PLATTE RIVER RECOVERY IMPLEMENTATION PROGRAM (PRRIP -or- PROGRAM)

PHRAGMITES STUDY

QUESTIONS FOR THE ISAC

Study design

- What adjustments should be made to the field sampling methods, specifically what number, type, and location of patches should be added/subtracted from the sample?

Herbicide

- Given the lack of patches treated with herbicide during June and September 2022, how do we evaluate the effectiveness of the herbicide treatments moving forward? Do we continue with the established protocol, or do we specifically target study patches with herbicide?

Inundation flow release

- What would convince you that the June inundation flows are working to control the expansion of Phragmites patches into the channel, and are we collecting the right metrics to test for that?
- How do we isolate the effects of June inundation flows from intra- and interannual variability in hydrology?
- How do we best evaluate the effects of elevated groundwater (potential root interaction/subirrigated conditions) versus inundation by surface water (direct root and stem interaction)?

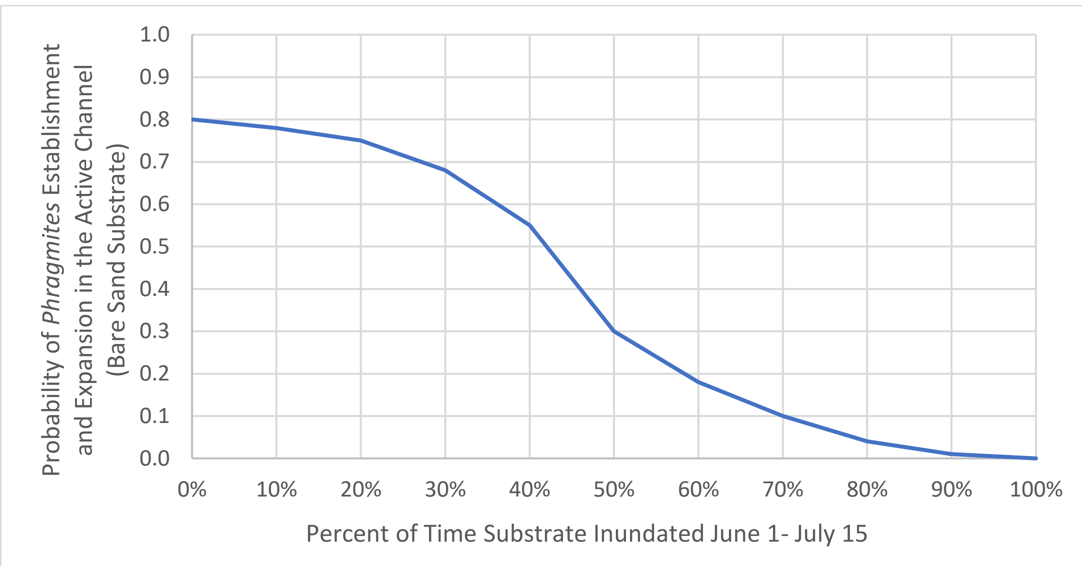
PHRAGMITES STUDY DESIGN

- **[Extension Big Question #2:] Clarify the context and scope of the research, i.e., the focus on June inundation flow release/herbicide effects on *Phragmites* expansion into the active channel.**

Hypotheses

Management Hypothesis: Releases to achieve a 30-day minimum flow target of 1,500 cfs between June 1 – July 15 in combination with continued herbicide spraying will slow *Phragmites* patch expansion into the active channel and increase the percent of AHR channel that remains highly suitable for whooping crane roosting.

Physical Process Hypothesis: Phragmites expansion rates into the active channel are a function of percent of time bare sand substrate is inundated during the 30-day period between June 1 – July 15.



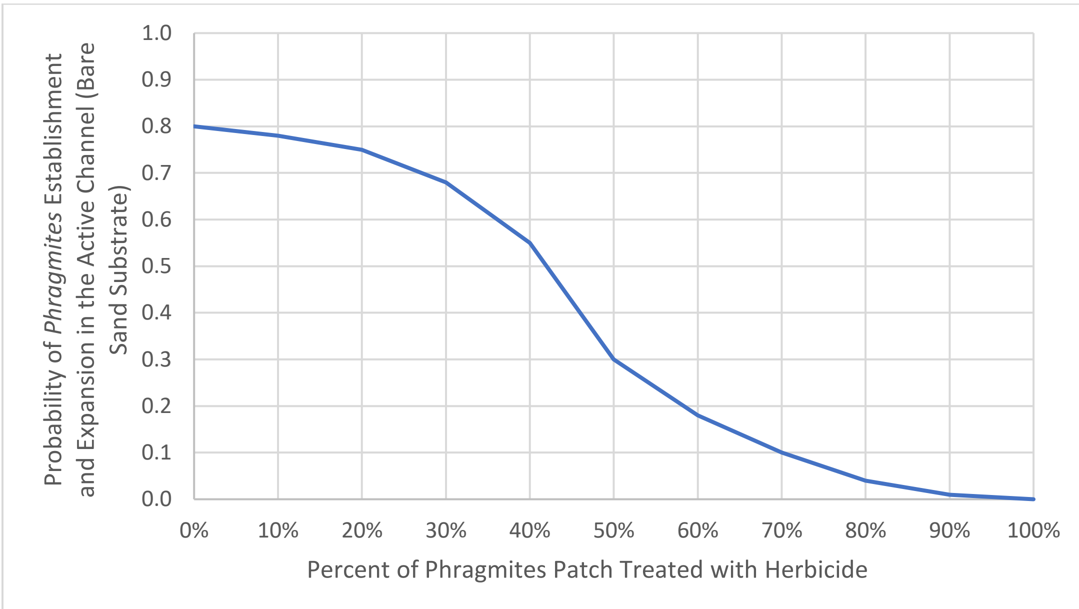
Hydrology Predictions:

- There is an inverse relationship between the **number of days** of patch inundation during a 30-day period between June 1 – July 15 and the **area** of *Phragmites* patch expansion into the active river channel.
- There is an inverse relationship between the **number of days** of patch inundation during a 30-day period between June 1 – July 15 and the **rate** of *Phragmites* patch expansion into the active river channel.

- There is an inverse relationship between the **percent of patch area** inundated during a 30-day period between June 1 – July 15 and the **area** of *Phragmites* patch expansion into the active river channel.
- There is an inverse relationship between the **percent of patch area** inundated during a 30-day period between June 1 – July 15 and the **rate** of *Phragmites* patch expansion into the active river channel.

Management Hypothesis: *Phragmites* patch expansion into the active river channel is primarily controlled by herbicide treatments during the spring and fall.

Physical Process Hypothesis: Phragmites expansion rates into the active channel are a function of area of Phragmites patch treated with herbicide and the frequency of application.



Herbicide Predictions:

- There is an inverse relationship between the **frequency** of patch treatment with herbicide and the **area** of *Phragmites* patch expansion into the active river channel.
- There is an inverse relationship between the **frequency** of patch treatment with herbicide and the **rate** of *Phragmites* patch expansion into the active river channel.
- There is an inverse relationship between the **percent of patch area** treated with herbicide and the **area** of *Phragmites* patch expansion into the active river channel.
- There is an inverse relationship between the percent of patch area treated with herbicide and the **rate** of *Phragmites* patch expansion into the active river channel.

Independent variables

Hydrology (continuous variable) – *Phragmites* patch interaction with June flows, based on intersection with 2-D flow models and gage station data.

- Number of days with 0% inundated area
- Number of days at minimum % inundated area
- Number of days at mean % inundated area
- Number of days at maximum % inundated area
- Number of days with >0% inundated area

Herbicide (continuous) – Phragmites patch interaction (yellow) with herbicide spray polygons (pink). Hatched areas are within the designated "no-spray zone".

