Too Much of a Good Thing:

Eutrophication and it's ecological and possible public health consequences via interactions with environmental Fe and S?

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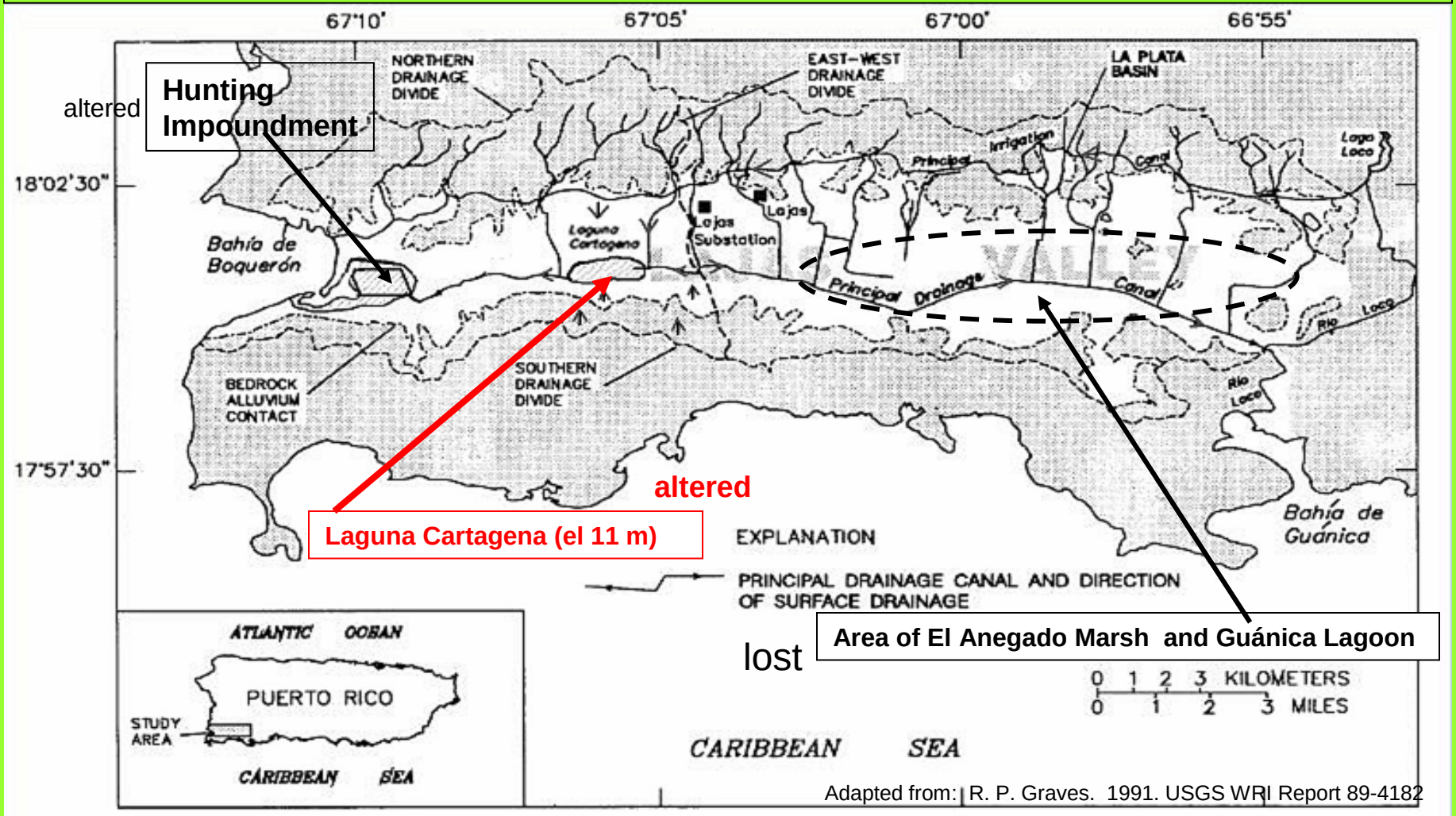
Laguna Cartagena was first used as a source of irrigation water for sugar cane in 1923, *then…* In the late 1950's a new regional irrigation system connected its drainage (effluent) discharge canals through the lagoon to the sea. (Culprits: Fed. Ag., PR Ag. & PR Elec. Power Authority)



Adapted from: R. P. Graves. 1991. USGS WRI Report 89-4182

Nominal lagoon surface at 11 m above mean sea level.

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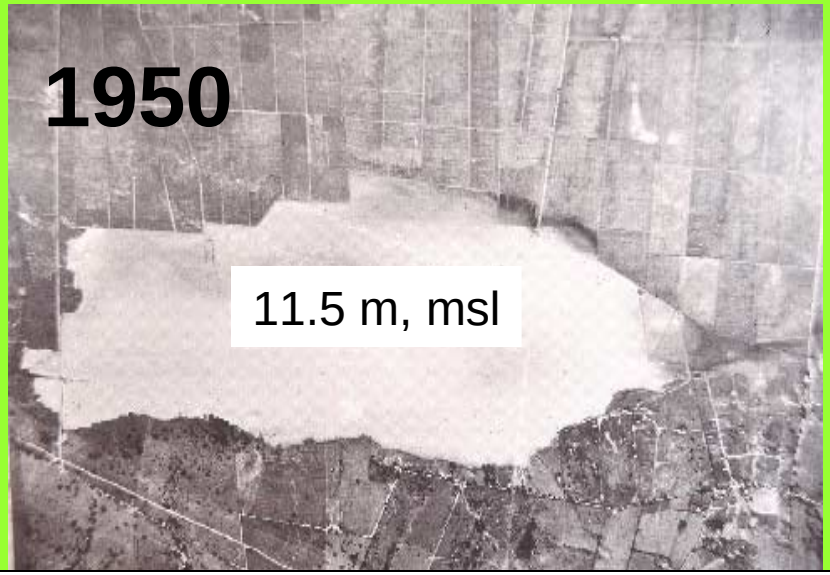
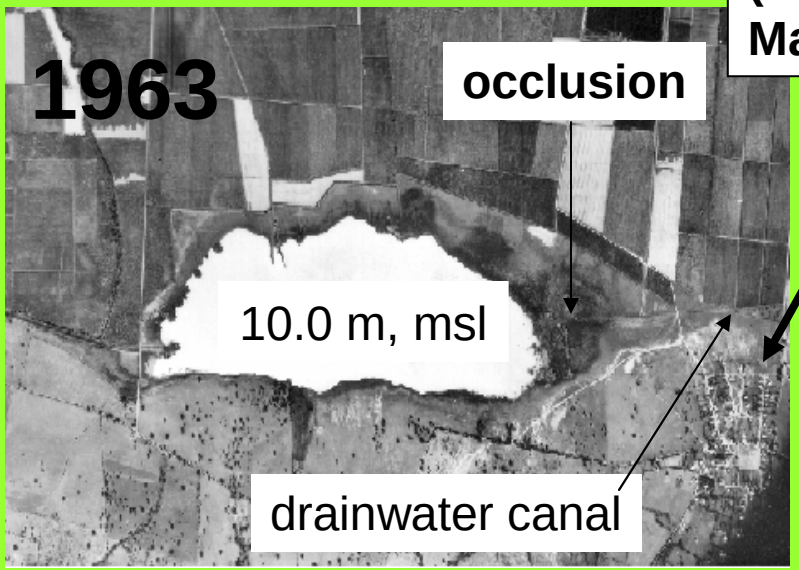
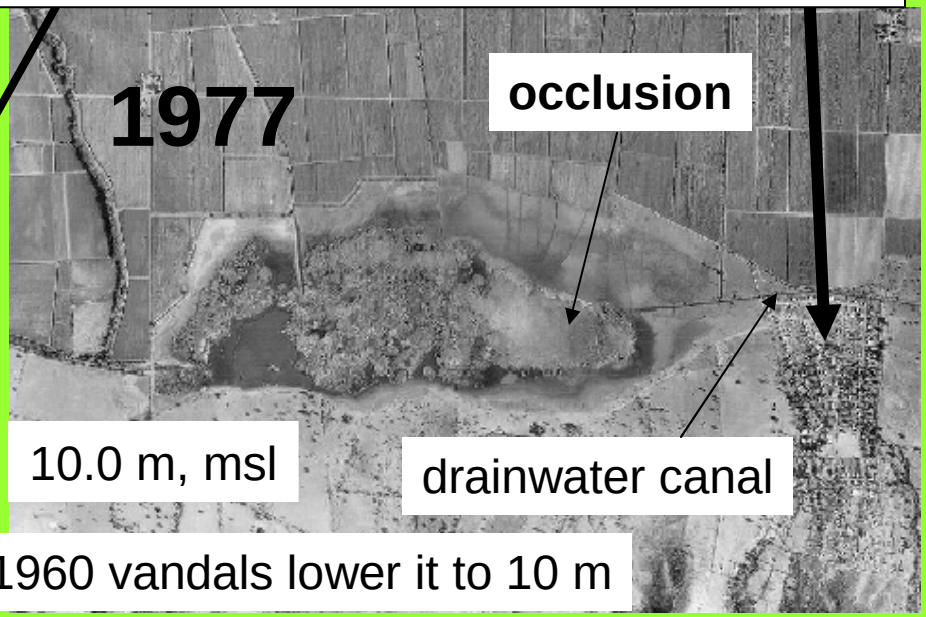


