Response of a Newly Created Marsh-Wetland Affected by Tidal Forcing, Upland Discharge, and Groundwater Interaction

Mouth of Columbia River, Cape Disappointment State Park, Washington

Hans R. Moritz[1], Rachel Hanna[1], James Burton[1], Barbara Cisneros[1], Chris Humphries[1], Brian Abel[2]

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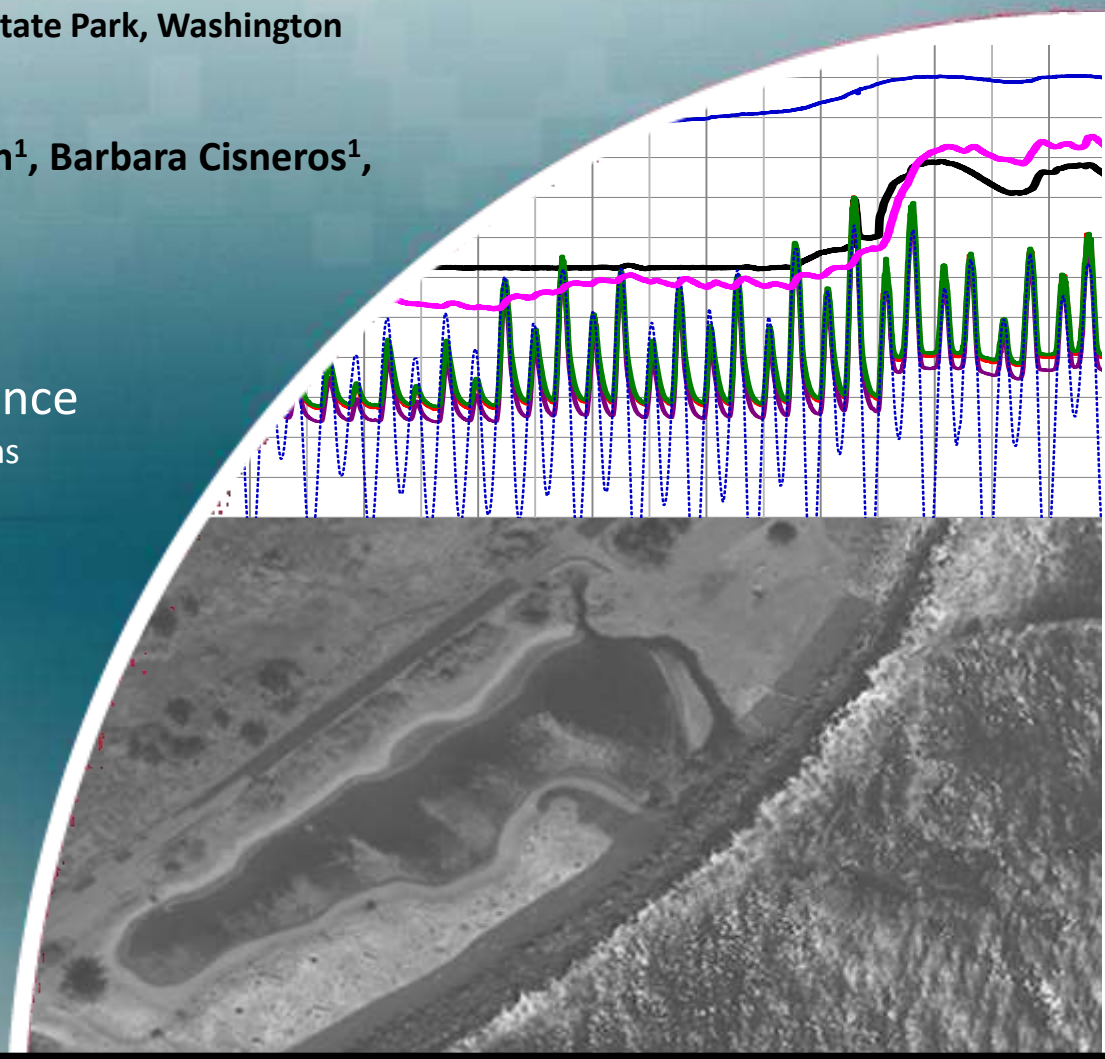


2016 Columbia River Estuary Conference

THEME: Recent Anomalous Environmental Conditions – Drivers and Consequences

Astoria, Oregon
24 MAY 2016

PRESENTATION OUTLINE

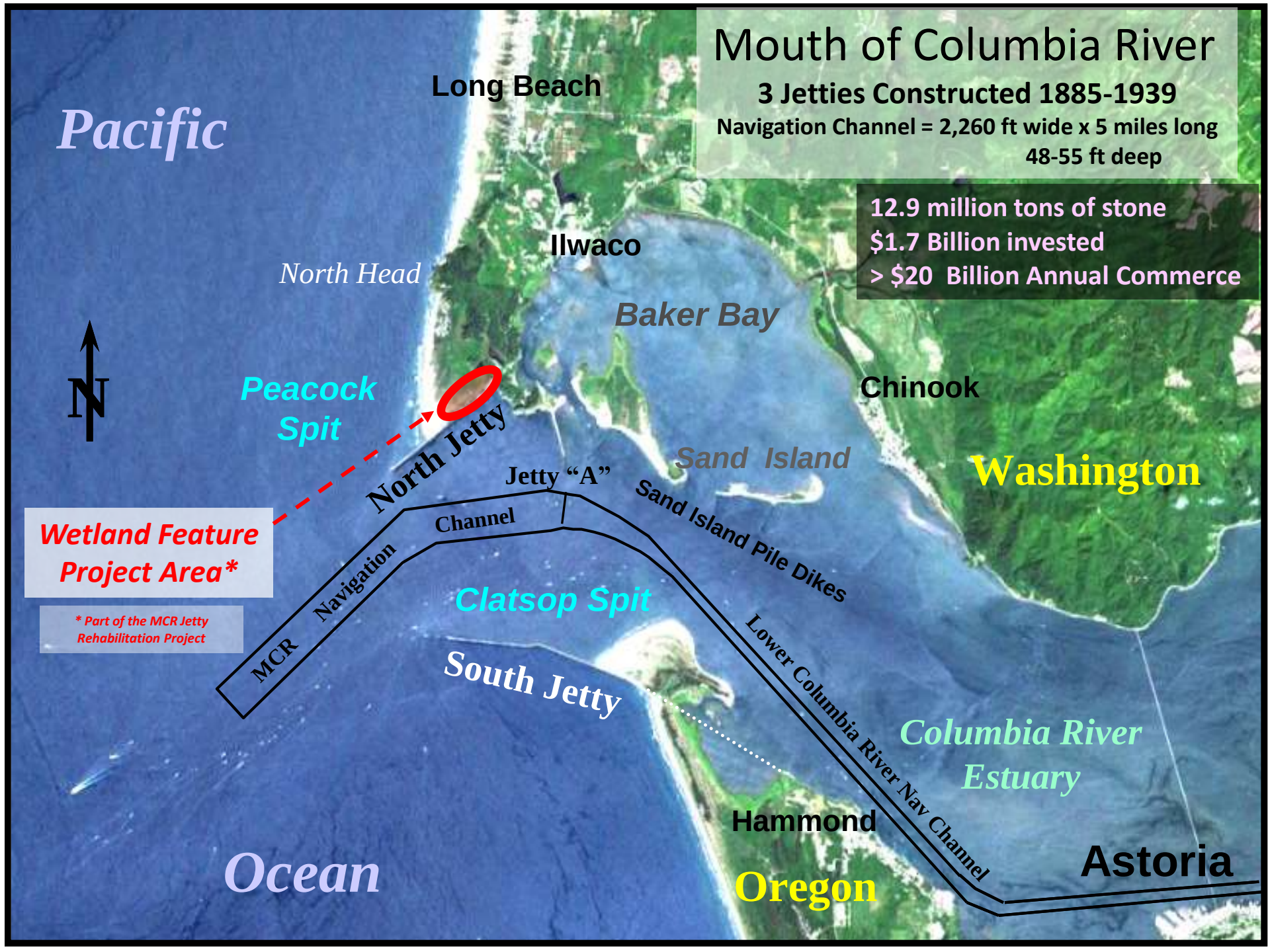
1) Highlight rationale for creating a new 3-acre intertidal marsh-wetland along the landward base of the MCR North Jetty