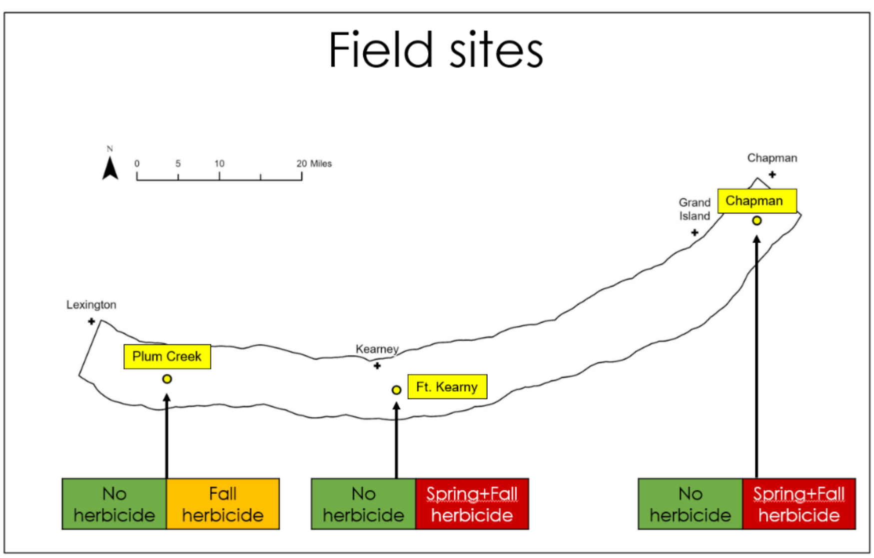
- Frequency of Phragmites patch (yellow) inclusion within spray polygon (pink)
- Area of Phragmites patch within spray polygon

Dependent variables

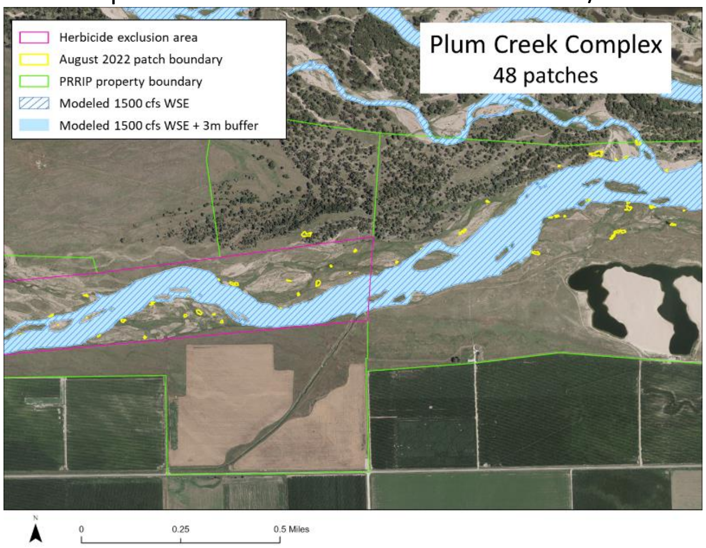
- Change in patch area over time (continuous)
- Percent change in patch area over time (continuous)
- Rate of change in patch area over time (ft^2/month)
- Directional patch expansion (continuous)
    - Patch centroids distance/directional change analysis (for patches with June centroids within 10 m of the 1500 cfs water surface elevation polygon)
        - Change in patch centroid distance to 1500 cfs 2-D flow model footprint (June vs. October)
        - Change in proportion of patch intersecting with 1500 cfs 2-D flow model footprint June, July, August, October
- Change in maximum stem height over time (continuous)
- Change in patch condition over time – increase, decrease, or no change (categorical)
- Change in stem density over time (categorical)

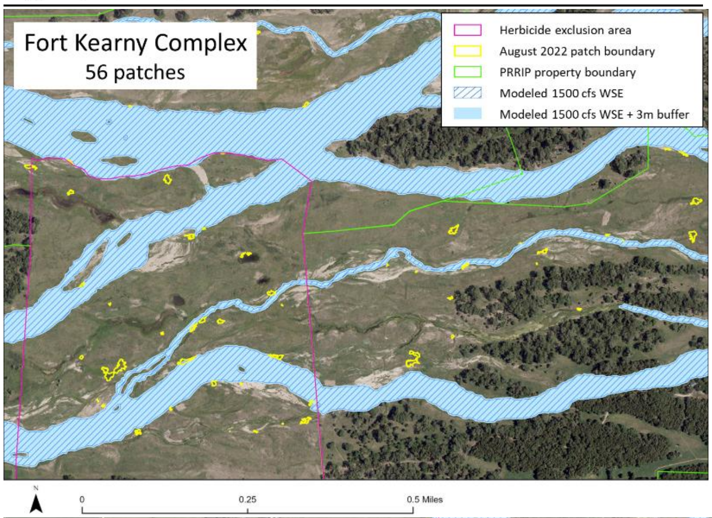
Field Methods Overview - Provide an overview of the *Phragmites* patch mapping and assessment methods.

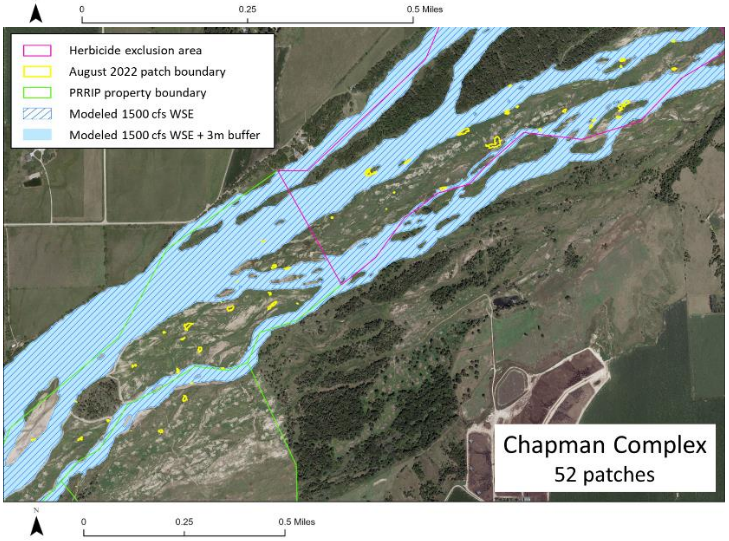
- Location of field sites



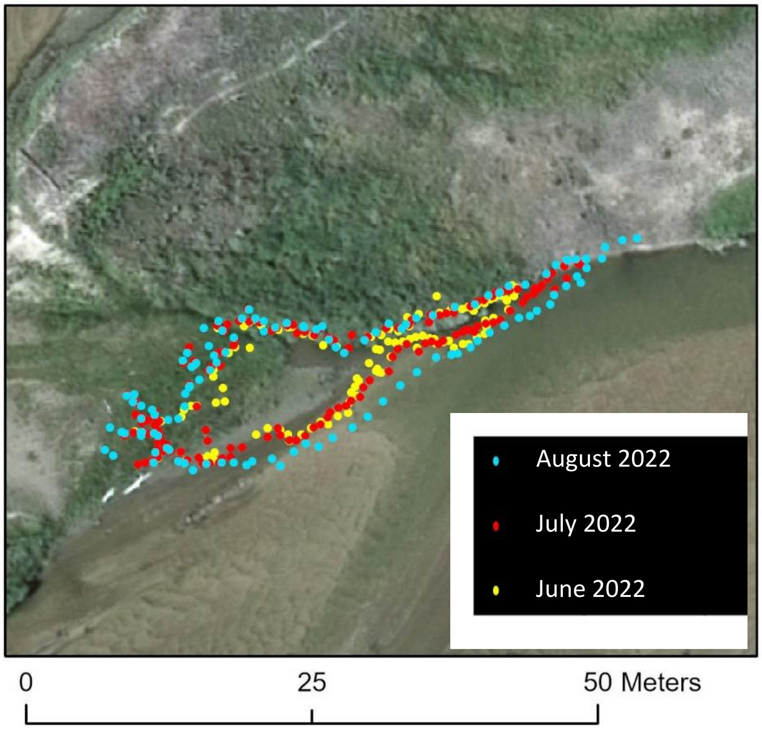
- Herbicide treatment blocks
- Random patch selection – broadscale abundance/distribution patterns





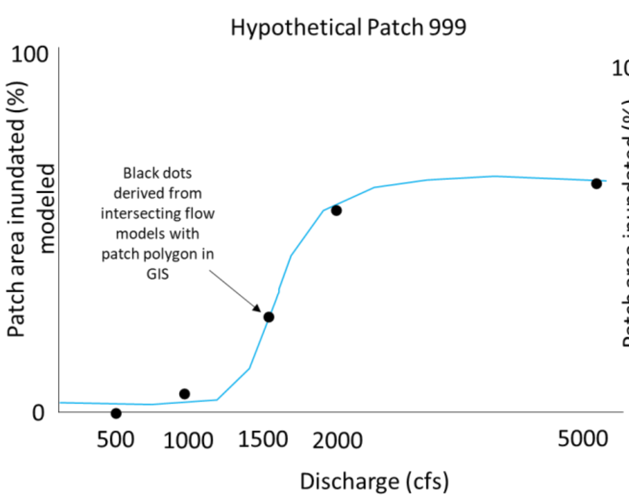


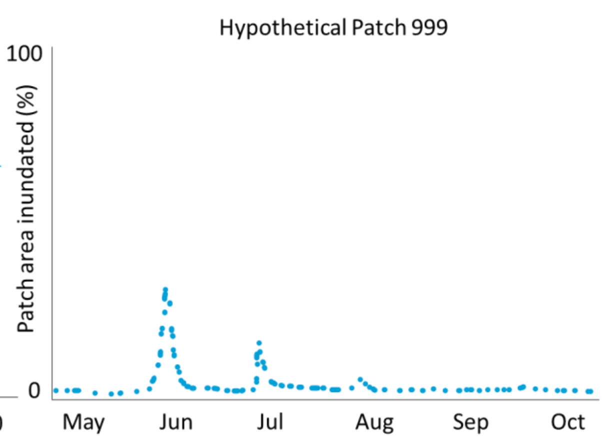
- Patch delineation and assessment
- Monthly sampling frequency, response over time