1960-1975: PR Rural Housing Authority (with Fed HHS Funds) establishes town of Magüayo along drainage canal.



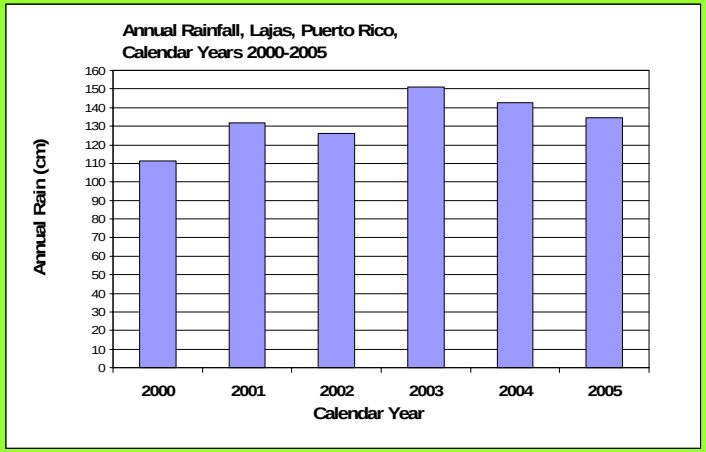


Water level set at 11m in 1950's, but in 1960 vandals lower it to 10 m

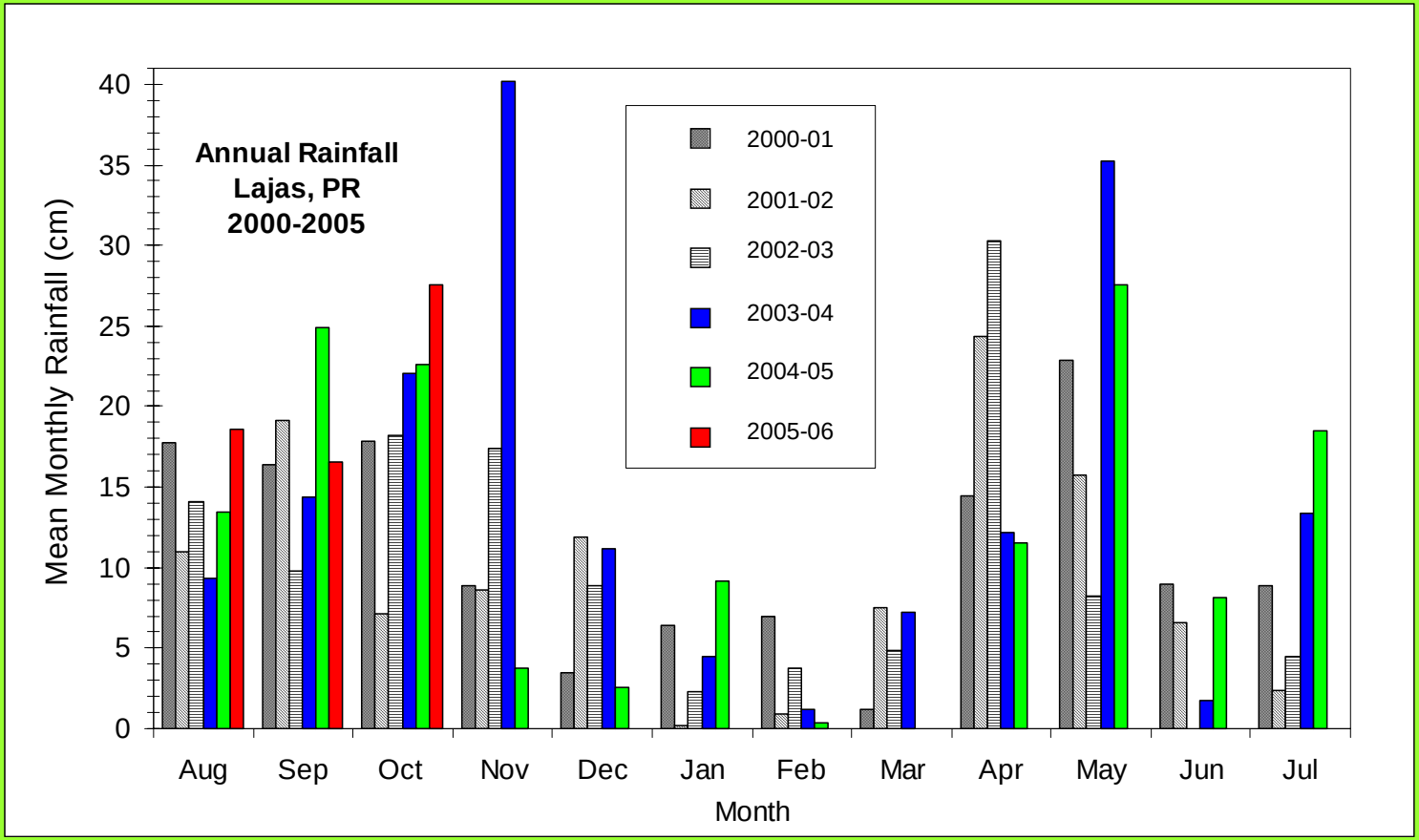
Canal Principal de Desagüe, El Anegado, Valle de Lajas
Earthen, above the surrounding terrain

