AgEcon SEARCH
RESEARCH IN AGRICULTURAL & APPLIED ECONOMICS

The World's Largest Open Access Agricultural & Applied Economics Digital Library

This document is discoverable and free to researchers across the globe due to the work of AgEcon Search.

Help ensure our sustainability.

Give to AgEcon Search

AgEcon Search
http://ageconsearch.umn.edu
aesearch@umn.edu

*Papers downloaded from **AgEcon Search** may be used for non-commercial purposes and personal study only. No other use, including posting to another Internet site, is permitted without permission from the copyright owner (not AgEcon Search), or as allowed under the provisions of Fair Use, U.S. Copyright Act, Title 17 U.S.C.*

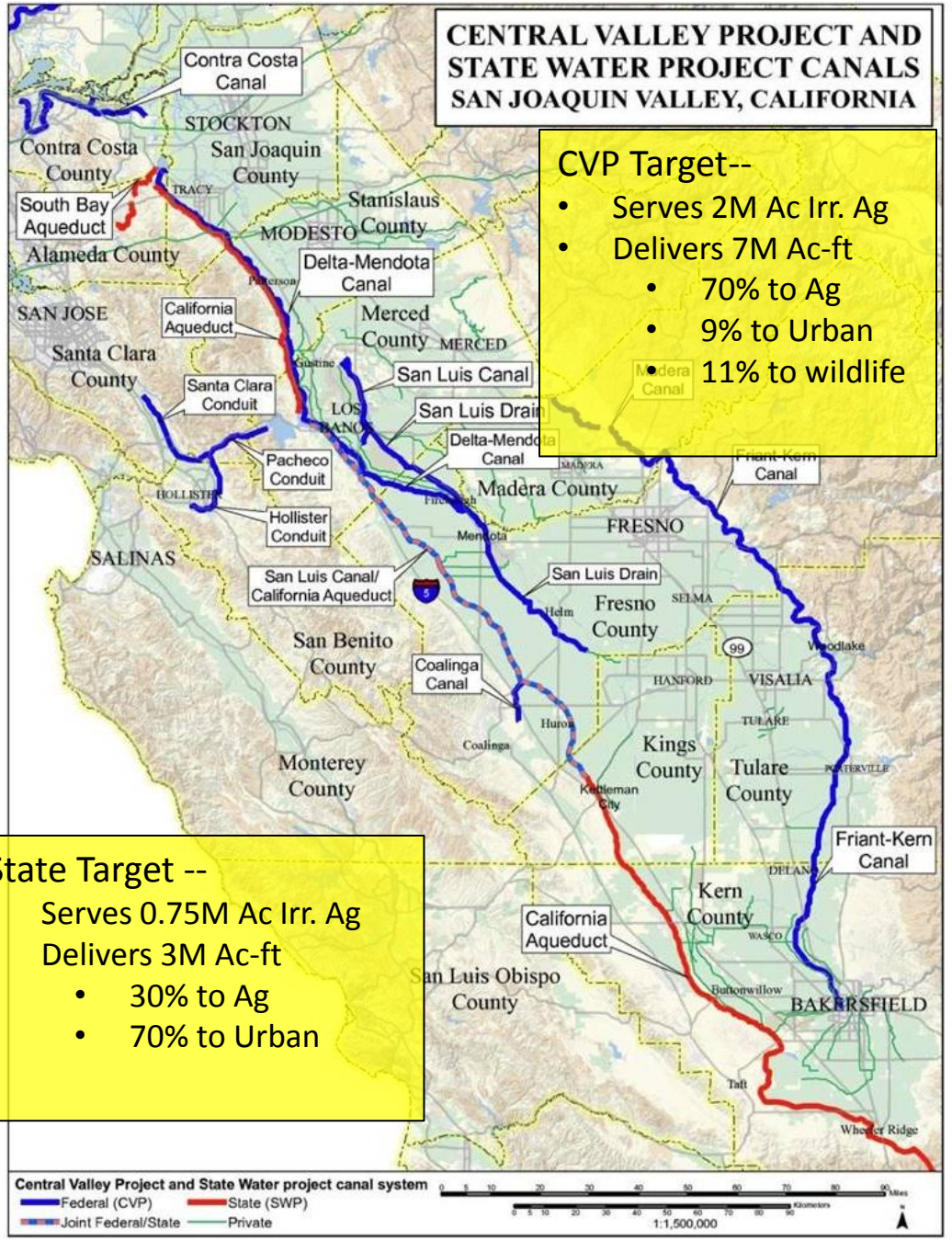
Economic Impacts of Subsidence and Accretion in the Sacramento-San Joaquin Delta

Leslie J. Butler
Department of Agricultural & Resource Economics
University of California-Davis

Duncan MacEwan
ERA, LLC
Davis, California

Contributed paper prepared for presentation at the 59th AARES Annual Conference, Rotorua, New Zealand, February 10-13, 2015

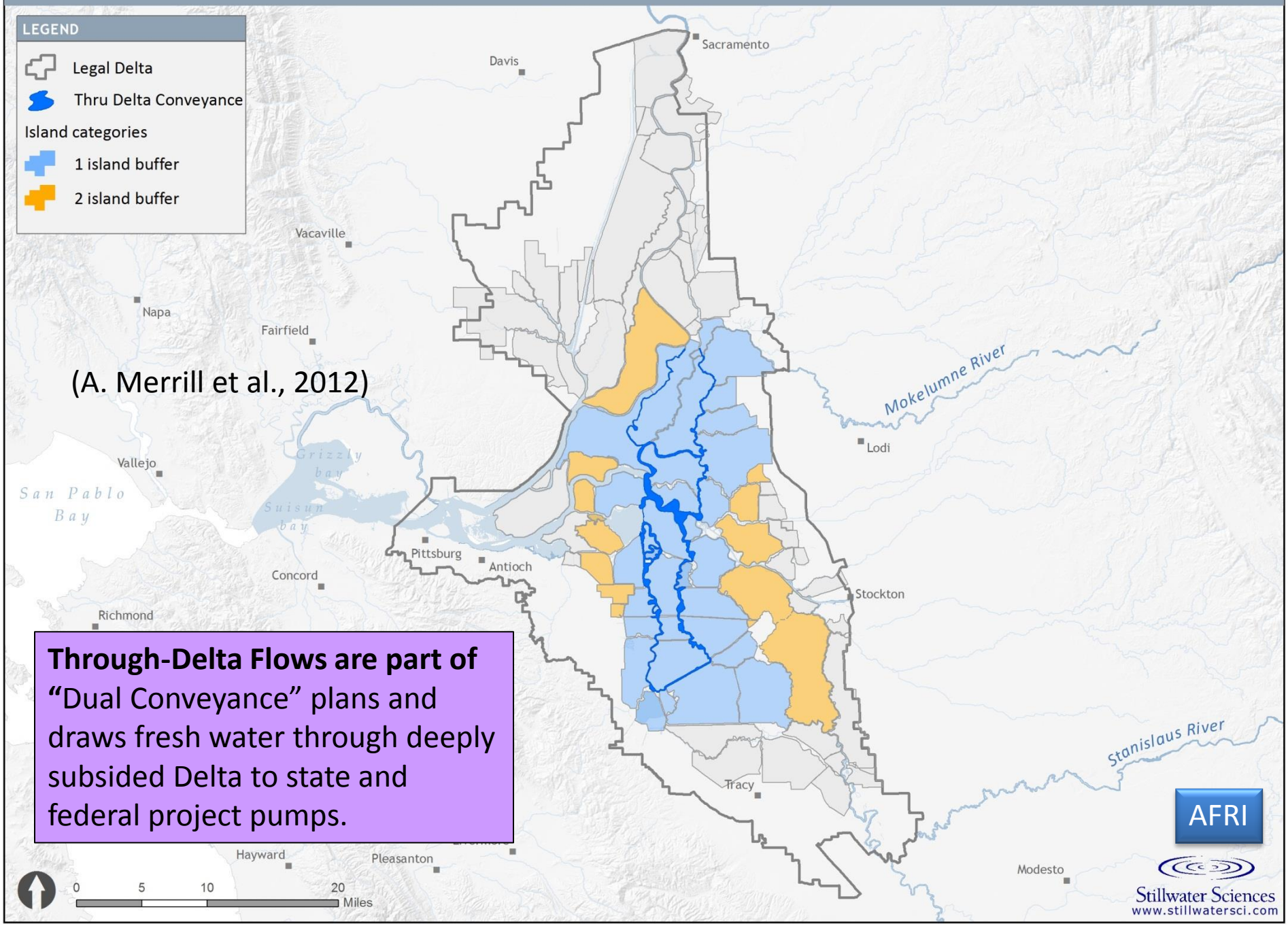
Watershed of the Sacramento-San Joaquin Delta and Regions that Use Delta Water