2) Illustrate how the newly created wetland is inundated by tides passing through a porous rock weir control structure

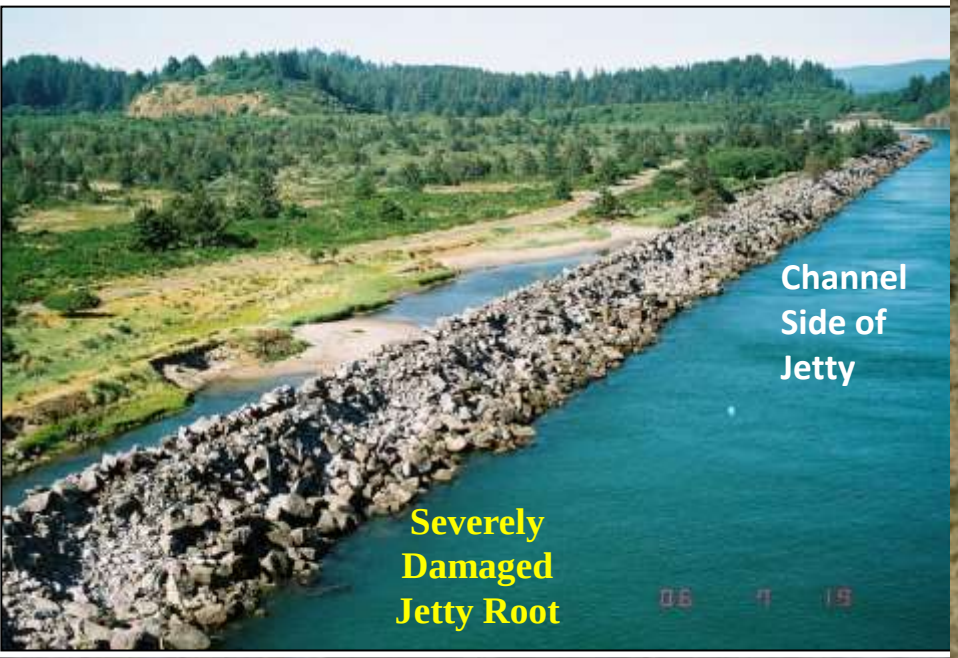
3) Examine how the newly created wetland hydrology interacts with adjacent groundwater and pre-existing wetland drainage during summer and winter

Newly Created Intertidal Wetland Feature

Created FEB-APR 2015 - Near MCR North Jetty (River Mile 1)

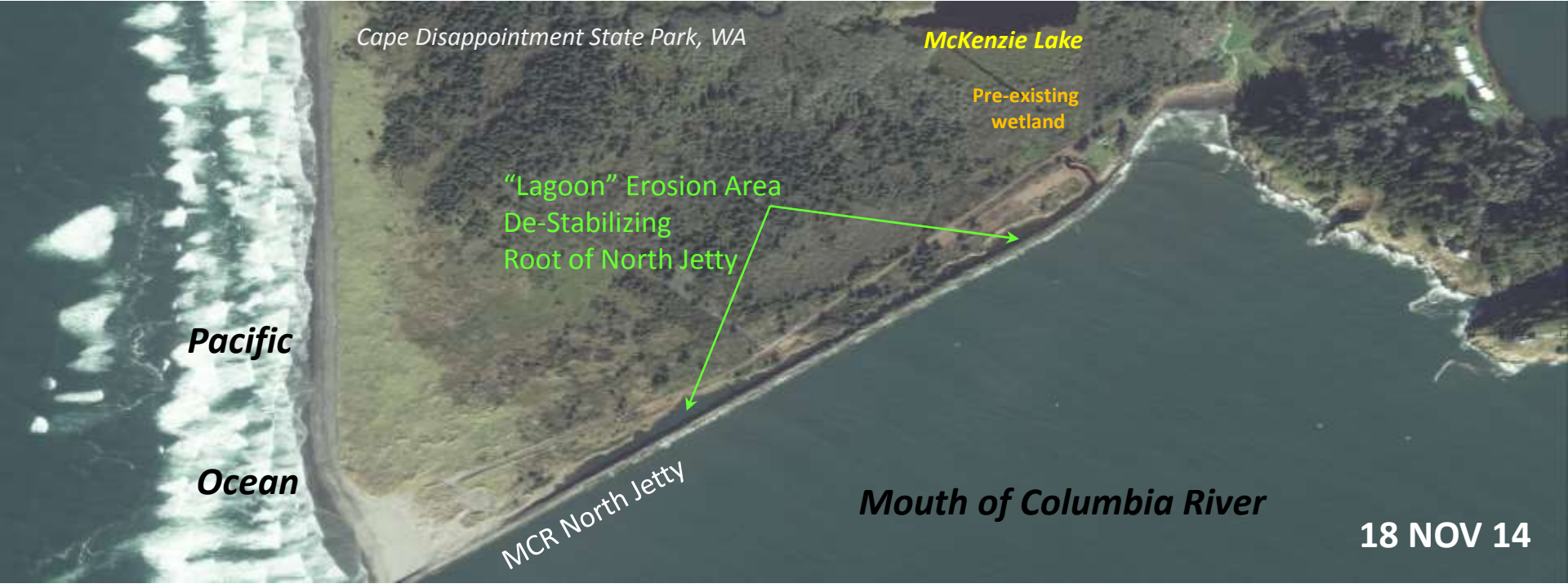

Mouth of Columbia River
3 Jetties Constructed 1885-1939
Navigation Channel = 2,260 ft wide x 5 miles long
48-55 ft deep
12.9 million tons of stone
$1.7 Billion invested
> $20 Billion Annual Commerce
Pacific
Long Beach
Ilwaco
North Head
Baker Bay
Chinook
Peacock Spit
North Jetty
Jetty "A"
Sand Island
Washington
Wetland Feature Project Area*
* Part of the MCR Jetty Rehabilitation Project
Channel
Navigation
MCR
Sand Island Pile Dikes
Clatsop Spit
South Jetty
Lower Columbia River Nav Channel
Columbia River Estuary
Hammond
Oregon
Astoria
Ocean
N