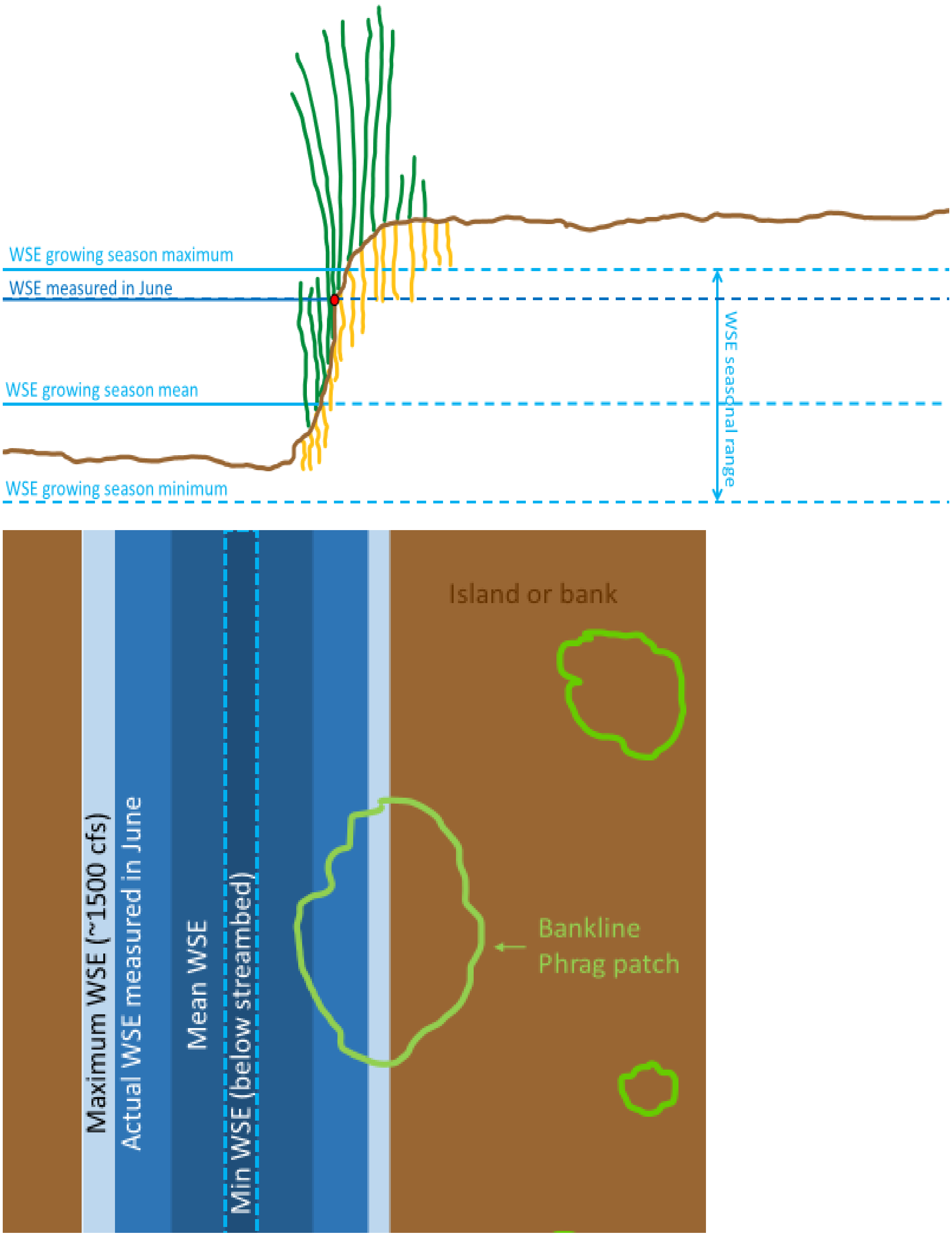


<u>Remotely Sensed Methods Overview -</u> **Provide an overview of the *Phragmites* patch mapping and assessment methods.**

- Use nearest gage data (mean daily flow), 2-D hydrodynamic model, and patch polygons to calculate inundation area, timing, and duration for flow magnitudes of interest.






WSE growing season maximum
WSE measured in June
WSE growing season mean
WSE growing season minimum
WSE seasonal range
Island or bank
Maximum WSE (~1500 cfs)
Actual WSE measured in June
Mean WSE
Min WSE (below streambed)
Bankline
Phrag patch

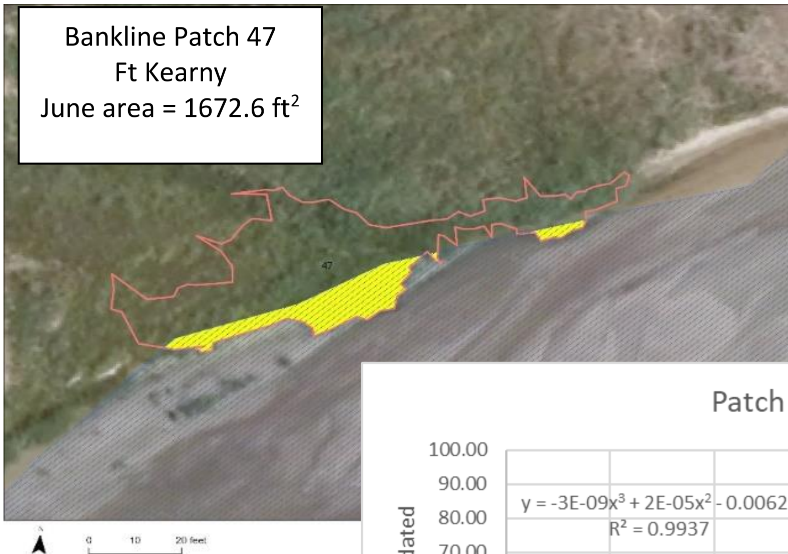
Results Overview

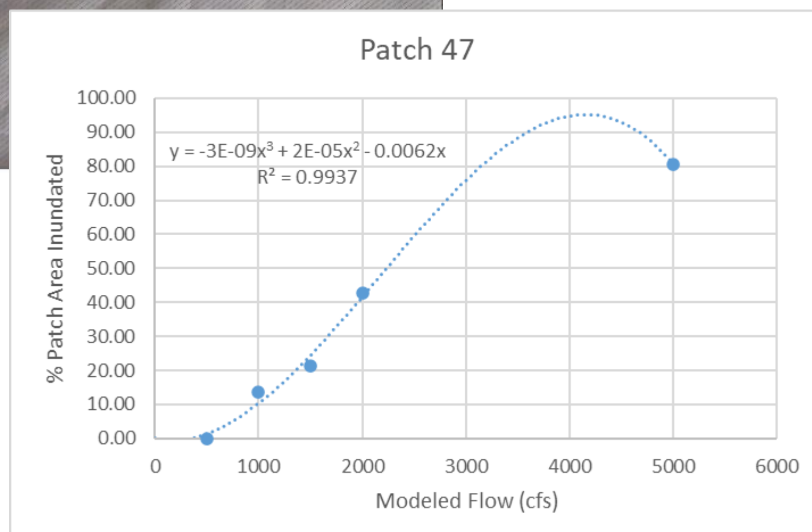
Provide a review of the field data collection completed to date and the major findings.