CVP Target--
- Serves 2M Ac Irr. Ag
- Delivers 7M Ac-ft
  - 70% to Ag
  - 9% to Urban
  - 11% to wildlife

State Target --
- Serves 0.75M Ac Irr. Ag
- Delivers 3M Ac-ft
  - 30% to Ag
  - 70% to Urban

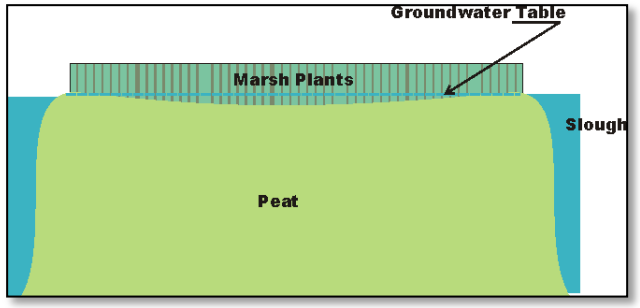
Existing Through-Delta Water Conveyance:



(A. Merrill et al., 2012)

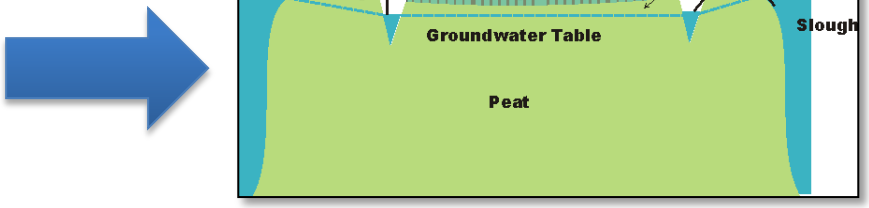
Through-Delta Flows are part of "Dual Conveyance" plans and draws fresh water through deeply subsided Delta to state and federal project pumps.