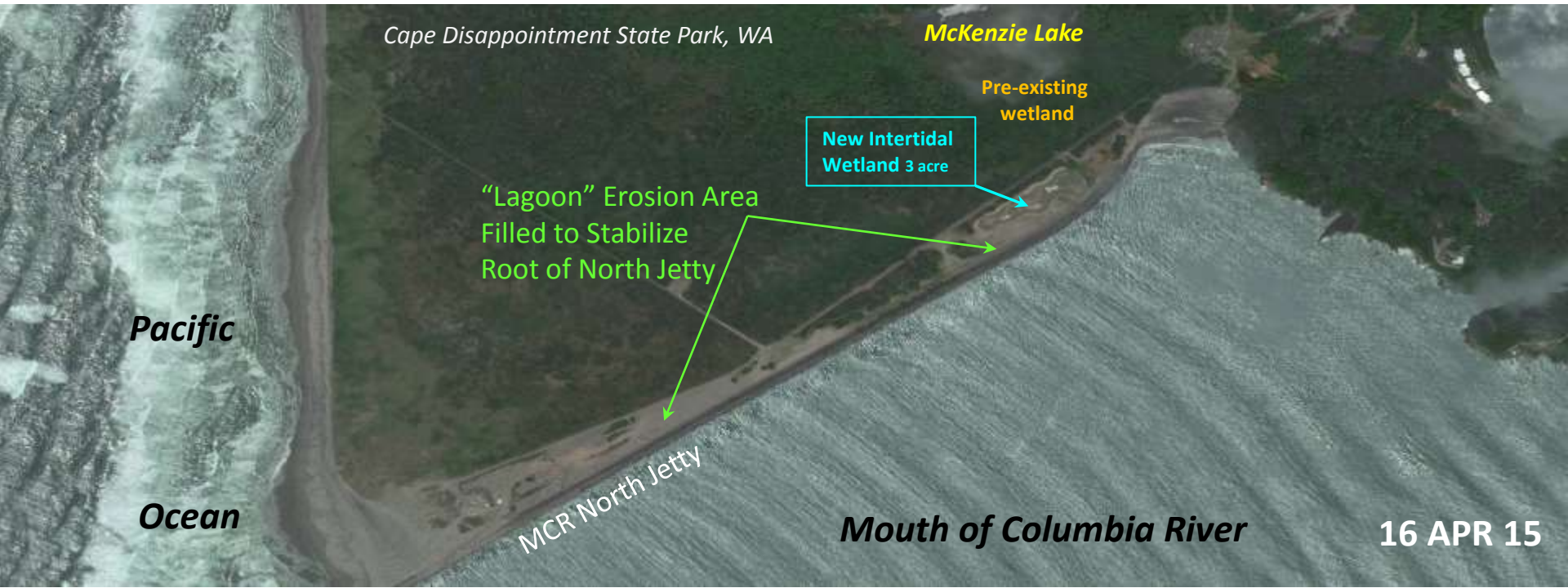
Damage along Root of MCR North Jetty



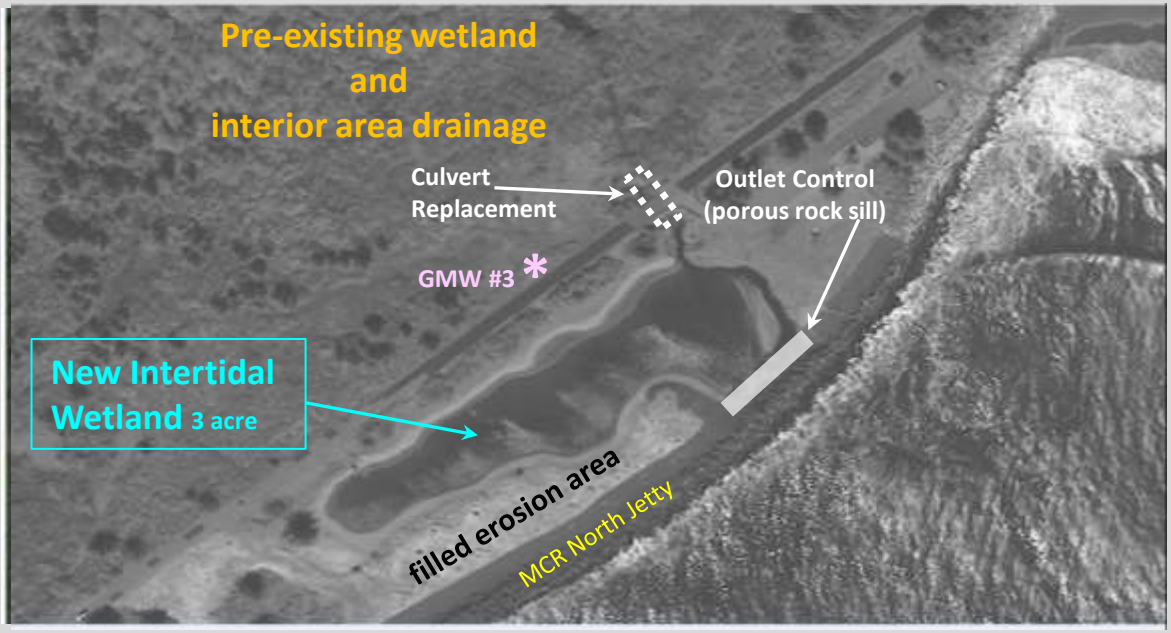
Continued Jetty Degradation Can Lead to a Jetty Breach…

…Allowing Significant Volume of Sediment to Enter the Inlet and Navigation Channel

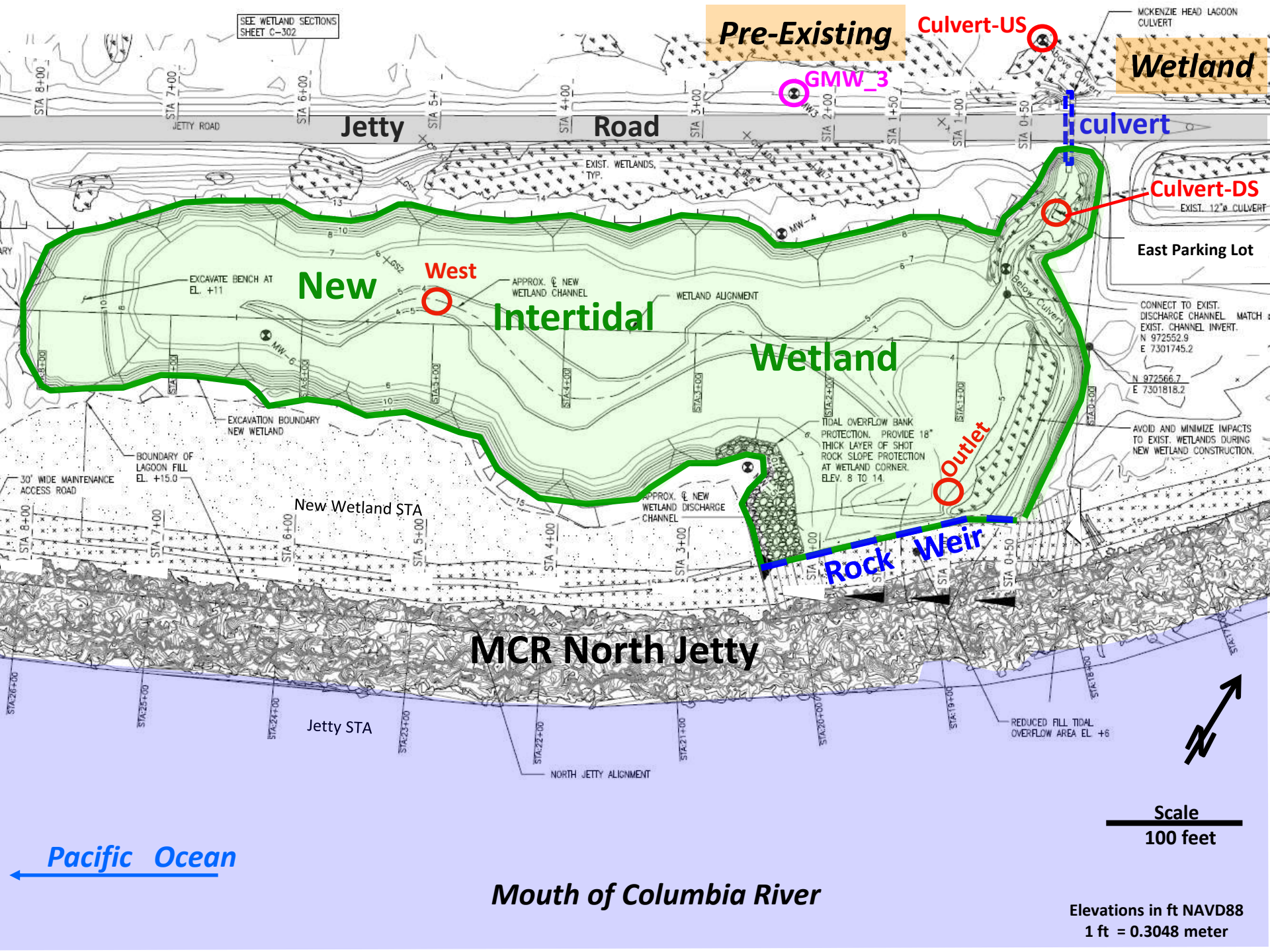

Cape Disappointment State Park, WA
McKenzie Lake
Pre-existing wetland
"Lagoon" Erosion Area
De-Stabilizing
Root of North Jetty
Pacific
Ocean
MCR North Jetty
Mouth of Columbia River
18 NOV 14


