Identifying Groundwater Discharge Locations in Tidal Wetlands using Environmental Thermography at Prime Hook National Wildlife Refuge, Delaware, USA

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Prime Hook National Wildlife Refuge (PHNWR)

- 10,100 acres (mostly wetlands)
- 3 riverine fresh water sources
- 2 connections to polyhaline Del Bay
- 3 water-control structures
- 4 water-management units bounded by: estuarine barrier / roads / uplands
- Units 2 and 3 managed as fresh water impoundments from 1980s to late 2000s
• Historically, wetlands were almost entirely tidal salt water wetlands (salt marsh)

• Many historical impacts/alterations since early 1900s: water control structures, ditching, mosquito management, cattle grazing, hay farming, trapping

• Fresh water impoundments installed in Units 2 and 3 to combat Phragmites invasion and provide waterfowl habitat (very successful in this regard)

(Delaware SWMP, 2003)
Storms impacting the Refuge

- 2008 - small breach of barrier in Unit 2 during nor'easter
- October 2008 - Unit 2 breach repaired
- Summer 2009 - Fresh water vegetation management successful in Units 2 and 3
- November 2009 - 2 breaches in Unit 2 during nor'easter
  > 1,000 acres of marsh - > open water
- October 2012 - 2 additional breaches into Unit 2 (Hurricane Sandy)

Güiteras, S. (USFW), 2015
Changes in wetlands/water land cover 2003 → 2007

(Delaware SWMP, 2003 & 2007)
continued conversion of wetlands to open water
2007 → 2013
example for parts of units 2 and 3
RESTORATION

- restore salt marsh and more natural water flow; repair breaks in existing dunes
- dredge material spread onto areas adjacent to channels
- focus is on sustainable salt marsh restoration but retain fresh water habitat if possible
  - Therefore, my charge is to locate groundwater discharge in the dredging area

- dredging underway and to conclude in 2015
- dredging depth is ~2 m
- have dredged up sand (anecdote)
Aquifer Setting

- Atlantic Coastal Plain
  - low topographic relief
  - dissected by tidal creeks

- Columbia Aquifer
  - surficial, water-table aquifer (locally confined)
  - sand and gravel aquifer
  - 15-45 m thick
  - depth to water table typically < 4 m
  - hydraulic conductivity ~ $10^{-4} – 10^{-5}$ m/s

- Beaverdam, Scotts Corners, and Lynch Heights formations
  - fine to coarse sand, gravelly sand, and sandy gravel with beds of silt and sandy silt
April 5, 2015  6:30 – 8:00 am
April 6, 2015  6:30 – 8:30 am
336 km flown at 330 meters altitude
FLIR SC6000 thermal video
GoPro Hero 4 visual video
audio recording, GPS
1946 Aeronca Champ aircraft
Pilot John Chirtea (Refuge friend)

In air at civil twilight before sunrise
Tide near the southern connection to Delaware Bay

Flights during ebbing tide

[Graph showing tide height over time with specific dates and times.]
Ambient Thermal Environment

**Air Temperature**

- 5-Apr
- 6-Apr

**Shallow Water**

- 4/6/2015: Slau 4/5, FowlN 4/5, BkllS1 4/5, BkllS2 4/5, Slau 4/6, FowlN 4/6, BkllS1 4/6, BkllS2 4/6

- 4/5/2015: Slau 4/5, FowlN 4/5, BkllS1 4/5, BkllS2 4/5

**Channel on 4/5**

- PHC, PDS, PDN, FB, BR, SC

**Channel on 4/6**

- PHC, PDS, PDN, FB, BR, SC
Locations of thermal anomalies (potential groundwater discharge sites)
Thermal anomaly at former mouth of Primehook Creek In Unit 3

7/7/2015
Tk = 27.5 °C
Salinity = 4.6

7/7/2015
Tk = 27.9 °C
Salinity = 7.4
Thermal anomaly in eastern part of Unit 3 near Primehook Beach
Thermal anomaly in eastern part of Unit 3 near Primehook Beach
Thermal anomalies in northeastern part of Unit 4 near Broadkill Beach Road

- T05
  - low-lying area
  - 10/22/2015
  - salinity = 11.2

- T04
  - 10/22/2015
  - salinity = 13.2

- T03
  - 7/7/2015
  - Salinity = 0.3
  - 10/22/2015
  - Salinity = 13.1

- T12
  - 7/7/2015
  - Salinity = 3.1
  - 10/22/2015
  - Salinity = 17

- \( T_r \) pond = 10 °C

- T04 pond

- T03 pond

- T04

- T03

- T05

- T12

- map of Unit 4

- 4
T09, T10, T11
+ T02, T08, T09
10/22/2015
salinity > 18
Primehook Creek

- warm water (groundwater source) cuts though bank of creek at breaches (A)
- creek temperature decreases >4 °C (B)
Conclusions

• **Thermal Survey**
  • Late date in the survey season (April) was conducive to locating discharge (ground-cover, atmospheric and tidal conditions, estuarine temperature)

• **Groundwater discharge**
  o Unit 2
    ▪ no locations identified (but Slaughter Cr not fully surveyed upstream of the first inland bridge)
  o Unit 3
    ▪ open water in former mouth of Primehook Creek
    ▪ one small pond just south of above
    ▪ upstream freshwater PH Creek (and many adjacent ponds not shown)
  o Unit 4
    ▪ ponds in high marsh or upland
    ▪ Open Water Marsh Management ponds and possibly ditches (not confirmed)

• **Implications**
  o All potential groundwater discharge sites identified are outside of the dredging areas and thin veneer disposal areas (Units 2 and 3)