Island Transitions from Wetlands to Today's Agriculture

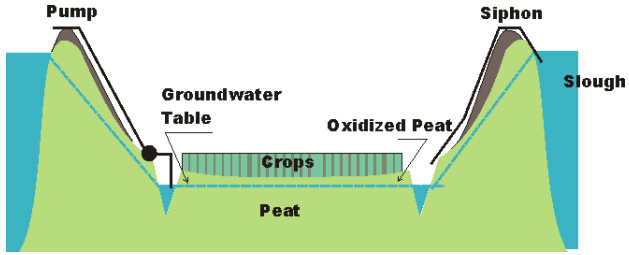


Flooded Marshland

Reclaimed
To Early
Agriculture

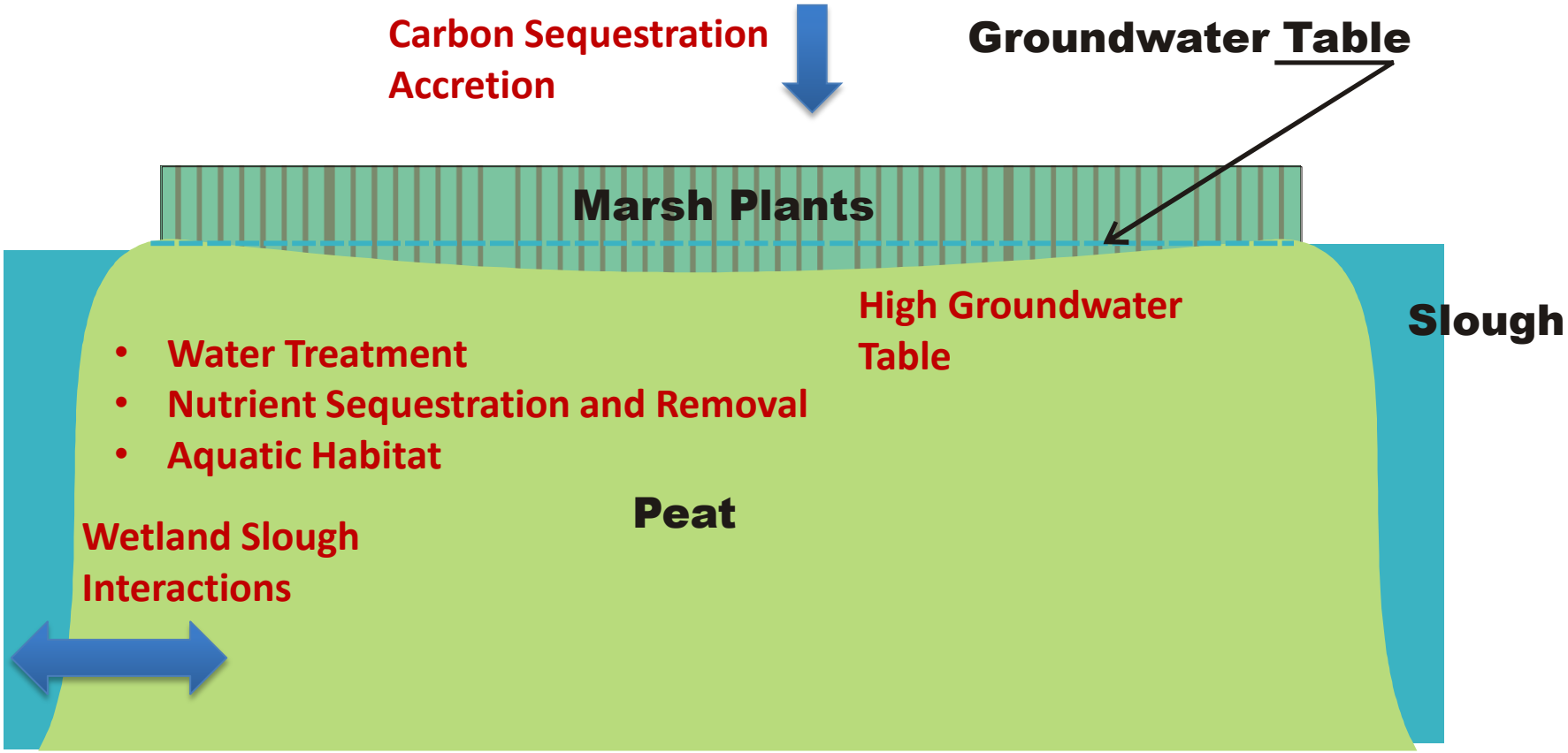


To Current
Agriculture



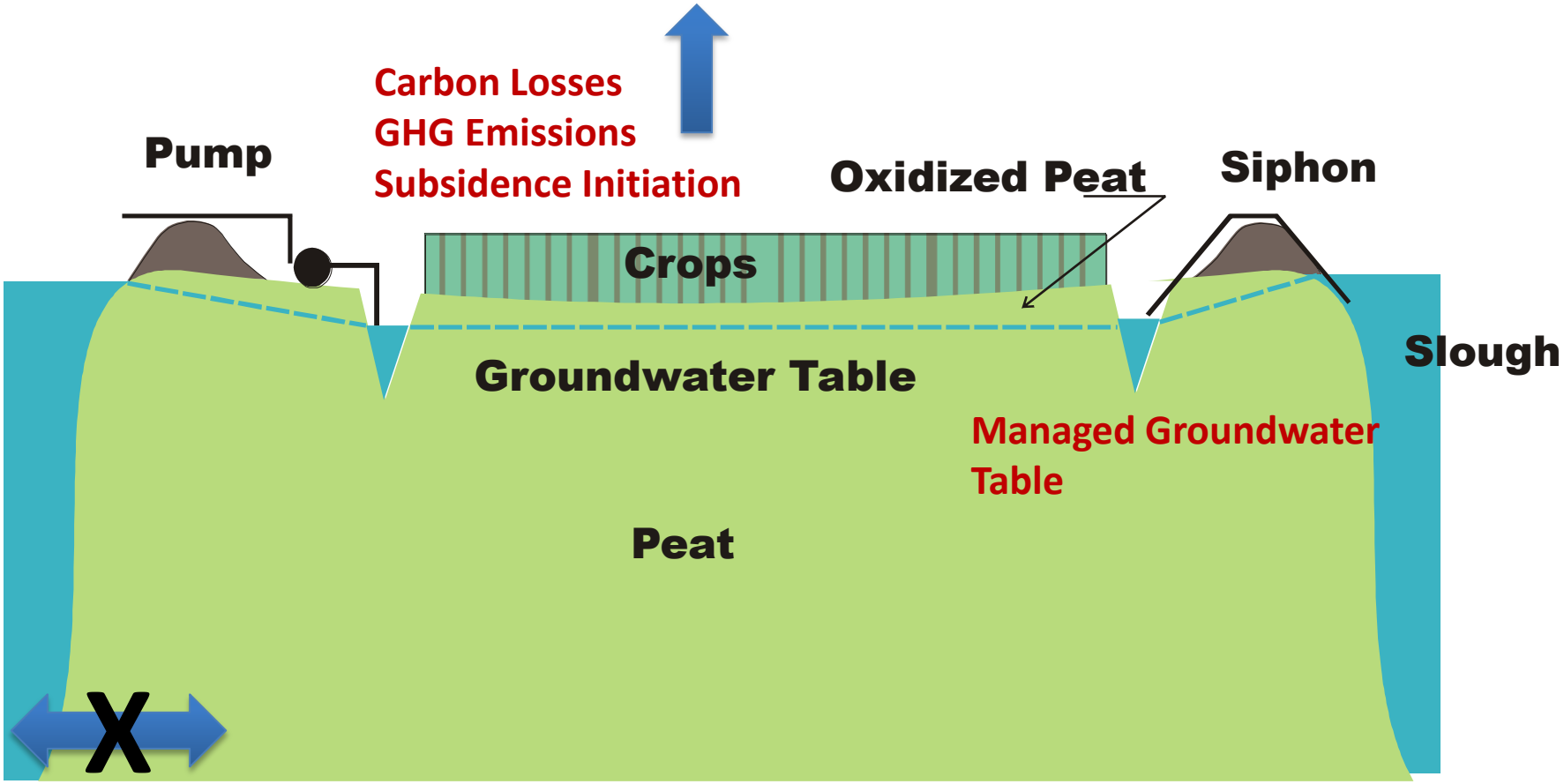
AFRI

Delta Island Model Before Farming



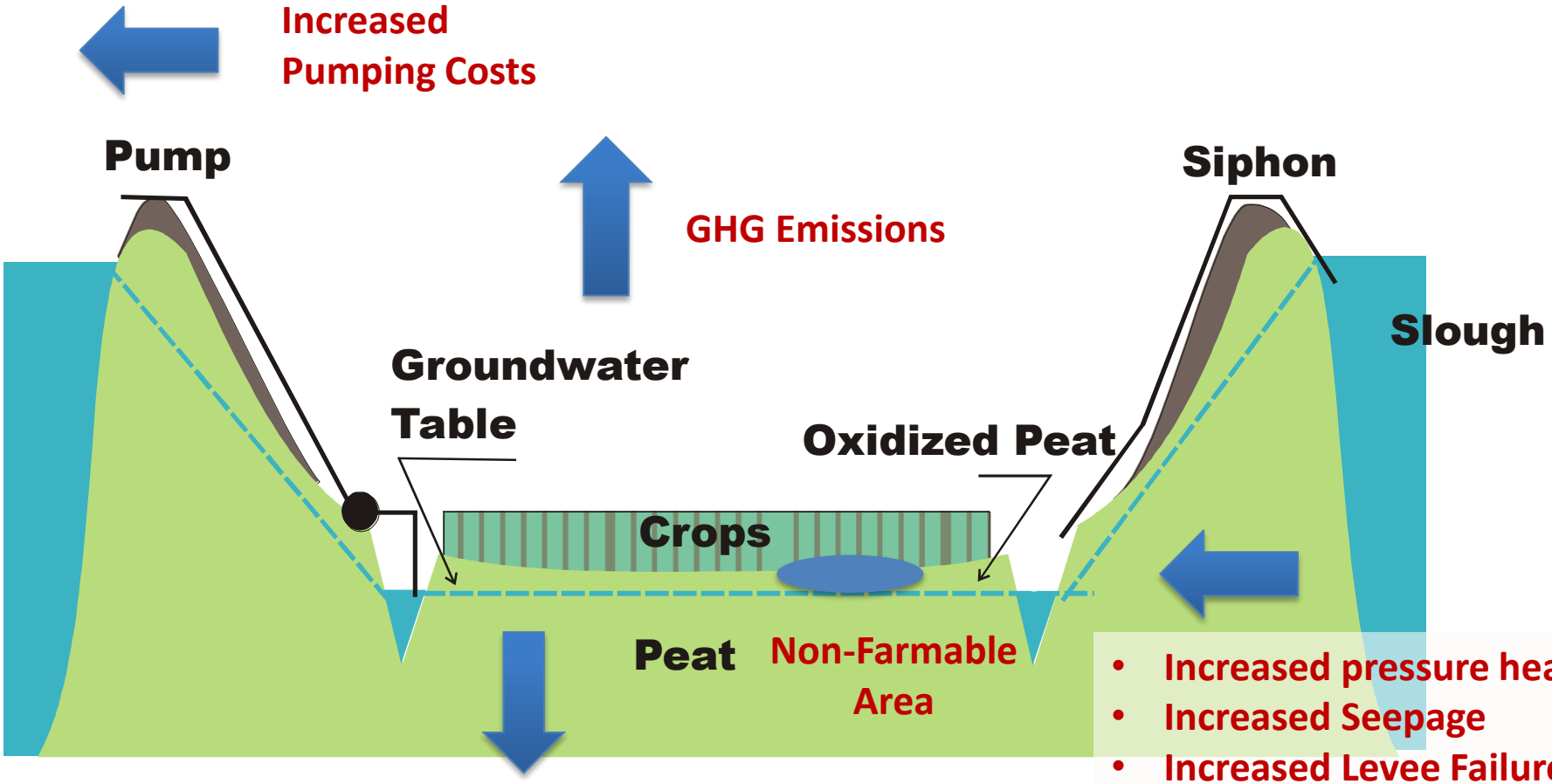
AFRI

Early Agriculture



AFRI

Current Agriculture



- Subsidence and Dropping Island Elevations
- Dropping GW Table
- Decreasing Peat Layer

