# Snow Surveys

**ABR, Inc.**
**Environmental Research & Services**

**Agency Information Meeting**
**November 2007**

# Snow Survey, Pebble Mine Region

Outline

- Background
- Objectives
- Study Area
- 2007 Field Surveys
- Snow Distribution Models
- Comparison to NRCS Snow Courses
- Snowpack Ablation

# Snow Survey, Pebble Mine Region

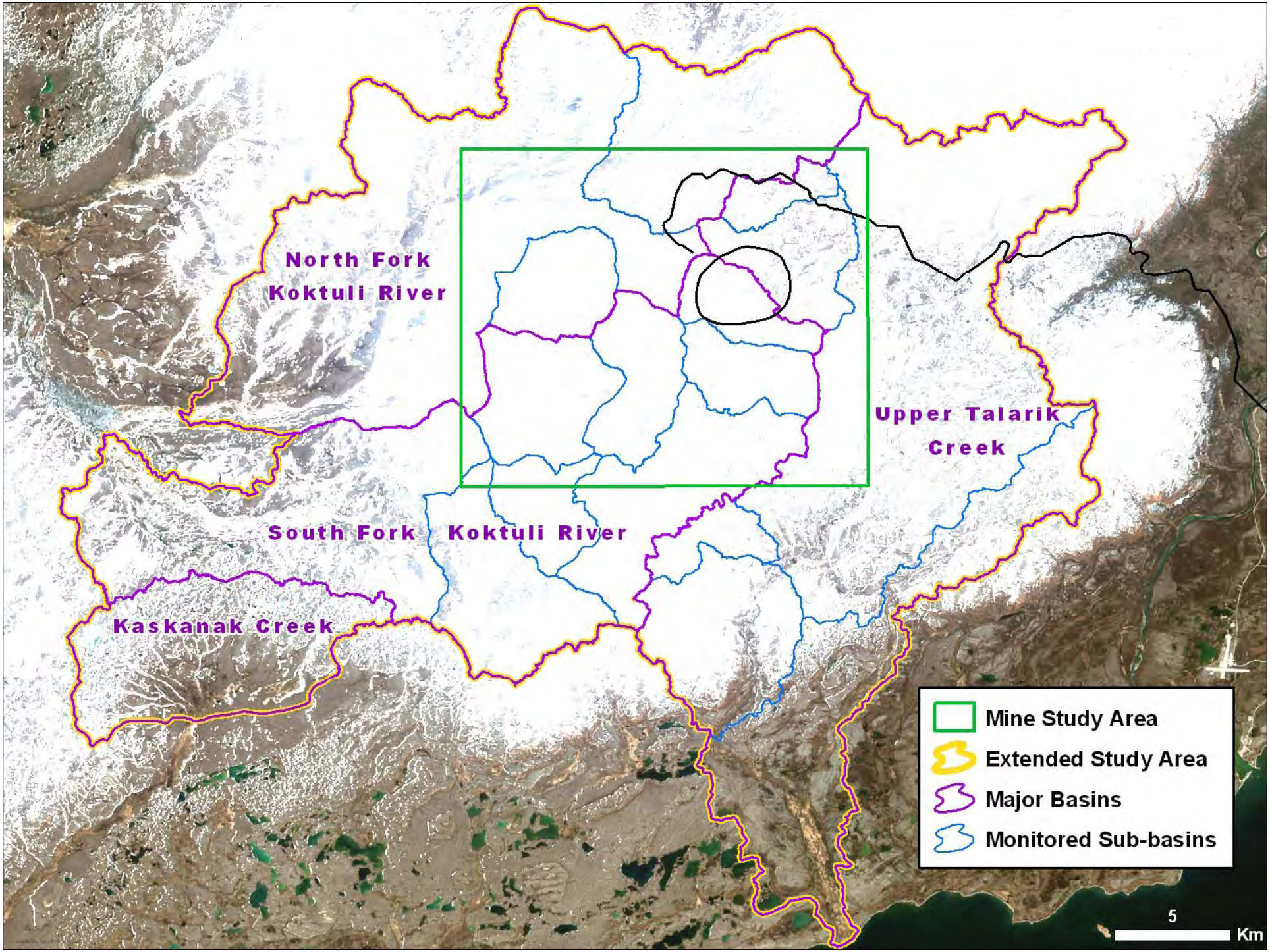
Background

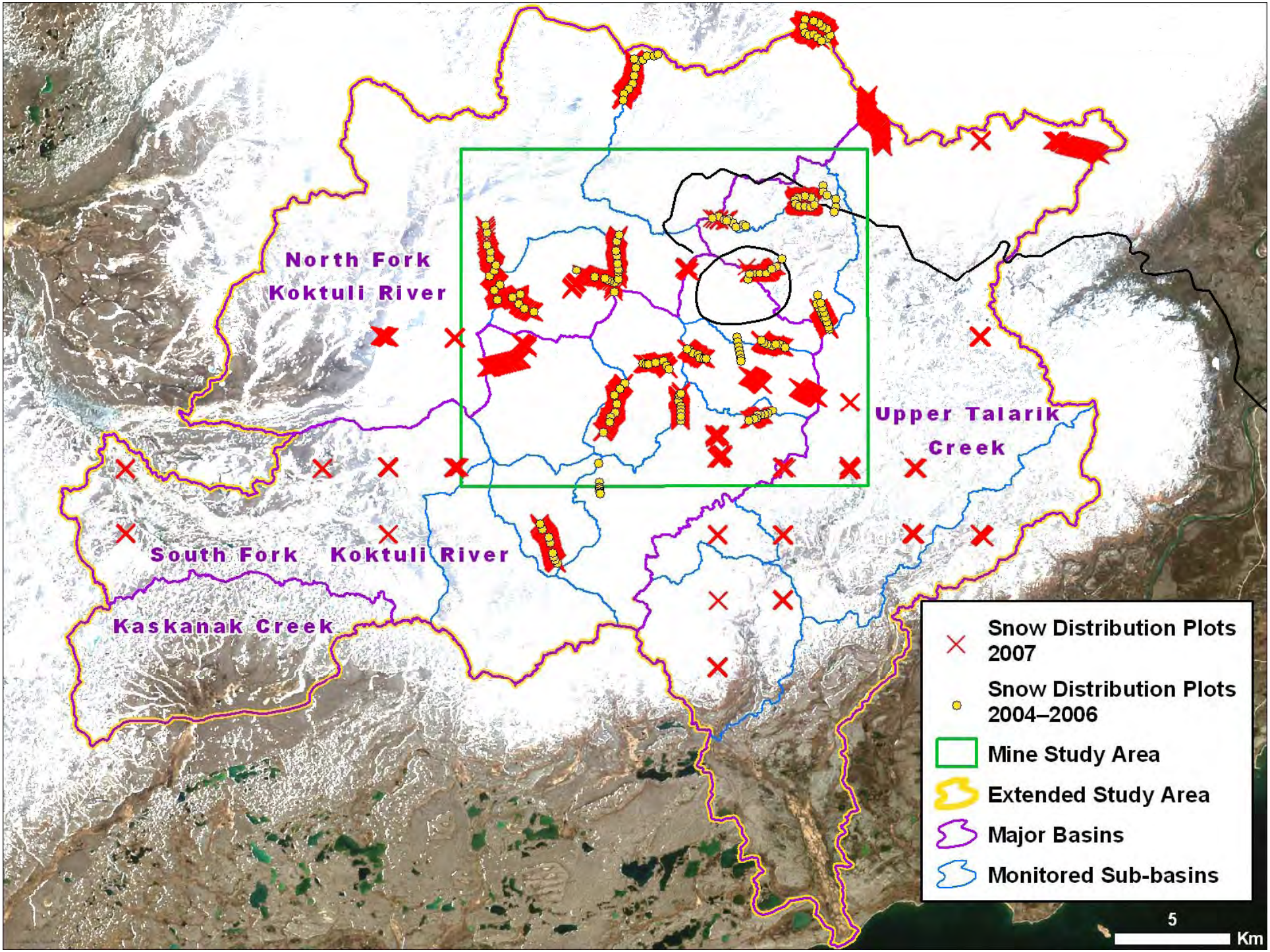
- Typically, 30–35% of precipitation at mine site falls as snow between October and April.
- Snow surveys complement concurrent surface water hydrology studies by characterizing snow water equivalent (SWE) and snowmelt rates of late season snow.

# Snow Survey, Pebble Mine Region

Objectives

- Create regional maps of annual spring snow distribution across the mine area.
- Determine the rate of snowmelt and potential runoff during breakup.
- Provide correlative measurements for met station, stream gauge, and local snow survey data sets.