Boqueron Bay

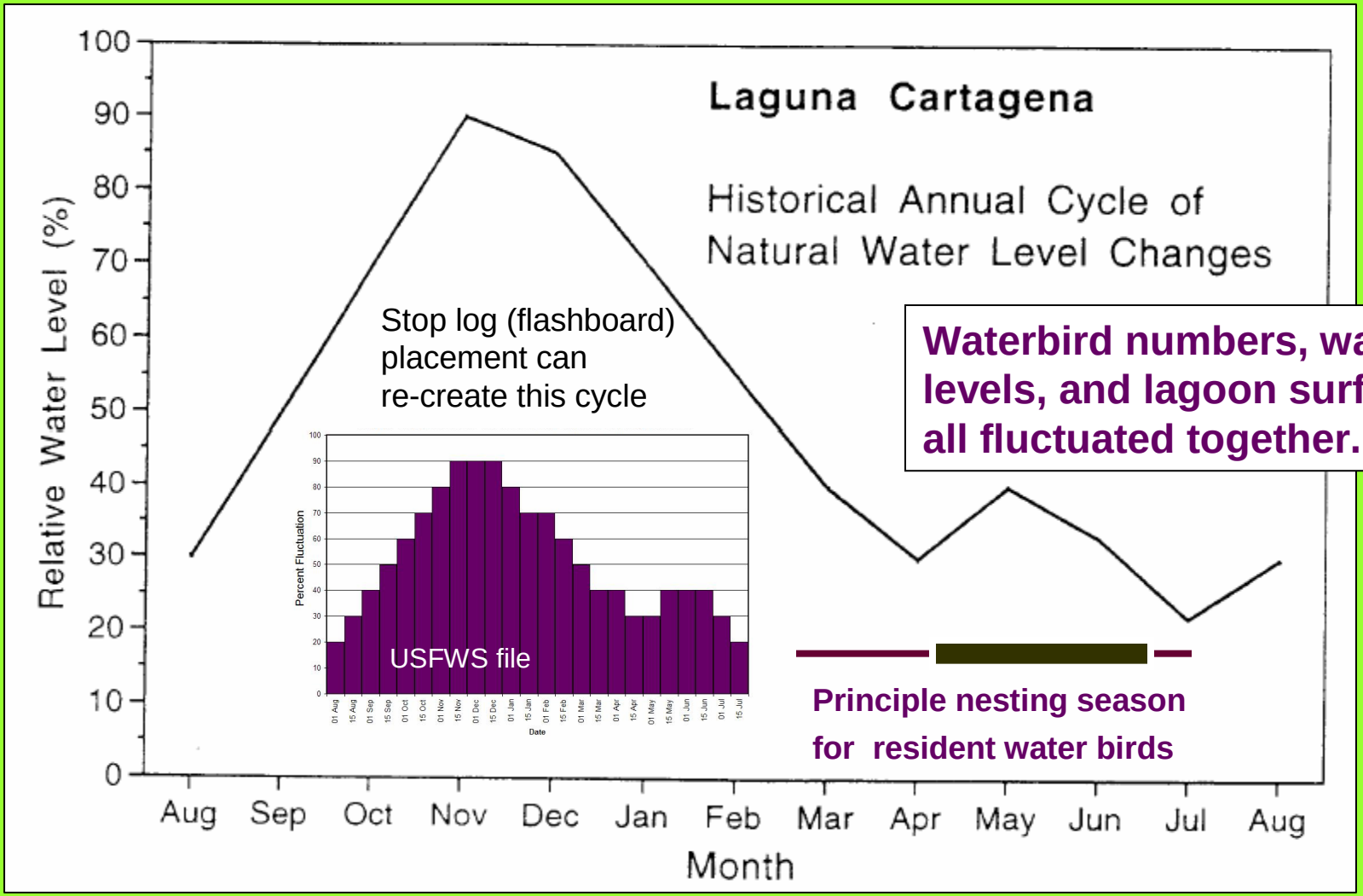
Laguna Cartagena is a shallow (2m) rainfall-charged 160-ha freshwater lagoon located in in semi-arid southwestern Puerto Rico (130 cm annual rainfall)



2 rainy Seasons per Year



Laguna Cartagena historically exhibited marked twice-yearly water level fluctuations, without complete dry-downs, through the 1920's and was a haven for thousands of aquatic birds: Waders, Waterfowl, Shorebirds, including seasonal migrants and nesting species (Danforth 1926).
Area = 150 ha; 160 total species of terrestrial and aquatic birds.



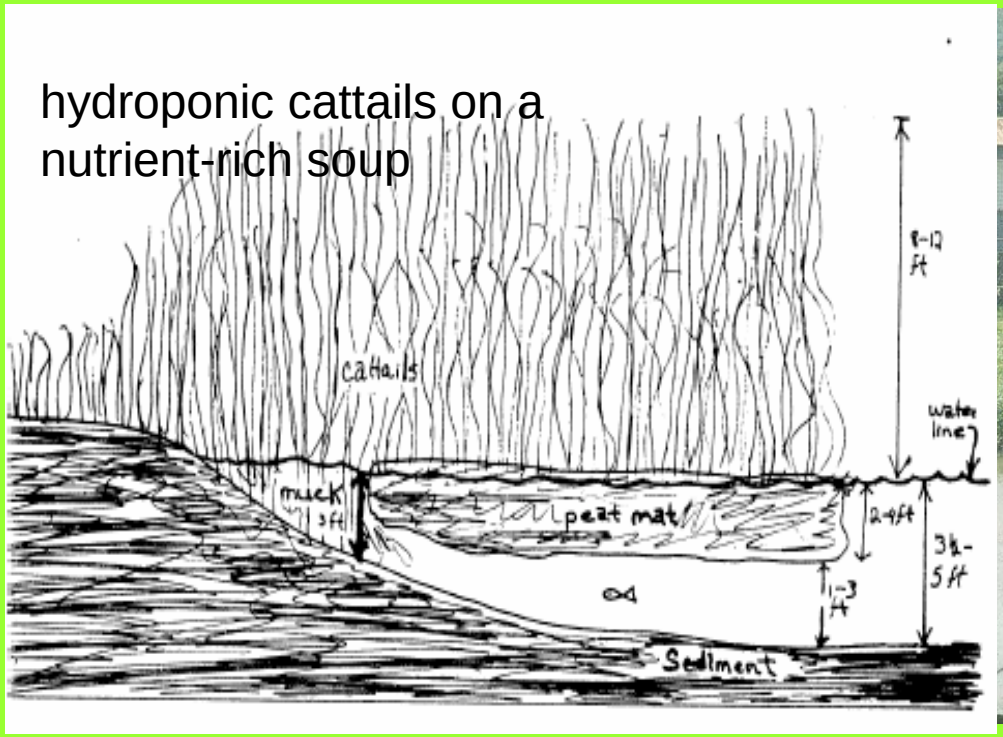
Waterbird numbers, water levels, and lagoon surface area all fluctuated together.