- Overview of fieldwork completed to date
  - Repeat sampled 156 patches 4x in 2022
  - June (pre-spring herbicide)
  - July (post-spring herbicide/pre-fall herbicide)
  - August (post-spring herbicide/pre-fall herbicide)
  - October (post-fall herbicide)
- Main takeaways from 2022
  - Most patches occurred at elevations above the June 2022 flow levels
  - Most patches in the herbicide zone did not receive herbicide
  - Patch boundaries have remained relatively stable in most cases
  - 20% of patches showed minor patch expansion
  - June flows induced stem tipping and lateral growth for some bankline patches
  - Some resprouting/rooting occurred along prostrate stems within formerly wet channel
  - Some patches decreased in area, showed drought stress and dieback
  - Most patches are low to medium density with medium to high cover of other plants

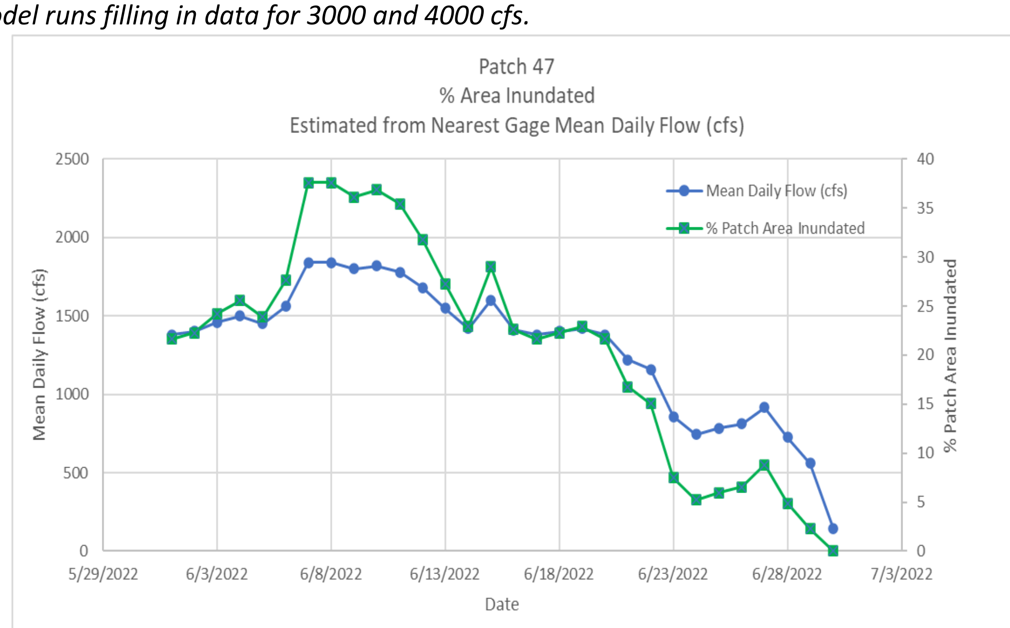
Independent variable – Hydrology

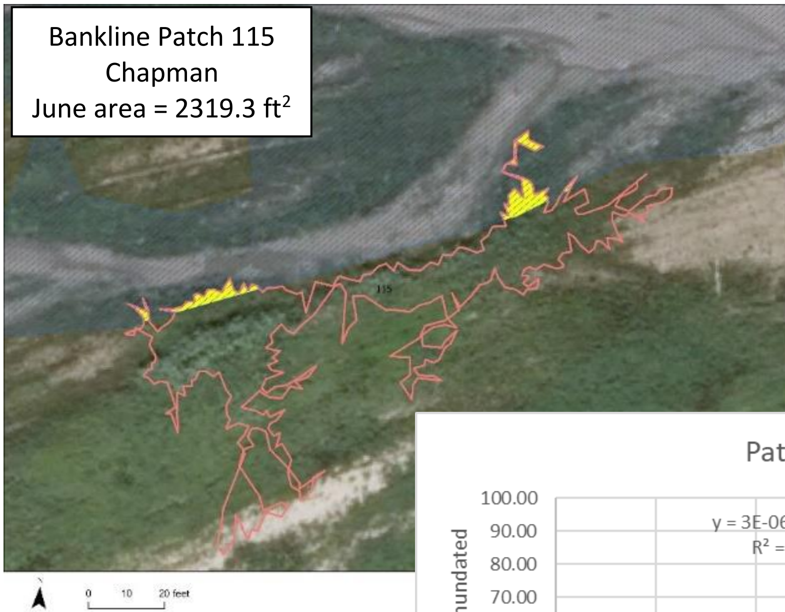
- Patch distribution in relation to 1500 cfs flow model – bankline vs inland patches
- Measures of extent of patch interaction with channel inundation – from field-derived patch polygons, 2-D hydrodynamic model (from previous Fall LiDAR), from July imagery, water elevation relationship to patch elevation, info from on-the-ground cameras and field notes on inundation for verification.

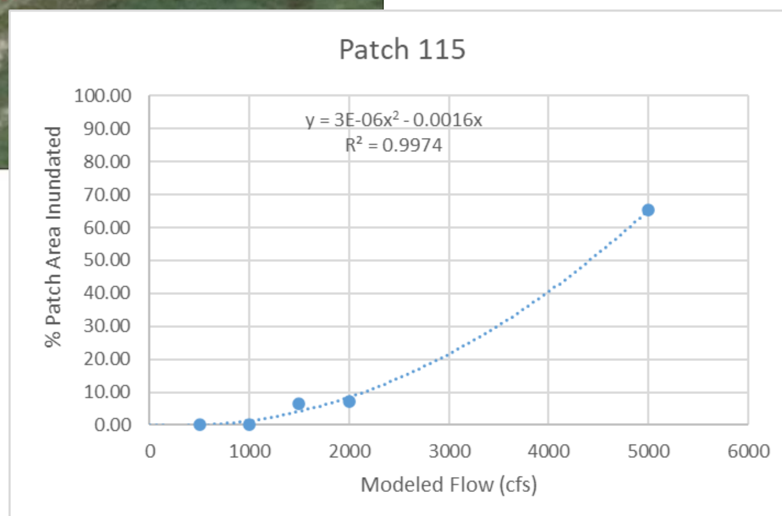


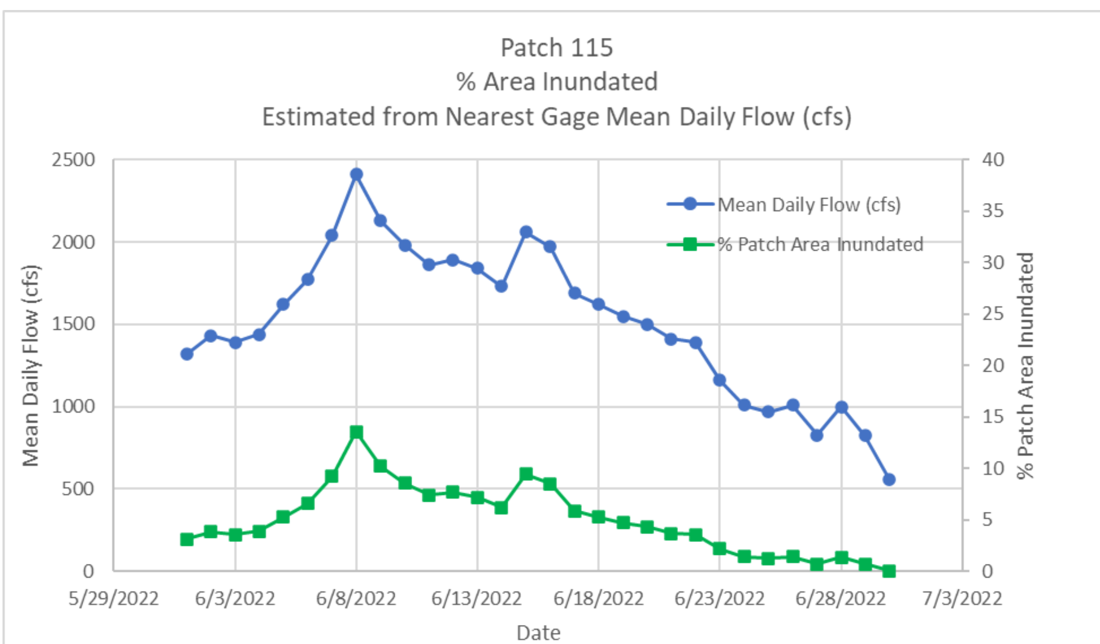


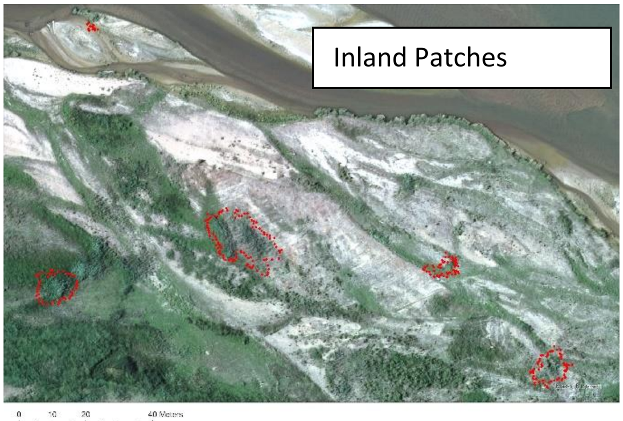
- *Note: Polynomial function chosen based on predicted sigmoidal relationship and improved curve fit. We will replace the polynomial function with linear interpolation from higher density 2D model runs filling in data for 3000 and 4000 cfs.*