North Fork
Koktuli River
Upper Talarik
Creek
South Fork Koktuli River
Kaskanak Creek
Mine Study Area
Extended Study Area
Major Basins
Monitored Sub-basins
5
Km

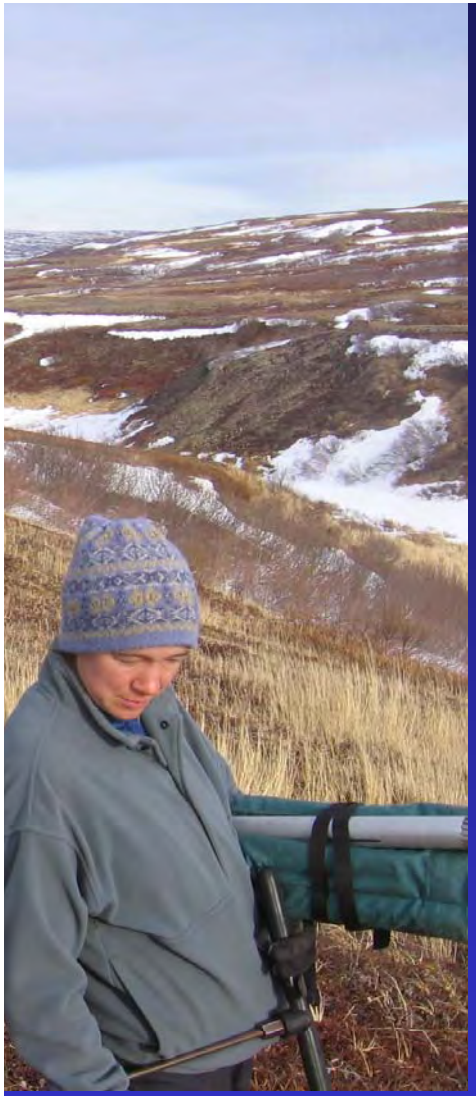

North Fork
Koktuli River
Upper Talarik
Creek
South Fork
Koktuli River
Kaskanak Creek
Snow Distribution Plots
2007
Snow Distribution Plots
2004–2006
Mine Study Area
Extended Study Area
Major Basins
Monitored Sub-basins
5
Km

# Field Survey Findings

- Snow depth in mid-April ranged to over 120 inches in both 2004 and 2005; up to 139 inches in 2006; and up to 215 inches in 2007.
- Snow-water equivalents exceeded 60 inches on the lee sides of upper slopes in 2004, 2005; 75 inches in 2006, 2007
- Equipment limitation resulted in underestimation of 2004 SWE (and 2005–2006, to a lesser extent)

# Field Survey Findings

- Surface features (sastrugi, cornices, etc.) suggest extensive redistribution from large wind events from multiple directions.
- Vegetation canopy (tall shrub zone) traps large amounts of snow in riparian zones, even with low snow accumulation on the nearby landscape



# 2007 Field Survey Findings

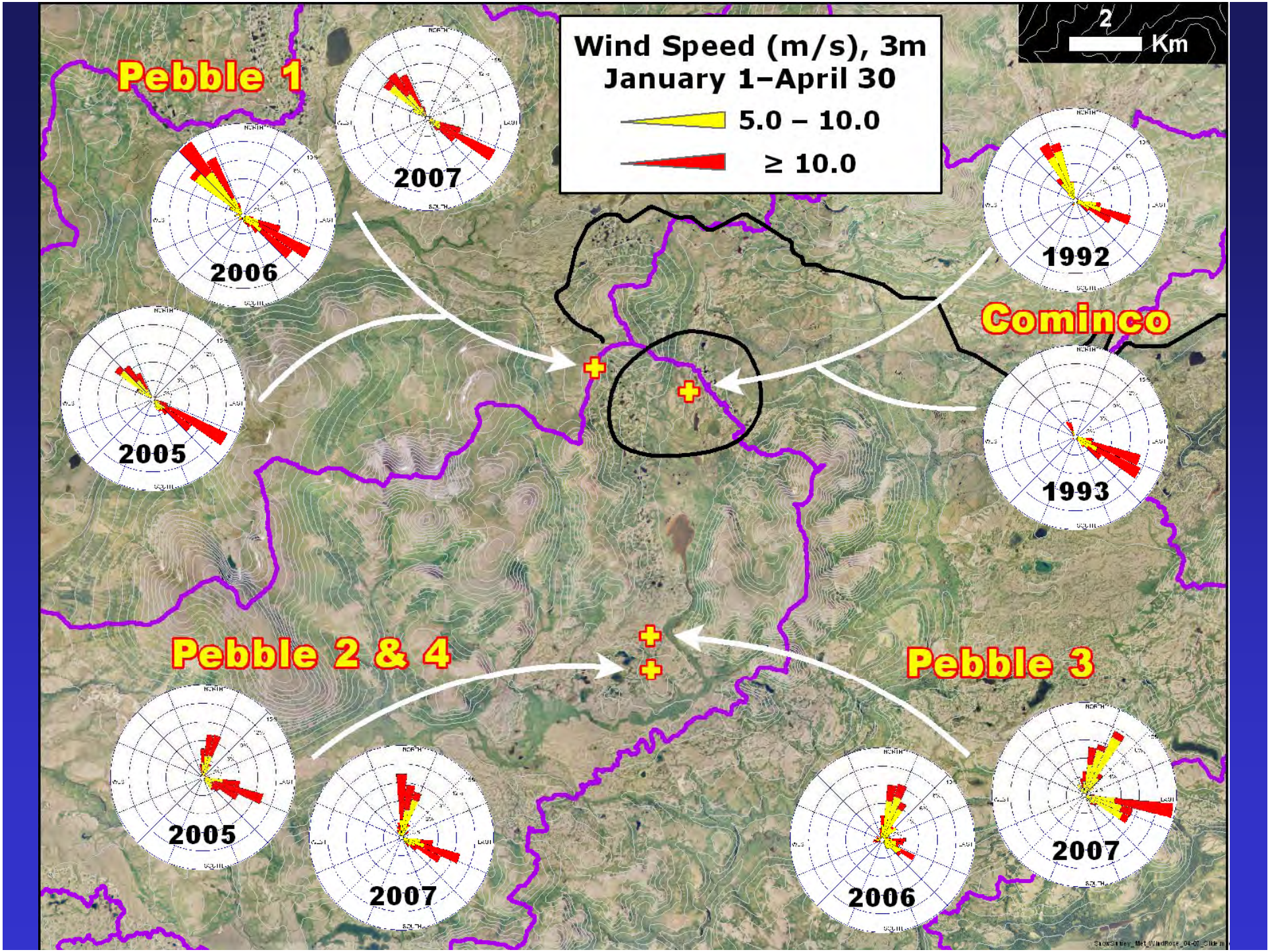
- Extensive area with thin to absent snowpack
- Snow rarely over-topped shrubs
- Ice fairly common beneath snowpack and at toe slopes
- Low elevations melted rapidly and early, higher elevation snowpack persisted

# Snow Distribution Mapping, 2007

- Incorporate field data from lower elevations
- Characterize wind variability and wind redistribution patterns
- Quantify large snow drifts

# Wind Distribution Effects

- Wind data for winters ending 2005–2007 and historical data (Cominco, winters ending 1992–1993) were used to determine predominant winter wind patterns.
- Standardized to 3 m above ground level
- Snow redistribution at wind speeds 5–10 m/sec and higher


Wind Speed (m/s), 3m
January 1–April 30
5.0 – 10.0
≥ 10.0
2
Km
Pebble 1
2007
2006
2005
1992
Cominco
1993
Pebble 2 & 4
2005
2007
Pebble 3
2006
2007

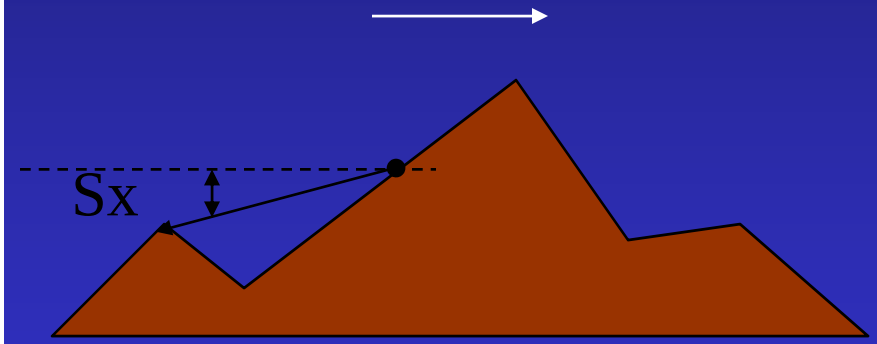
# Wind Distribution Effects

- Wind patterns fairly consistent across years
- Southeast wind vector predominant, N/NE wind vector secondary
- Wind patterns vary with local topography
- Digital elevation model (DEM) of the study used to generate snow distribution predictors based on wind directions
- This step generates two sets of direction-dependent grids (digital representations): “Shelter” and “Drift” (Winstral, et al. 2002)