These blunders produced:

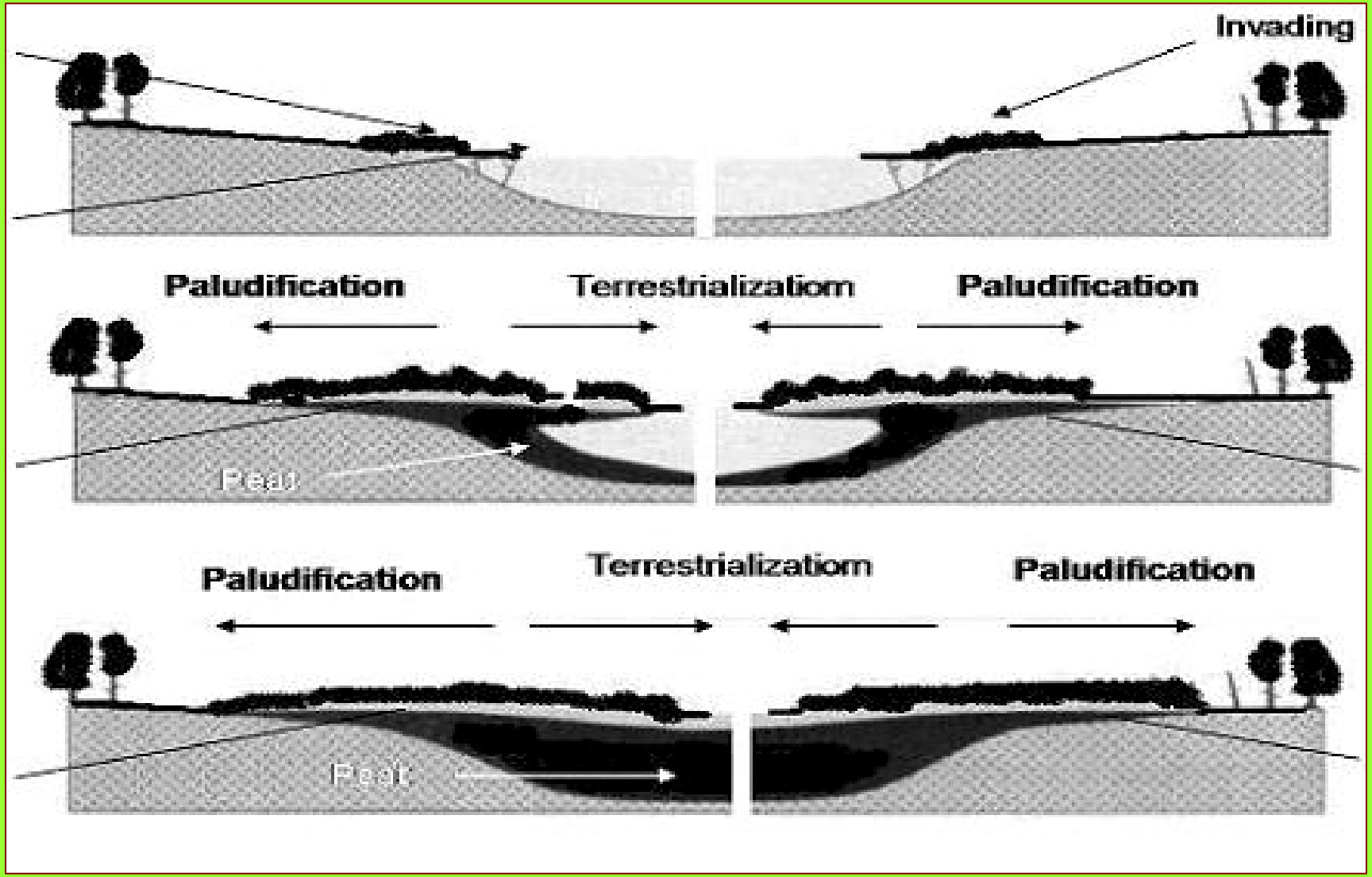
(1) disrupted hydroperiods and hydrologic regime,
(2) very excessive nutrient inputs (100's to 1,000's ppb Ortho-P),
(Currently, nutrient concentrations coming out of the lagoon usually exceed those entering the lagoon),
(3) the development of a meter-thick floating peat mat and floating islands covered with cattails *(Typha domingensis)* that eliminated nearly all quality habitat for aquatic birds,

(4) Flooding in the town.

hydroponic cattails on a nutrient-rich soup



Peat formation and terrestrialization



1989 – Acquisition by the US Fish and Wildlife Service, “Laguna Cartagena National Wildlife Refuge”

Two Congressional Mandates:
(1) Acquisition
(2) Restoration

Hills: cherts and serpentine
Valley: alluvium
Lagoon bottom: clay

Estimated Costs (1987):

Acquisition - $500,000 (realized)
Restoration and Maintenance - $500,000 (estimated). *Funds were allocated in 1989, 1991, 1993 but used elsewhere.*

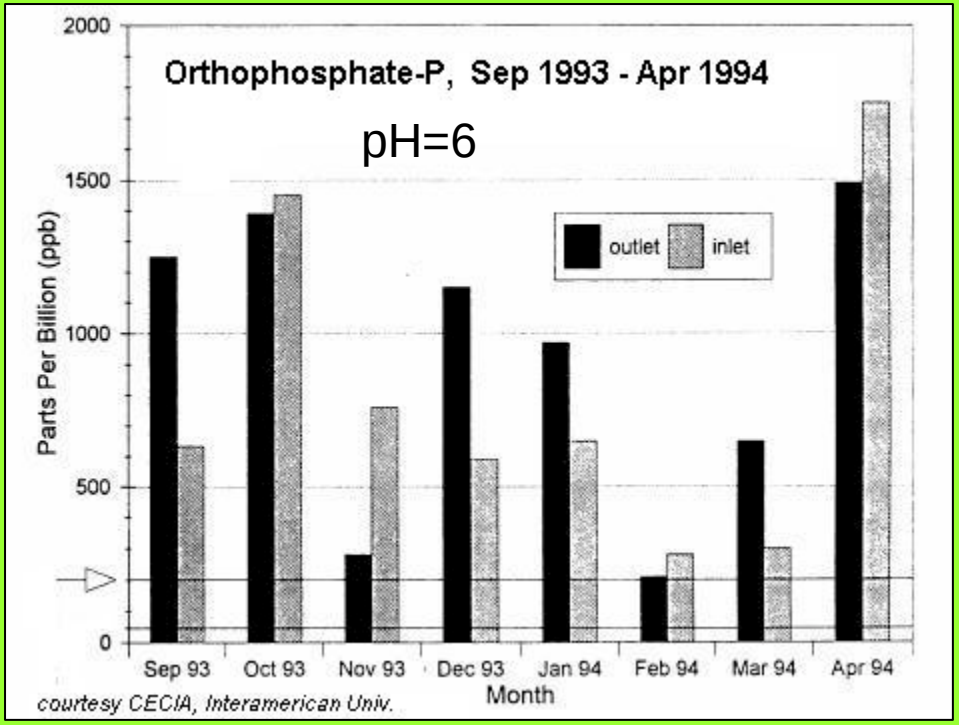
See:
http://www.fws.gov/birdhabitat/NAWCA/projects/USprojects/smallgrants060904/PRLajasValley.pdf

Sugar cane and subsidized fertilizer through 1998

USFWS file photo

While nutrient concentrations (e.g. phosphorus) have declined in recent years, and may continue to decline, they remain high enough to promote accelerated plant growth, thus requiring repeated, periodic maintenance.

