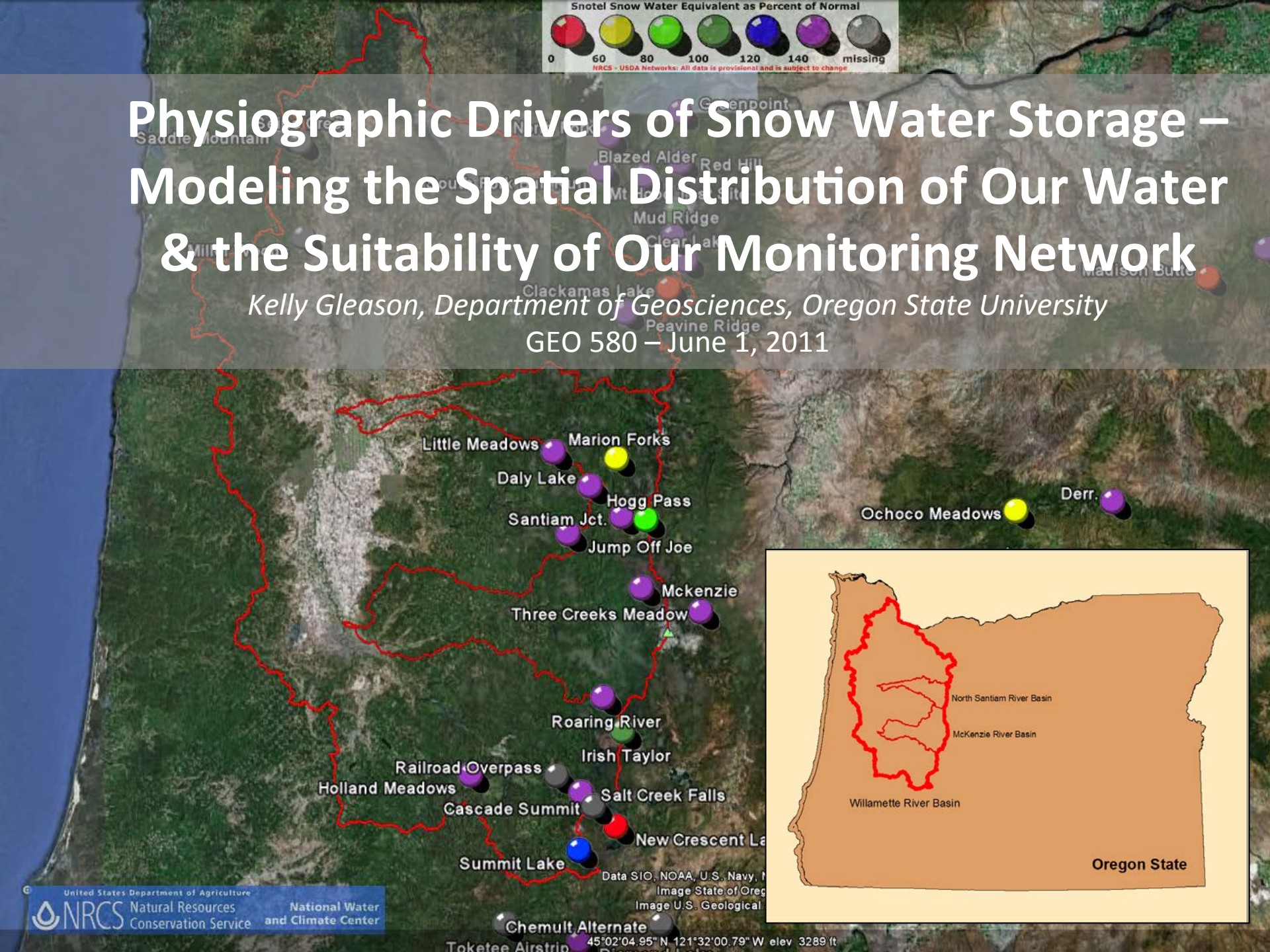
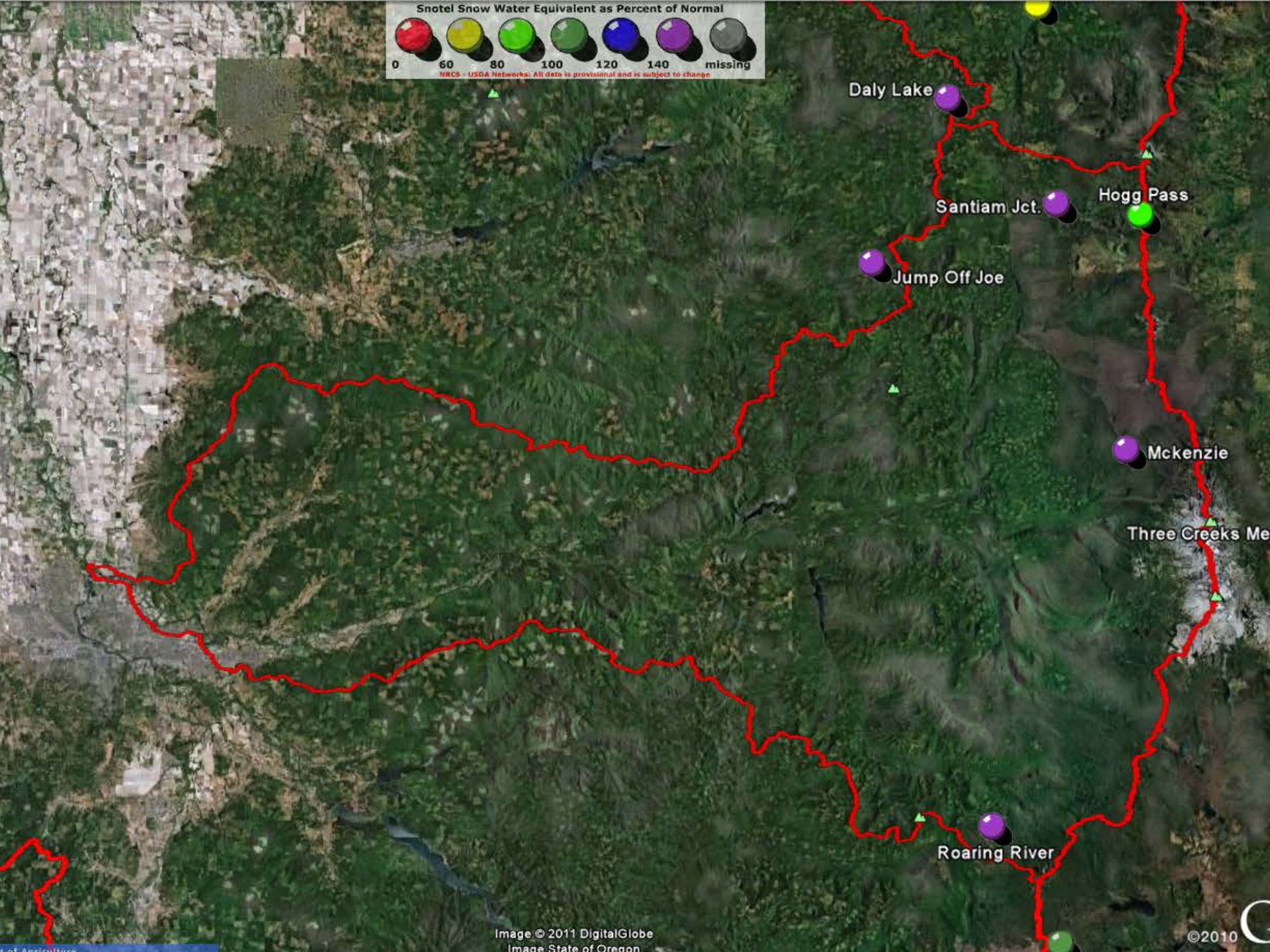
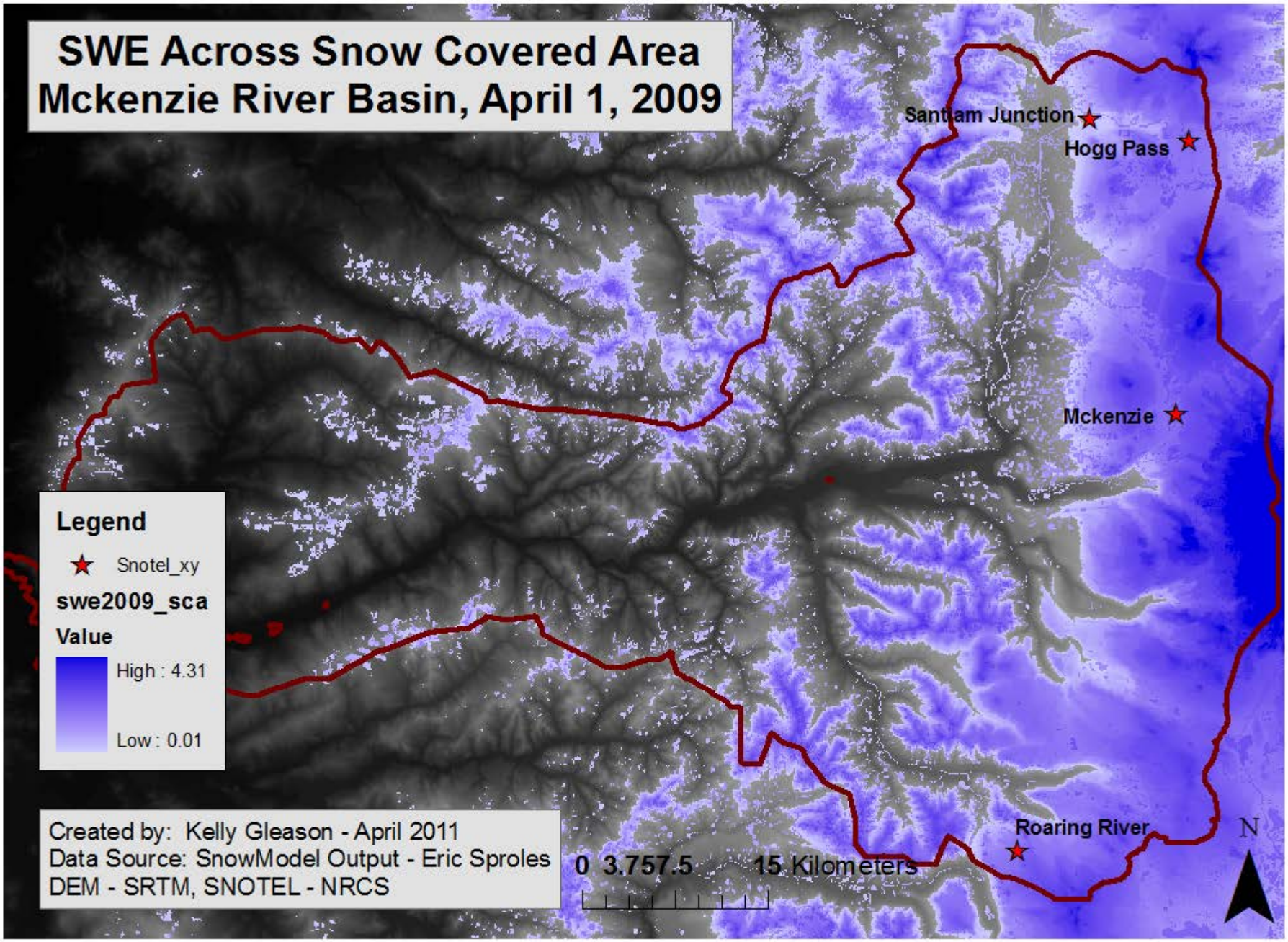


Physiographic Drivers of Snow Water Storage – Modeling the Spatial Distribution of Our Water & the Suitability of Our Monitoring Network