Cape Disappointment State Park, WA
McKenzie Lake
Pre-existing wetland
New Intertidal Wetland 3 acre
"Lagoon" Erosion Area
Filled to Stabilize
Root of North Jetty
Pacific
Ocean
MCR North Jetty
Mouth of Columbia River
16 APR 15

18 NOV 14
Higher tide
Pre-project



16 APR 15
Higher tide
Post-project

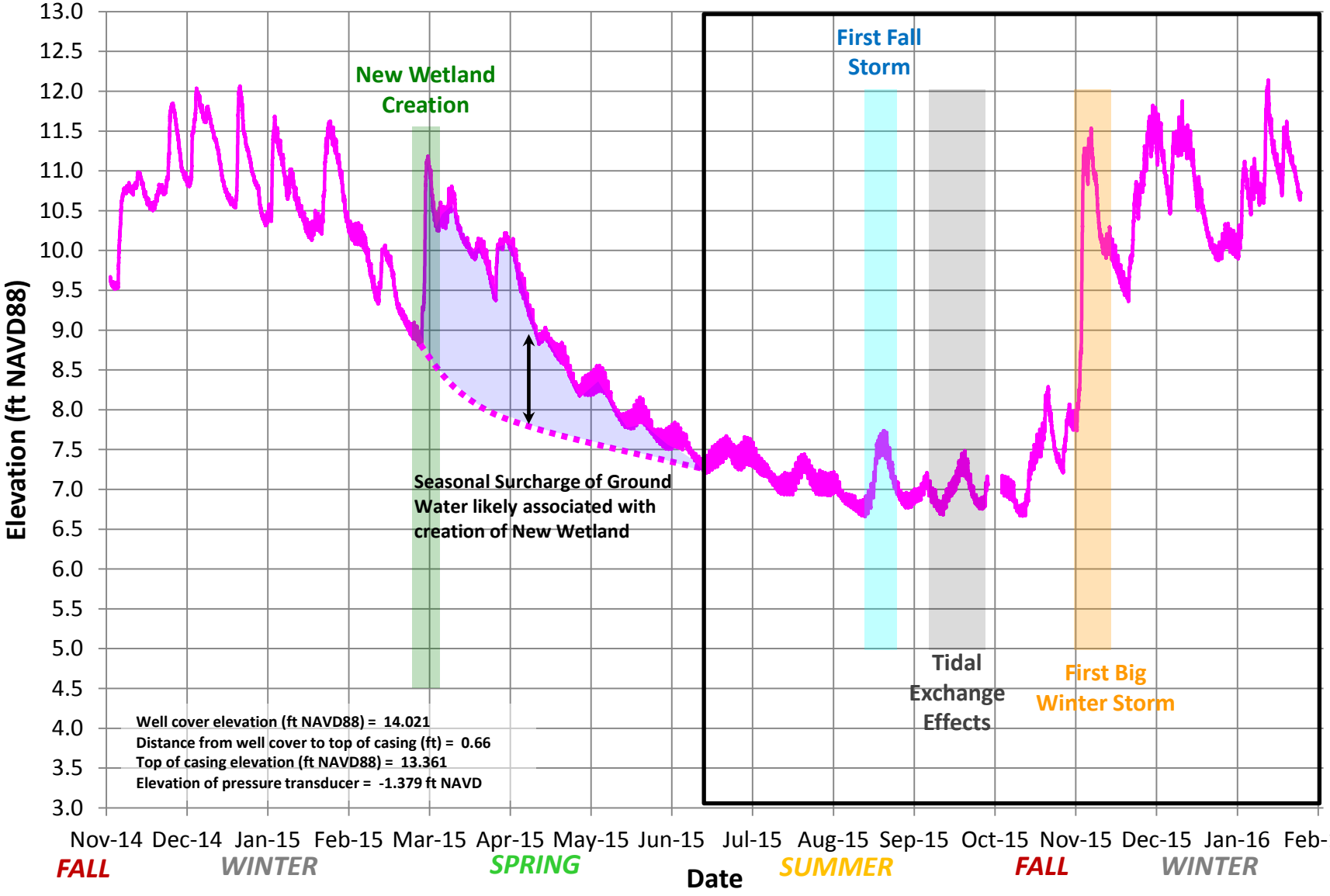

Pre-Existing
Culvert-US
Wetland
GMW_3
Jetty Road
culvert
Culvert-DS
East Parking Lot
New
West
Intertidal
Wetland
Outlet
Rock Weir
New Wetland STA
MCR North Jetty
Jetty STA
Pacific Ocean
Mouth of Columbia River
Scale
100 feet
Elevations in ft NAVD88
1 ft = 0.3048 meter

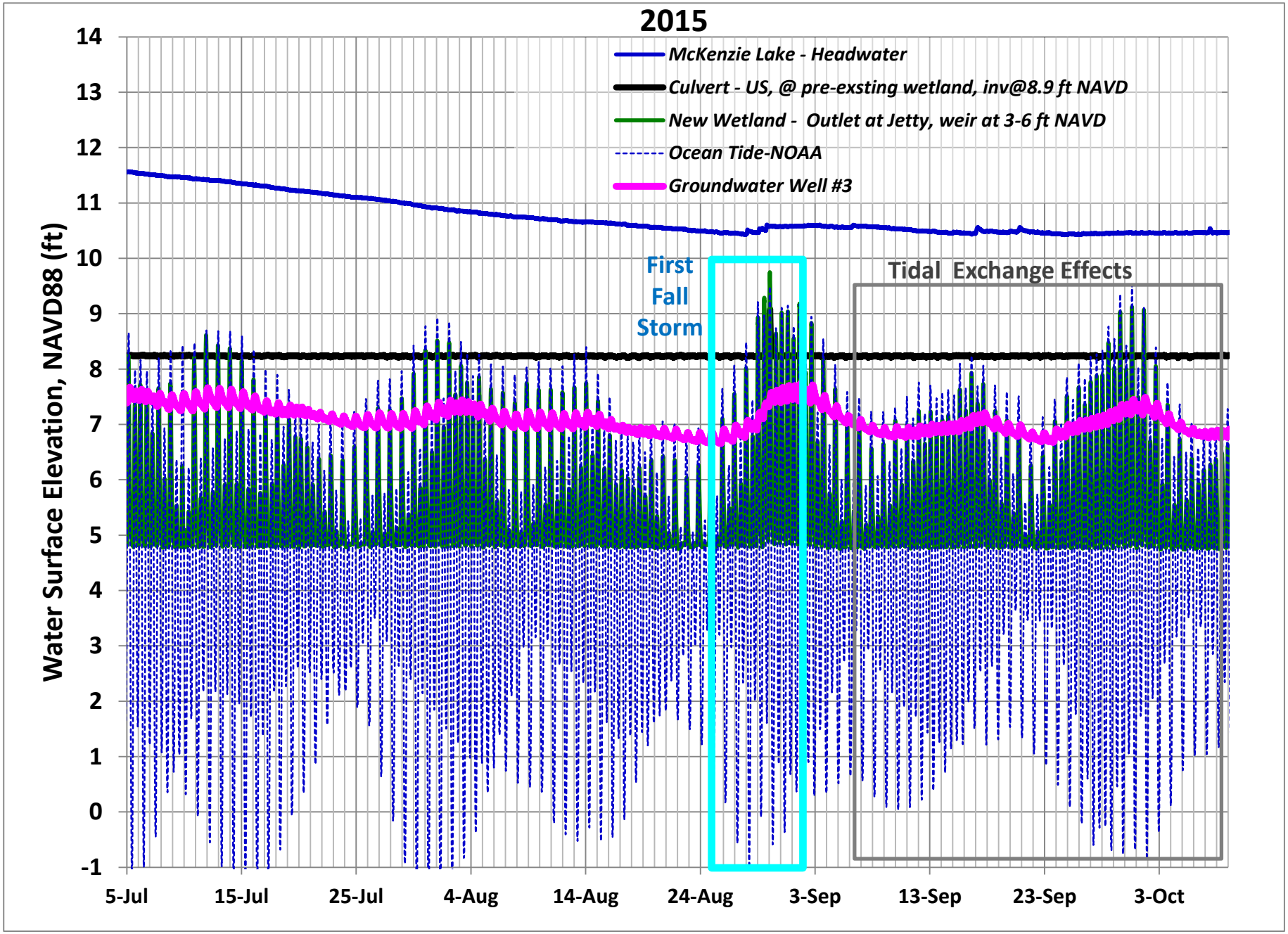
Rock Sill (crest at 6 ft NAVD)
150 ft long
25 ft wide
3 ft high (3-6 ft NAVD)