Field Orthophosphate P concentrations
One month before hurricane Georges
1998-08-23
Lagoon Center: 500 ppb
Lagoon Outlet: 267 ppb
One month after hurricane Georges
1998-10-25
Lagoon Center: 933 ppb
Lagoon Outlet: 1,000 ppb pH=6



Ortho-P = 5% to 20% of Total-P

2005 Field Orthophosphate P concentrations (ppb), pH =7.5-8

Date	Center	Outlet
17 Jan	27	40
20 Feb	40	80
21 May	107	67
30 May	107	67
25 Sep	60	120
16 Oct	47	113
13 Nov	67	100

	Total	Ortho	
Oligitrophic =	3-10	< 0.05-.15	ppb
Mesotrophic =	18-27	< 0.9-1.35	ppb
Eutrophic =	30-50	< 1.5-2.50	ppb
Dystrophic	>50	>2.5	ppb

Interagency Committee for Laguna Cartagena
Formed in 1991

Goals: Restore, to the extent possible, aquatic bird habitat to pre-disturbance conditions, and alleviate flooding in the town.

Recommendations (proposed since 1991):

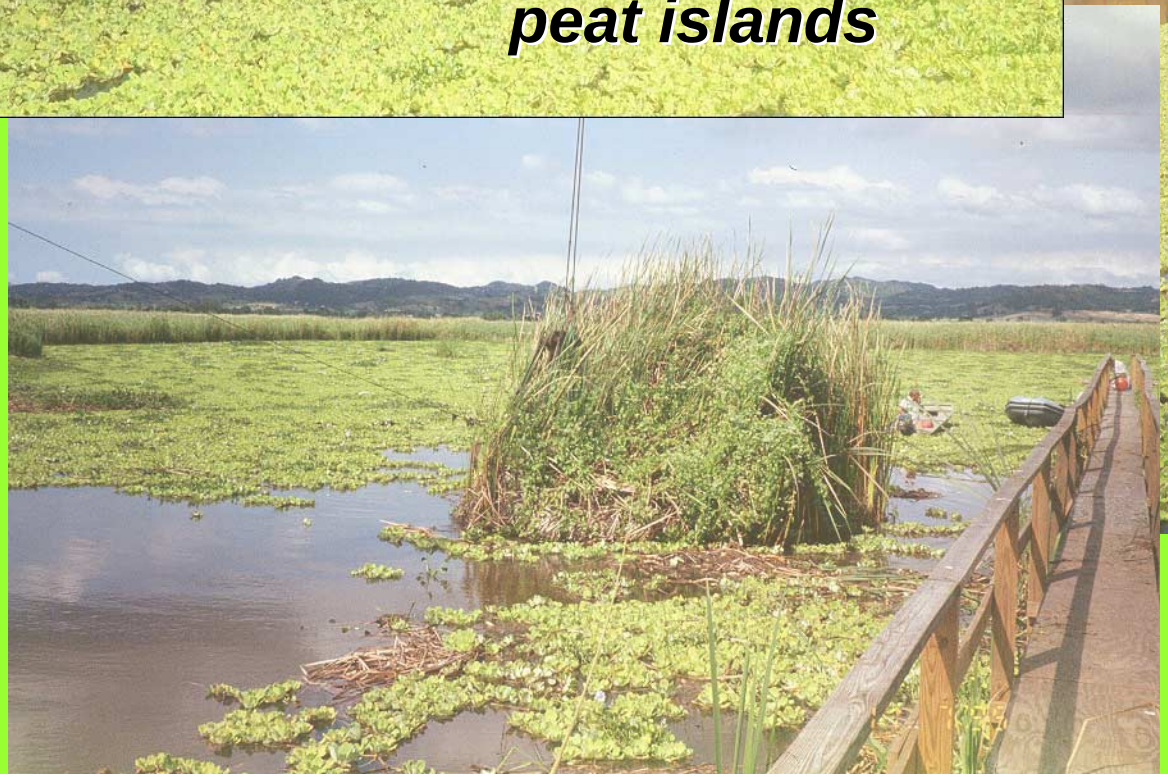
(1) Mechanical removal of peat mat and floating islands

(2) Restoration of hydroperiod and hydrologic regime
(removal of unneeded ditches and levees built for sugar cane cultivation)

(3) Control of vegetative overgrowth, using livestock, and through a coordinated combination of burning and water level management.

Note: FWS has no control over the principle irrigation and drainwater canal inputs or rainfall…


One way or another…
Pulling floating peat islands



Peat is a Highly Marketable Commodity in Puerto Rico!

A community co-op from Magüayo proposes to eliminate the occlusion, alleviate flooding, and begin restoration of the lagoon by harvesting the peat mat and floating islands. Thus far FWS has been in opposition.

Your advice and recommendations are welcomed!

Courtesy Mike Holtkamp, PE, Southwest Florida Water Management District

FWS response - 1996-2005:

(Contrary to Committee recommendations)

Efforts to drain the lagoon.
Dig more ditches. **Sept 2001**

Since 1996 the agency has taken actions that resulted in the accelerated decline of the system. Focusing on eradicating cattails, rather than restoring quality aquatic habitat, and failing to understand the fundamental ecology of the system, the agency began an effort to completely drain the lagoon from 1996 through April, 2005 that resulted in the complete terrestrialization of the outer areas of lagoon and the further proliferation for cattails in the inner, moist-soil area.