# Wind Distribution Effects

## Shelter Grid

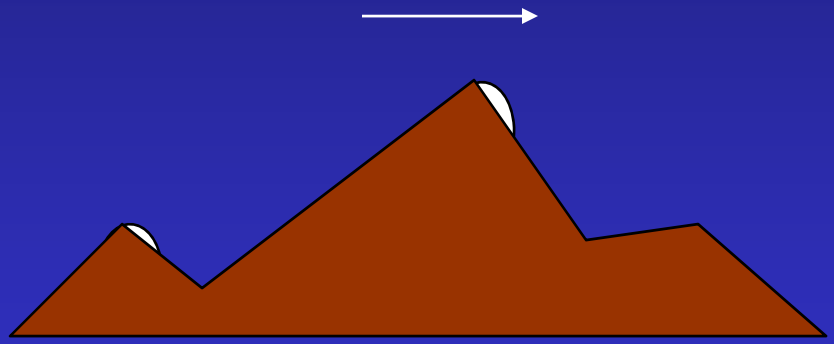
Wind Direction




Shelter value of each grid cell is the upwind look angle to the highest feature within the search distance. Value for the point shown is approx. -30 degrees

## Drift Grid

Wind Direction



A drift zone requires both an abrupt change in slope and a source of snow (unsheltered terrain) upwind.

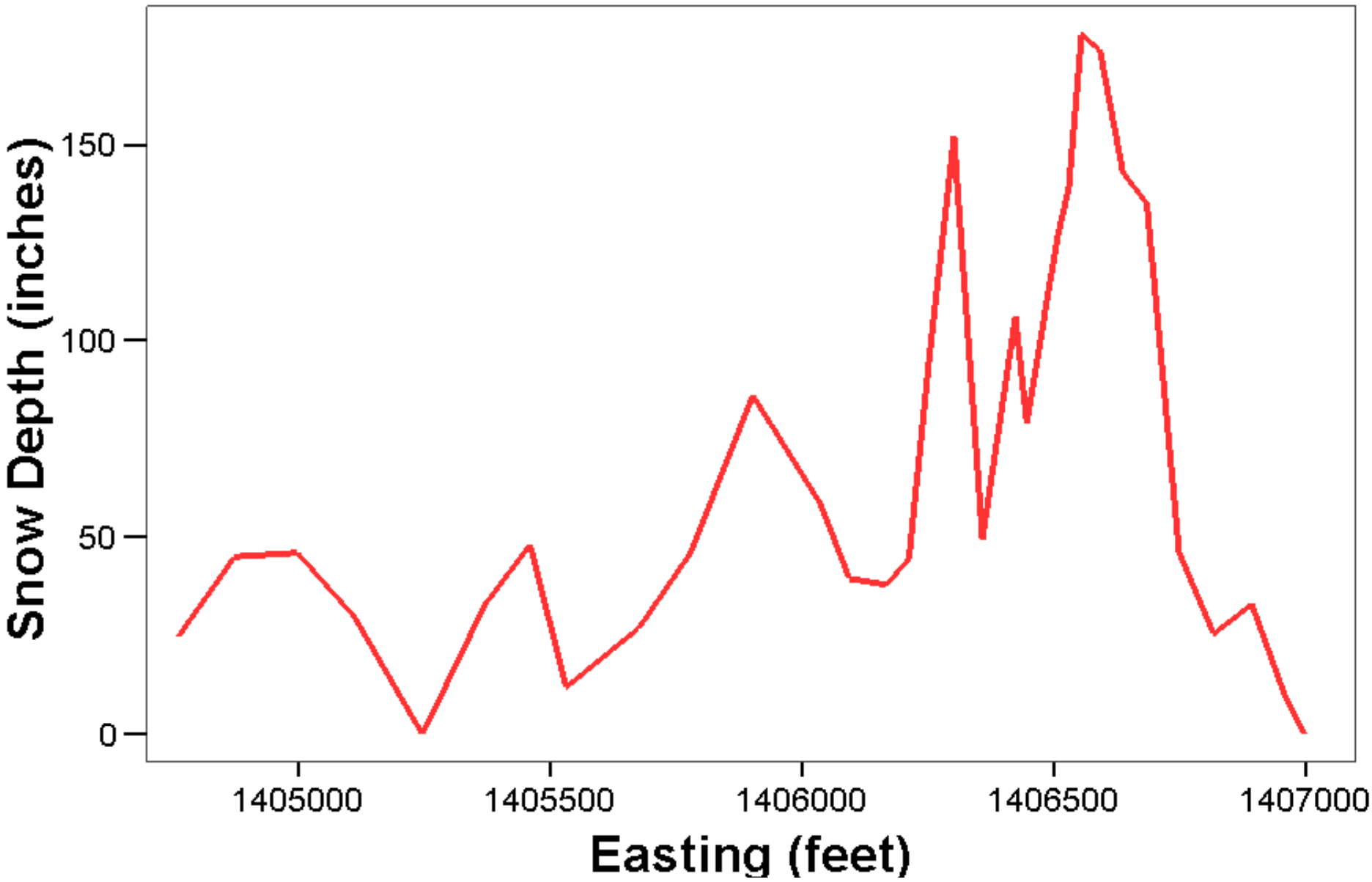
# Drift Profiles

- Quantify large snow drifts
- Depth probe (up to 20’) and survey GPS used to record transects across large snow drifts

# Drift Profiles

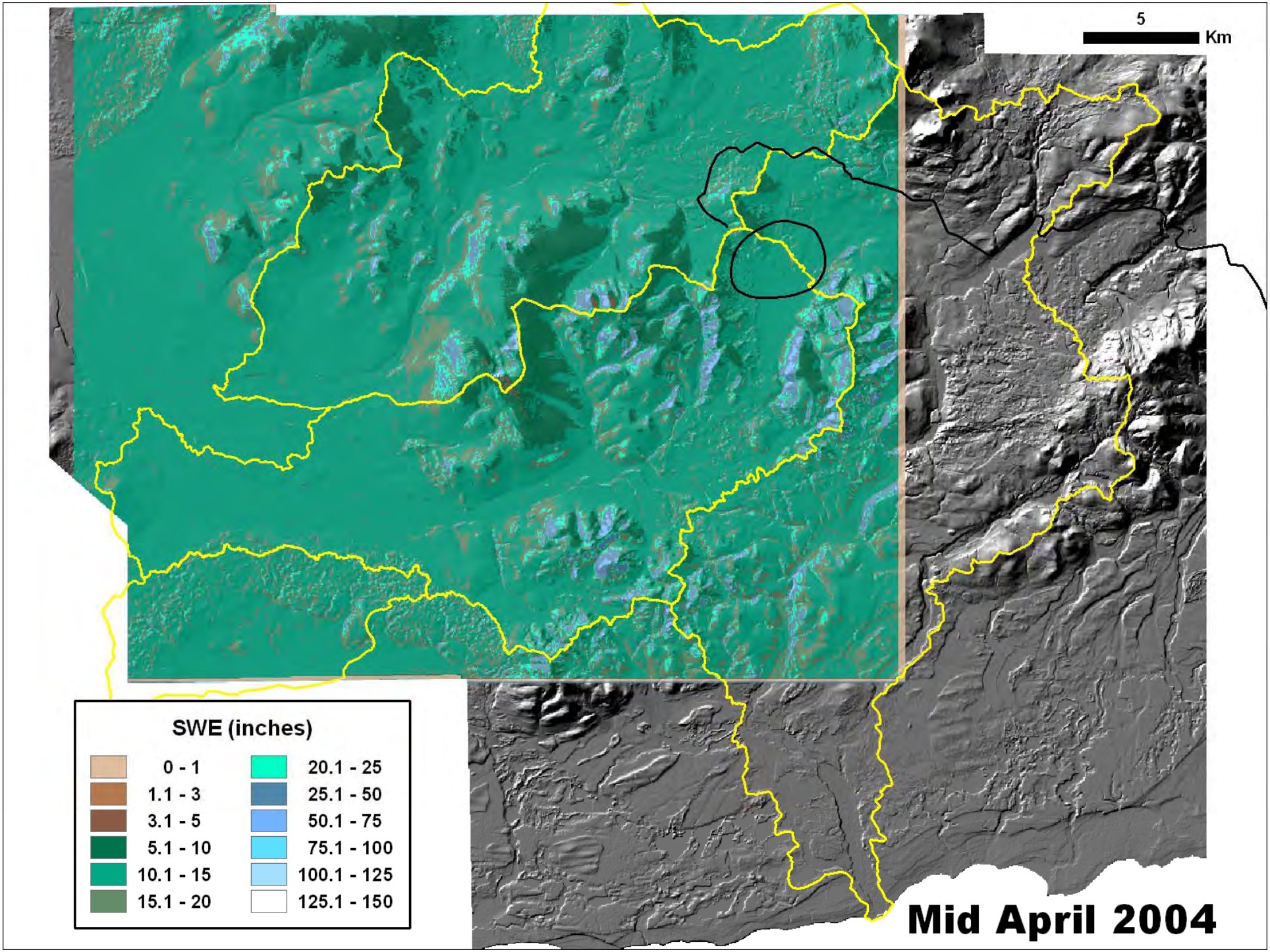
- Combined with snow density estimates, drift profiles constrain upper limits for snow accumulation
- Low snow accumulation in 2007, but deepest snow measurements to date (up to 215 inches)