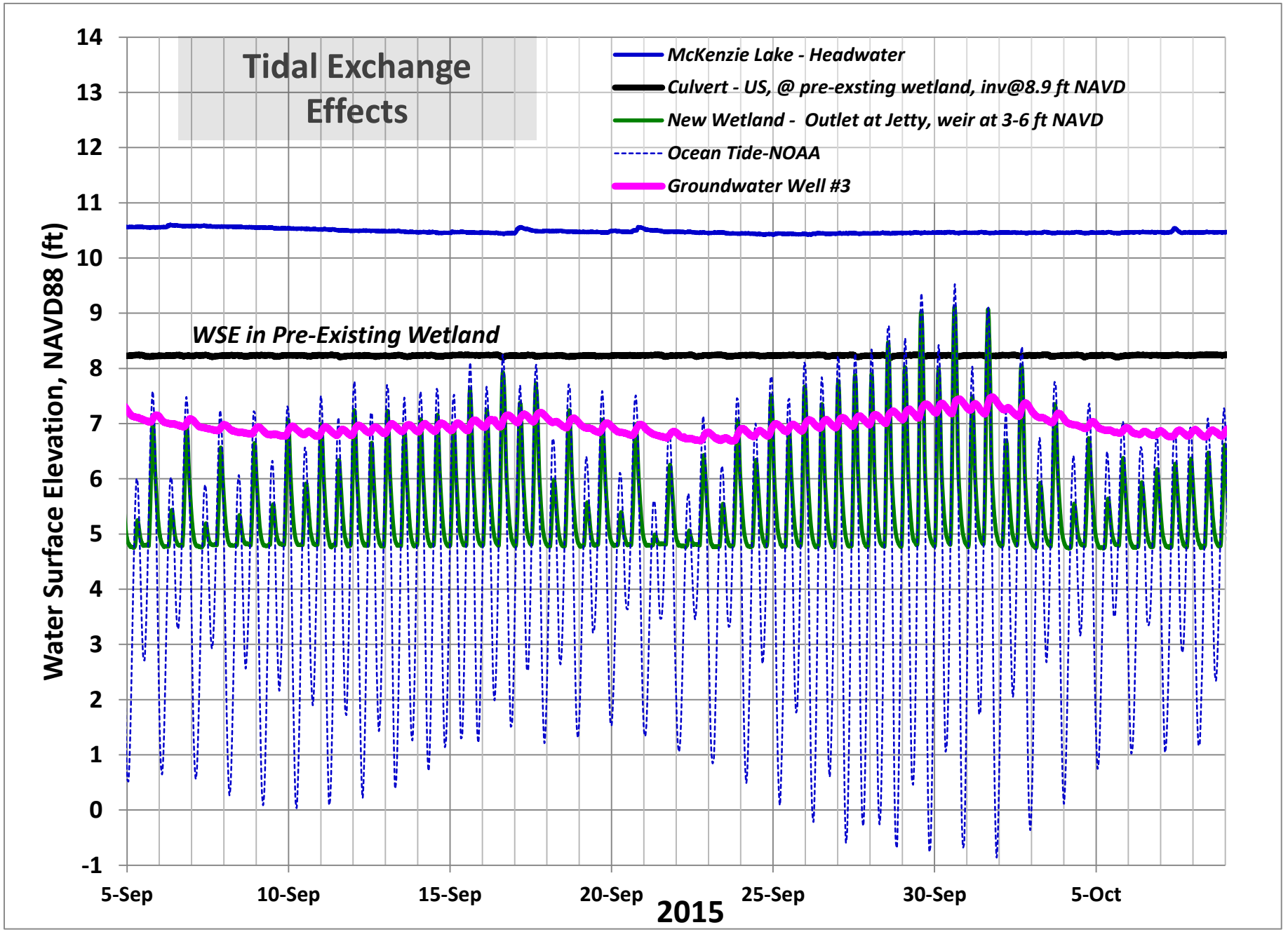
All Photos MAR-APR 2015

MW-3 Ground Water Elevations (NOV 2014 - FEB 2016)

Ground water elevation recorded 16 ft below "ground surface" of 15 ft NAVD, 100 ft North of New Wetland




2015
McKenzie Lake - Headwater
Culvert - US, @ pre-exsting wetland, inv@8.9 ft NAVD
New Wetland - Outlet at Jetty, weir at 3-6 ft NAVD
Ocean Tide-NOAA
Groundwater Well #3
First Fall Storm
Tidal Exchange Effects
Water Surface Elevation, NAVD88 (ft)
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
-1
5-Jul
15-Jul
25-Jul
4-Aug
14-Aug
24-Aug
3-Sep
13-Sep
23-Sep
3-Oct


Tidal Exchange Effects
McKenzie Lake - Headwater
Culvert - US, @ pre-exsting wetland, inv@8.9 ft NAVD
New Wetland - Outlet at Jetty, weir at 3-6 ft NAVD
Ocean Tide-NOAA
Groundwater Well #3
WSE in Pre-Existing Wetland
Water Surface Elevation, NAVD88 (ft)
14
13
12
11
10
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8
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2
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-1
5-Sep
10-Sep
15-Sep
20-Sep
25-Sep
30-Sep
5-Oct
2015

Tidal Response of New Intertidal Wetland Feature

Minimum water surface elevation (WSE) within New Wetland is limited by base elevation of Outlet Structure (Porous Rock Sill). ***Minimum WSE within new intertidal wetland >= 4.8 ft NAVD near outlet (4.3 ft NAVD at west end).***

New Wetland Tides are affected by daily amplitude and monthly phasing of ocean tide.

When Ocean daily-high tide amplitude < 7 ft NAVD, tidal response within New Wetland LAGS ocean tide by 1 hour.

As Ocean daily-high tide amplitude < 5.5 ft NAVD, tidal response within New Wetland diminishes.

When Ocean daily high tide amplitude > 7.8 ft NAVD, phasing of tidal response within New Wetland becomes coincident with ocean tide.

When successive Ocean diurnal high tides >8 ft NAVD, high tide water level within New Wetland can become elevated above ocean high tide (groundwater & outlet effects)

Ground water response LAGS New Wetland WSE variation by 3.5 hours (within 100 ft).

Groundwater Transport in Saturated Granular Soils

COMPARE Darcy Equation versus Observations

Seepage Velocity = (hydraulic conductivity) * (hydraulic gradient)

= **K** * (**Head Differential** / **Path Length**) [Darcy Equation]

assumes stead- state conditions

K = 0.01 cm/sec (medium sand) to 10 cm/sec (medium gravel), assume course sand to medium gravel.

K = 1 to 7 cm/sec

Head Differential = Tidal Elevation in New Wetland - Ground Water Elevation at point of Interest

MAX Transport Velocity of Groundwater between New Wetland and GMW #3 occurs when difference in GW elevation and Tide in New Wetland is MAX.