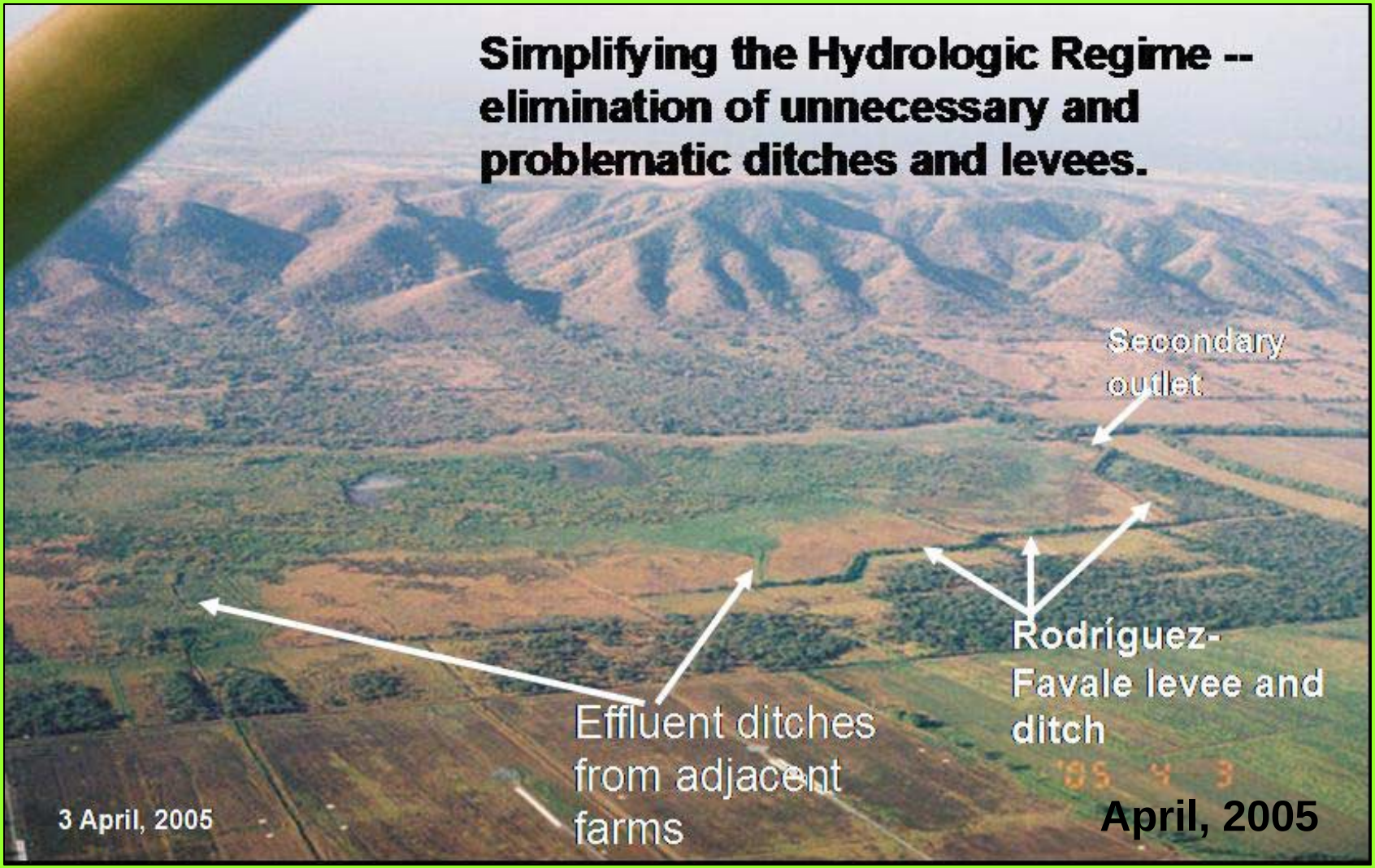
USFWS file photo

Inside the peat mat during the dry season – evaporative salts – Lots of phosphorus.

Habitat continues to decline, and most short-term gains are lost.

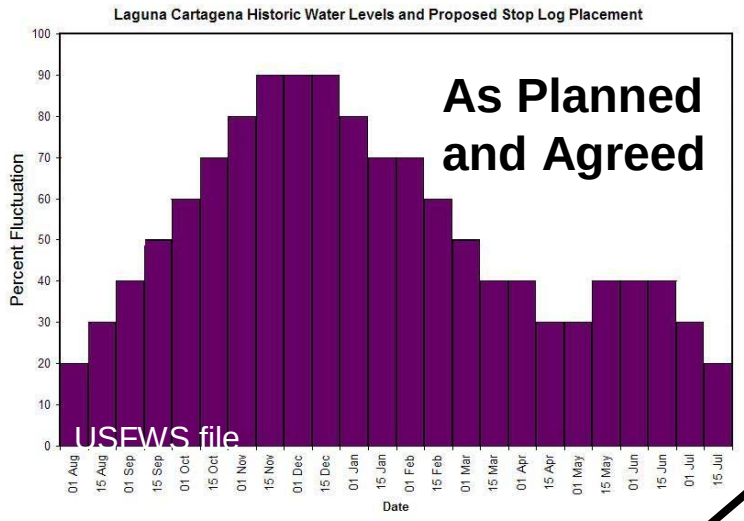
Flooding in Magüayo continues – caused by the occlusion (residence time) and has little relation to lagoon water level, *per se.*

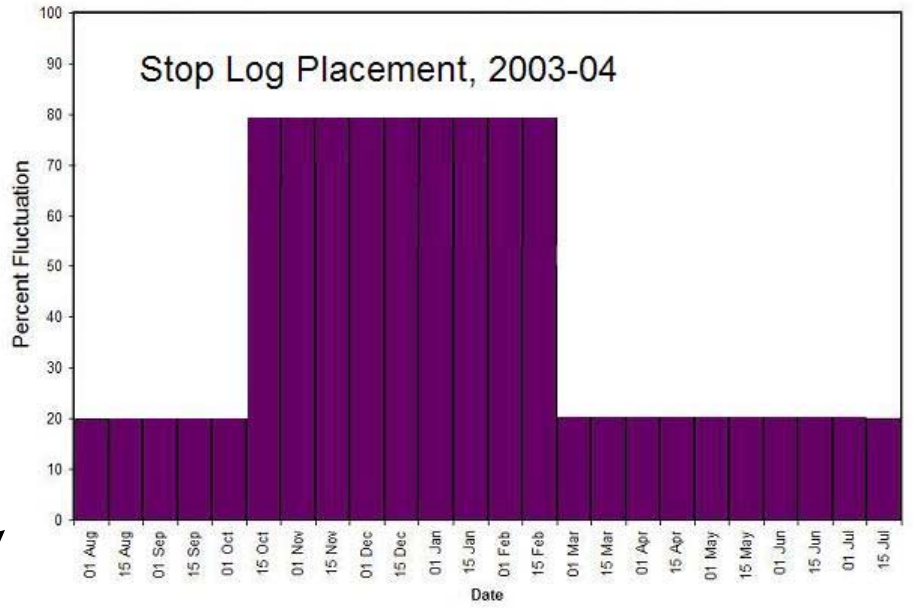
Work with the land, not against it!
(Our proposal)