Kelly Gleason, Department of Geosciences, Oregon State University

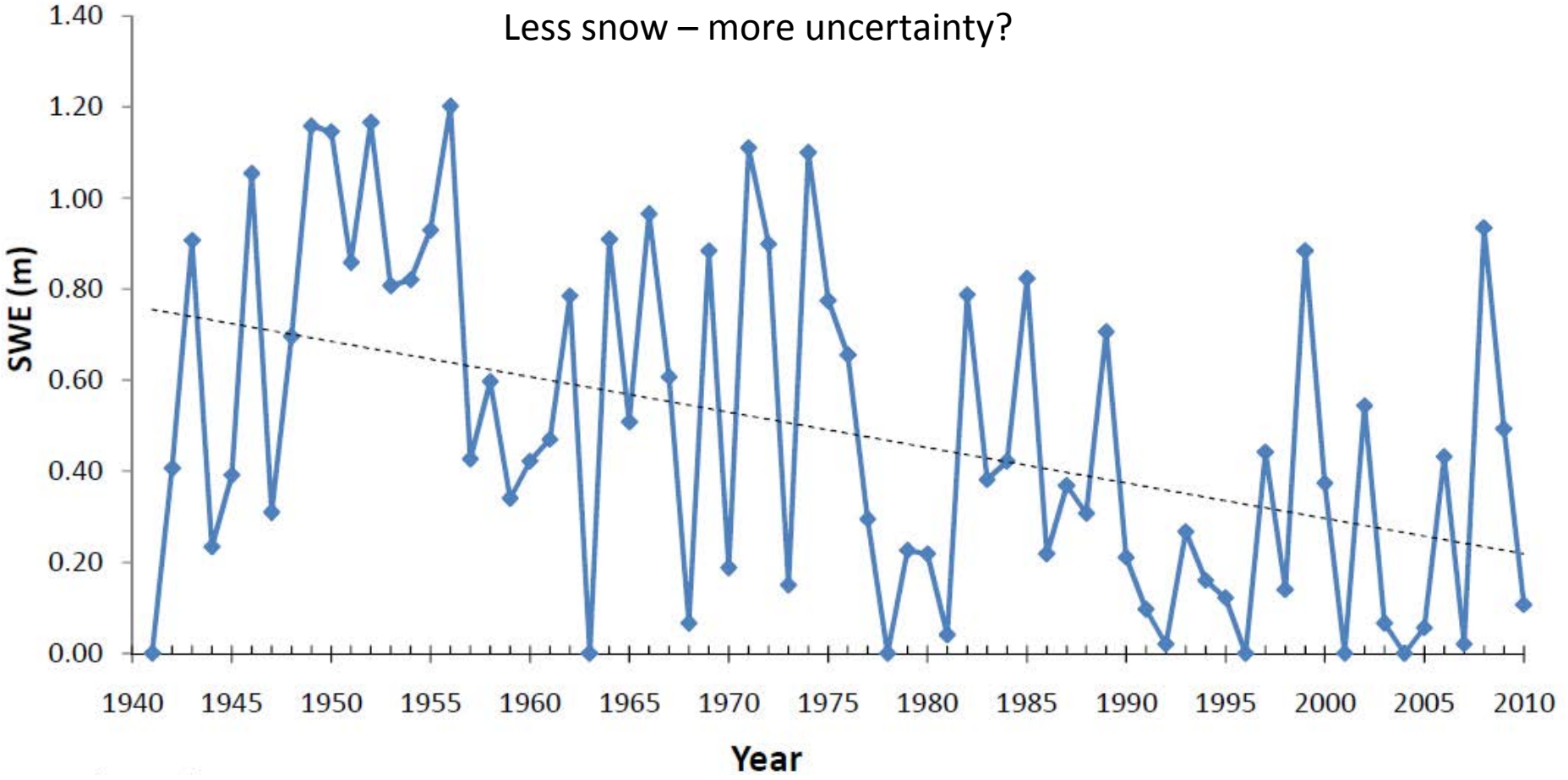
GEO 580 – June 1, 2011


Snotel Snow Water Equivalent as Percent of Normal
0
60
80
100
120
140
missing
NRCS - USDA Networks. All data is provisional and is subject to change
Daly Lake
Santiam Jct.
Hogg Pass
Jump Off Joe
Mckenzie
Three Creeks Me
Roaring River
Image © 2011 DigitalGlobe
Image State of Oregon
©2010


SWE Across Snow Covered Area
Mckenzie River Basin, April 1, 2009
Santiam Junction
Hogg Pass
Mckenzie
Roaring River
Legend
Snotel_xy
swe2009_sca
Value
High : 4.31
Low : 0.01
Created by: Kelly Gleason - April 2011
Data Source: SnowModel Output - Eric Sproles
DEM - SRTM, SNOTEL - NRCS
0 3.757.5 15 Kilometers
N

Measured SWE at Santiam Junction on April 1 (Elevation 1143 m)

Less snow – more uncertainty?

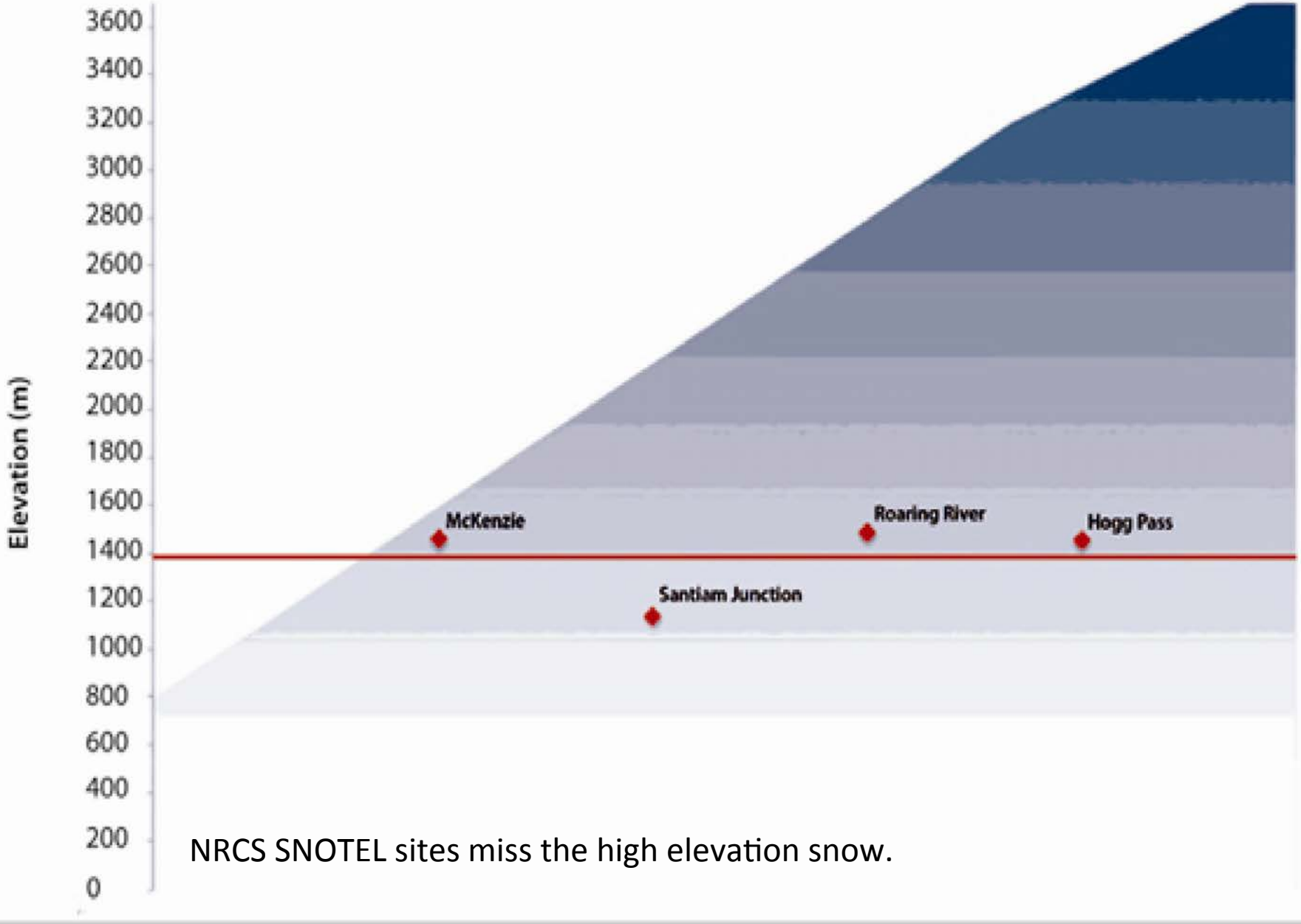


Decline = 8 mm / year ***

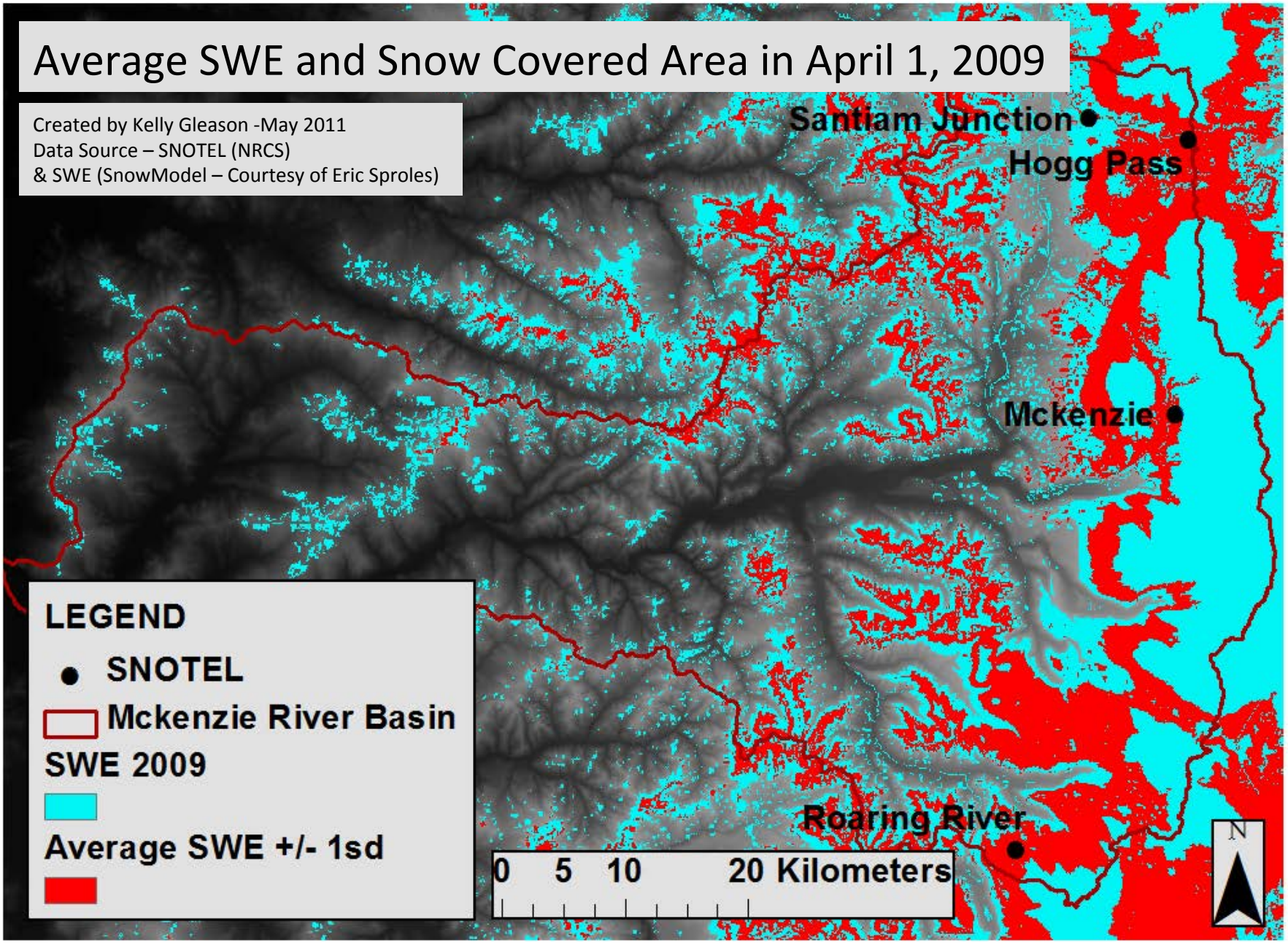
Water Volume Loss in a 500-m Elevation Band = 0.5 km^3