MAX Head Differential = 2 ft

Path Length = 100 ft, Distance between New Wetland (shore) and GM Well #3

Max Seepage Velocity = **1 cm/sec** * (**2 ft***30.5 cm per ft / **100 ft***30.5 cm/ft) **= 0.02 cm/sec (sand)**

= 0.14 cm/sec (gravel)

Time for Tide in Wetland to affect Ground Water at GMW #3 = 100 ft*30.5 cm per ft / 0.02 cm/sec)

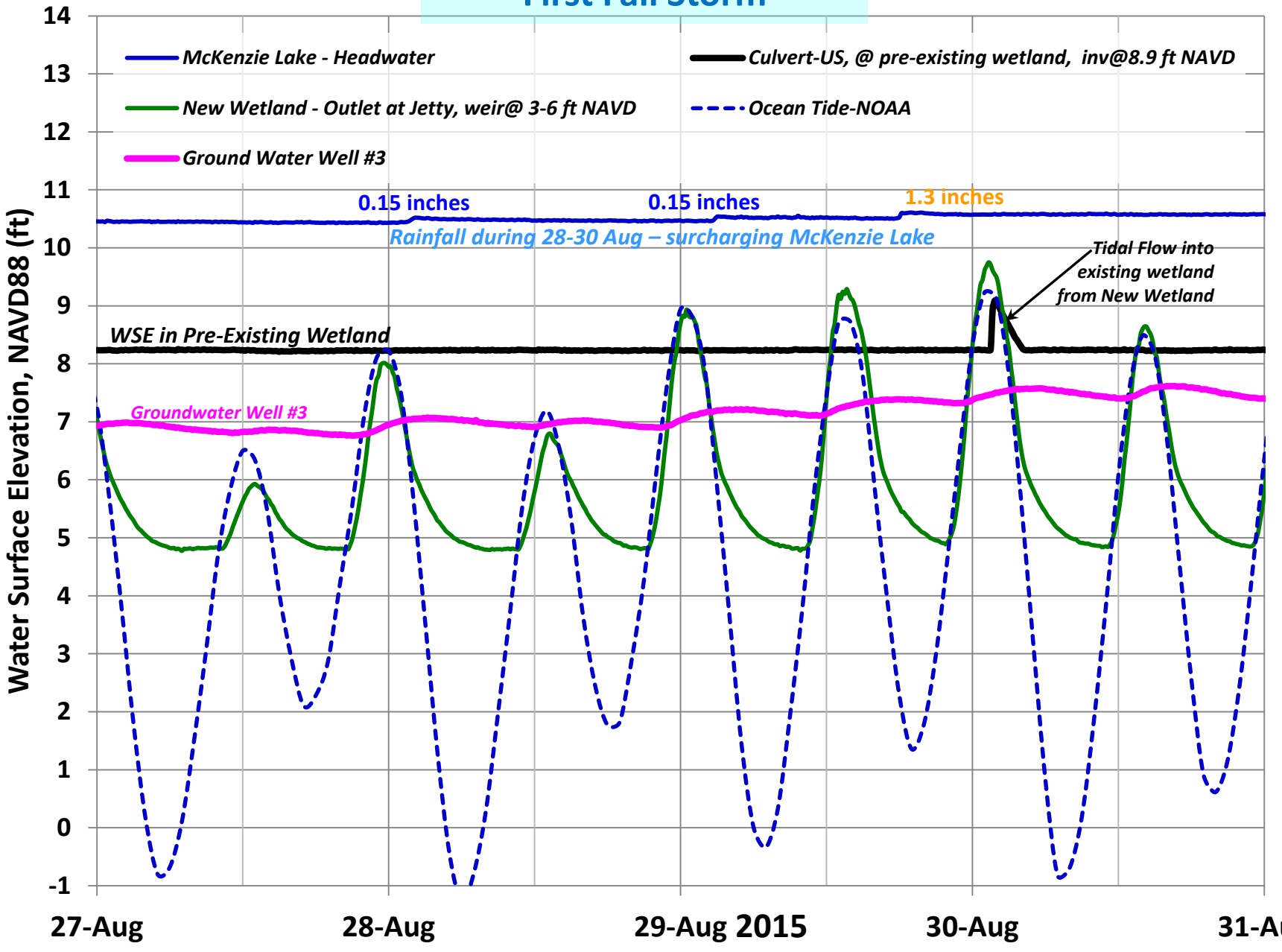
= 42 hours (sand)

= 6 hours (gravel)

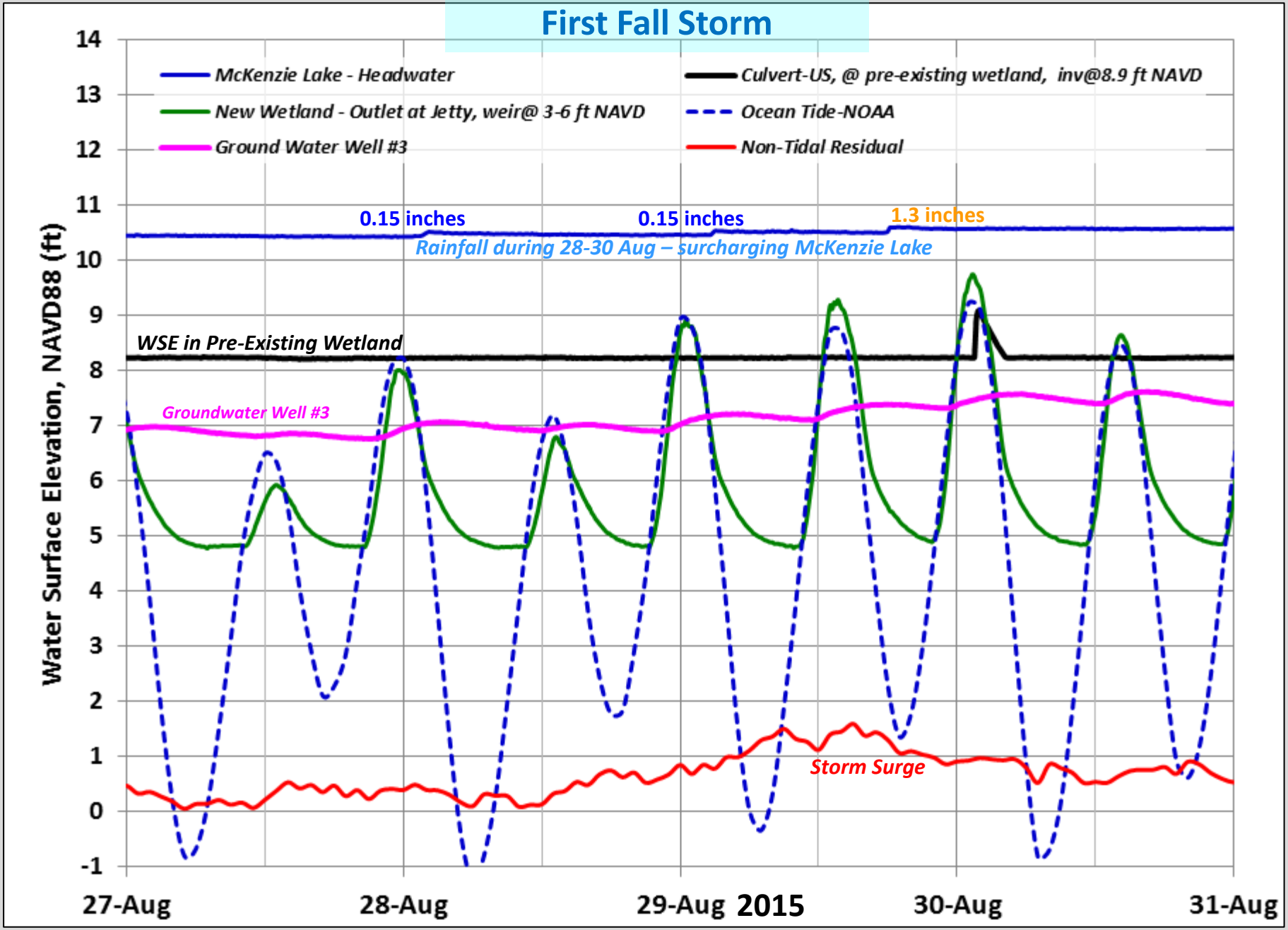
Monitoring **indicates that WSE within New Wetland affects groundwater at GMW #3** ***within 3.5 hours***