- Increased pressure head
- Increased Seepage
- Increased Levee Failure Risks

AFRI

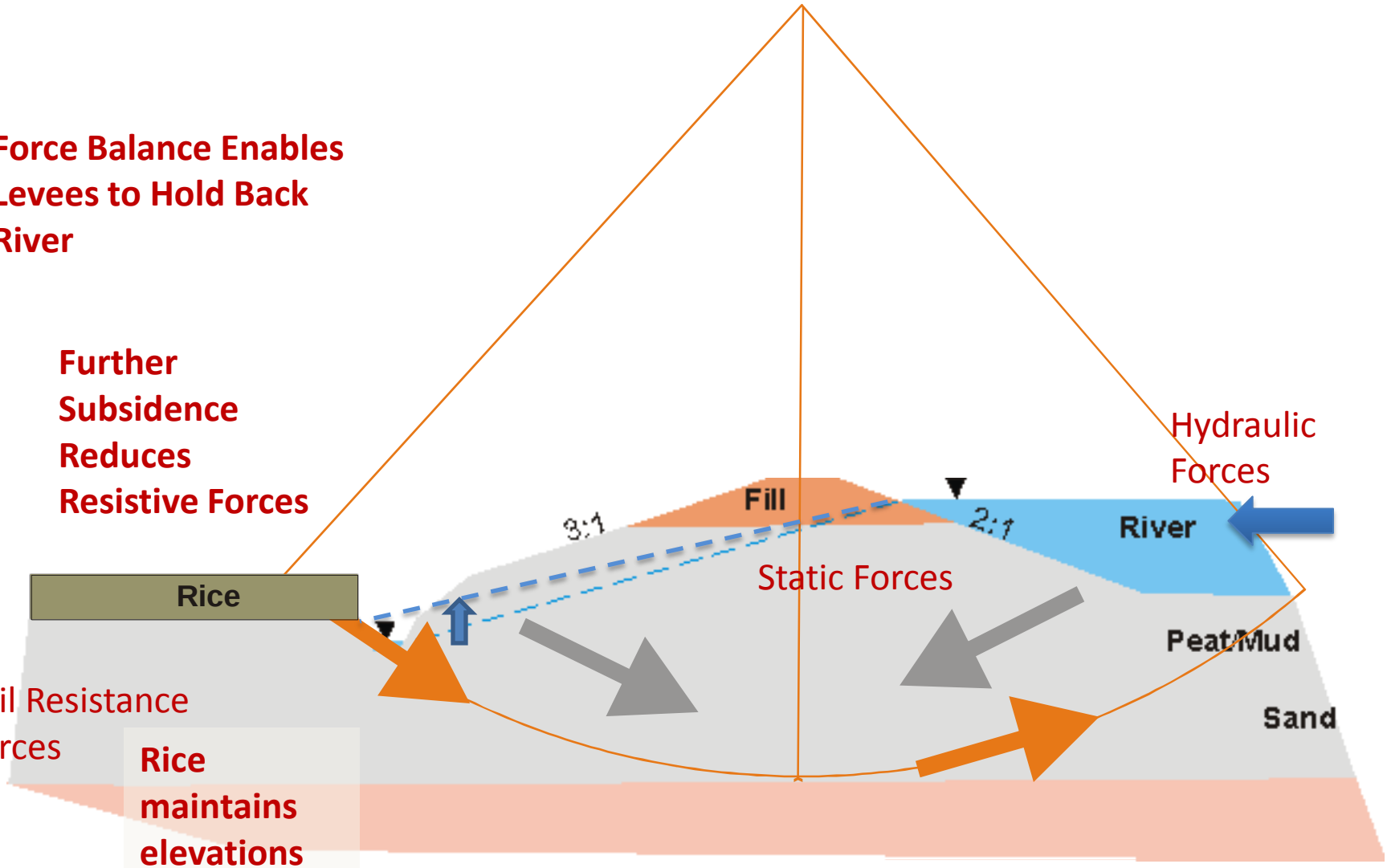
Objectives

- The objective of our project is to show that establishing rice-based cropping systems in the Delta can:
  - Slow or stop subsidence → decreased soil loss → increased stability of levees → reduced risk of failure of Delta for conveyance of water
  - Reduce GHG emissions and increase C sequestration
  - Improve water quality