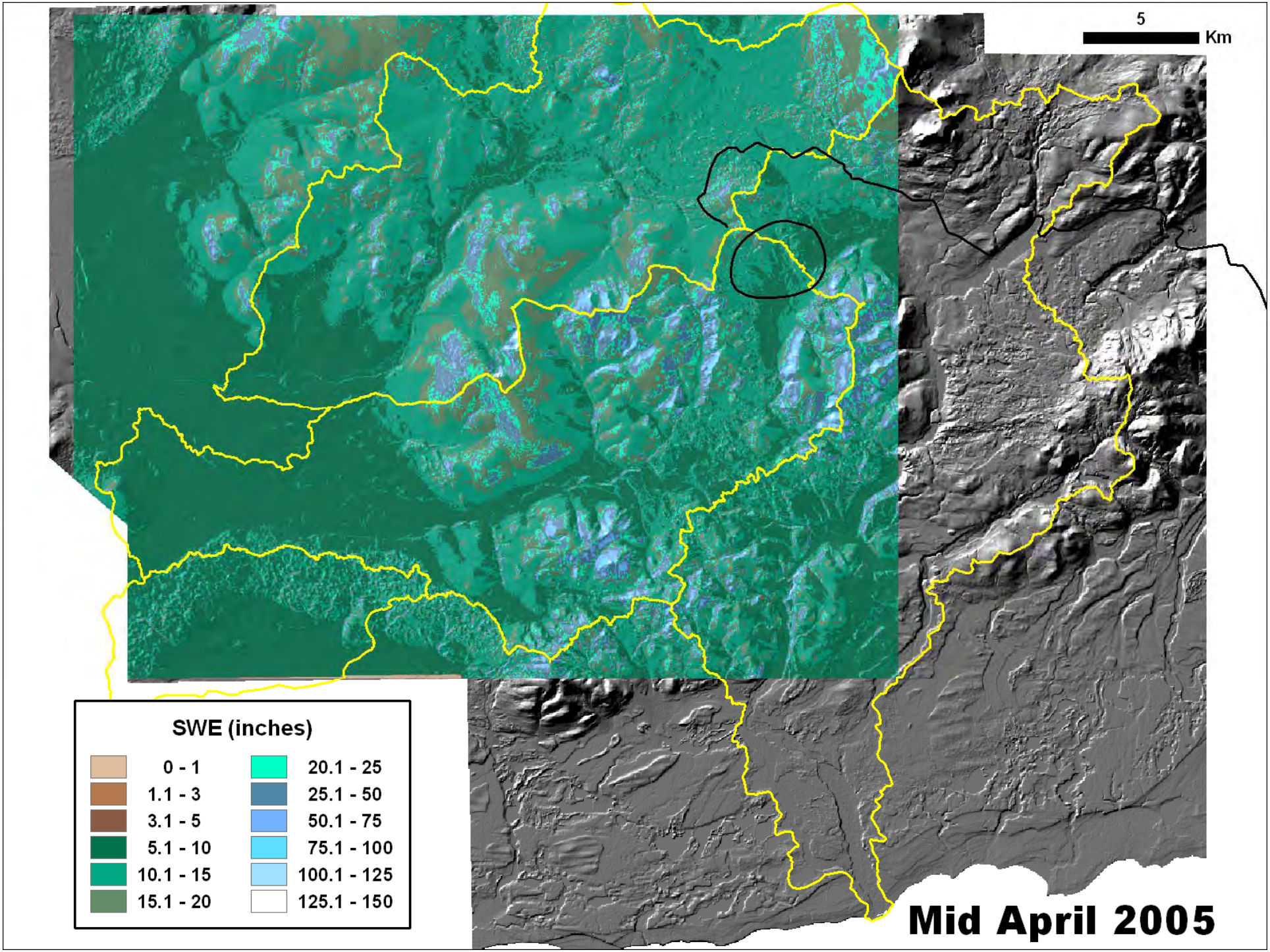
# Snow Drift East of Frying Pan Lake

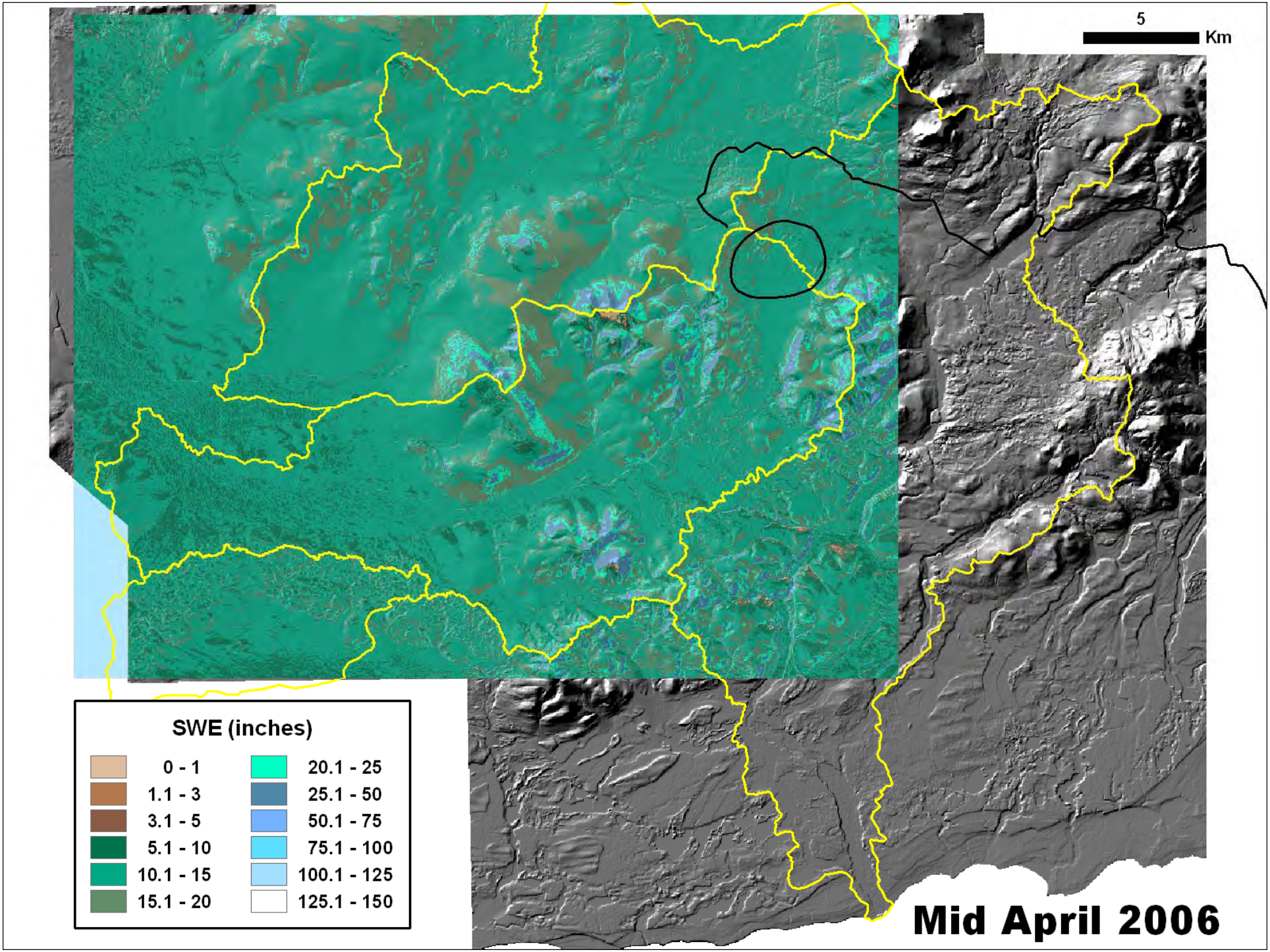


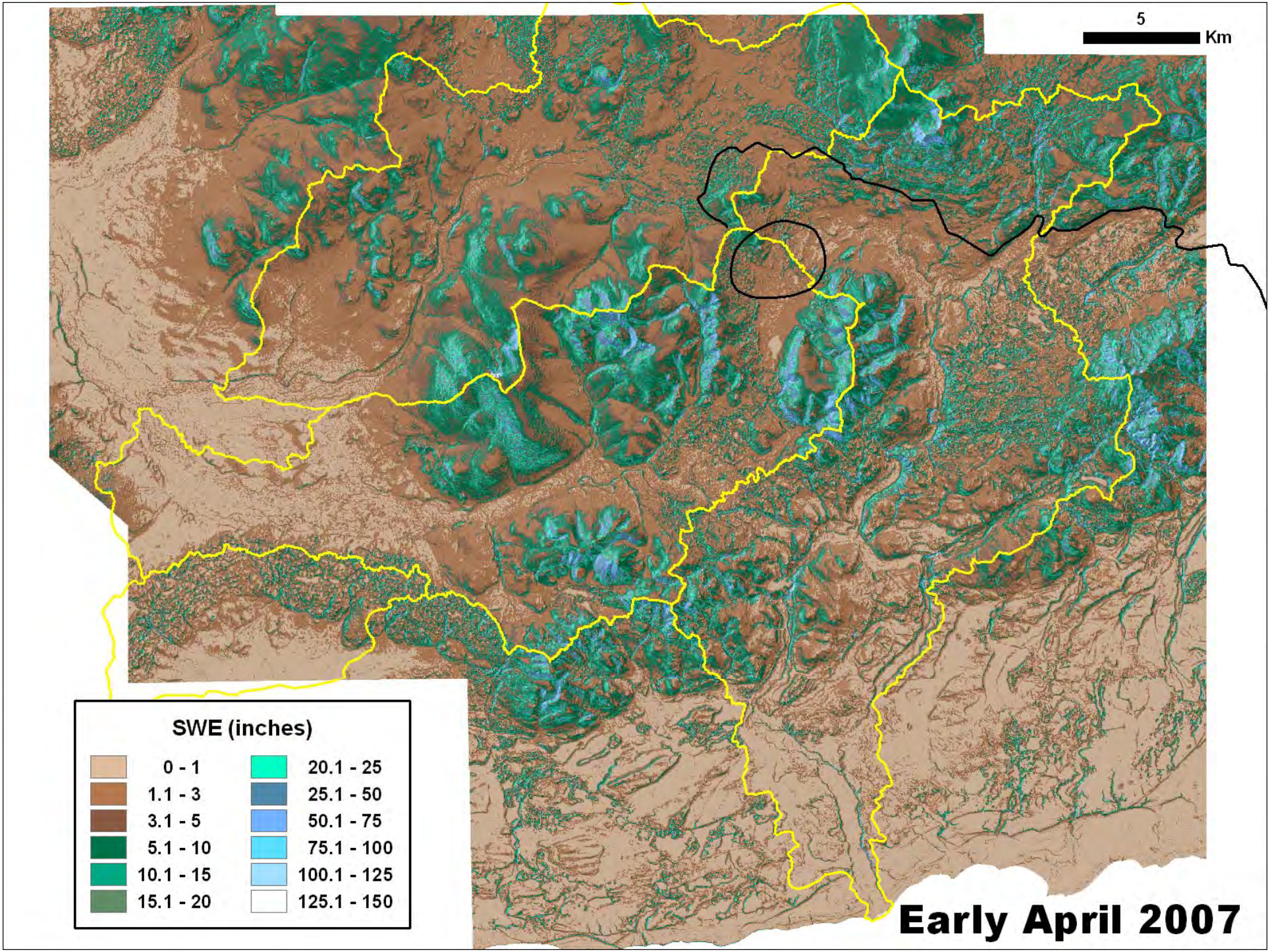
# Snow Distribution Model Results, 2004–2007

- Elevation
- Slope
- Aspect category
- Equivalent Latitude