Bankline Patch 115
Chapman
June area = 2319.3 ft^2
0 10 20 feet


Patch 115
y = 3E-06x² - 0.0016x
R² = 0.9974
% Patch Area Inundated
100.00
90.00
80.00
70.00
60.00
50.00
40.00
30.00
20.00
10.00
0.00
0
1000
2000
3000
4000
5000
6000
Modeled Flow (cfs)


Patch 115
% Area Inundated
Estimated from Nearest Gage Mean Daily Flow (cfs)
Mean Daily Flow (cfs)
% Patch Area Inundated
2500
2000
1500
1000
500
0
40
35
30
25
20
15
10
5
0
5/29/2022
6/3/2022
6/8/2022
6/13/2022
6/18/2022
6/23/2022
6/28/2022
7/3/2022
Date

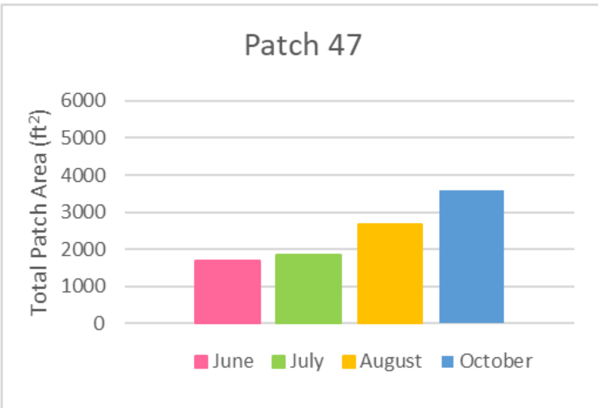


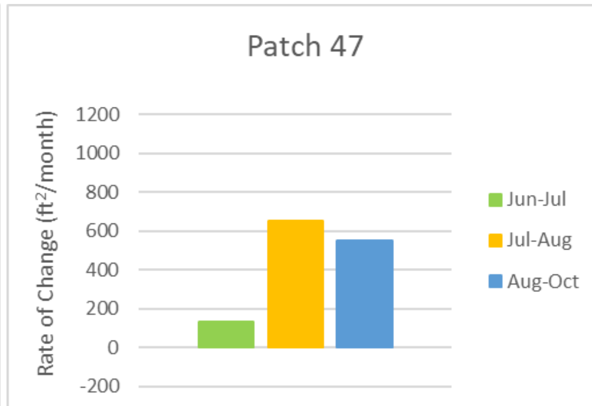
Attribute *(WSE = Water Surface Elevation)*	**Number of Patches**			
	Plum Creek (48)	**Fort Kearny (56)**	**Chapman (52)**	**Total (156)**
June patch intersects modeled 1500 cfs WSE	**5**	**7**	**13**	**25**
June patch intersects modeled 1500 cfs WSE +3m buffer	9	11	17	37
July patch intersects modeled 1500 cfs WSE +3m buffer	9	11	17	37
August patch intersects modeled 1500 cfs WSE +3m buffer	15	20	21	56
October patch intersects modeled 1500 cfs WSE +3m buffer	15	20	23	58
Patch intersects modeled 1500 cfs WSE any sampling interval Jun-Oct	9	11	17	37
Patch intersects modeled 1500 cfs WSE+3m buffer any sampling interval Jun-Oct	15	20	23	58
Patch >3m from modeled 1500 cfs WSE all sampling intervals Jun-Oct	**33**	**36**	**29**	**98**
Any kind of bankline designation (=**BANKLINE PATCH**)	21	23	24	**68**
No bankline designation (=**INLAND PATCH**)	27	33	28	**88**

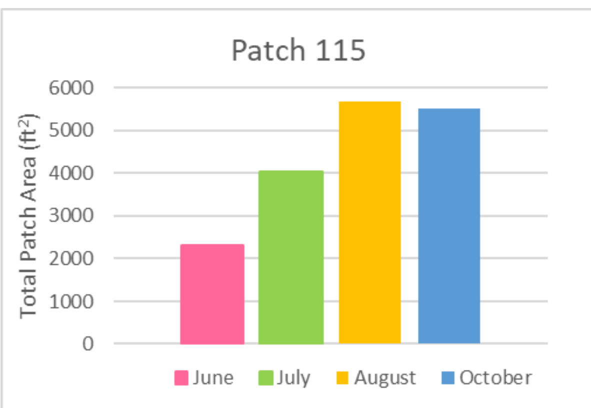
- Bankline patches defined as: patches that at some point during the growing season intersected with modeled 1500 cfs water surface + 3 m buffer AND/OR patch inundation was observed in the field.

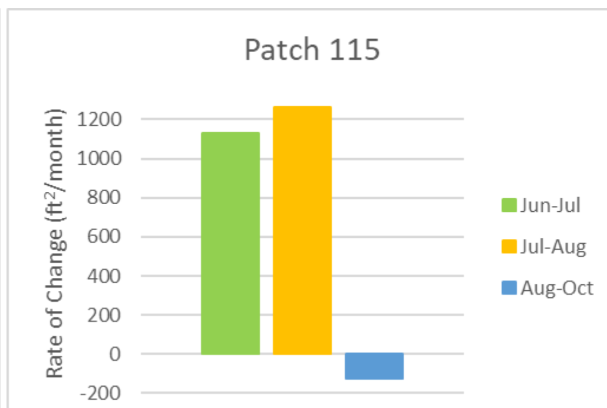
Dependent Variable – Patch area

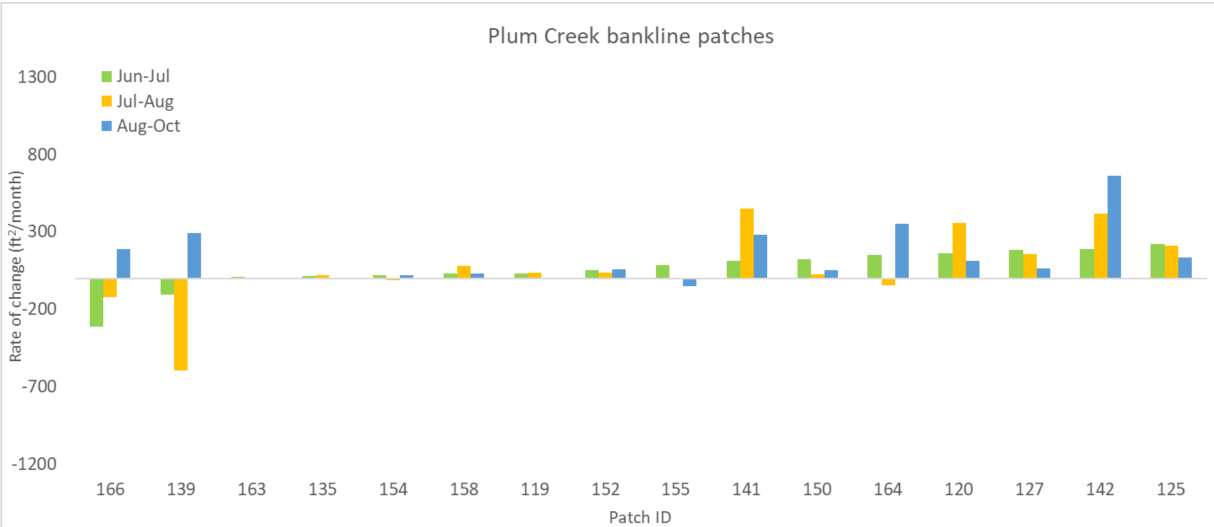
- Initial descriptive statistics for response variables such as patch area and expansion rates (change in patch area, rate of change (ft^2/month).
  - Over time
  - Bankline vs. inland patches
  - Plum Creek vs. Ft. Kearny vs. Chapman (from west to east)
  - Change in patch centroid distance to 1500 cfs 2-D flow model footprint (June vs. October)