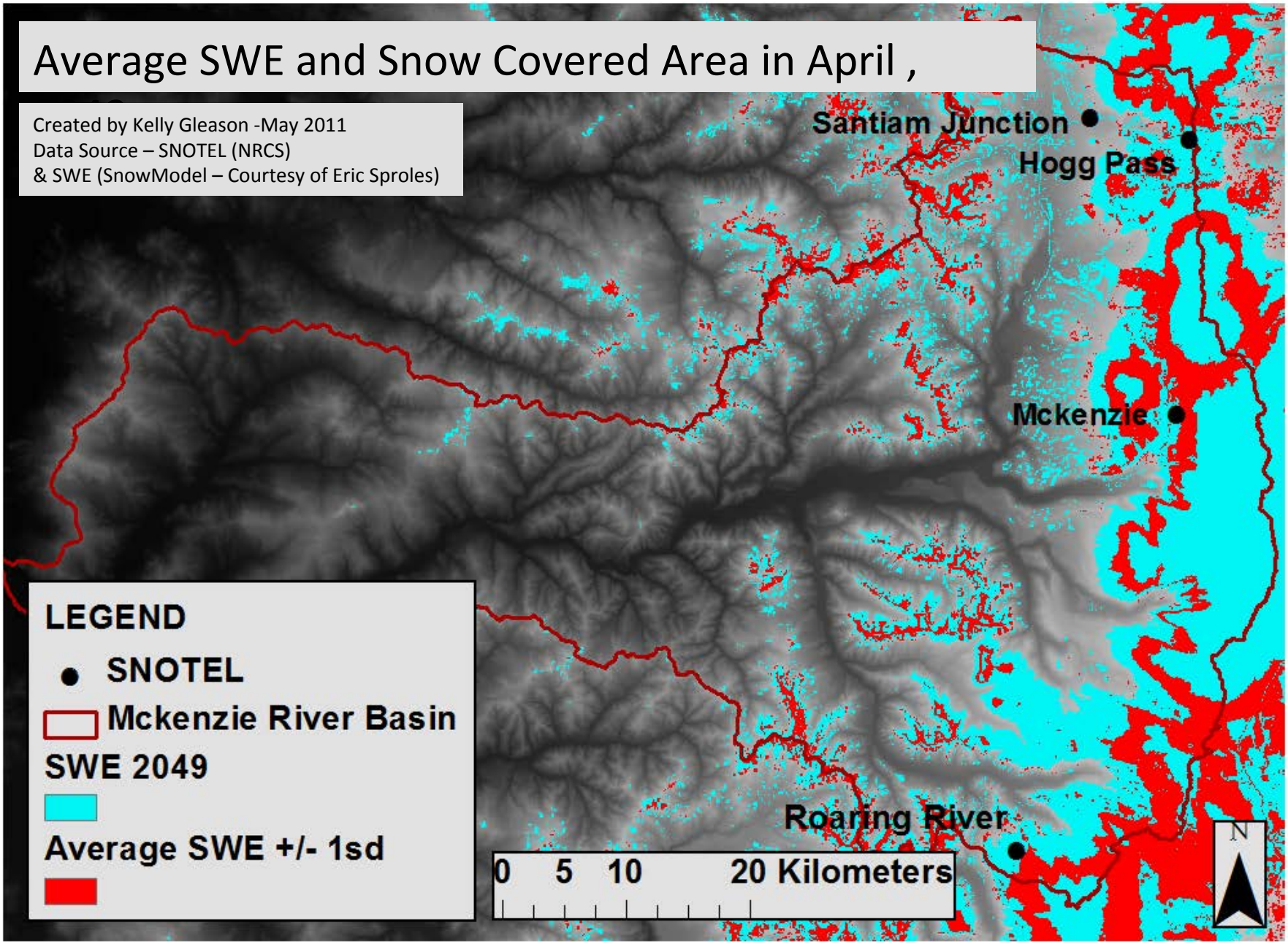
OSU Oregon State University

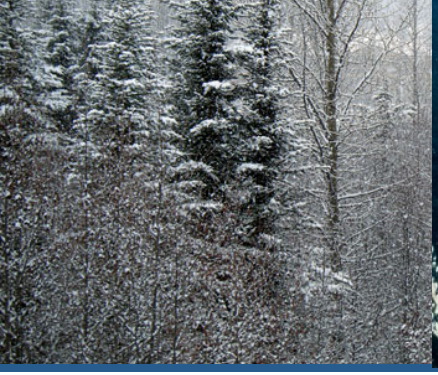
Area-Elevation Relationship for Snow in the McKenzie River Basin

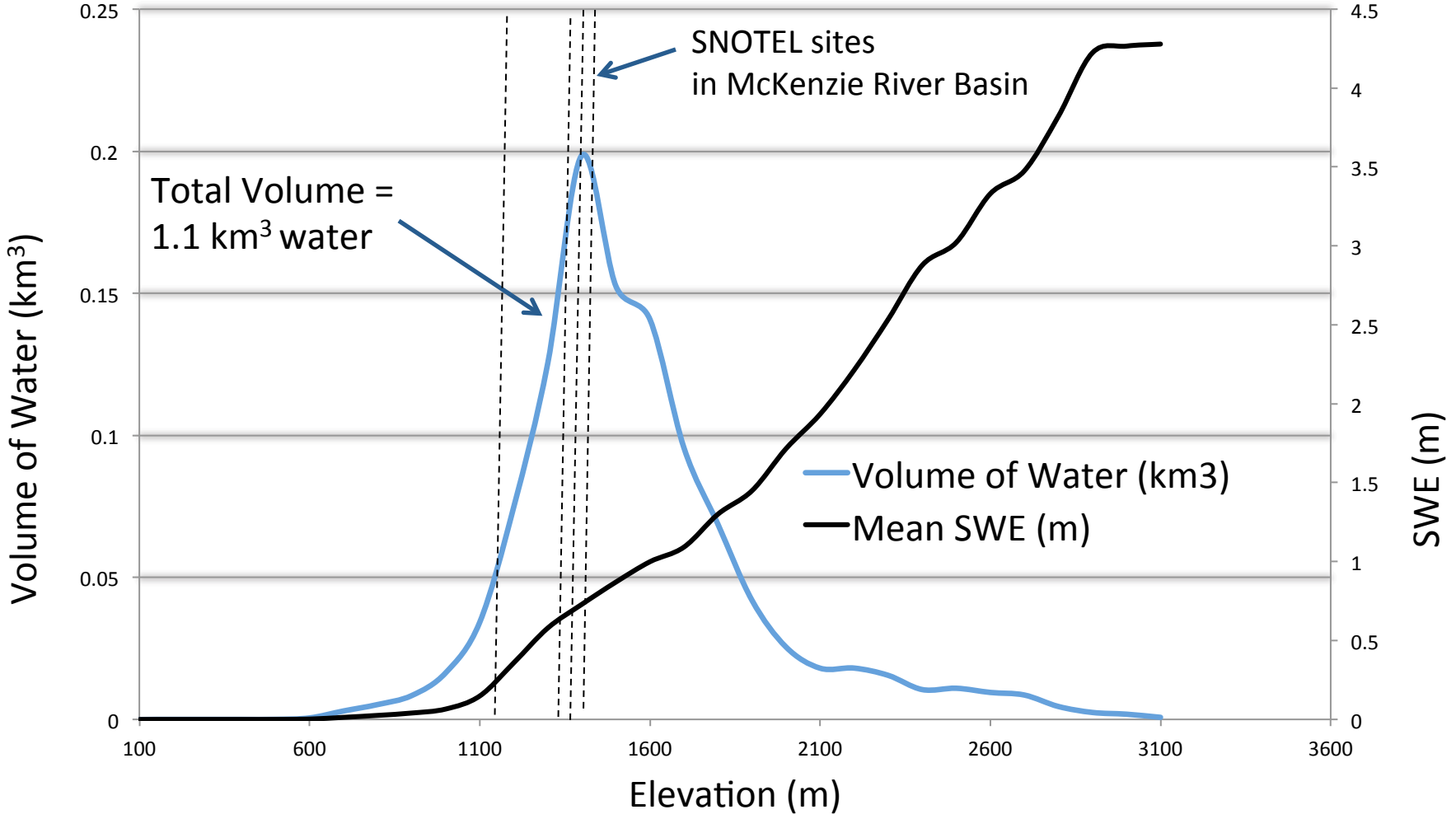


NRCS SNOTEL sites miss the high elevation snow.

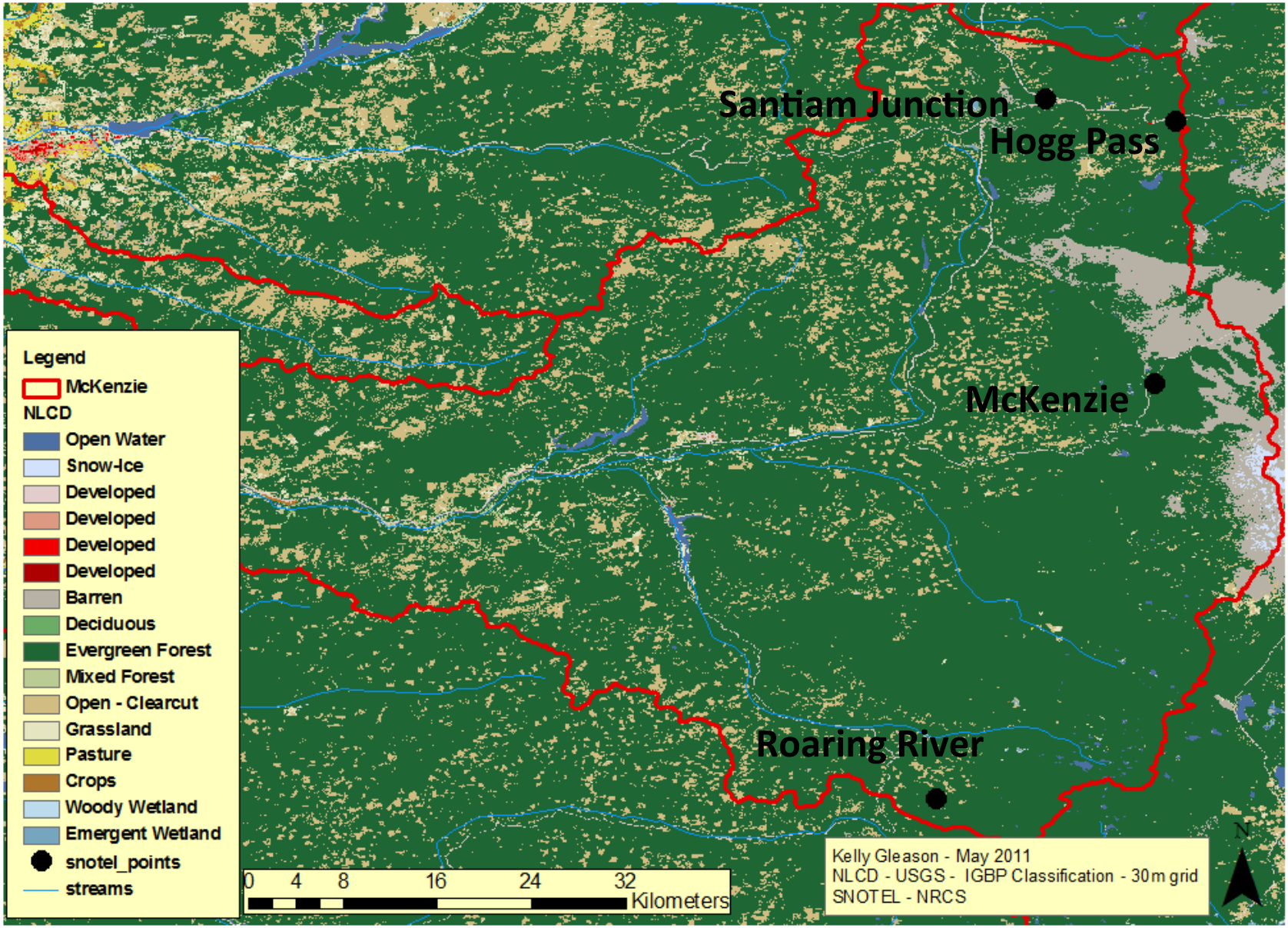

Average SWE and Snow Covered Area in April 1, 2009
Created by Kelly Gleason -May 2011
Data Source – SNOTEL (NRCS)
& SWE (SnowModel – Courtesy of Eric Sproles)
Santiam Junction
Hogg Pass
Mckenzie
Roaring River
LEGEND
SNOTEL
Mckenzie River Basin
SWE 2009
Average SWE +/- 1sd
0 5 10 20 Kilometers
N


Average SWE and Snow Covered Area in April ,
Created by Kelly Gleason -May 2011
Data Source – SNOTEL (NRCS)
& SWE (SnowModel – Courtesy of Eric Sproles)
Santiam Junction
Hogg Pass
Mckenzie
Roaring River
LEGEND
SNOTEL
Mckenzie River Basin
SWE 2049
Average SWE +/- 1sd
0 5 10 20 Kilometers
N




SNOTEL sites
in McKenzie River Basin
Total Volume =
1.1 km3 water
Volume of Water (km3)
Mean SWE (m)
Volume of Water (km3)
SWE (m)
Elevation (m)
0.25
0.2
0.15
0.1
0.05
0
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
100
600
1100
1600
2100
2600
3100
3600

Land Cover in the McKenzie River Basin, Oregon



Questions

- What are important physiographic drivers of snow accumulation processes in the Western Oregon Cascades?
- Can a landscape-based Binary Regression Tree model be used to predict snow distribution, depth, and variability in the McKenzie River Basin (3,000 km^2)? N. Santiam River Basin? Willamette River Basin (30,000 km^2)?
- Can this characterization be used to distribute a representative monitoring network to capture the future spatial variability in snowpack?