- Shelter (SE, NW)
- Drift (SE, NW)
- Field survey data

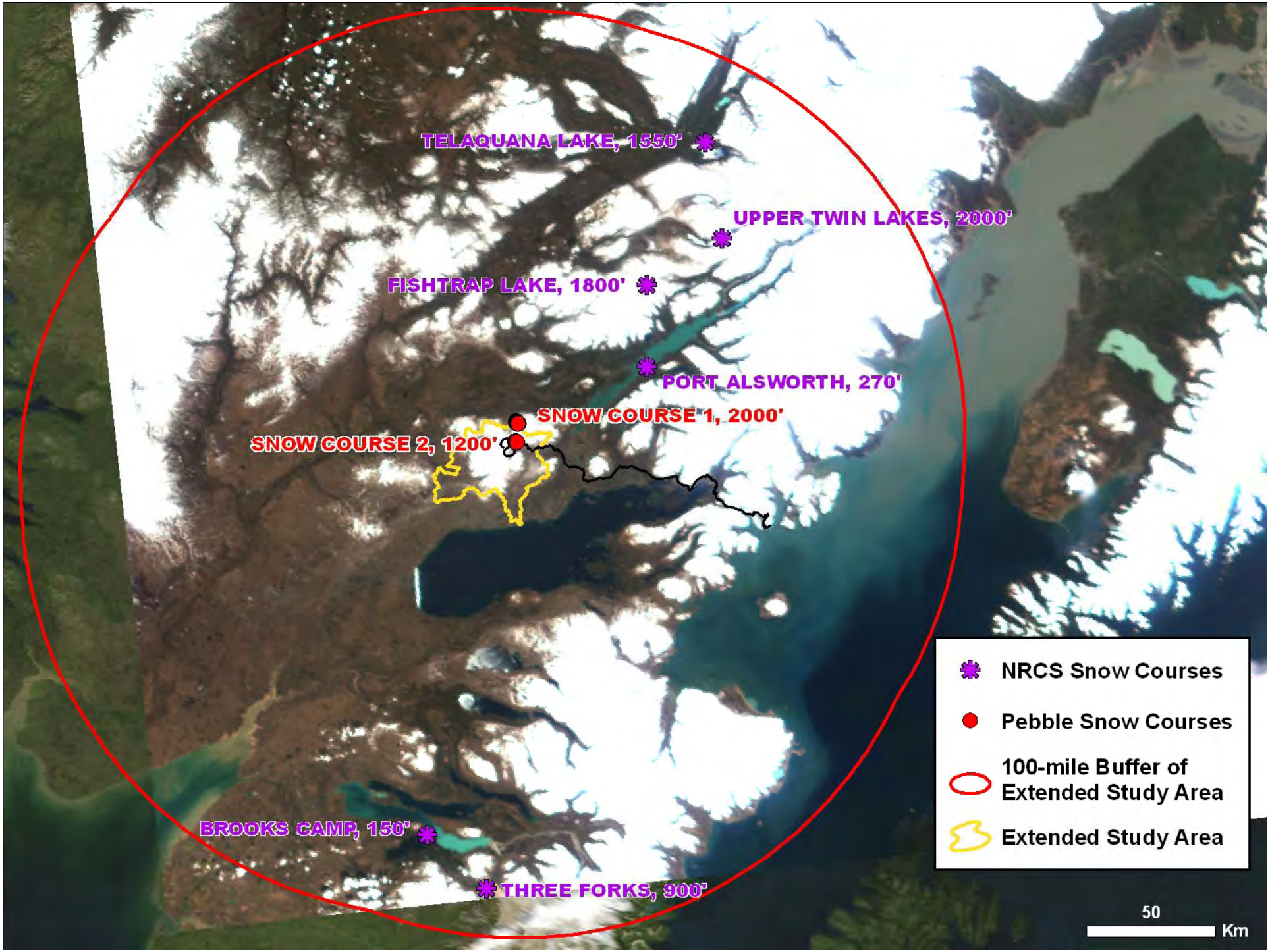

5
Km
SWE (inches)
0 - 1
1.1 - 3
3.1 - 5
5.1 - 10
10.1 - 15
15.1 - 20
20.1 - 25
25.1 - 50
50.1 - 75
75.1 - 100
100.1 - 125
125.1 - 150
Mid April 2004