Conceptual Model – Levee Force Diagram

Force Balance Enables Levees to Hold Back River

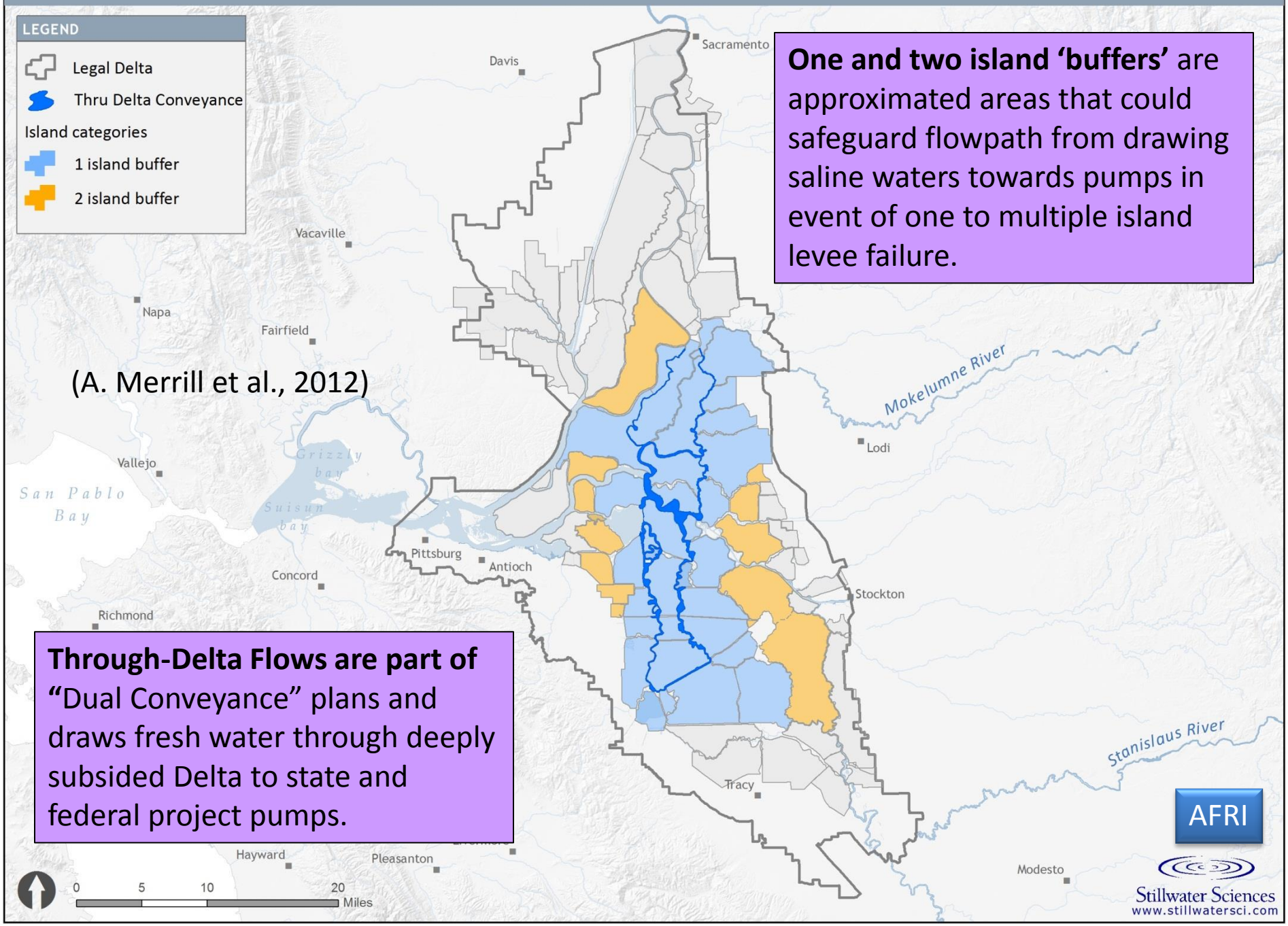
Further Subsidence Reduces Resistive Forces



Rice maintains elevations and forces

AFRI

Existing Through-Delta Water Conveyance:



One and two island 'buffers' are approximated areas that could safeguard flowpath from drawing saline waters towards pumps in event of one to multiple island levee failure.

(A. Merrill et al., 2012)

Through-Delta Flows are part of "Dual Conveyance" plans and draws fresh water through deeply subsided Delta to state and federal project pumps.

AFRI

Stillwater Sciences
www.stillwatersci.com

Question

- To slow or stop subsidence requires soil to be covered with water to prevent oxidation.
- Thus can only sustain rice and/or wetlands as productive agriculture
- Rice is a productive cash crop that maintains agricultural base of the Delta
- Wetlands can sequester carbon and accrete soil → reversal of subsidence and improved water quality
- What is the trade-off, in terms of benefits, between the two strategies??

THE TRADE-OFF

- Rice is productive cash crop – but does not contribute much to reversal of subsidence.
- Wetlands is not very profitable for producers, but accretes up to 10X more organic matter (OM) than rice, thus increasing subsidence reversal potential.
- So which is the most useful in terms of the objectives of our project?
- And which one should we encourage?

Trade-Off in Costs & Benefits

- The answer, of course, is that it should be MARKET based!
- If, for example, I offer a producer $250/acre to grow rice, then how much should I offer the producer to establish a wetlands??
- More? Less? The same?
- And what are the costs and benefits of the trade-off?

Modeling of Levee Failure

$$CF = 0.5\rho g H^2 L$$

CF = cumulative hydrostatic force, (measured in Newtons)

ρ = the density of water,

g = gravitational acceleration,

H = the difference between the channel water surface elevation and the average elevation of the island,

L = the levee length of the island.

- NOTE: H changes over time and is unique to each islands base elevation

Also Note: L is unique to each island

$$H(t) = BE + S(t) - A(t) + SL(t)$$

H(t) = the difference between the channel water surface elevation and the average elevation of the island at time t;

BE = Base elevation at a given (known) time

S(t) = Subsidence in time t

A(t) = Accretion in time t

SL(t) = Sea-level at time t

Thus, Cumulative Hydrostatic Force at time t is:

$$CF(t) = 0.5\rho g H(t)^2 L$$

CUMULATIVE HYDROSTATIC FORCE CF(t) as an index of change

- Thus CF(t) becomes an index of the changing forces on a levee due to subsidence, accretion, and changes in sea-level.
- Assuming that a levee has a known probability of failure at a particular point in time, we can use CF(t) to project the probability of levee failure over time.
- AP(t) = ƒ[BP, CF(t)]