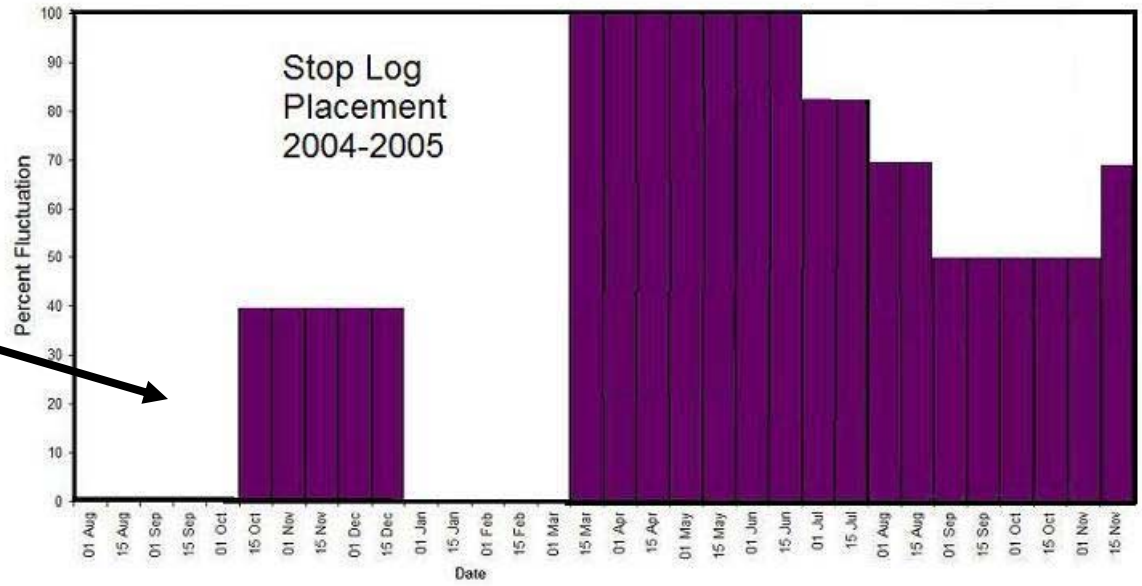

F. C. Schaffner, 2005-04-17

Stop Log (flashboard) Placement



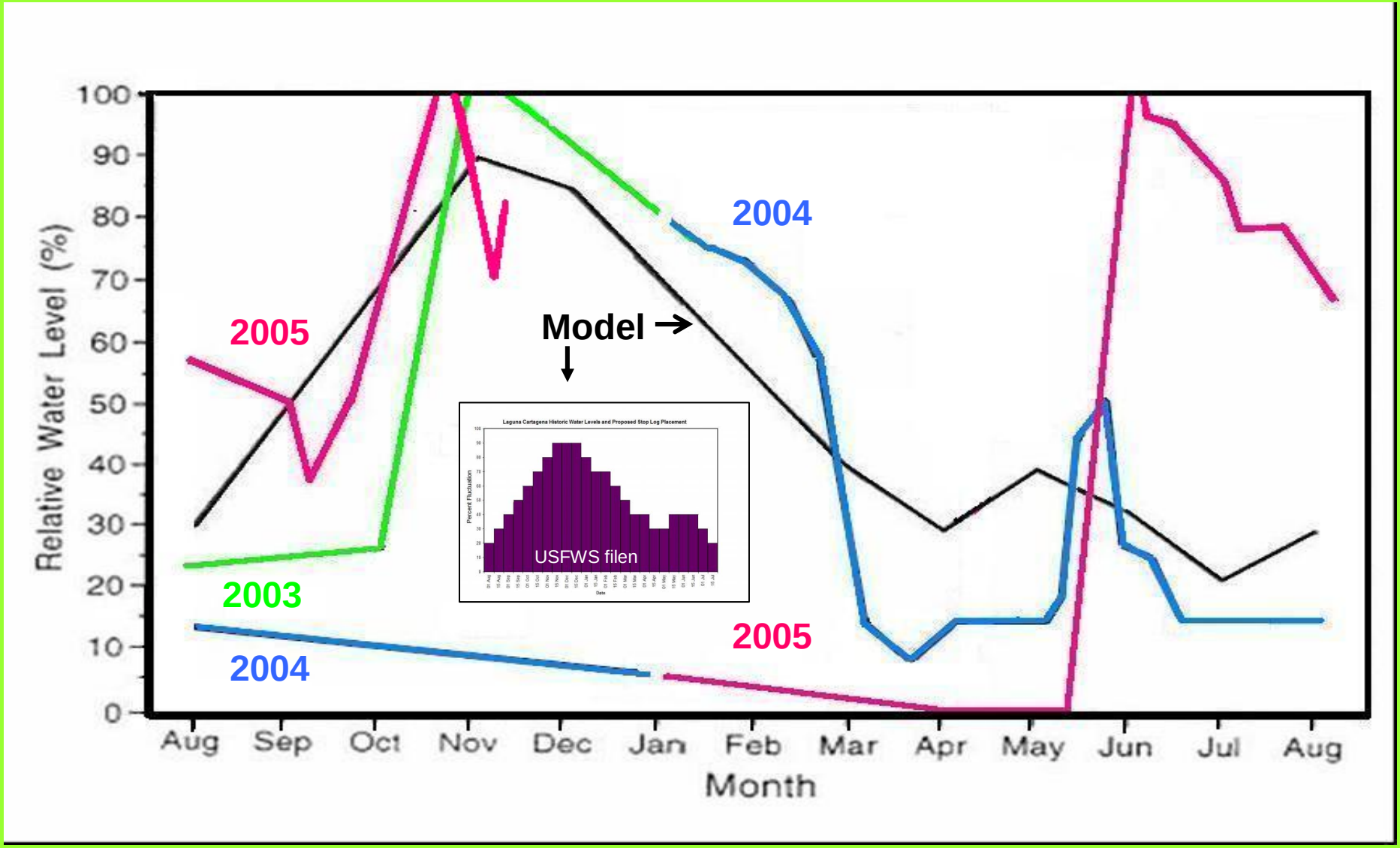


Implemented by FWS



FWS Hydroperiod manipulation

Observed Water Level Changes August 2003 – November 2005



F. C. Schaffner, 2005-05-15

"Shock" re-filling of the lagoon by a single 3.5 in rainstorm (second of the season) – flooding the terrestrialized portions of the lagoon and drowning the terrestrial vegetation.