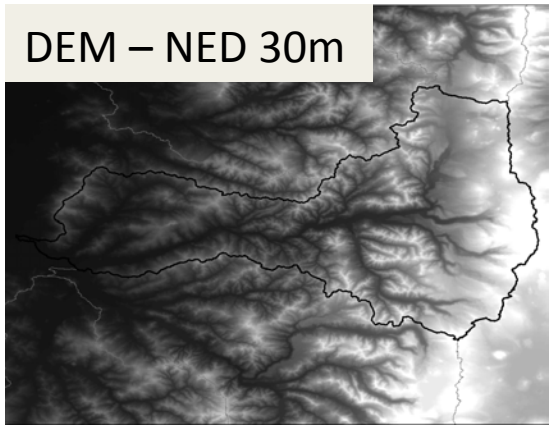
Objectives

- Use physiographic variables to develop a landscape-based model to characterize SWE within the McKenzie River Basin.
- Use that model to classify SWE in nearby watersheds.
- Randomly select objective and representative monitoring network.

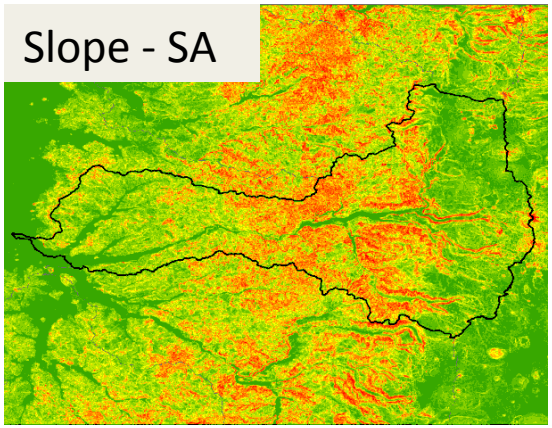
ArcGIS Methods

- Import physiographic and modeled SWE data
- Zonal statistics with elevation
- Extract physiographics and SWE in Mckenzie River
- Develop BRT snow classification model based on landscape characteristics
- Use this BRT to develop GIS analysis model to predict SWE using landscape physiographics
- Select representative sampling locations
- Test on N.Santiam River and extrapolate to Willamette River

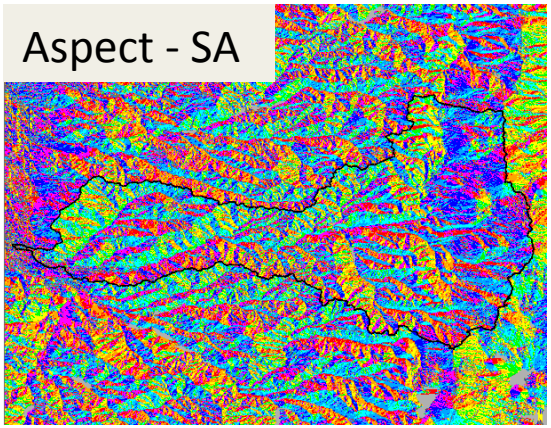
DEM – NED 30m



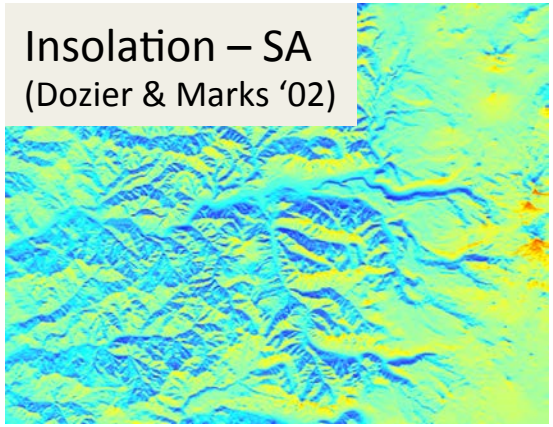
Slope - SA



Aspect - SA

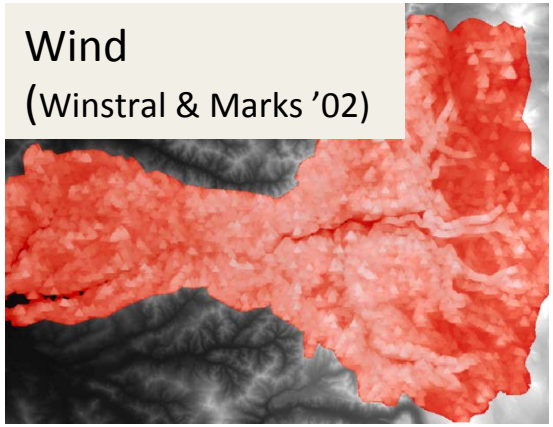


Insolation – SA
(Dozier & Marks '02)

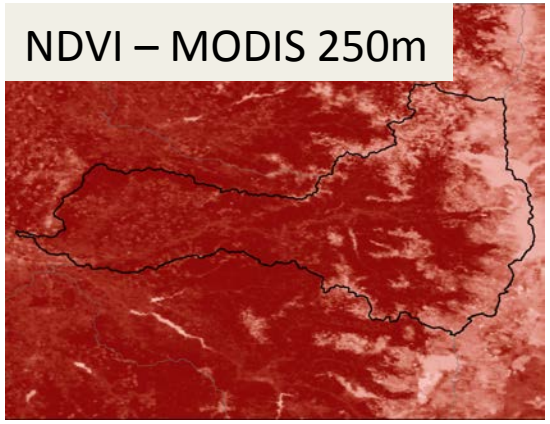


Land Cover -NLCD

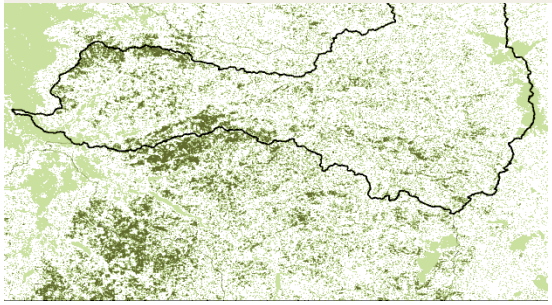
Wind
(Winstral & Marks '02)



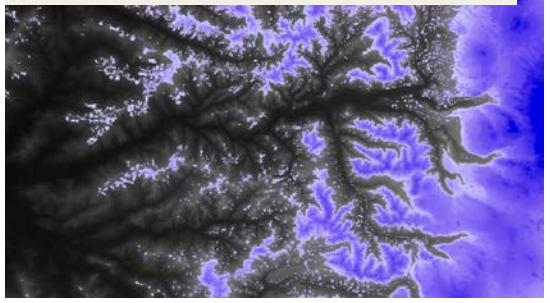
NDVI – MODIS 250m



% Canopy Cover –LANDFIRE
(Veatch et al '09)



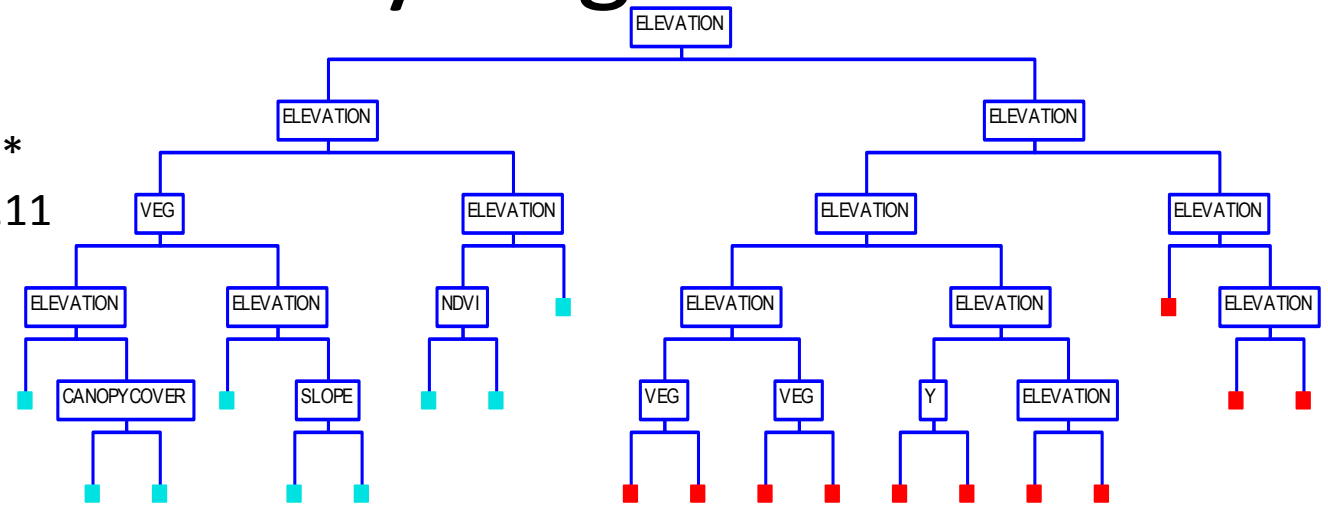
SWE 2009 – SnowModel
100m (Liston and Elder '06)