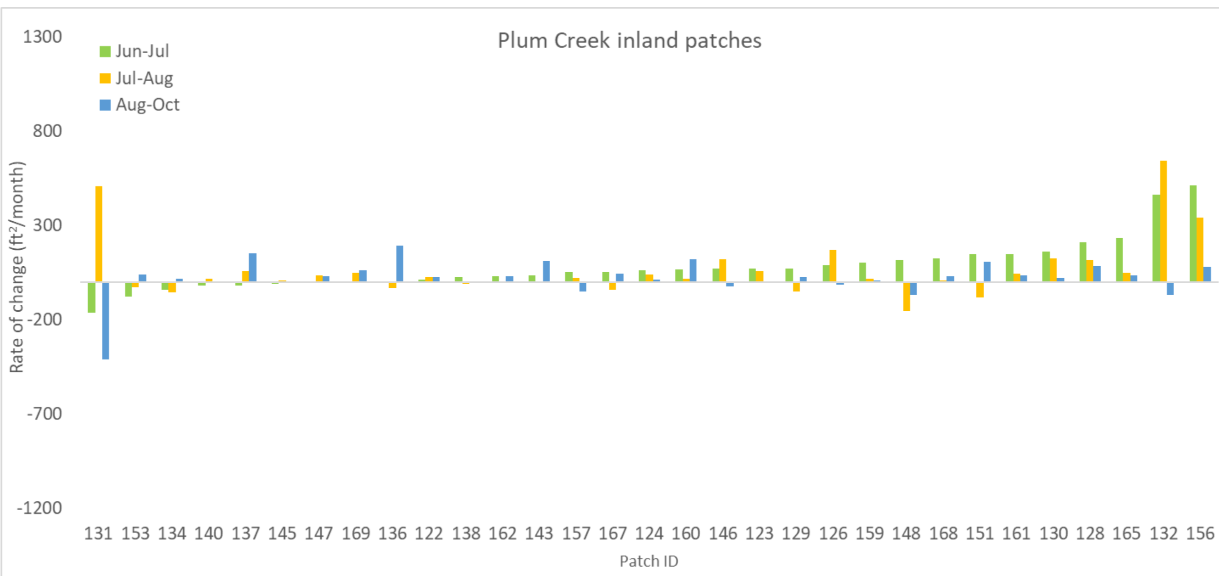


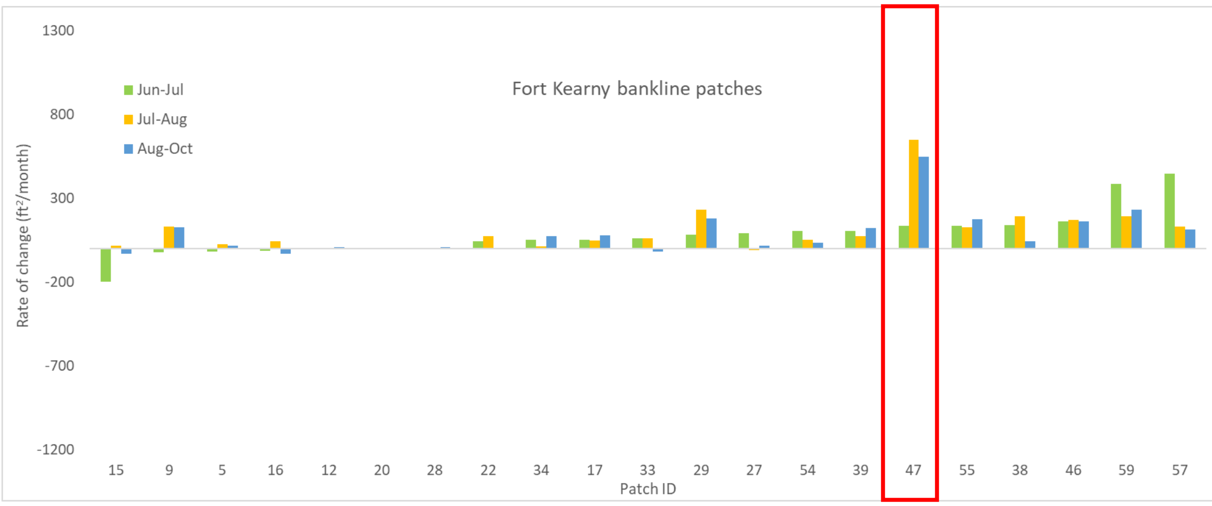


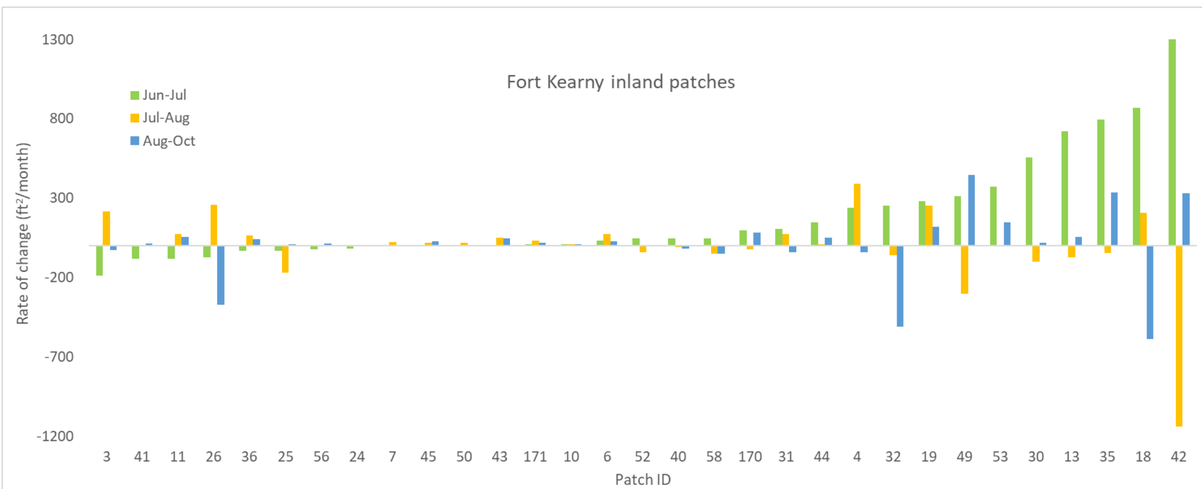


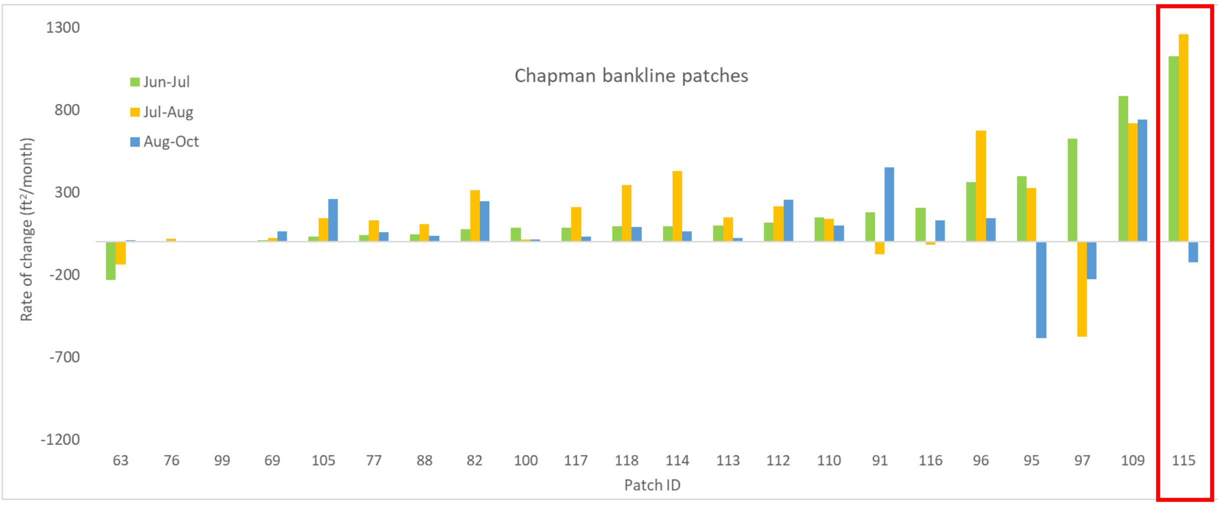


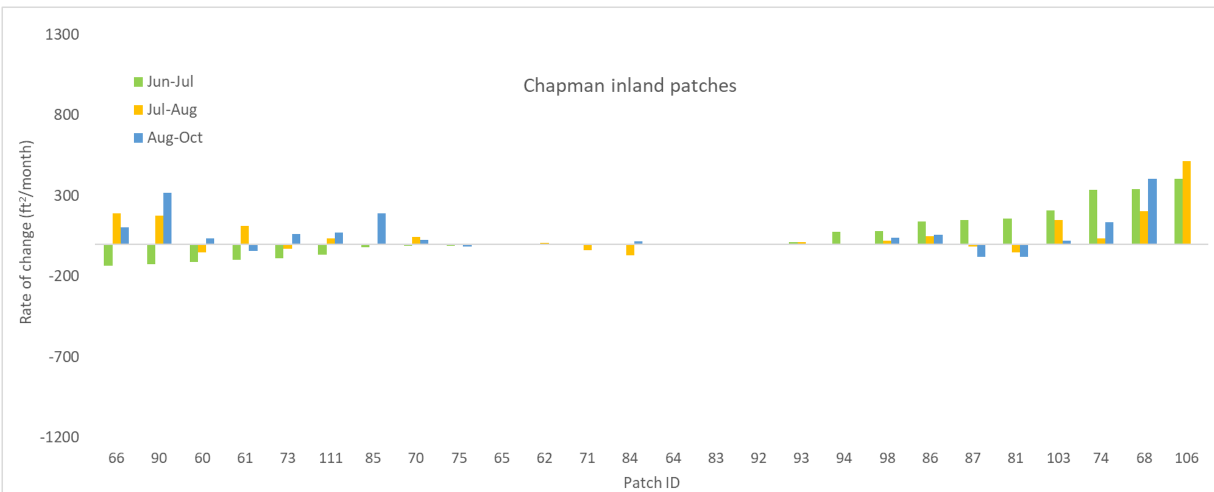

Plum Creek bankline patches
Jun-Jul
Jul-Aug
Aug-Oct
1300
800
300
-200
-700
-1200
Rate of change (ft²/month)
166 139 163 135 154 158 119 152 155 141 150 164 120 127 142 125
Patch ID