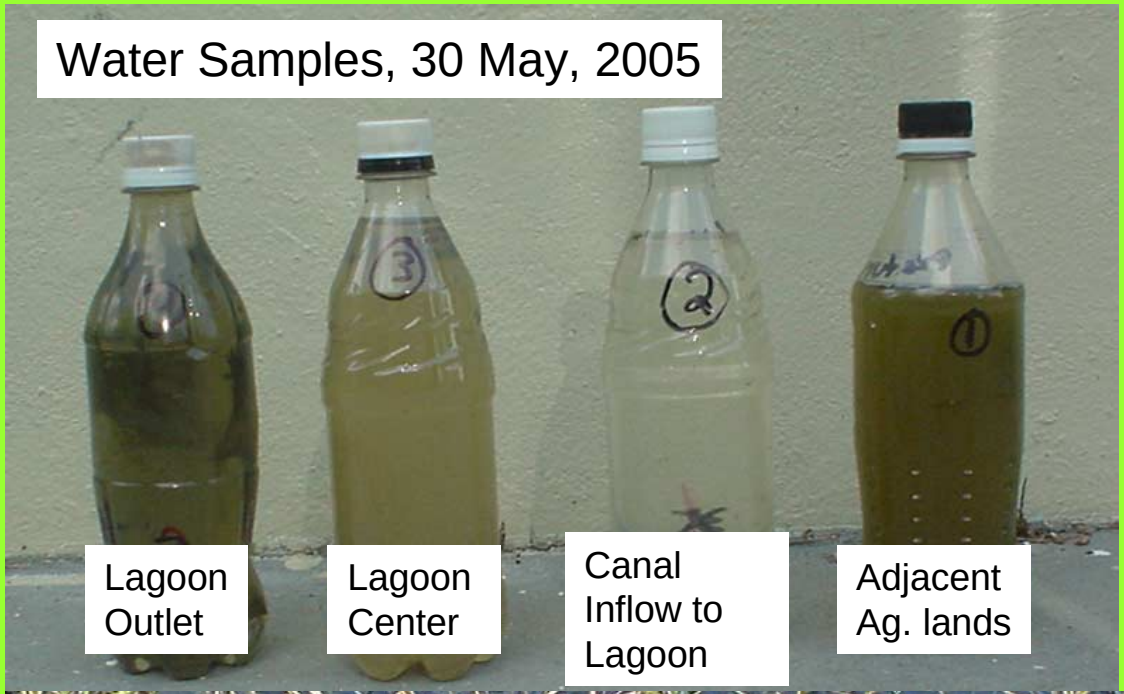
F. C. Schaffner, 2005-05-21


30 May, 2005
Choking Stench of H_2S at Lagoon Outlet Structure

30 May, 2005

Choking Stench of H_2S at Lagoon Outlet Structure

Filamentous yellow streamers in moving water

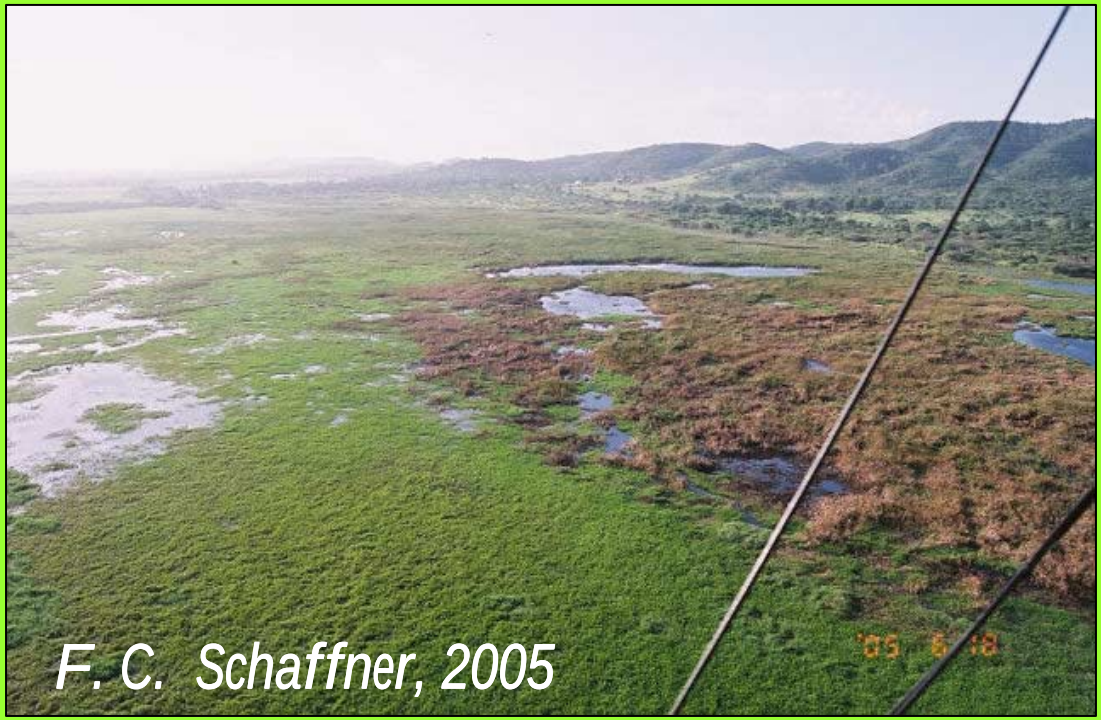


Black Water:

Sulfides?

Mammalian Toxicity?

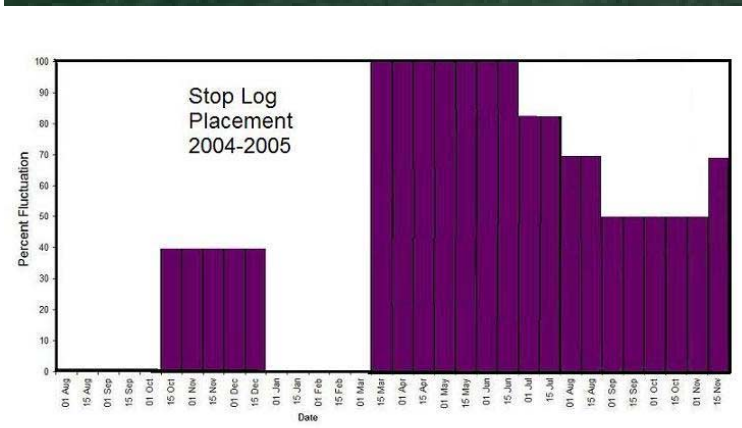
Dead Horses
30 May, 2005



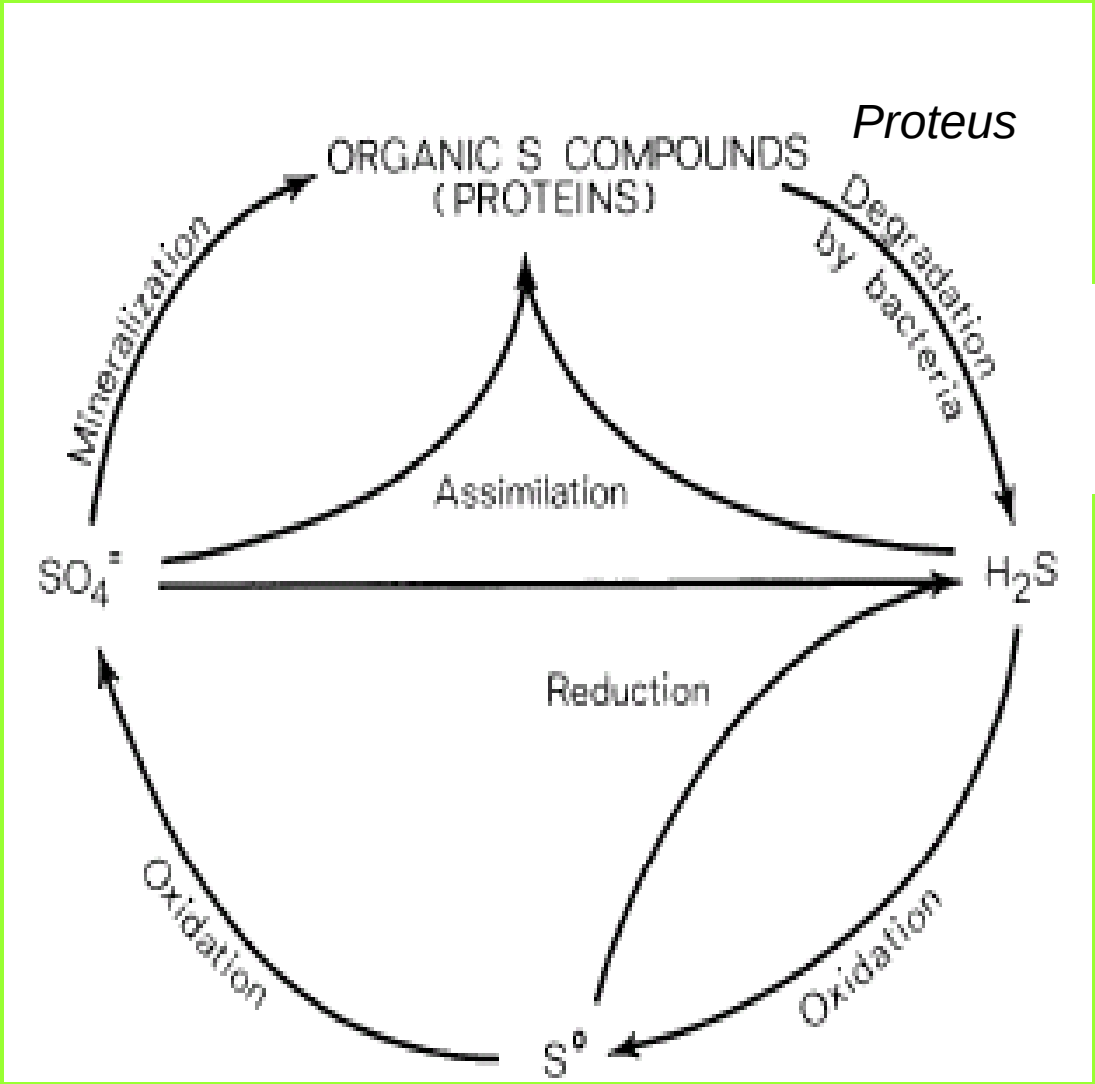
18 June 2005

14 Sept. 2005

vigorous cattail recovery (3m ++)




25 Sept 2005



Proteus

Desulfovibrio, Desulfotomaculum

$$H_2SO_4 + 2(CH_2O) \longrightarrow 2CO_2 + 2H_2O + H_2S$$

$$H_2SO_4 + 4H_2 \longrightarrow 4H_2O + H_2S$$

Fe^{+2}

FeS to anaerobic sediments

Toxicity of S^{-2}?

$$S^0 + 1\tfrac{1}{2}O_2 + H_2O \longrightarrow H_2SO_4$$

Beggiaotoa, Thiothrix

***Plecostomus* sp.**, Laguna Cartagena, 2005-02-20