Binary Regression Tree

R = 0.95 **

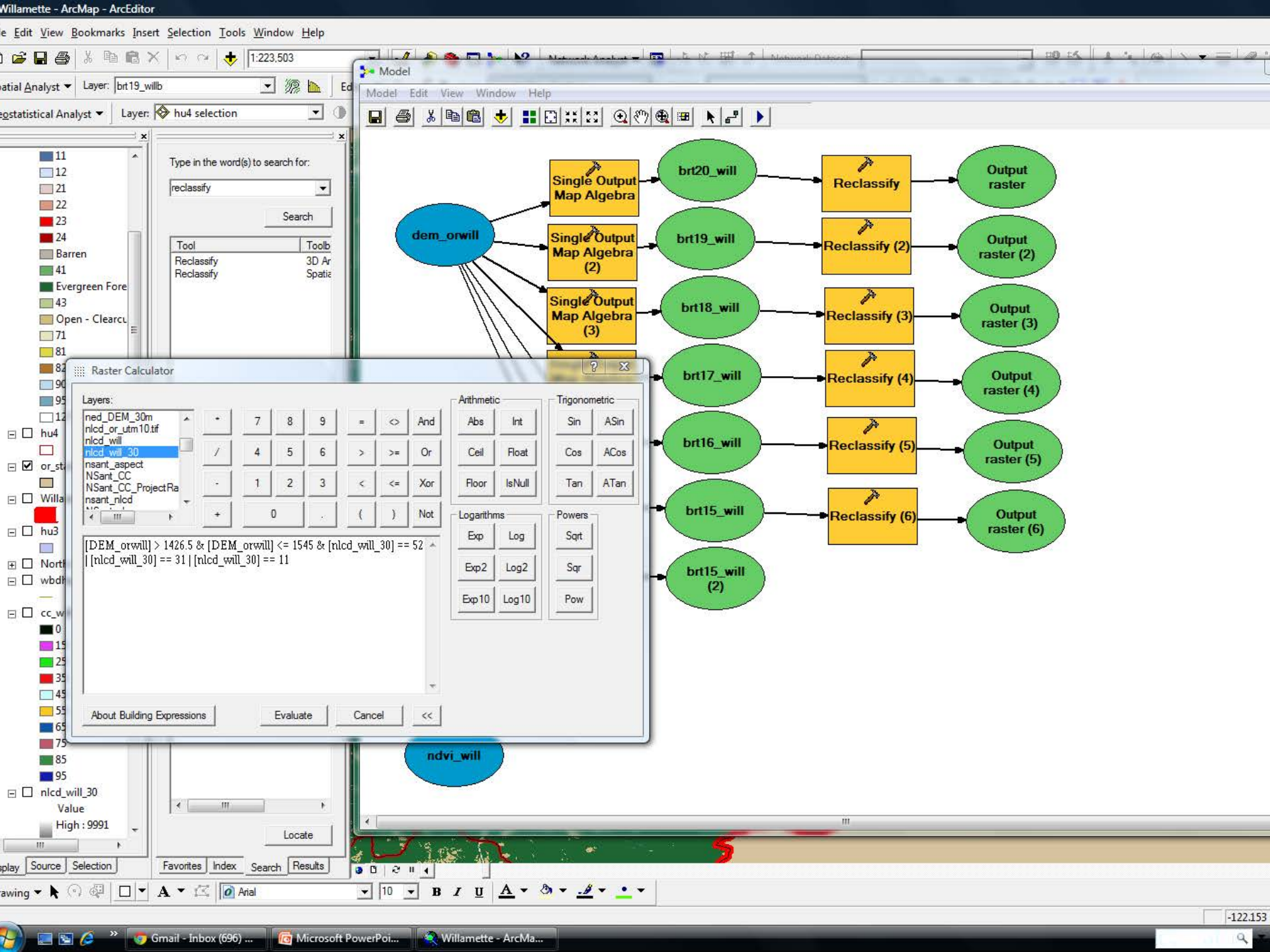
RMSE = 0.11

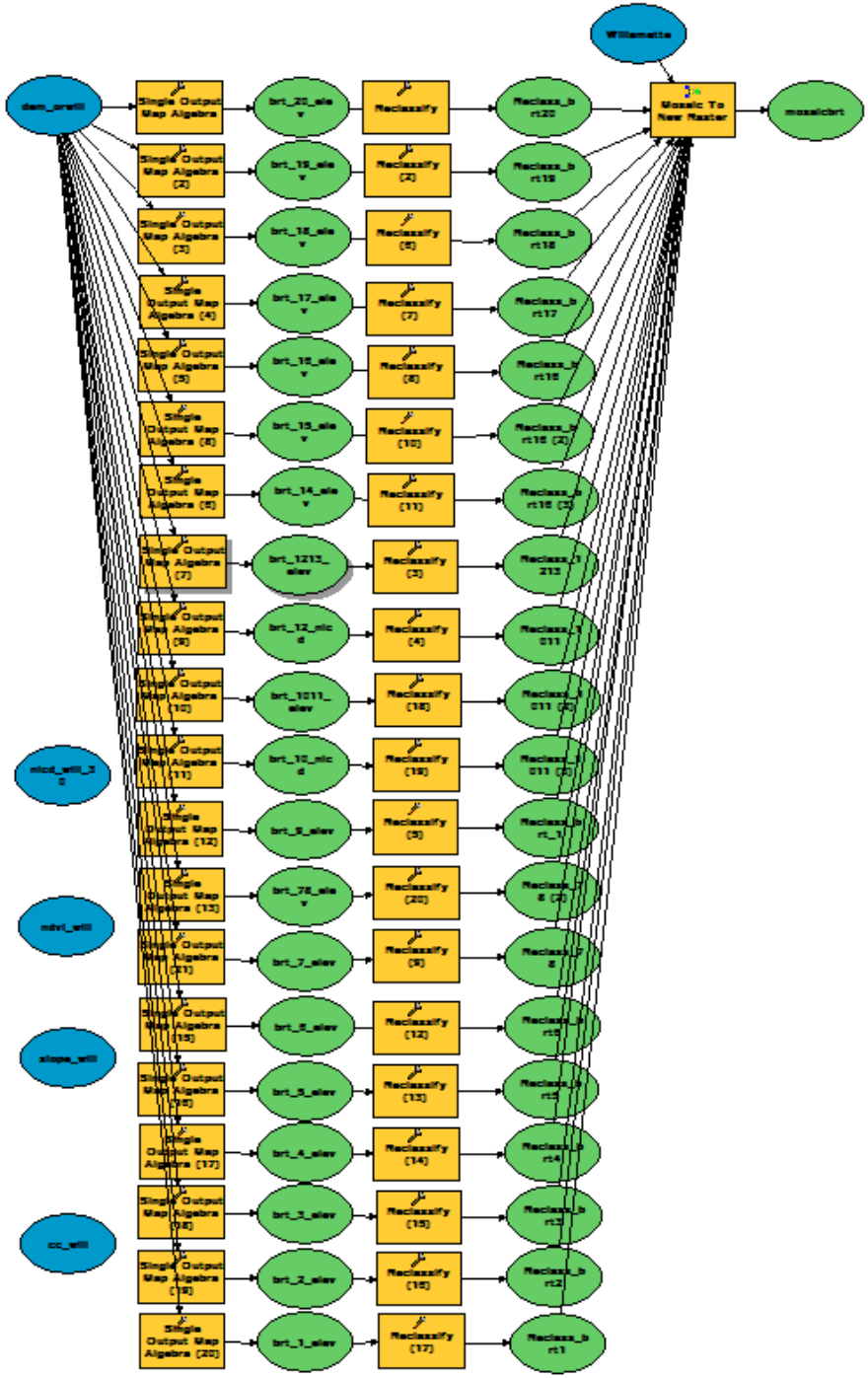


Landscape Class	Elevation	Veg Class	Other
1	<-1121	Forest	
2	>1121 <-1198.5	Forest	%CC <-20
3	>1121 <-1198.5	Forest	%CC >20
4	<-977	Open	
5	>977 <-1198.5	Open	Slope <-26.84
6	>977 <-1198.5	Open	Slope >26.84
7	>1198.5 <-1255		NDVI <-2063
8	>1198.5 <-1255		NDVI >2063
9	>1255 <-1332.5		
10	>1332.5 <-1426.5	Forest	

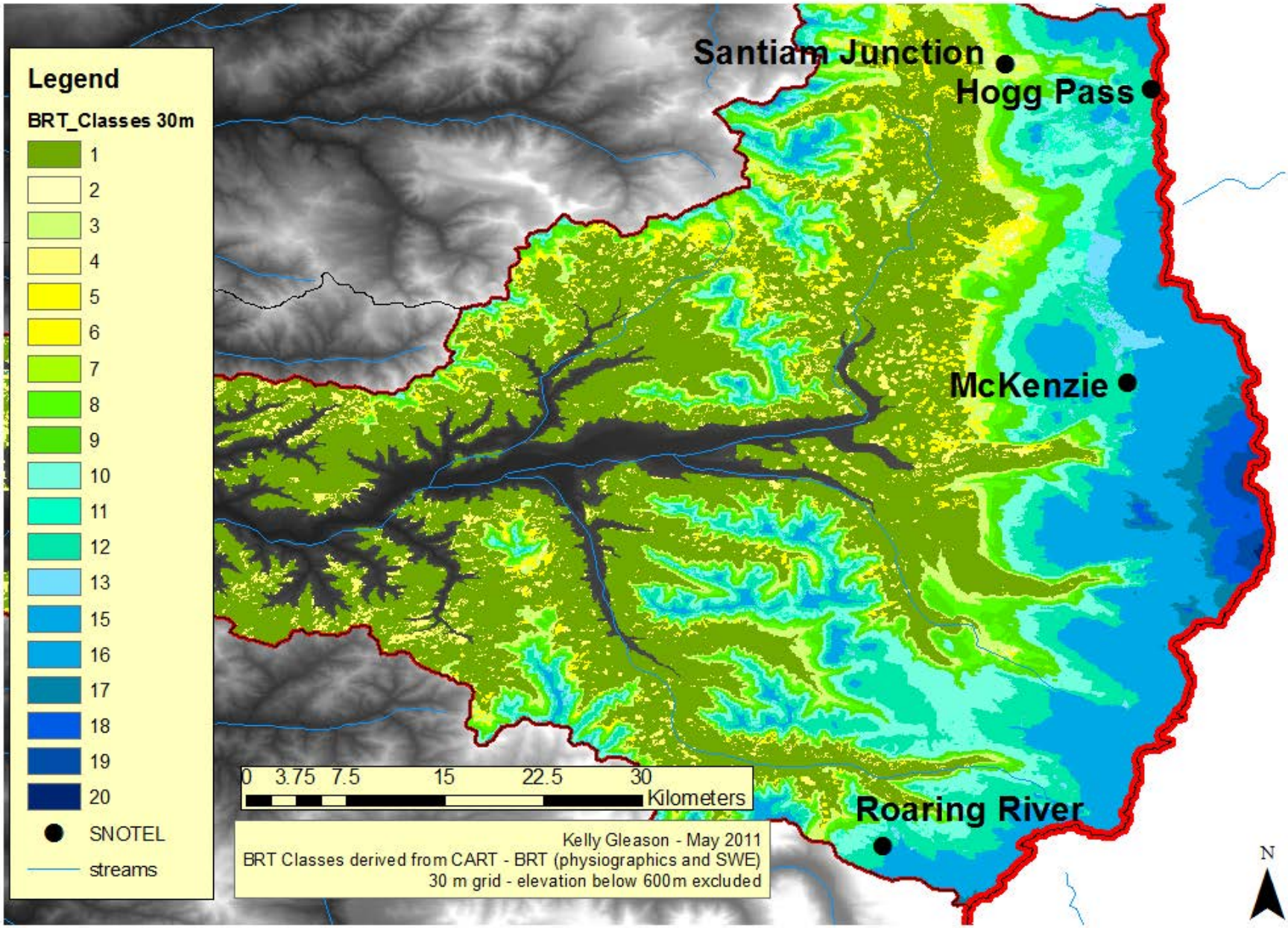
Landscape Class	Elevation	Veg Class	Other
11	>1332.5 <-1426.5	Open	
12	>1426.5 <-1545	Forest	
13	>1426.5 <-1545	Open	
14	>1545 <-1791		Y >4878574
15	>1545 <-1791		Y <-4878574
16	>1791 <-1919.5		
17	>1919.5 <-2039		
18	>2039 <-2371		
19	>2371 <-2788		
20	>2788		

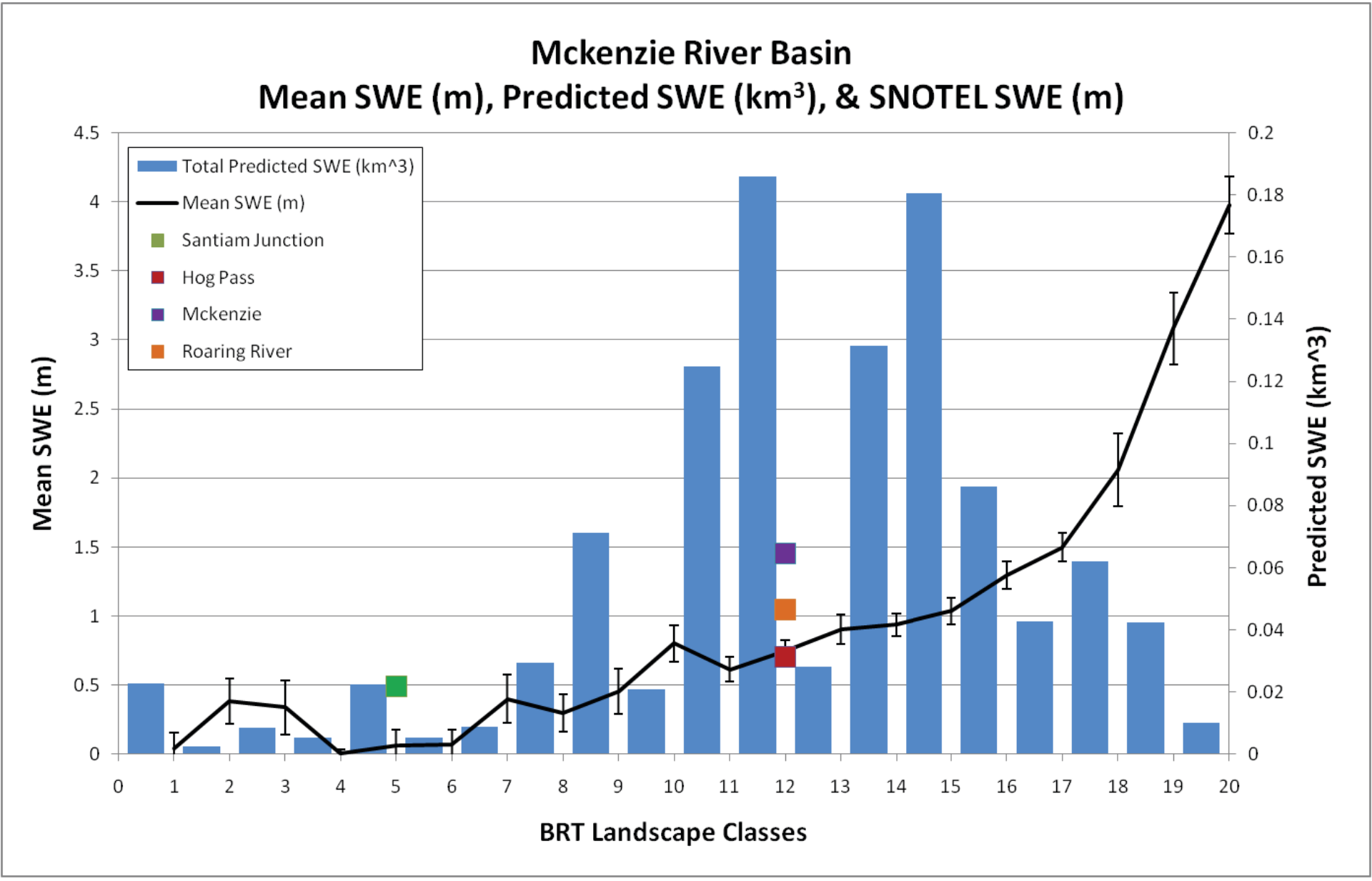
Molotch and Bales, 2006


Willamette - ArcMap - ArcEditor
Edit View Bookmarks Insert Selection Tools Window Help
1:223,503
Layer: brt19_willb
Layer: hu4 selection
Model
Model Edit View Window Help
Type in the word(s) to search for:
reclassify
Search
Tool
Reclassify
Reclassify
Locate
Favorites Index Search Results
Source Selection
Raster Calculator
Layers:
ned_DEM_30m
nlcd_or_utm10.tif
nlcd_will
nlcd_will_30
nsant_aspect
NSant_CC
NSant_CC_ProjectRa
nsant_nlcd
[DEM_orwill] > 1426.5 & [DEM_orwill] <= 1545 & [nlcd_will_30] == 52 | [nlcd_will_30] == 31 | [nlcd_will_30] == 11
Arithmetic
Trigonometric
Logarithms
Powers
About Building Expressions
Evaluate
Cancel
dem_orwill
Single Output Map Algebra
Single Output Map Algebra (2)
Single Output Map Algebra (3)
brt20_will
brt19_will
brt18_will
brt17_will
brt16_will
brt15_will
brt15_will (2)
ndvi_will
Reclassify
Reclassify (2)
Reclassify (3)
Reclassify (4)
Reclassify (5)
Reclassify (6)
Output raster
Output raster (2)
Output raster (3)
Output raster (4)
Output raster (5)
Output raster (6)
nlcd_will_30
Value
High : 9991
-122.153
Gmail - Inbox (696) ...
Microsoft PowerPoi...
Willamette - ArcMa...