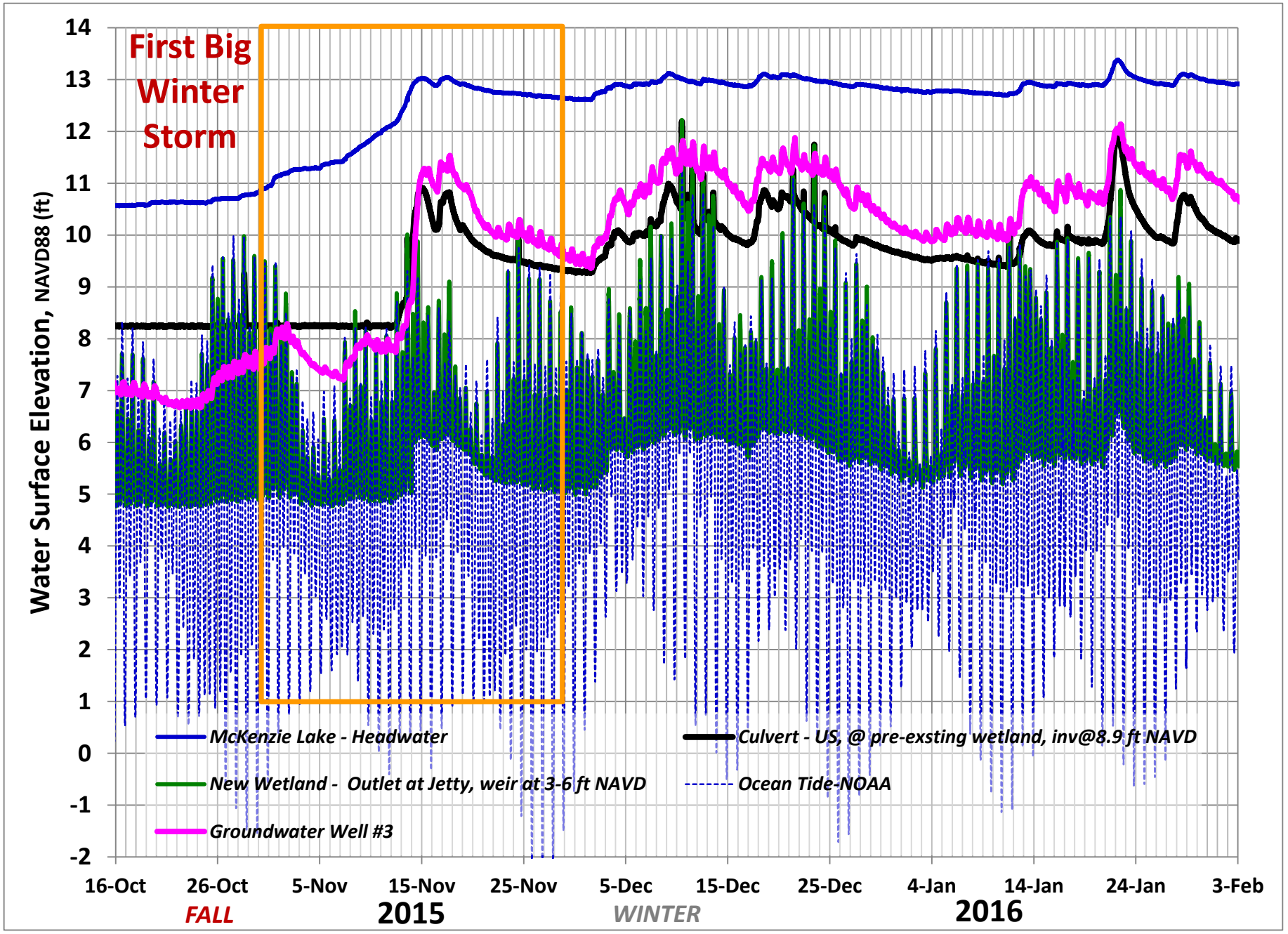
Observed Seepage Velocity > Darcy Velocity (likely due to transient conditions or varied substrate)

First Fall Storm



First Fall Storm




First Big Winter Storm
Water Surface Elevation, NAVD88 (ft)
14
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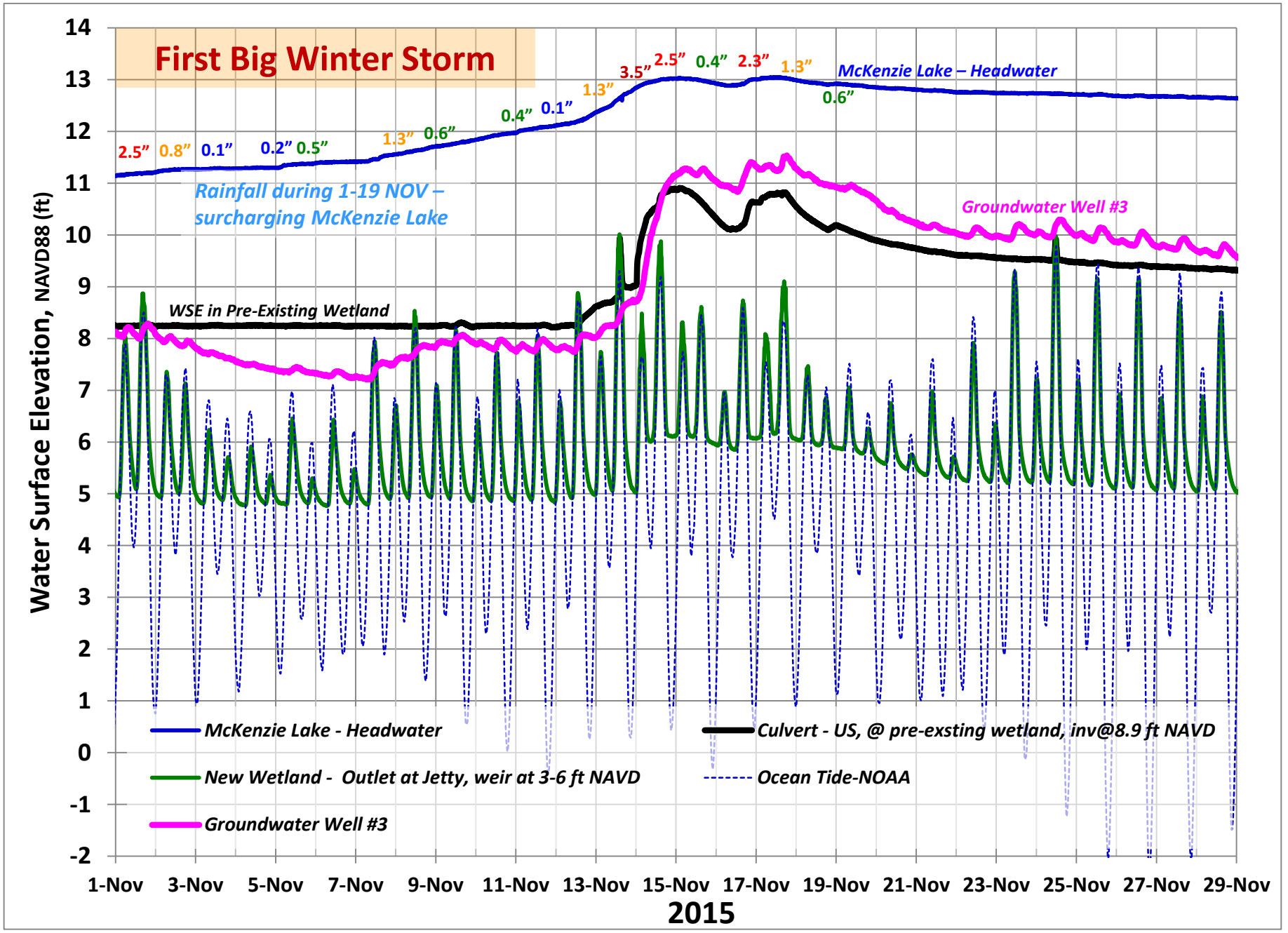
-1
-2
16-Oct
26-Oct
5-Nov
15-Nov
25-Nov
5-Dec
15-Dec
25-Dec
4-Jan
14-Jan
24-Jan
3-Feb
FALL
2015
WINTER
2016
McKenzie Lake - Headwater
Culvert - US, @ pre-exsting wetland, inv@8.9 ft NAVD
New Wetland - Outlet at Jetty, weir at 3-6 ft NAVD
Ocean Tide-NOAA
Groundwater Well #3