  AP(t) = Annual Probability of Levee Failure at time t

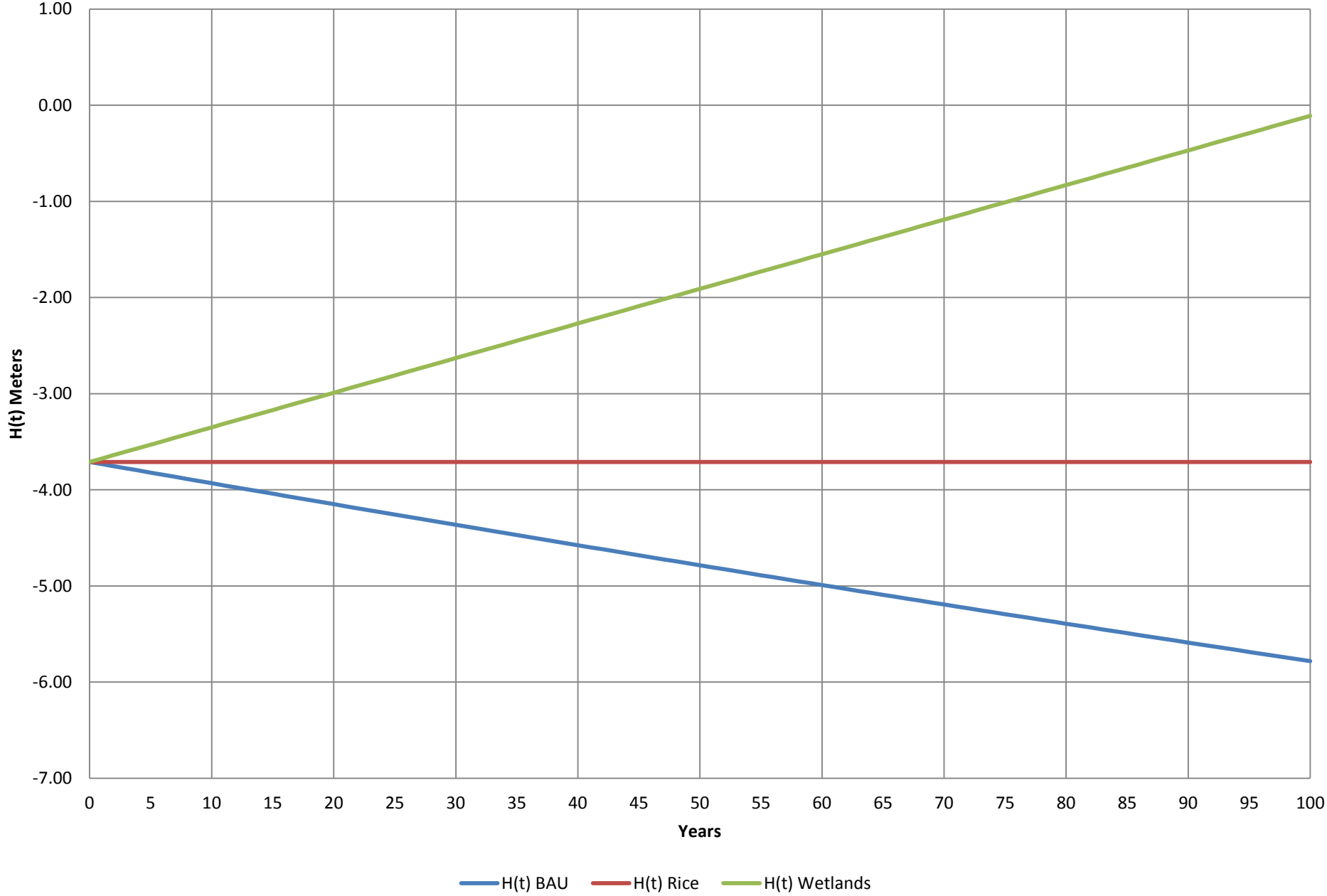
  BP = Base probability of levee failure at a known time in the present/past

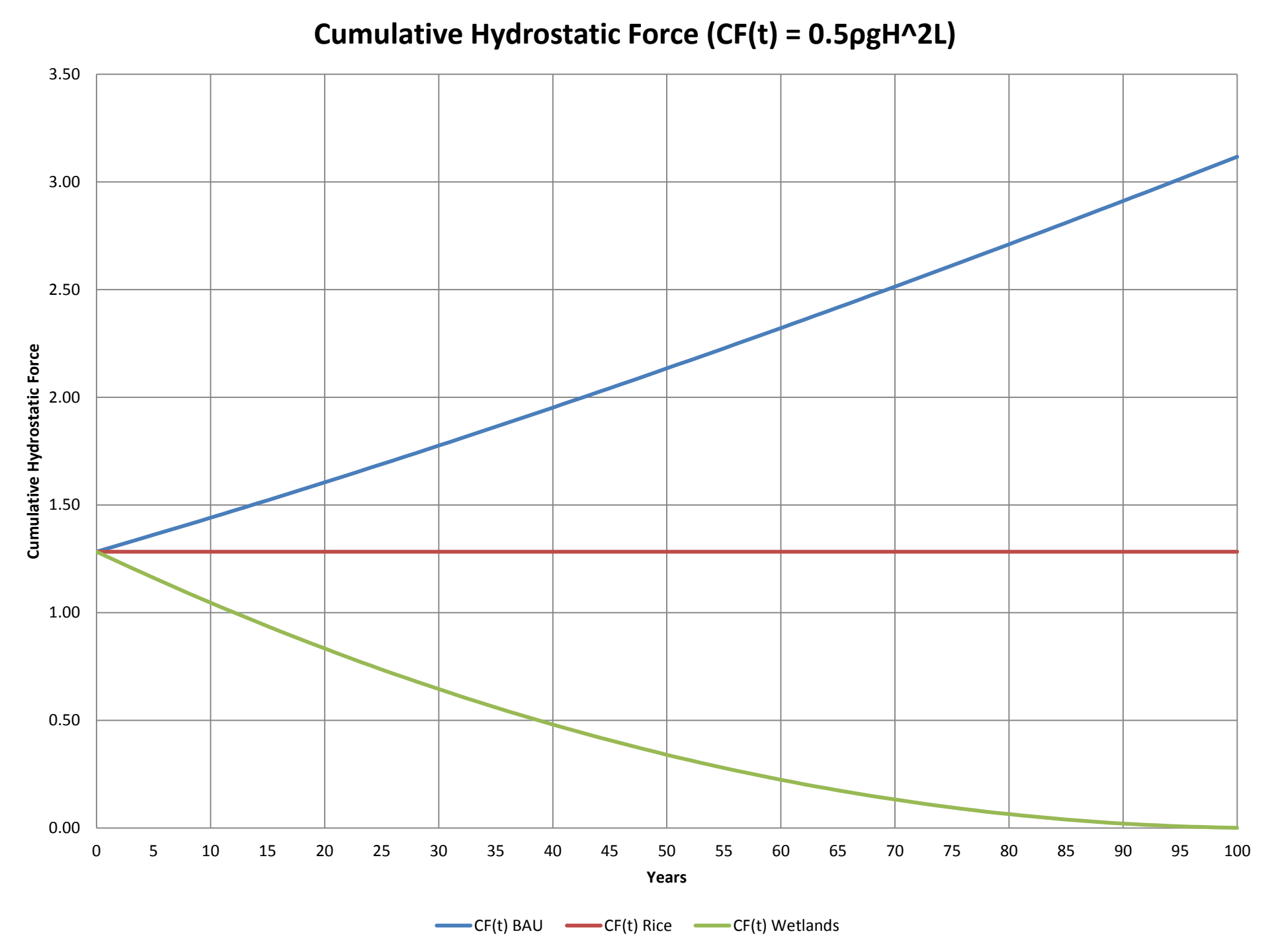
  CF(t) = Cumulative Hydrostatic Force over time, as defined above.