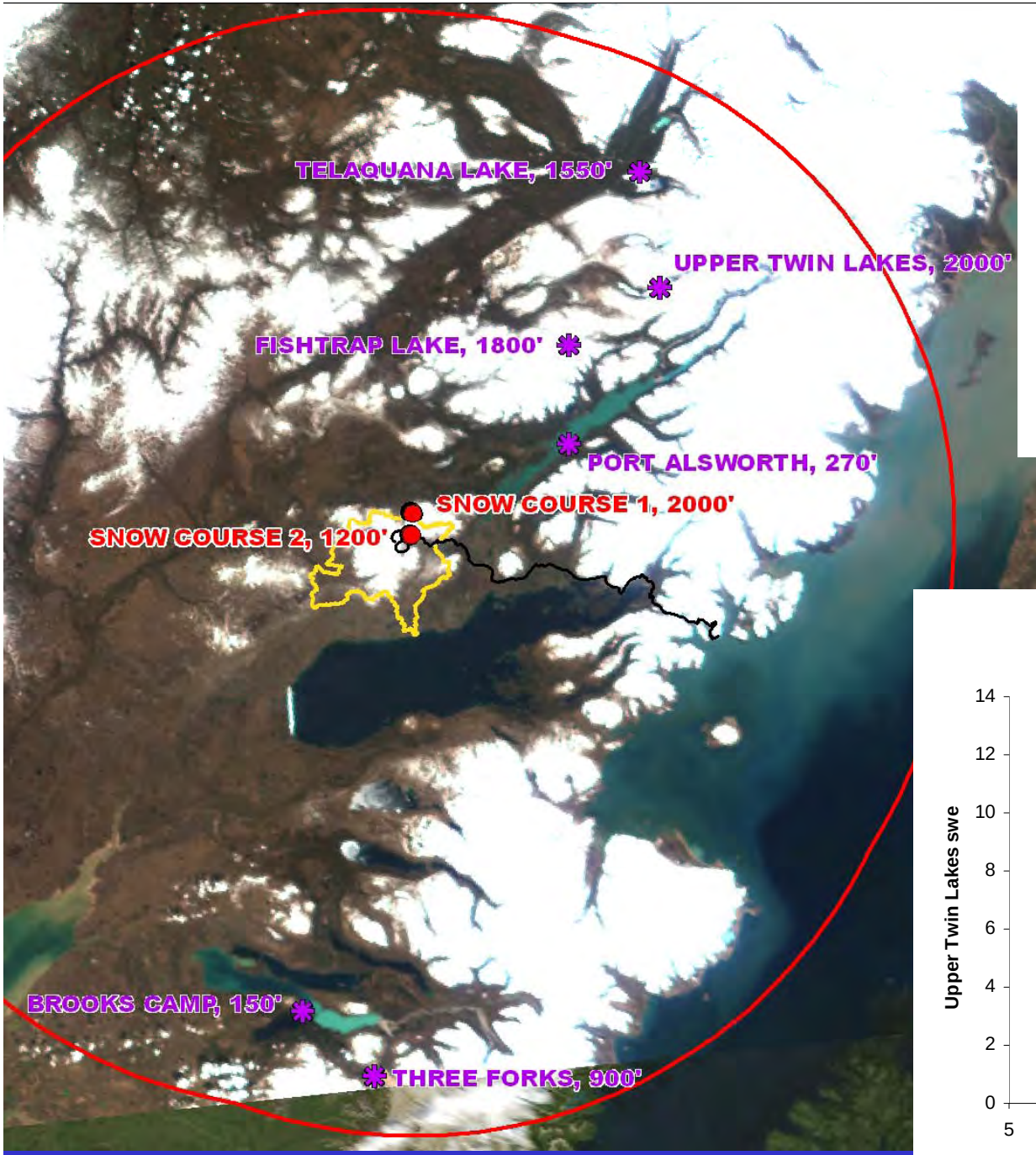

5
Km
SWE (inches)
0 - 1
1.1 - 3
3.1 - 5
5.1 - 10
10.1 - 15
15.1 - 20
20.1 - 25
25.1 - 50
50.1 - 75
75.1 - 100
100.1 - 125
125.1 - 150
Mid April 2005

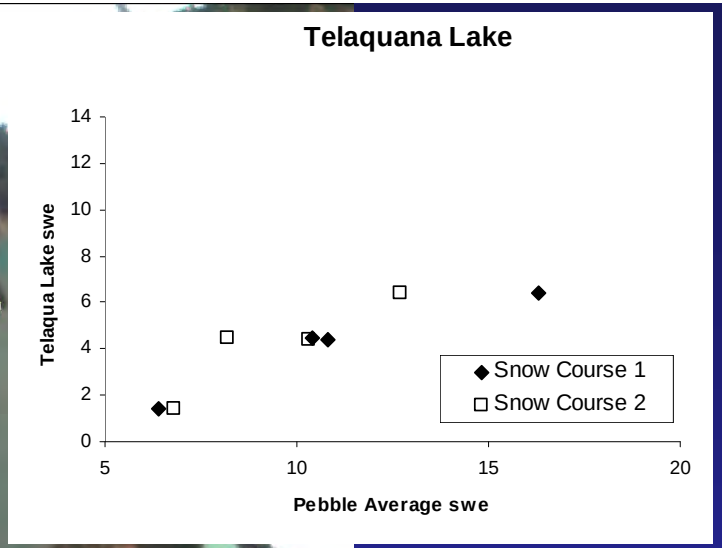

5
Km
SWE (inches)
0 - 1
1.1 - 3
3.1 - 5
5.1 - 10
10.1 - 15
15.1 - 20
20.1 - 25
25.1 - 50
50.1 - 75
75.1 - 100
100.1 - 125
125.1 - 150
Mid April 2006

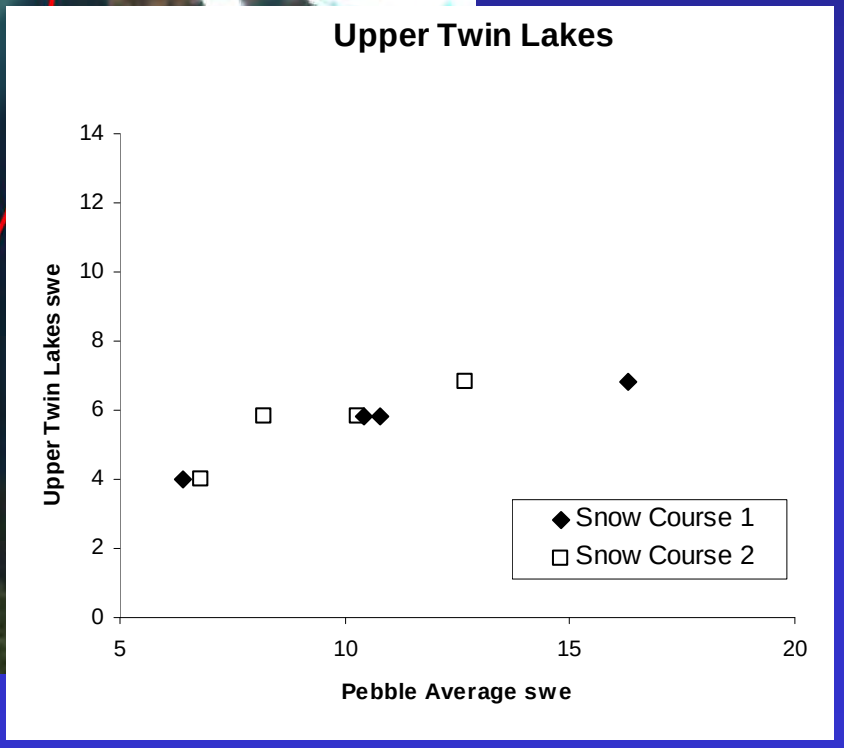

5
Km
SWE (inches)
0 - 1
1.1 - 3
3.1 - 5
5.1 - 10
10.1 - 15
15.1 - 20
20.1 - 25
25.1 - 50
50.1 - 75
75.1 - 100
100.1 - 125
125.1 - 150
Early April 2007