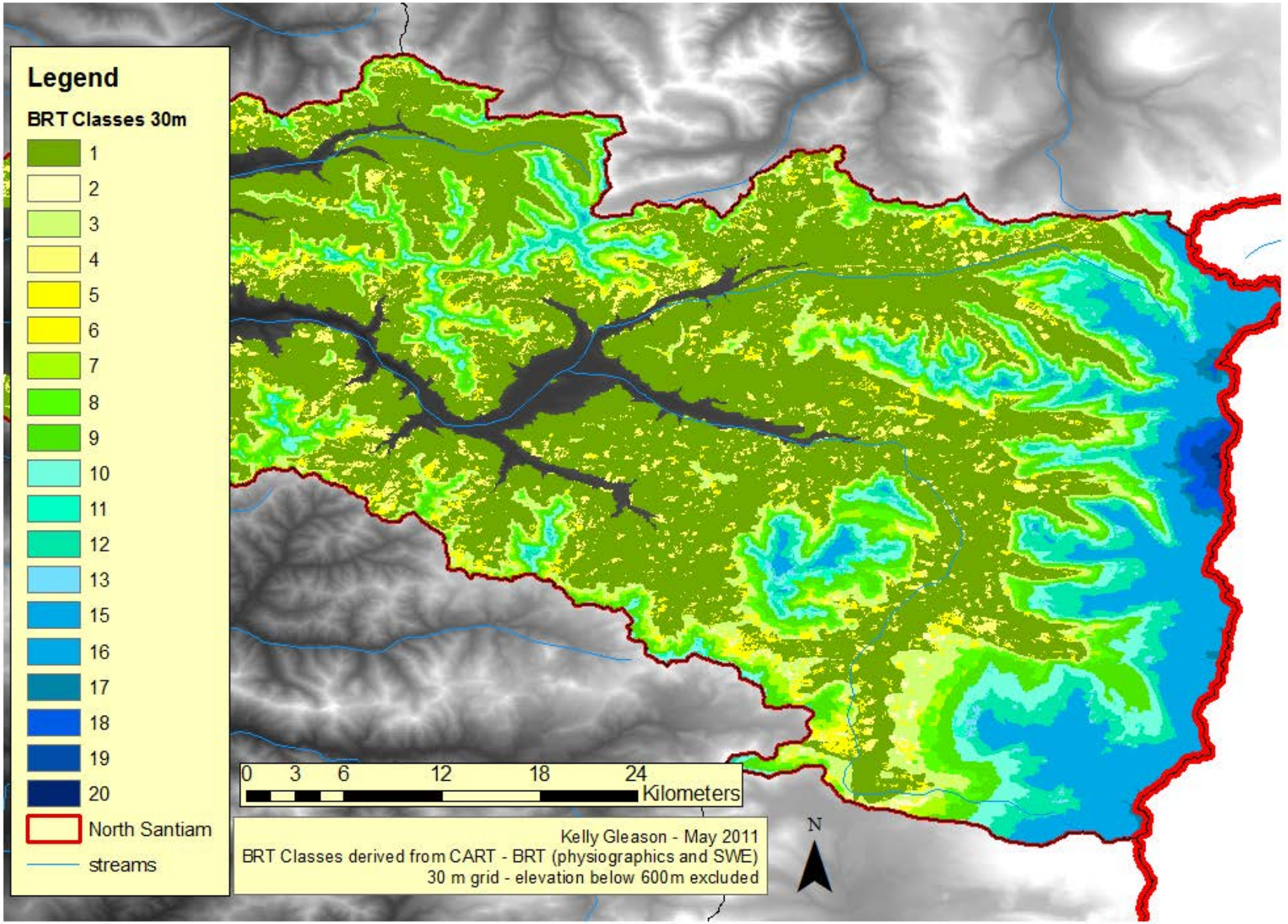

Willamette
dem_crefil
Single Output Map Algebra
brt_22_elev
Reclassify
Reclass_brt20
Mosaic To New Raster
mosaicbrt
Single Output Map Algebra (2)
brt_19_elev
Reclassify (2)
Reclass_brt19
Single Output Map Algebra (3)
brt_18_elev
Reclassify (6)
Reclass_brt18
Single Output Map Algebra (4)
brt_17_elev
Reclassify (7)
Reclass_brt17
Single Output Map Algebra (5)
brt_16_elev
Reclassify (8)
Reclass_brt16
Single Output Map Algebra (6)
brt_15_elev
Reclassify (10)
Reclass_brt15 (2)
Single Output Map Algebra (8)
brt_14_elev
Reclassify (11)
Reclass_brt15 (3)
Single Output Map Algebra (7)
brt_1213_elev
Reclassify (3)
Reclass_brt213
Single Output Map Algebra (9)
brt_12_nlcd
Reclassify (4)
Reclass_brt011
Single Output Map Algebra (10)
brt_1011_elev
Reclassify (18)
Reclass_brt011 (2)
nlcd_will_10
Single Output Map Algebra (11)
brt_10_nlcd
Reclassify (19)
Reclass_brt011 (3)
Single Output Map Algebra (12)
brt_9_elev
Reclassify (5)
Reclass_brt_1
ndvi_will
Single Output Map Algebra (13)
brt_78_elev
Reclassify (20)
Reclass_brt8 (2)
Single Output Map Algebra (21)
brt_7_elev
Reclassify (9)
Reclass_brt7
slope_will
Single Output Map Algebra (15)
brt_6_elev
Reclassify (12)
Reclass_brt6
Single Output Map Algebra (16)
brt_5_elev
Reclassify (13)
Reclass_brt5
Single Output Map Algebra (17)
brt_4_elev
Reclassify (14)
Reclass_brt4
cc_will
Single Output Map Algebra (18)
brt_3_elev
Reclassify (15)
Reclass_brt3
Single Output Map Algebra (19)
brt_2_elev
Reclassify (16)
Reclass_brt2
Single Output Map Algebra (20)
brt_1_elev
Reclassify (17)
Reclass_brt1

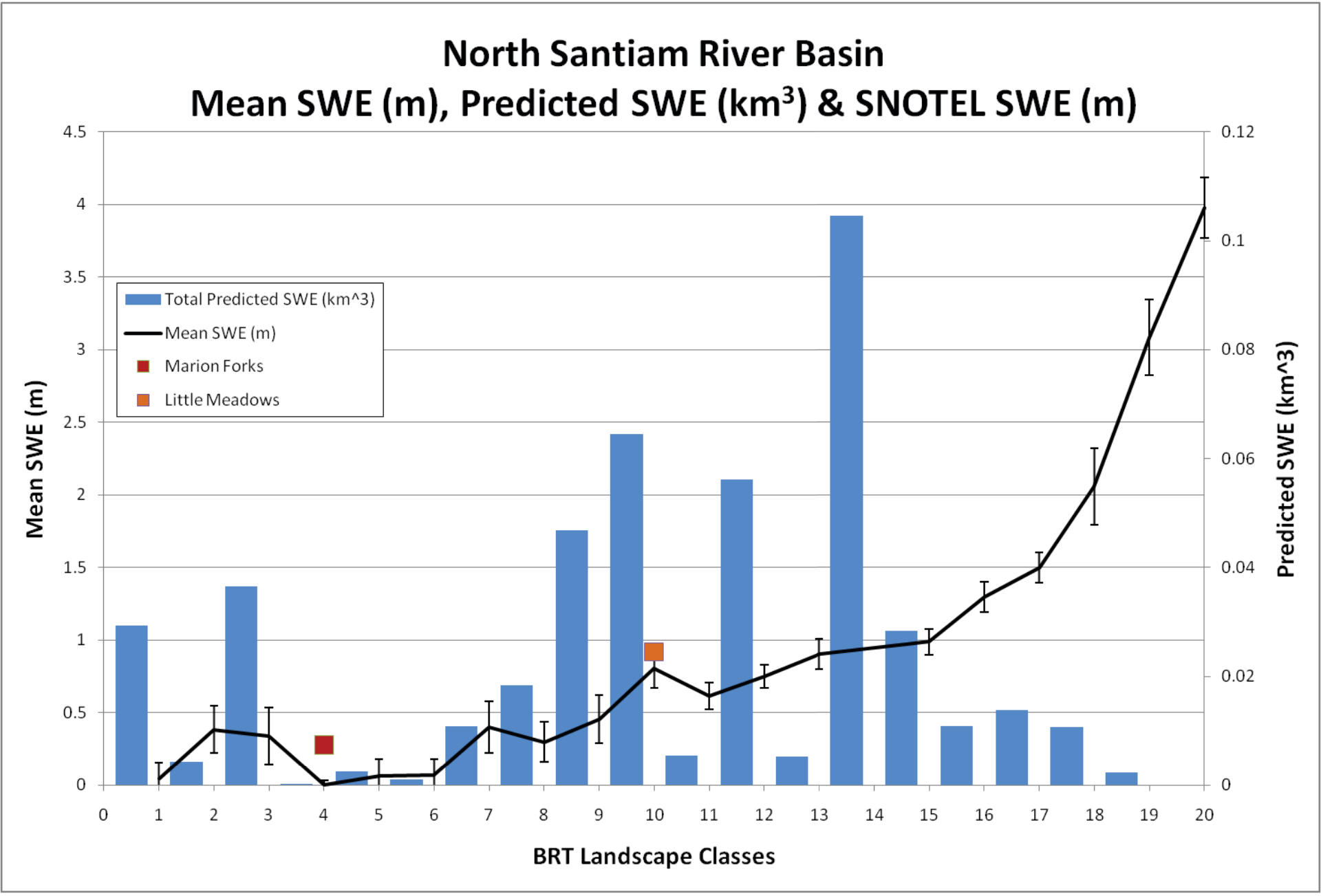
BRT Classification of the McKenzie River Basin, Oregon



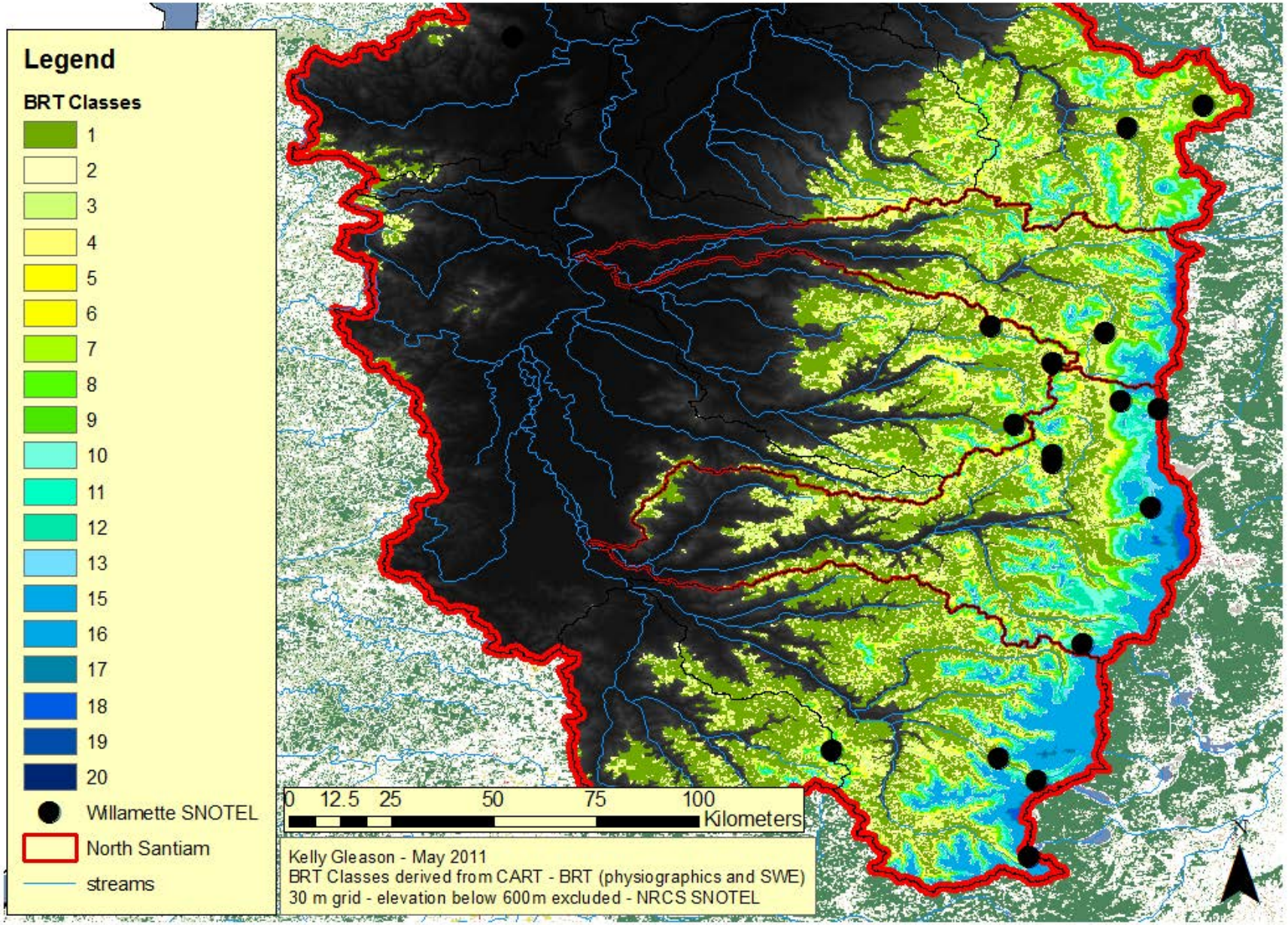

Mckenzie River Basin
Mean SWE (m), Predicted SWE (km³), & SNOTEL SWE (m)
Total Predicted SWE (km^3)
Mean SWE (m)
Santiam Junction
Hog Pass
Mckenzie
Roaring River
Mean SWE (m)
Predicted SWE (km^3)
BRT Landscape Classes
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
0.02
0.04
0.06
0.08
0.1
0.12
0.14
0.16
0.18
0.2
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20

