0.20 (0.27)	230.2 (95.8)	149.8 (69.7)
	RS2 Slough	0.51 (0.30)	0.28 (0.28)	347.1 (84.3)	101.2 (81.6)

Table 1. Average velocity and flow direction calculated for 2010 and 2011 for sites with either continuous or on-site data collection. Direction is given as degrees clockwise from true north.

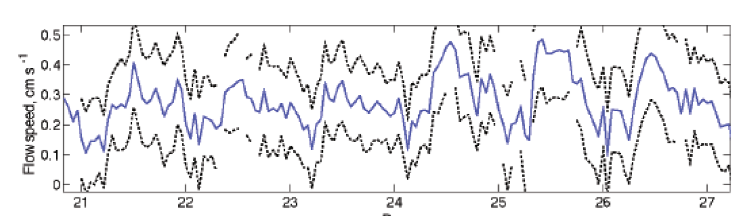


Figure 7. Average hourly flow speed at site S1 demonstrates high variability in instantaneous velocity due to wind and thermal overturn.

Vegetation Effects on Flow Velocity

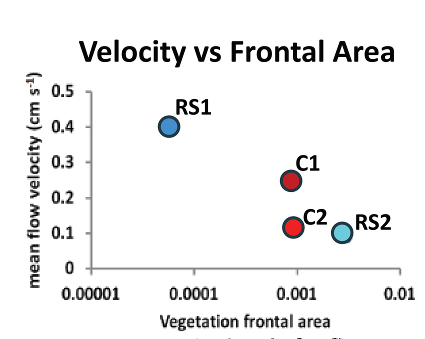
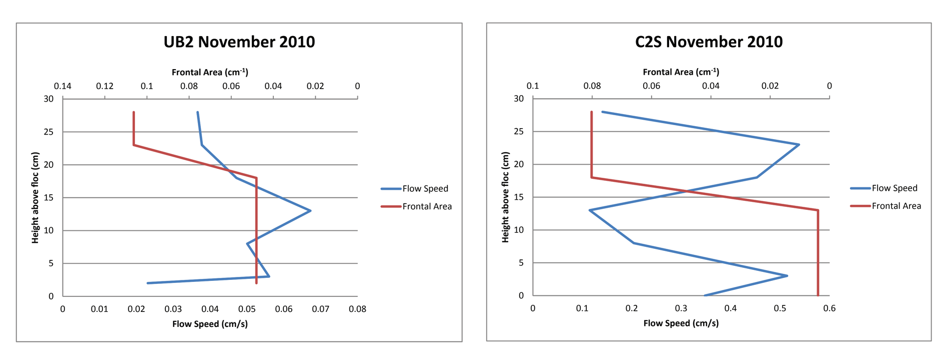


Figure 8. Relationship between depth-averaged flow velocity and vegetation frontal area in several DPM sites. As expected, as vegetation density increases, local velocity decreases.



Figures 9 & 10. Vertical flow speed and vegetation frontal area (on reversed axis) profiles at two different sites. At UB2, flow speed and frontal area are inversely related, while at C2S, there is no clear relationship between velocity and frontal area profiles. Lack of a relationship between velocity and frontal area may arise from local variability in vegetation communities; vegetation clip plots were harvested at locations near but not immediately at the ADV profile locations.