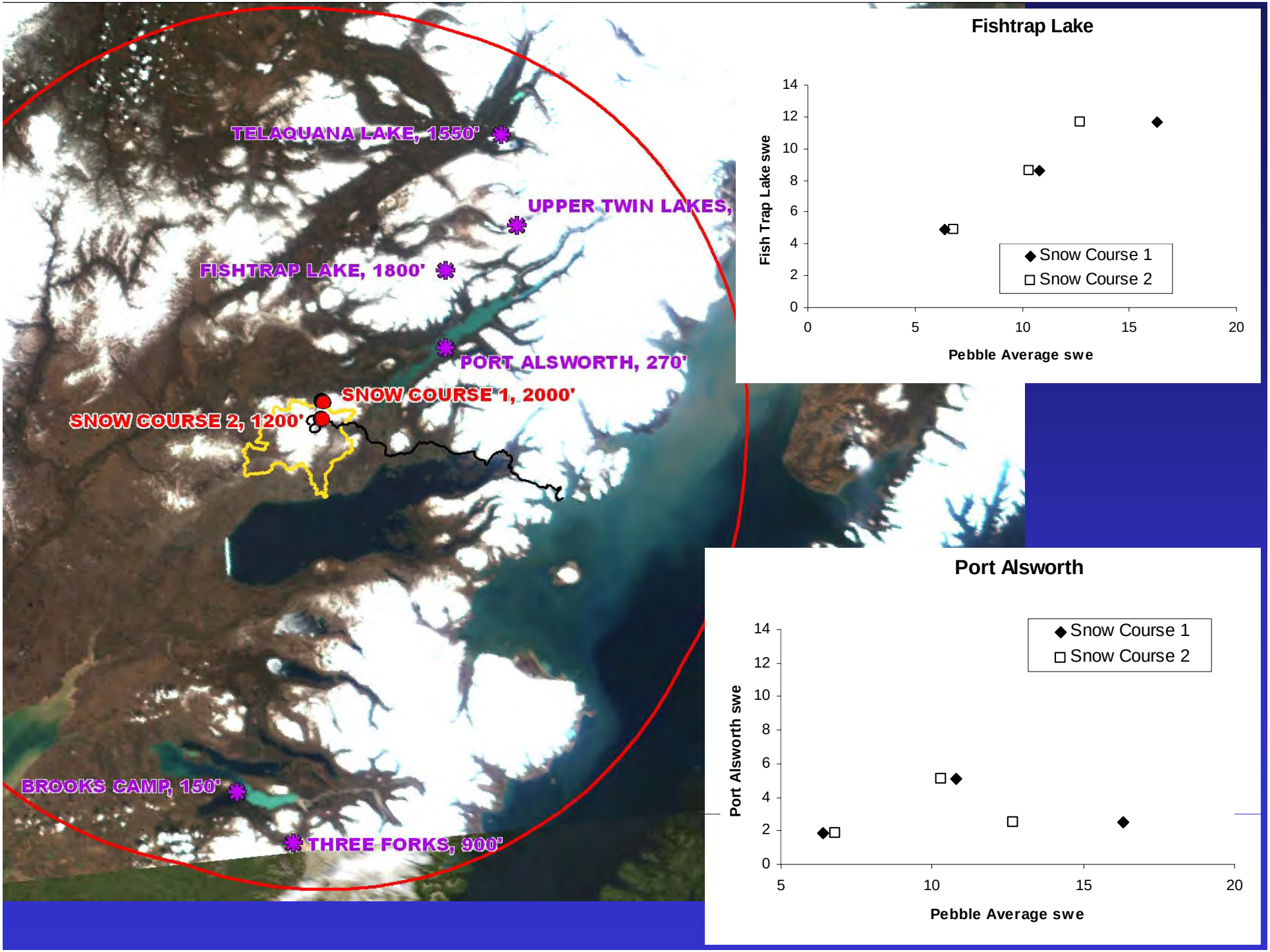
# Comparison of Pebble Snow Courses to Regional NRCS Snow Courses


TELAQUANA LAKE, 1550'
UPPER TWIN LAKES, 2000'
FISHTRAP LAKE, 1800'
PORT ALSWORTH, 270'
SNOW COURSE 1, 2000'
SNOW COURSE 2, 1200'
BROOKS CAMP, 150'
THREE FORKS, 900'
NRCS Snow Courses
Pebble Snow Courses
100-mile Buffer of Extended Study Area
Extended Study Area
50
Km


TELAQUANA LAKE, 1550'
UPPER TWIN LAKES, 2000'
FISHTRAP LAKE, 1800'
PORT ALSWORTH, 270'
SNOW COURSE 1, 2000'
SNOW COURSE 2, 1200'
BROOKS CAMP, 150'
THREE FORKS, 900'

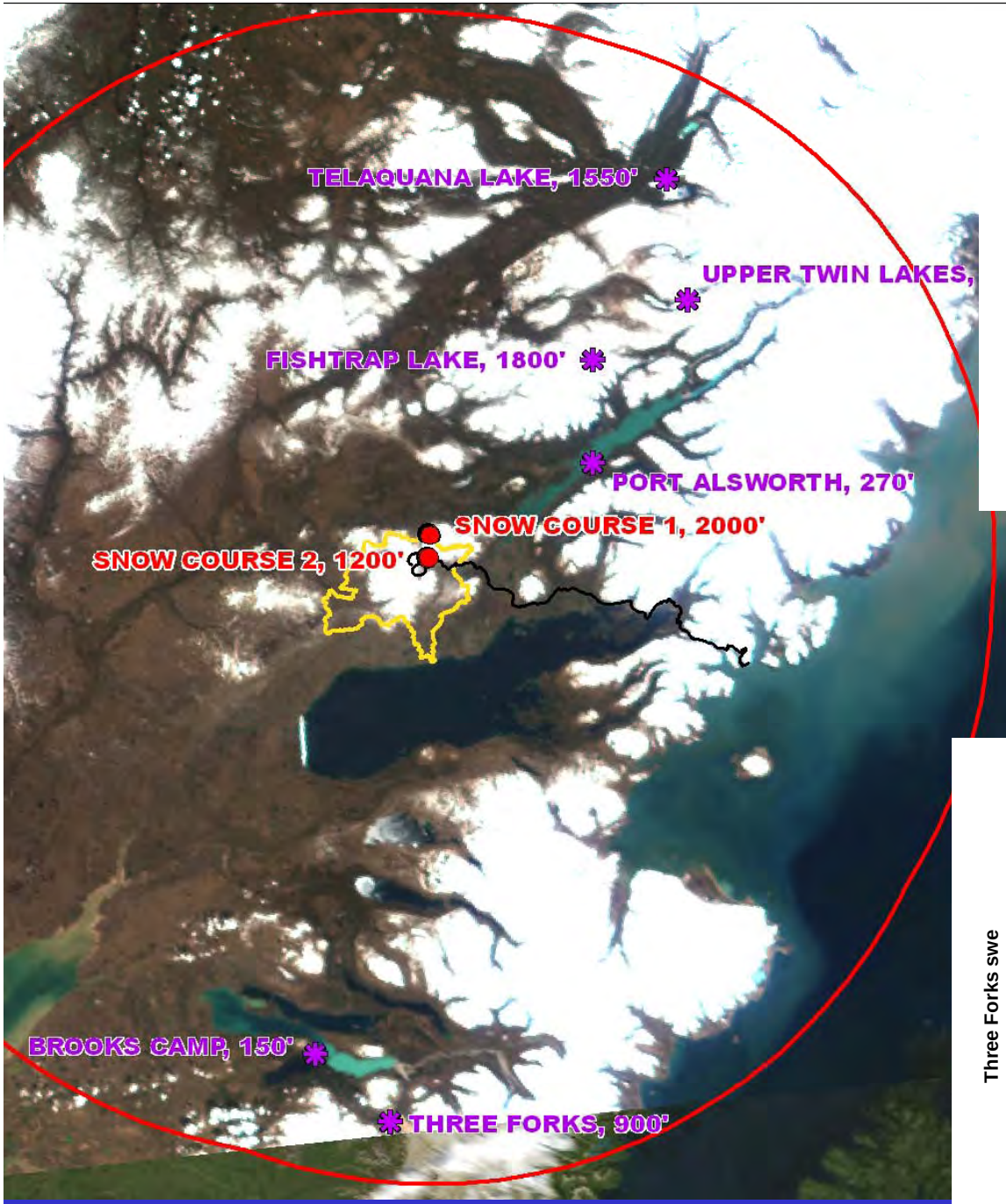

Telaquana Lake
Telaqua Lake swe
Pebble Average swe
Snow Course 1
Snow Course 2
0
2
4
6
8
10
12
14
5
10
15
20