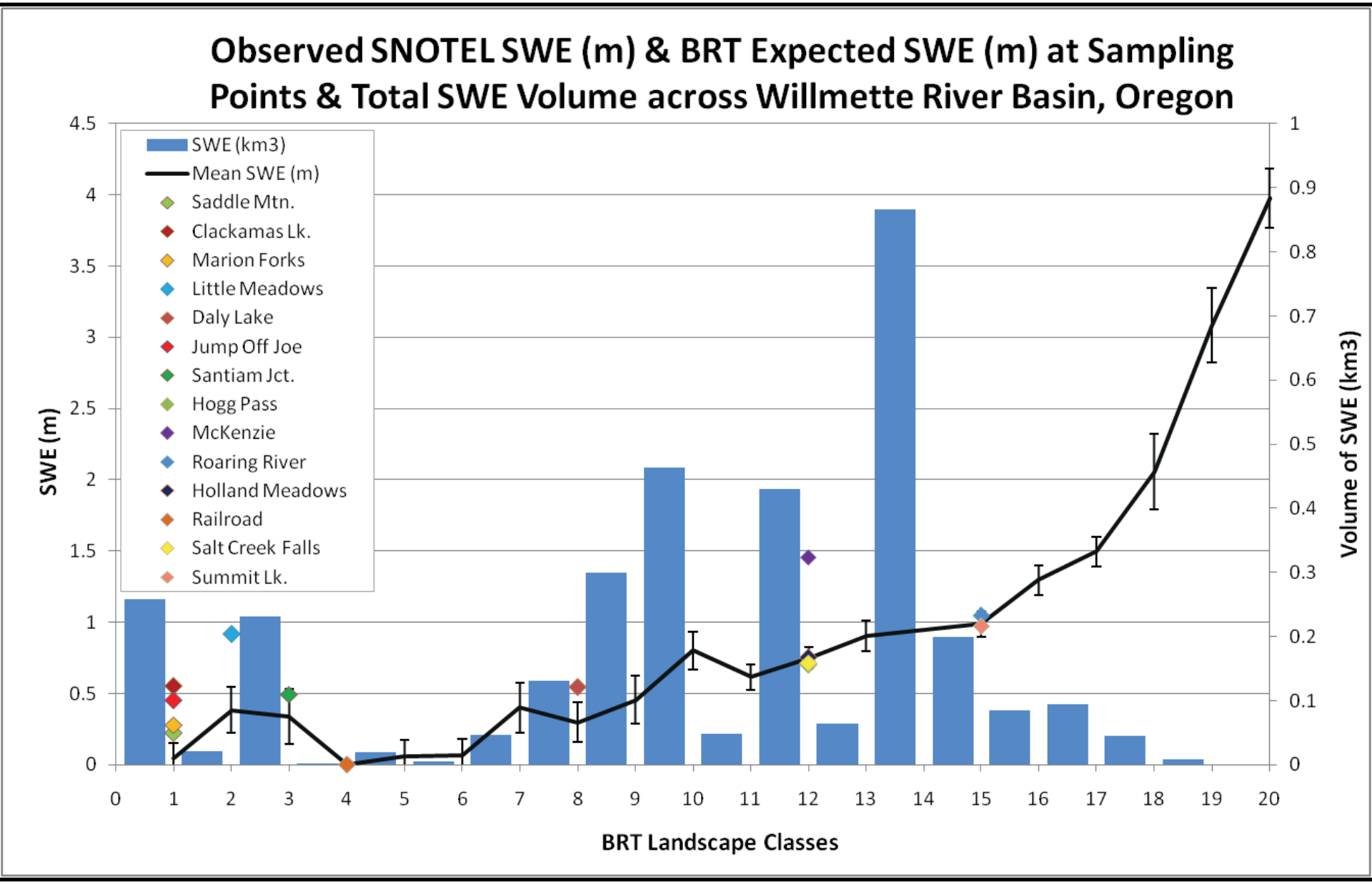
BRT Classification of the North Santiam River Basin, Oregon




North Santiam River Basin
Mean SWE (m), Predicted SWE (km3) & SNOTEL SWE (m)
Total Predicted SWE (km^3)
Mean SWE (m)
Marion Forks
Little Meadows
Mean SWE (m)
Predicted SWE (km^3)
BRT Landscape Classes
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
0.02
0.04
0.06
0.08
0.1
0.12
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20

BRT Classification of the Willamette River Basin, Oregon




Observed SNOTEL SWE (m) & BRT Expected SWE (m) at Sampling Points & Total SWE Volume across Willmette River Basin, Oregon
SWE (km3)
Mean SWE (m)
Saddle Mtn.
Clackamas Lk.
Marion Forks
Little Meadows
Daly Lake
Jump Off Joe
Santiam Jct.
Hogg Pass
McKenzie
Roaring River
Holland Meadows
Railroad
Salt Creek Falls
Summit Lk.
SWE (m)
Volume of SWE (km3)
BRT Landscape Classes
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20

Not all areas land available – used criteria selection model

- In Raster Calculator:

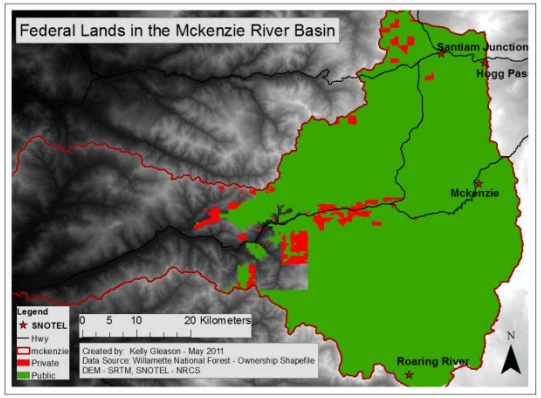
(binary public) * (buff 500 - buff100)

=

available land for sampling sites

- Used output to extract by mask BRT Classes area
- Created random raster w/in extracted BRT area to determine random location that meets criteria

Binary Selection Model to Select Public Land & 200-500 m of Road



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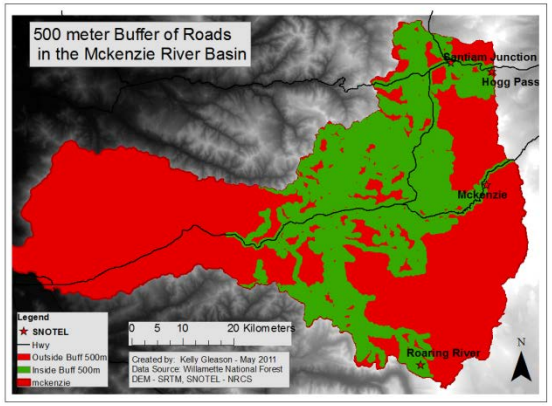

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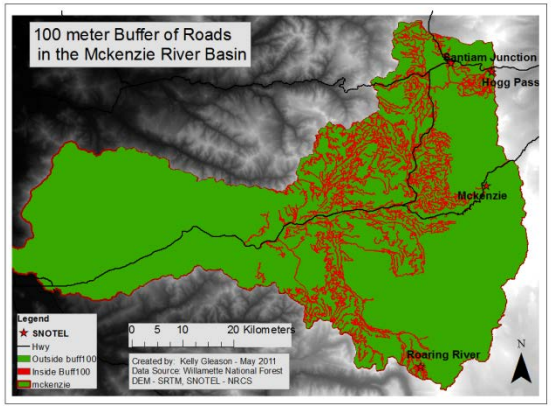