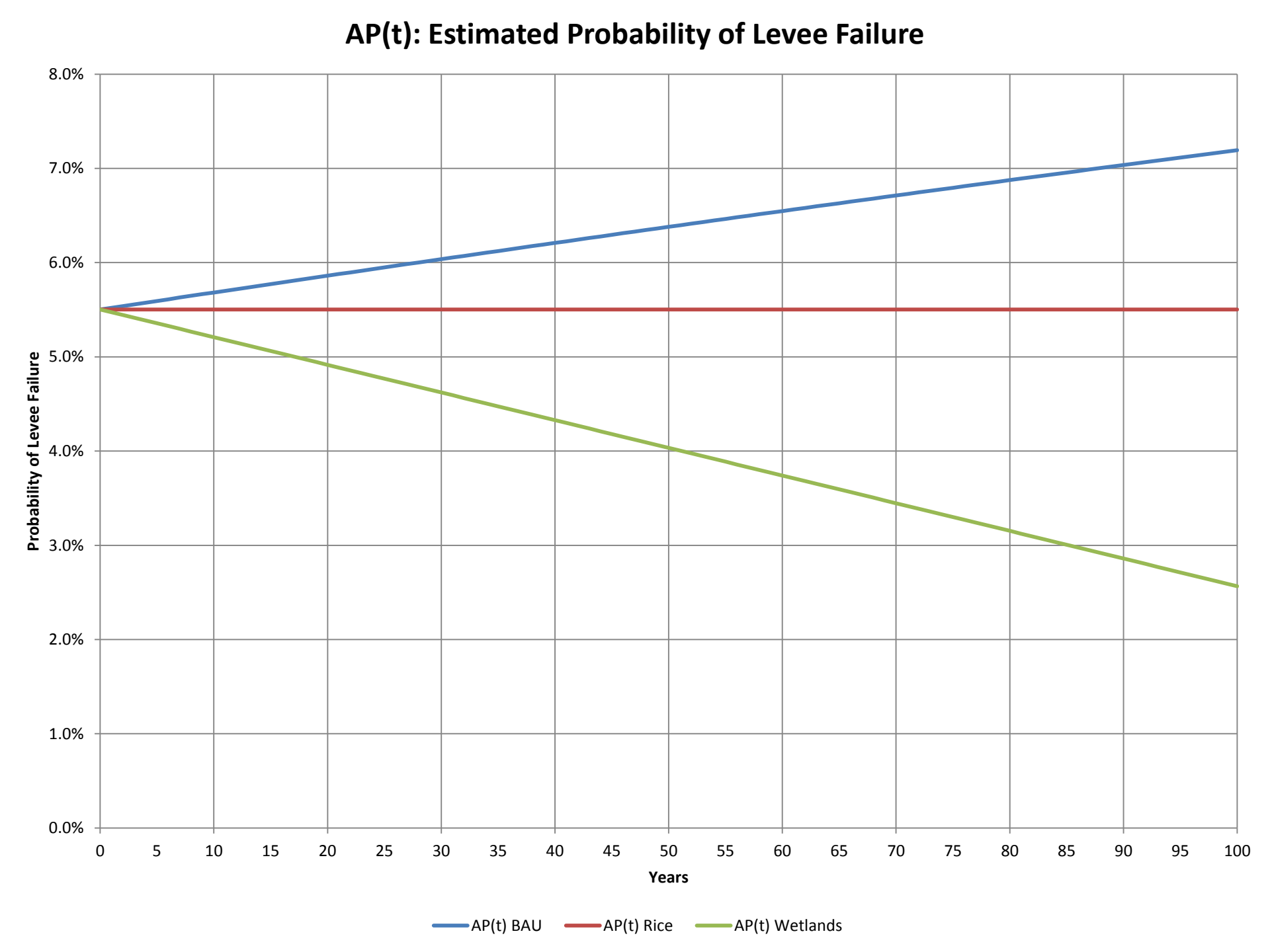
Summary

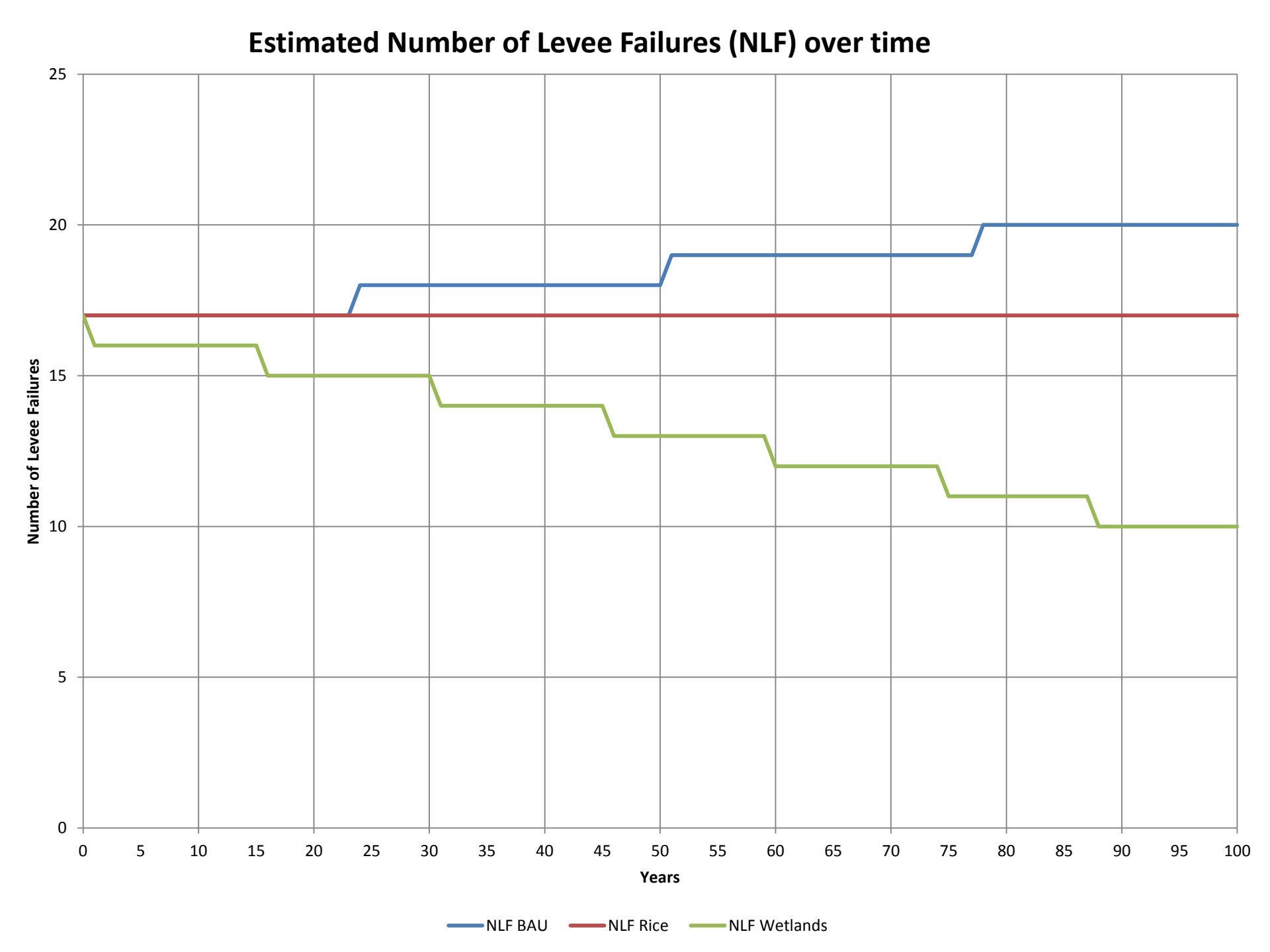
- $CF(t) = 0.5\rho g H(t)^2 L$
  - where:
- $H(t) = BE + S(t) - A(t) + SL(t)$
- Thus:
  - Annual Probability of Levee Failure (AP(t)) = ƒ[Base Probability of Levee Failure, CF(t)]
- AP(t) is unique to each island at a particular time t.