First Big Winter Storm
McKenzie Lake – Headwater
2.5" 0.8" 0.1" 0.2" 0.5" 1.3" 0.6" 0.4" 0.1" 1.3" 3.5" 2.5" 0.4" 2.3" 1.3" 0.6"
Rainfall during 1-19 NOV – surcharging McKenzie Lake
Groundwater Well #3
WSE in Pre-Existing Wetland
Water Surface Elevation, NAVD88 (ft)
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McKenzie Lake - Headwater
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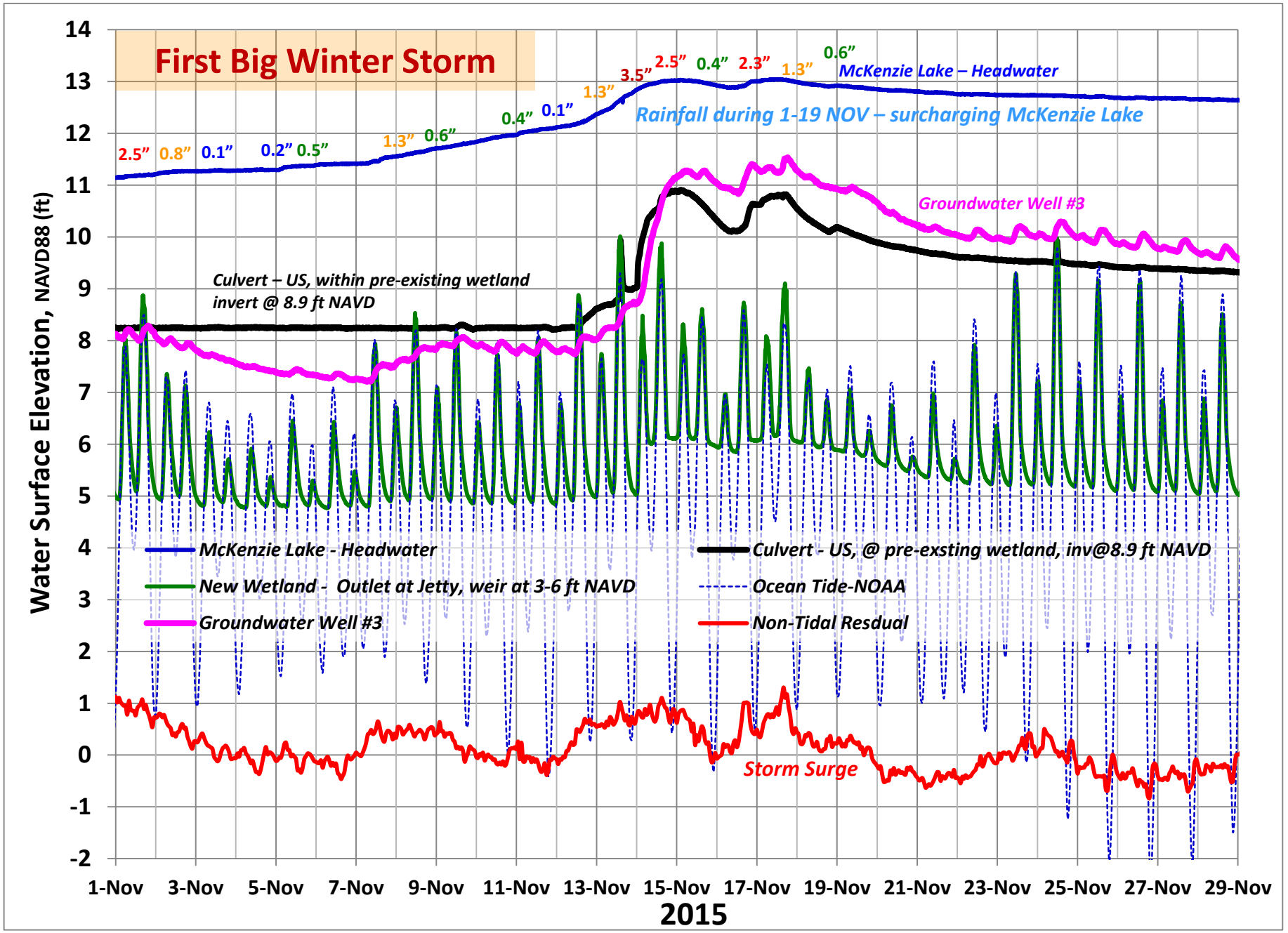
New Wetland - Outlet at Jetty, weir at 3-6 ft NAVD
Ocean Tide-NOAA
Groundwater Well #3
1-Nov 3-Nov 5-Nov 7-Nov 9-Nov 11-Nov 13-Nov 15-Nov 17-Nov 19-Nov 21-Nov 23-Nov 25-Nov 27-Nov 29-Nov
2015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Water Surface Elevation, NAVD88 (ft)
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7-Nov
9-Nov
11-Nov
13-Nov
15-Nov
17-Nov
19-Nov
21-Nov
23-Nov
25-Nov
27-Nov
29-Nov
2015
2.5”
0.8”
0.1”
0.2”
0.5”
1.3”
0.6”
0.4”
0.1”
1.3”
3.5”
2.5”
0.4”
2.3”
1.3”
0.6”
McKenzie Lake – Headwater
Rainfall during 1-19 NOV – surcharging McKenzie Lake
Groundwater Well #3
Culvert – US, within pre-existing wetland
invert @ 8.9 ft NAVD
McKenzie Lake - Headwater
New Wetland - Outlet at Jetty, weir at 3-6 ft NAVD
Groundwater Well #3
Culvert - US, @ pre-exsting wetland, inv@8.9 ft NAVD
Ocean Tide-NOAA
Non-Tidal Resdual
Storm Surge

Interaction of New Wetland With Groundwater

Groundwater Elevation is affected by the monthly phasing and daily amplitude of WSE within New Wetland.

Daily Variation of GW WSE: 0.4 ft during spring diurnal tide & 0.2 ft during neap tide.

Bi-Weekly Variation of GW WSE : 0.7 ft from spring to neap phase.

During periods of sustained Storm Surge, Groundwater Elevation can be elevated accordingly without the upland or precipitation effects.

The combination of Upland Surcharging of the Existing Wetland, Precipitation, and Elevated Ocean WSE can increase Groundwater Elevation near the New Wetland such that GWE exceeds WSE with the New and Existing Wetlands (GWE is super-elevated)

When GWE is super-elevated, it can have a feed-back effect on sustaining an elevated WSE within the New Wetland….In winter GWE > 11 ft NAVD

Groundwater Exchange with Wetland Features is complex, unsteady, and seasonal. Monitoring is needed to resolve site-specific hydrologic complexities to understand wetland function.

Interaction of New Wetland With Pre-Existing Wetland

Water Surface Elevation (Hydrology) within Pre-Existing Wetland is affected primarily by surcharging from upland flow (McKenzie Lake), and not by the New Wetland. This effect diminishes during summer, when regular precipitation stops.

The New wetland feature maintains similar hydraulic connectivity to the Pre-Existing wetland as compared to pre-construction conditions….Culvert replacement was implemented according previous culvert aspects. Terminal drainage through North Jetty is similar as for the previous "Lagoon Condition".

When WSE within New Wetland > 8.9 ft NAVD, direct tidal surcharging can be imposed on the Pre-existing Wetland (by inland flow though reconstructed culvert). This process can occur during annual-spring tide conditions or when storm surge affects high tide.

Hydrology of the Pre-Existing Wetland can significantly Affect the New Wetland though direct discharge of surface water (via culvert when WSE >8.9 ft NAVD) or by Elevated groundwater elevation.

The Two Wetlands are intrinsically linked as a dynamic Freshwater-Saltwater System