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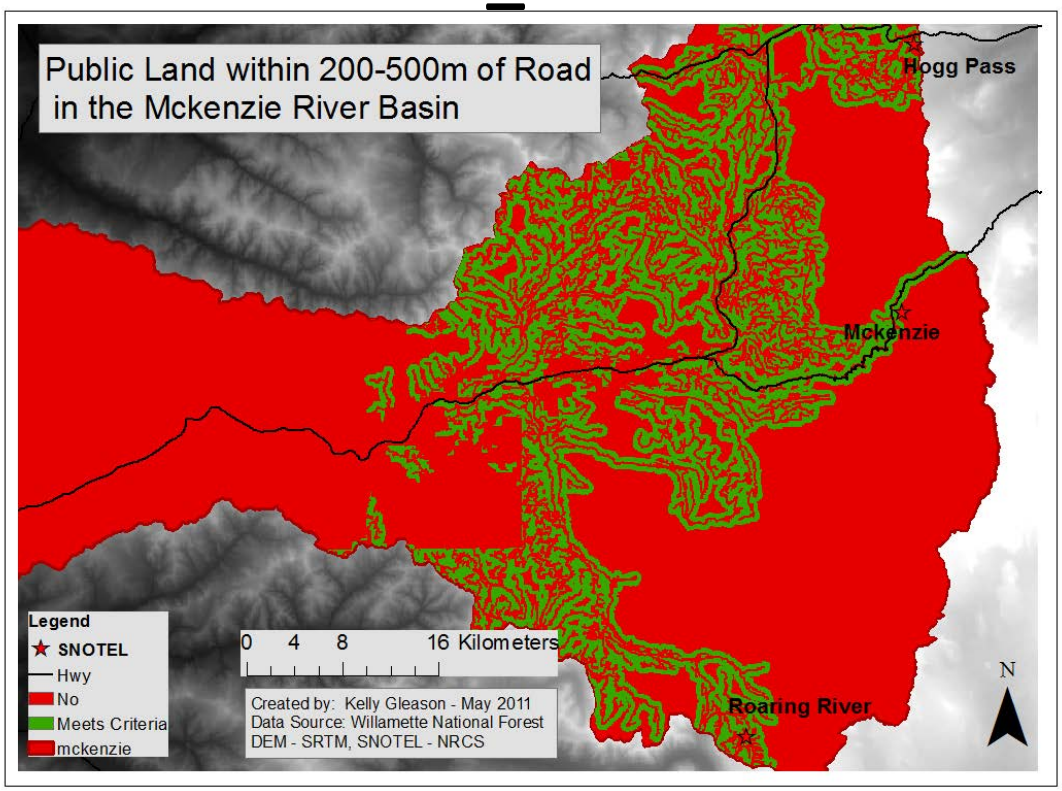
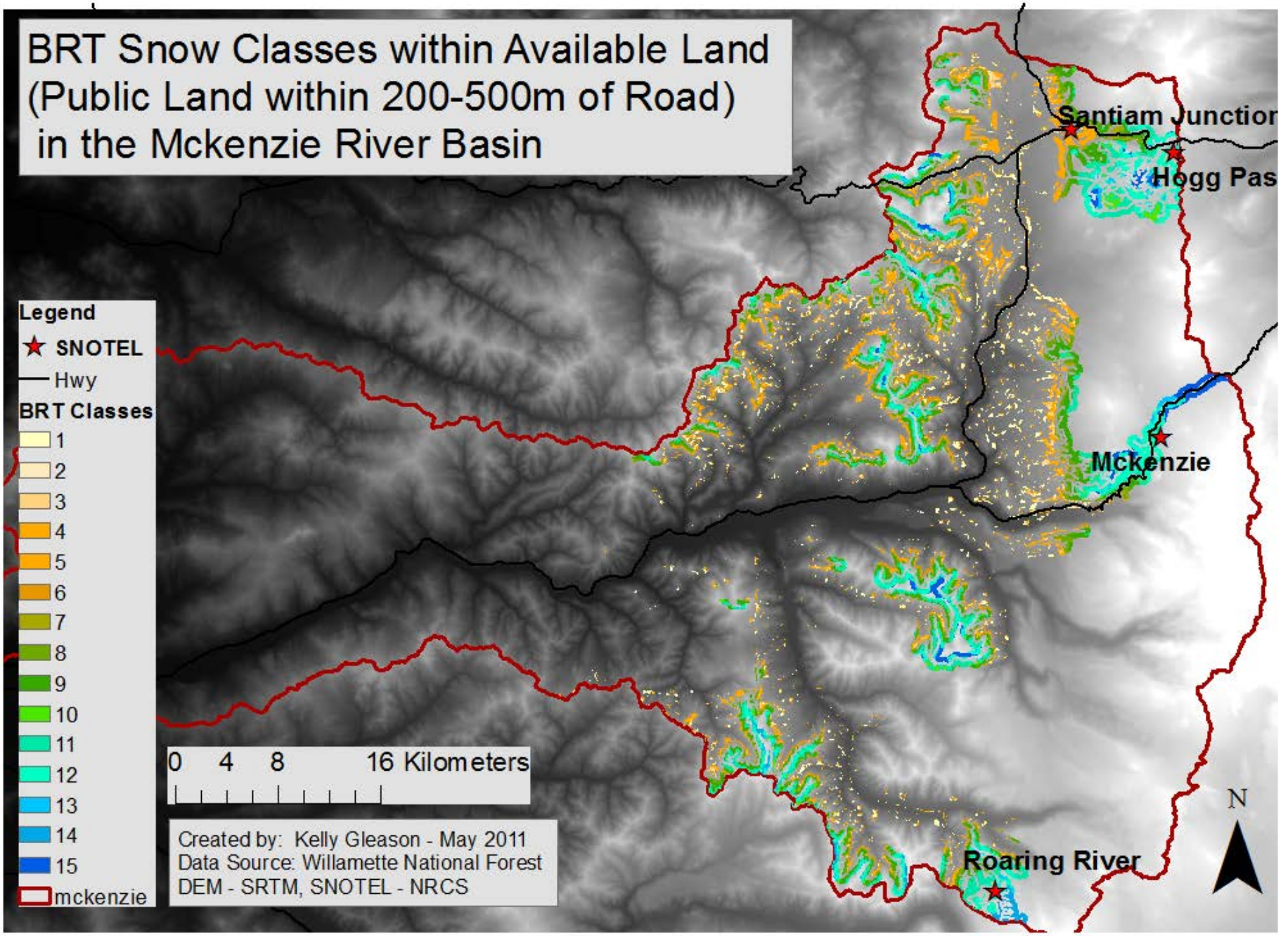
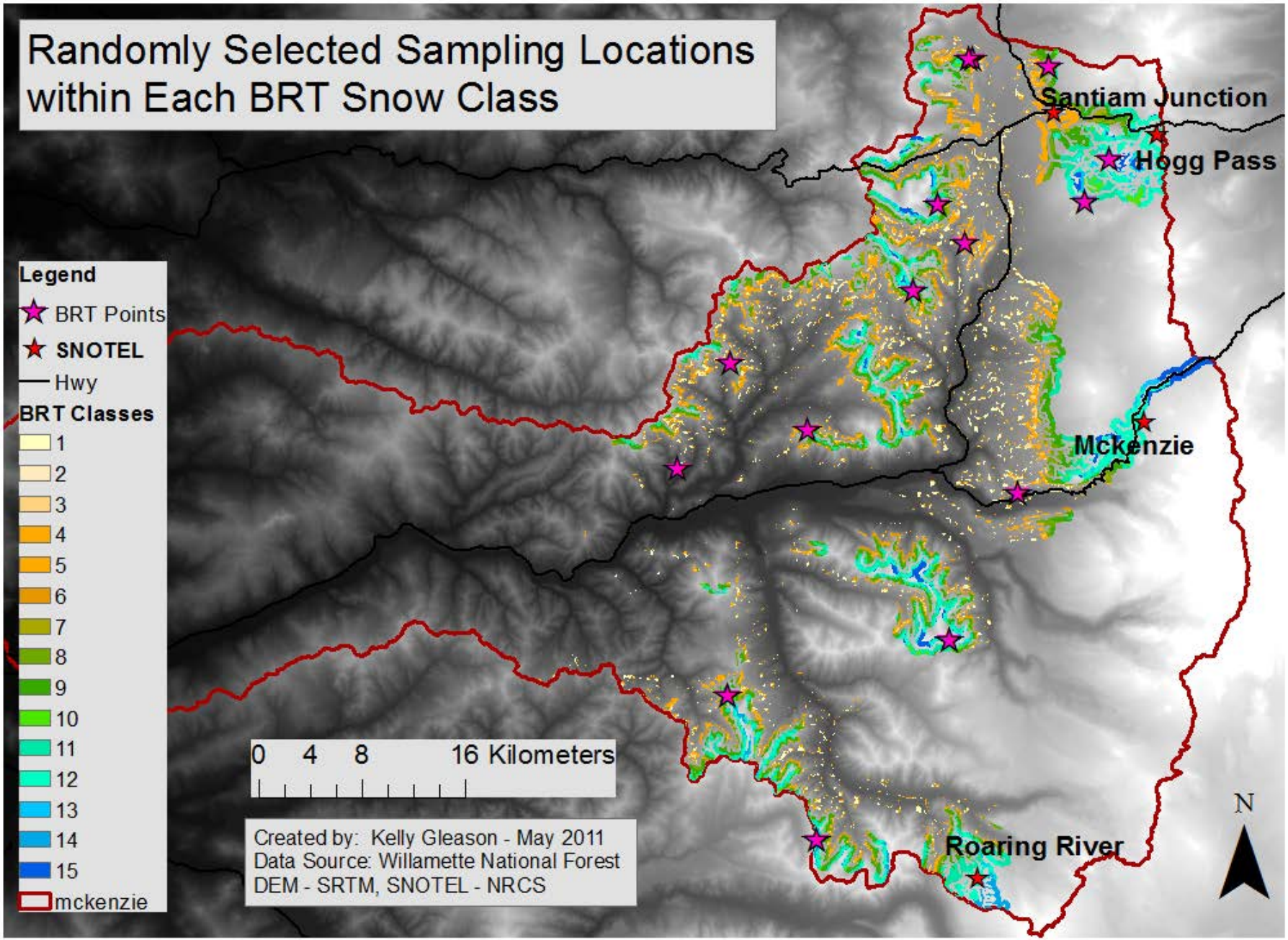
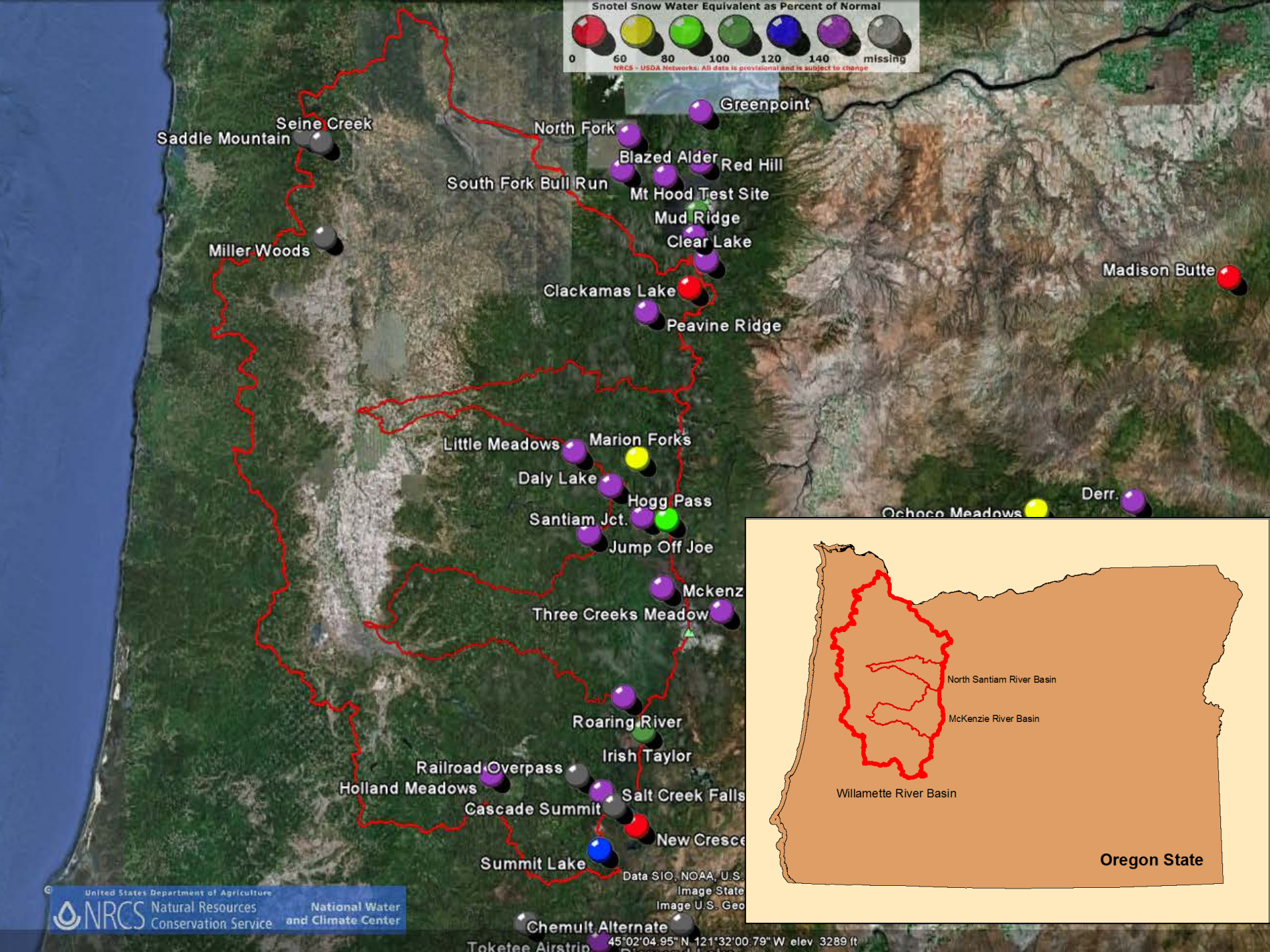



BRT Snow Classes within Available Land
(Public Land within 200-500m of Road)
in the Mckenzie River Basin
Santiam Junctior
Hogg Pas
Mckenzie
Roaring River
Legend
SNOTEL
Hwy
BRT Classes
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
mckenzie
0 4 8 16 Kilometers
Created by: Kelly Gleason - May 2011
Data Source: Willamette National Forest
DEM - SRTM, SNOTEL - NRCS
N


Randomly Selected Sampling Locations within Each BRT Snow Class
Santiam Junction
Hogg Pass
Mckenzie
Roaring River
Legend
BRT Points
SNOTEL
Hwy
BRT Classes
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
mckenzie
0 4 8 16 Kilometers
Created by: Kelly Gleason - May 2011
Data Source: Willamette National Forest
DEM - SRTM, SNOTEL - NRCS
N


Snotel Snow Water Equivalent as Percent of Normal
0
60
80
100
120
140
missing
NRCS - USDA Networks: All data is provisional and is subject to change
Greenpoint
Seine Creek
Saddle Mountain
North Fork
Blazed Alder
Red Hill
South Fork Bull Run
Mt Hood Test Site
Mud Ridge
Clear Lake
Miller Woods
Madison Butte
Clackamas Lake
Peavine Ridge
Little Meadows
Marion Forks
Daly Lake
Hogg Pass
Derr.
Ochoco Meadows
Santiam Jct.
Jump Off Joe
Mckenz
Three Creeks Meadow
Roaring River
Irish Taylor
Railroad Overpass
Holland Meadows
Salt Creek Falls
Cascade Summit
New Cresce
Summit Lake
Data SIO, NOAA, U.S.
Image State
Image U.S. Geo
Chemult Alternate
Toketee Airstrip
45°02'04.95" N 121°32'00.79" W elev 3289 ft
United States Department of Agriculture
NRCS Natural Resources Conservation Service
National Water and Climate Center
North Santiam River Basin
McKenzie River Basin
Willamette River Basin
Oregon State

Conclusions

- BRT landscape classification shows promise for characterizing snow zones – but difficult to validate using point based SNOTEL information.
- Current underestimation of SWE by model to be further calibrated & validated using fractional snow covered area remote sensing model.
- Present-day snow monitoring sites will not be in representative locations in the future – need an objective approach to monitor climate impacts.


Questions?