H(t) - The difference between channel water and elevation of island
= Base Elevation + Subsidence – Accretion + Sea Level Rise




Cumulative Hydrostatic Force (CF(t) = 0.5ρgH^2L)
Cumulative Hydrostatic Force
3.50
3.00
2.50
2.00
1.50
1.00
0.50
0.00
0
5
10
15
20
25
30
35
40
45
50
55
60
65
70
75
80
85
90
95
100
Years
CF(t) BAU
CF(t) Rice
CF(t) Wetlands


AP(t): Estimated Probability of Levee Failure
8.0%
7.0%
6.0%
5.0%
4.0%
3.0%
2.0%
1.0%
0.0%
Probability of Levee Failure
0
5
10
15
20
25
30
35
40
45
50
55
60
65
70
75
80
85
90
95
100
Years
AP(t) BAU
AP(t) Rice
AP(t) Wetlands


Estimated Number of Levee Failures (NLF) over time
Number of Levee Failures
25
20
15
10
5
0
0
5
10
15
20
25
30
35
40
45
50
55
60
65
70
75
80
85
90
95
100
Years
NLF BAU
NLF Rice
NLF Wetlands

Approach

- We use Bernoulli trials in simulations to estimate the number of levee failures simultaneously for each of the 3 scenarios (BAU, Rice and Wetlands) for each year for 100 years.
- For each levee failure the PV of the cost of levee repair, cost savings (PV of BAU cost – PV Cost of Rice/Wetlands), and NPV is estimated for Rice and for Wetlands.

Benefits

i) The cost savings associated with reduced levee failure by slowing, stopping or reversing subsidence.

ii) Ecosystem services include:

- reduced GHG emissions
- increased carbon sequestration,
- increases in water quality,
- increases in recreational and existence values.

Ecosystem Service Values (Annual per acre)		
	Rice	Wetlands
GHG emission & C sequestration	$88.40	$165.90
Water Quality	??	$127.76
Recreation	$57.50	$115.10
Existence	??	??
less Methyl Mercury	??	??
less Mosquitos	??	??
TOTAL	$145.90	$408.76

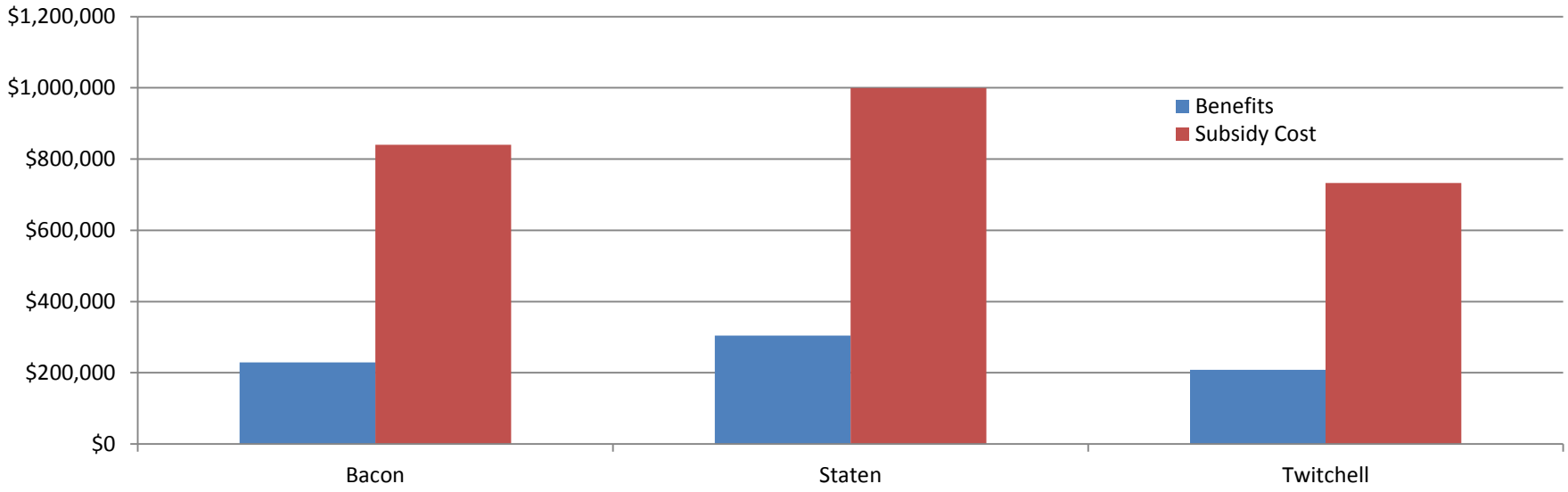
Costs

- Agricultural producers are unlikely to establish rice and/or wetlands without some incentive
- Therefore it is likely that producers will have to be subsidized into establishing the desired acreage of rice and/or wetlands.
- These subsidies then become the costs of establishing rice and/or wetlands in the Delta.

Delta-wide Analysis

- Subsidy rate of $300 per ha
  - Delta-wide Benefit-Cost ratio of 0.27
  - Variation between islands depending on the existing land use and the relative profitability of rice
    - Highest BCR on Deadhorse Island (0.86) – small island of primarily corn, thus accretion benefits of rice can be achieved over a small island footprint
- Total costs of rice subsidy: $24 million
- Total benefits of reduced levee failure risk: $6.2 million

Example Islands



- Excludes ecosystem service and regional economic benefits
- Wetlands will be included as an alternate land use practice in future analyses