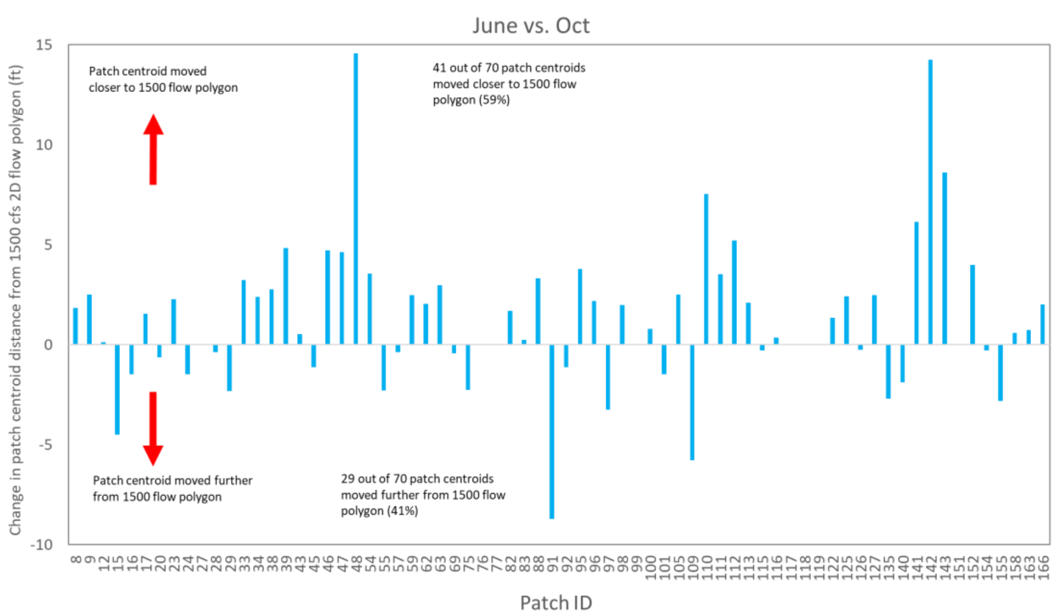

Plum Creek inland patches
Jun-Jul
Jul-Aug
Aug-Oct
1300
800
300
-200
-700
-1200
Rate of change (ft²/month)
131 153 134 140 137 145 147 169 136 122 138 162 143 157 167 124 160 146 123 129 126 159 148 168 151 161 130 128 165 132 156
Patch ID


Fort Kearny bankline patches
Jun-Jul
Jul-Aug
Aug-Oct
Rate of change (ft²/month)
1300
800
300
-200
-700
-1200
15 9 5 16 12 20 28 22 34 17 33 29 27 54 39 47 55 38 46 59 57
Patch ID


Fort Kearny inland patches
Jun-Jul
Jul-Aug
Aug-Oct
Rate of change (ft²/month)
1300
800
300
-200
-700
-1200
3 41 11 26 36 25 56 24 7 45 50 43 171 10 6 52 40 58 170 31 44 4 32 19 49 53 30 13 35 18 42
Patch ID


Chapman bankline patches
Jun-Jul
Jul-Aug
Aug-Oct
1300
800
300
-200
-700
-1200
Rate of change (ft²/month)
63 76 99 69 105 77 88 82 100 117 118 114 113 112 110 91 116 96 95 97 109 115
Patch ID


Chapman inland patches
Jun-Jul
Jul-Aug
Aug-Oct
1300
800
300
-200
-700
-1200
Rate of change (ft²/month)
66 90 60 61 73 111 85 70 75 65 62 71 84 64 83 92 93 94 98 86 87 81 103 74 68 106
Patch ID


June vs. Oct
Patch centroid moved closer to 1500 flow polygon
41 out of 70 patch centroids moved closer to 1500 flow polygon (59%)
Patch centroid moved further from 1500 flow polygon
29 out of 70 patch centroids moved further from 1500 flow polygon (41%)
15
10
5
0
-5
-10
Change in patch centroid distance from 1500 cfs 2D flow polygon (ft)
8 9 12 15 16 17 20 23 24 27 28 29 33 34 38 39 43 45 46 47 48 54 55 57 59 62 63 69 75 76 77 82 83 88 91 92 95 96 97 98 99 100 101 105 109 110 111 112 113 115 116 117 118 119 122 125 126 127 135 140 141 142 143 151 152 154 155 158 163 166
Patch ID

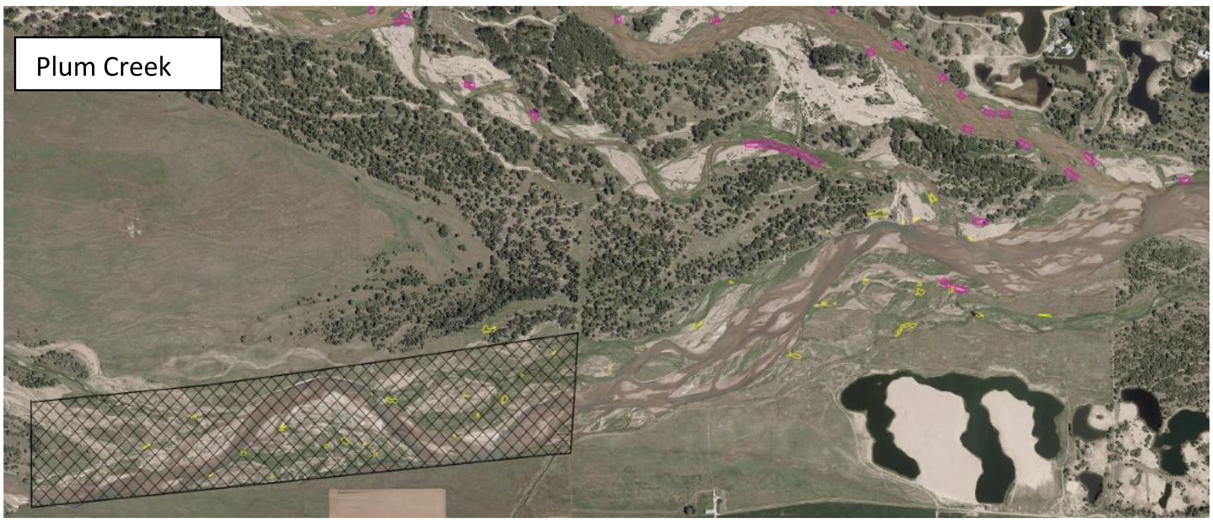
Metric	Rate of change in patch area (ft^2/month) Bankline	Inland
June - July		
Minimum	-311.8	-186.7
Mean	118.4	103.1
Maximum	1129.1	1301.1
SD	219.7	229.0
July - August		
Minimum	-595.1	-1140.1
Mean	126.3	39.5
Maximum	1263.9	644.9
SD	275.5	186.8
August - October		
Minimum	-584.9	-589.6
Mean	99.7	23.4
Maximum	742.7	447.4
SD	199.2	144.3