Seasonal Shift in Flow Direction

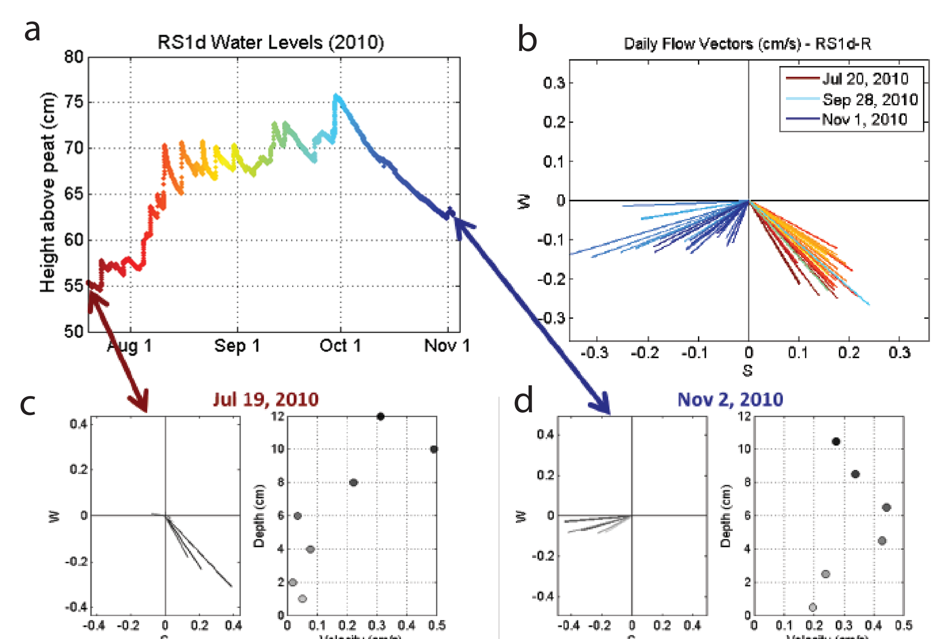
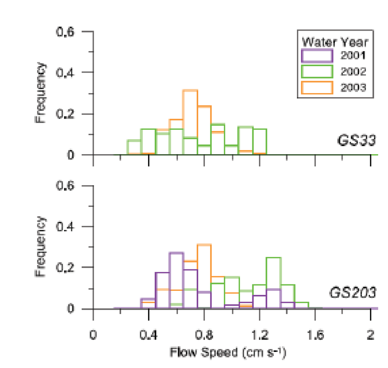


Figure 11. (a) Water levels above peat surface at RS1d during 2010 season, (b) daily flow vectors at RS1d during three months of 2010 demonstrating flow direction shift from wet to dry season, (c) velocity profile at RS1d during the summer and (d) during the fall.

Implications for Restoration

Flow velocities and hydraulic retention times are critical drivers in sediment transport, nutrient cycling and function of aquatic ecosystems, particularly the Everglades, where flow that redistributes particulate organic sediment is thought to be necessary for maintenance of the patterned ridge and slough landscape structure. Current flow velocities, strongly related to water surface slope and vegetation frontal area, are insufficient to entrain sediment. We expect that managed flow releases scheduled to occur as part of the DPM in 2012 and 2013 will achieve the velocities needed for sediment redistribution, particularly in the northern, less vegetated part of the experimental footprint.

Current and Projected Flow Speeds



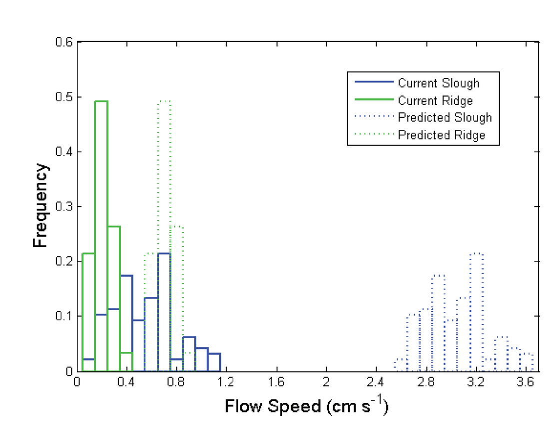


Figure 12 (left). Flow speed distributions at Shark River Slough, a section of relatively unimpounded Everglades (from Riscassi & Schaffranek, 2004)

Figure 13 (right). Flow speed distributions for current and predicted conditions at the impounded DPM Ridge-Slough Impact Site

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