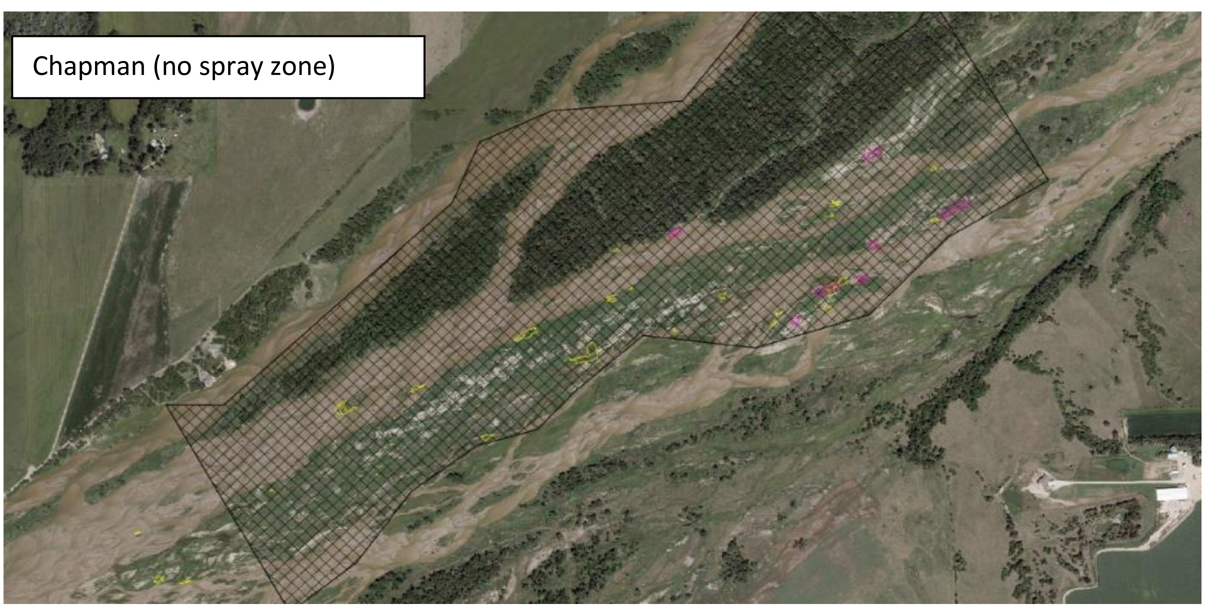
	Bankline patches Rate of change in patch area (ft^2/month)			Inland patches Rate of change in patch area (ft^2/month)		
Metric	**Chapman**	**Fort Kearny**	**Plum Creek**	**Chapman**	**Fort Kearny**	**Plum Creek**
June - July						
Minimum	-230.7	-198.6	-311.8	-131.6	-186.7	-164.5
Mean	198.8	77.6	61.3	49.5	171.8	79.0
Maximum	1129.1	448.3	220.1	406.8	1301.1	510.7
SD	306.2	132.2	131.3	140.2	329.8	134.4
July - August						
Minimum	-576.2	-10.5	-595.1	-69.6	-1140.1	-154.9
Mean	211.6	99.9	63.4	49.6	-9.1	65.7
Maximum	1263.9	648.9	448.8	514.4	391.6	644.9
SD	367.0	139.3	243.5	121.5	240.1	162.5
August - October						
Minimum	-584.9	-92.1	-49.0	-77.8	-589.6	-408.5
Mean	87.1	76.5	137.2	49.7	5.8	20.1
Maximum	742.7	546.9	664.4	404.6	447.4	191.9
SD	252.7	130.7	184.4	109.4	196.1	99.0

<u>Independent variable – Herbicide</u>

- Most patches in the herbicide zone did not receive herbicide

	Number of patches						
Attribute	**Plum Creek herbicide (23)**	**Plum Creek no herbicide (25)**	**Fort Kearny herbicide (24)**	**Fort Kearny no herbicide (32)**	**Chapman herbicide (27)**	**Chapman no herbicide (25)**	**Total**
Received herbicide June 2022	0	0	5	0	6	0	11
Received herbicide Sept 2022	1	0	0	0	0	1	2

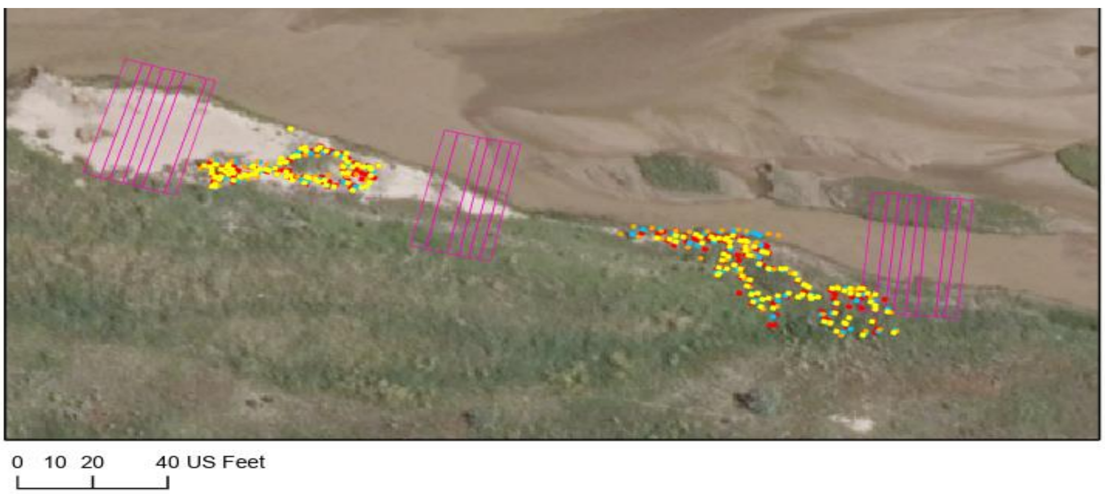




- Patches receiving herbicide were only partially covered.

Number of patches					
Site name	W/in designated herbicide zone	Partially sprayed in June	Fully sprayed in June	Partially sprayed in Sept	Fully sprayed in Sept
Chapman	27	5	1	1*	0
Fort Kearny	24	5	0	0	0
Plum Creek	23	NA	NA	1	0
Total	**74**	**11**	**1**	**2**	**0**

*Patch located in designated herbicide exclusion zone.



SUGGESTED ADJUSTMENTS TO STUDY DESIGN

- Increase the number of bankline (near-channel) patches and reduce the number of inland patches. Target: Monthly sample comprised of 30% INLAND patches and 70% BANKLINE patches.

  - A note on the value of inland patches: It will be important to maintain 30% interior patches to provide a method of comparison. For example, we want to know how much patch expansion during the growing season is due to hydrology in the near-channel environment versus normal seasonal growth. We can better understand the relative contribution of different growth variables by comparing expansion rates between bankline patches and inland patches.

  - Continue to map all inland patches once annually in late August.

INLAND patch selection criteria - maintain existing patches that meet selection criteria, with a target of 30% of total patches at each site:

Tier 1 criteria

- Patch exhibits medium-high stem density and low-medium cover of other plants
- Patch area ≥30m^2 (~two parking spaces)
- Patch does not occur within 10m of another patch
- Patch does not occur along an inland pond/waterbody

	Number of bankline patches (68)				Number of inland patches (88)			
Property complex	**TIER 1**	**TIER 2**	**TIER 3**	**TIER 4**	**TIER 1**	**TIER 2**	**TIER 3**	**TIER 4**
Plum Creek (48)	11	8	2	0	14	8	3	2
Fort Kearny (56)	11	9	2	1	14	7	9	3
Chapman (52)	8	9	7	0	1	15	12	0
Total (156)	**30**	**26**	**11**	**1**	**29**	**30**	**24**	**5**

- TIER 1: July stem density med and other plant cover low OR July stem density med and other plant cover med OR July stem density high and other plant cover med OR July stem density high and other plant cover high
- TIER 2: July stem density med and other plant cover high
- TIER 3: July stem density low and other plant cover low OR July stem density low and other plant cover med, OR July stem density low and other plant cover high
- TIER 4: Along pond or excavated channel fed by groundwater/low management priority
- Recommend dropping tiers in red text from the 2023 monthly sampling
- Recommend adding bankline patches in tiers 1-2 (aiming for a certain % of the total sample, e.g, 70% bankline, 30% inland)

BANKLINE patch selection criteria - maintain all existing bankline patches, and add new patches that meet the sampling criteria, with a target of 70% of total patches at each site:

- Patch boundary occurs inside and/or within 3m of modeled 1,500 cfs water line – select patches from random points within search area
- Patch exhibits medium-high stem density and <50% cover of other plants
- Patch area $\geq 10m^2$
- Patch does not occur within 10m of another patch

- Add the following metrics for bankline patches during field collection
  - Map bankline for reference
  - Measure individual stolon length and direction of growth with reference to bankline and active channel
  - Take more frequent measurements of stolen length and direction of growth throughout summer to address rate of stolon growth into the active channel

PROPOSED ANALYSES

- Calculate flow/patch relationships – solve for percent of patch area inundated – analyze for relationship between patch area inundated and the patch area, dependent var through time
    - Calculate the hydrologic regime for each patch (independent variables) using 2-D flow models, sigmoid curves, and gage data.
- Calculate patch area through time, percent change in patch area over time, monthly rate of change in patch area.
- Calculate descriptive statistics for patch assessment metrics through time (height, condition, stem density, etc.).
- Are these relationships consistent across the AHR from W to E, in high and dry vs. bankline or near bankline patches?