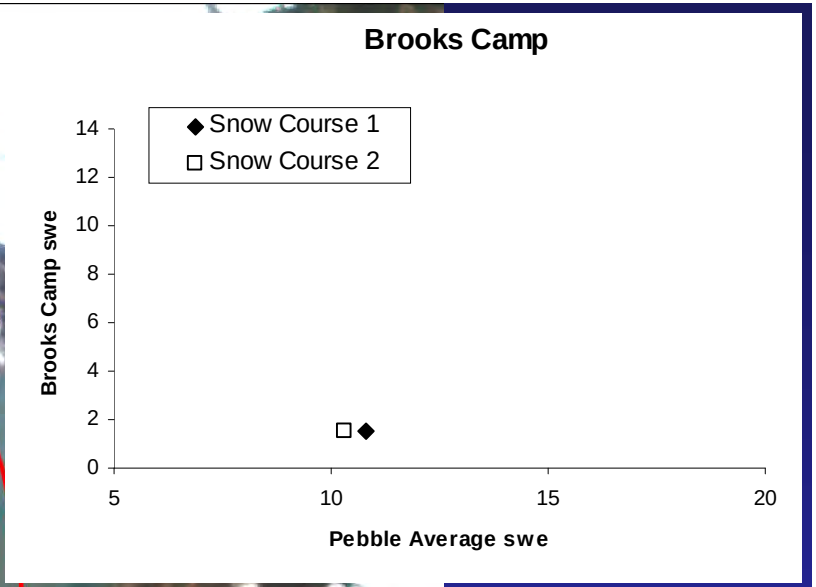

Upper Twin Lakes
Upper Twin Lakes swe
Pebble Average swe
Snow Course 1
Snow Course 2
0
2
4
6
8
10
12
14
5
10
15
20

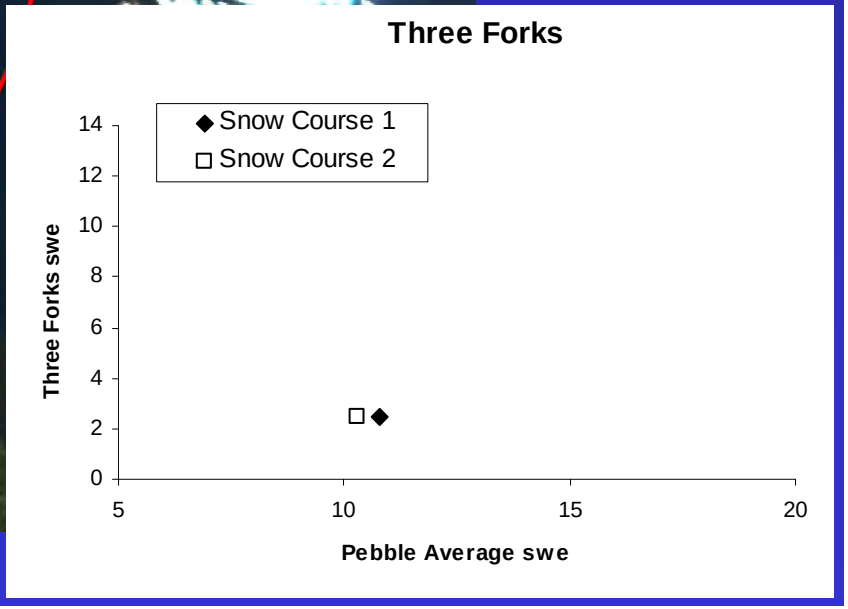

TELAQUANA LAKE, 1550'
UPPER TWIN LAKES,
FISHTRAP LAKE, 1800'
PORT ALSWORTH, 270'
SNOW COURSE 1, 2000'
SNOW COURSE 2, 1200'
BROOKS CAMP, 150'
THREE FORKS, 900'

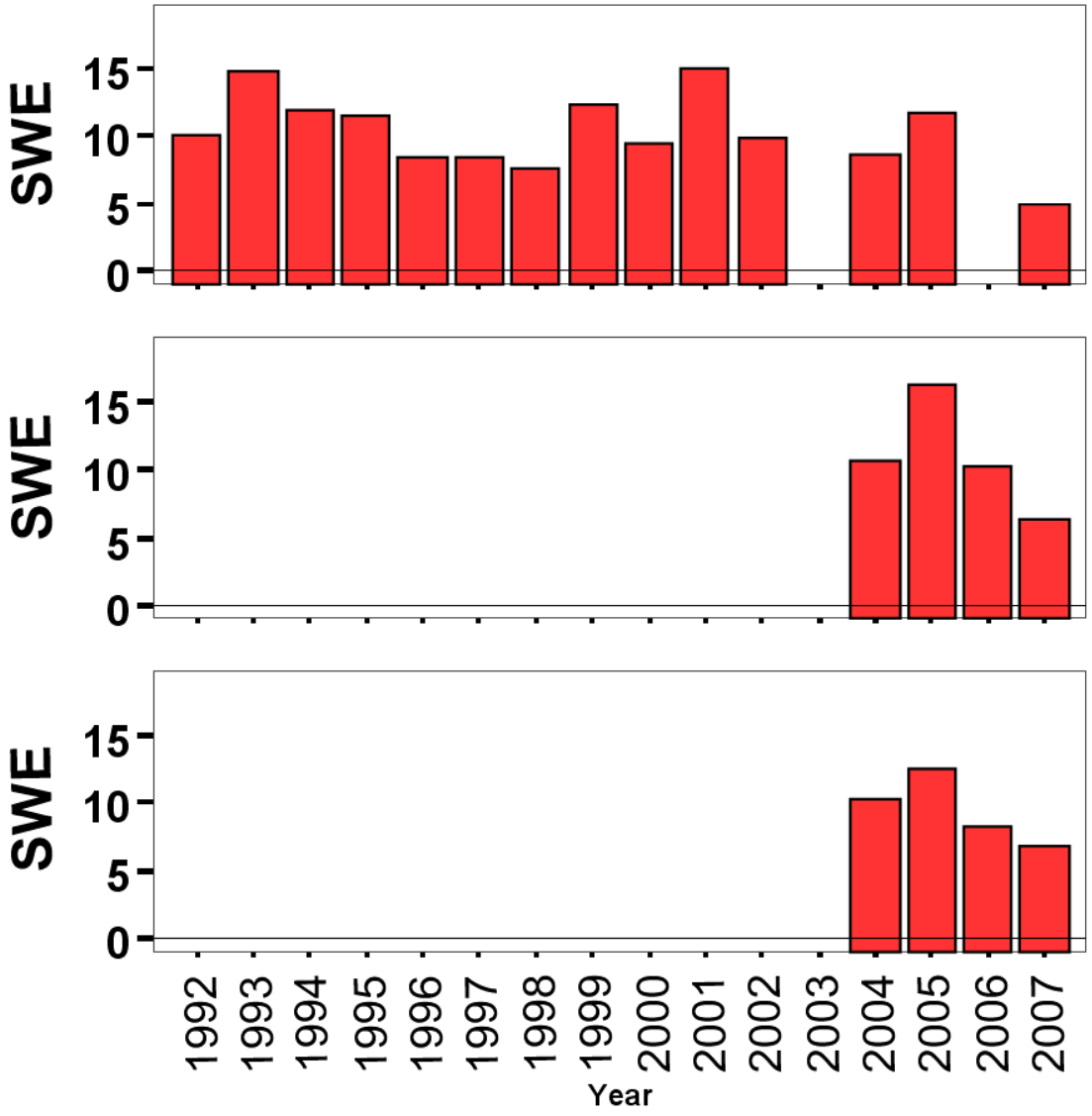

Fishtrap Lake
Fish Trap Lake swe
Pebble Average swe
Snow Course 1
Snow Course 2
0
2
4
6
8
10
12
14
0
5
10
15
20


Port Alsworth
Port Alsworth swe
Pebble Average swe
Snow Course 1
Snow Course 2
0
2
4
6
8
10
12
14
5
10
15
20


TELAQUANA LAKE, 1550'
UPPER TWIN LAKES,
FISHTRAP LAKE, 1800'
PORT ALSWORTH, 270'
SNOW COURSE 1, 2000'
SNOW COURSE 2, 1200'
BROOKS CAMP, 150'
THREE FORKS, 900'


Brooks Camp
Snow Course 1
Snow Course 2
Brooks Camp swe
Pebble Average swe
0
2
4
6
8
10
12
14
5
10
15
20


Three Forks
Snow Course 1
Snow Course 2
Three Forks swe
Pebble Average swe
0
2
4
6
8
10
12
14
5
10
15
20




# Fishtrap Lake

# Pebble 1

# Pebble 2

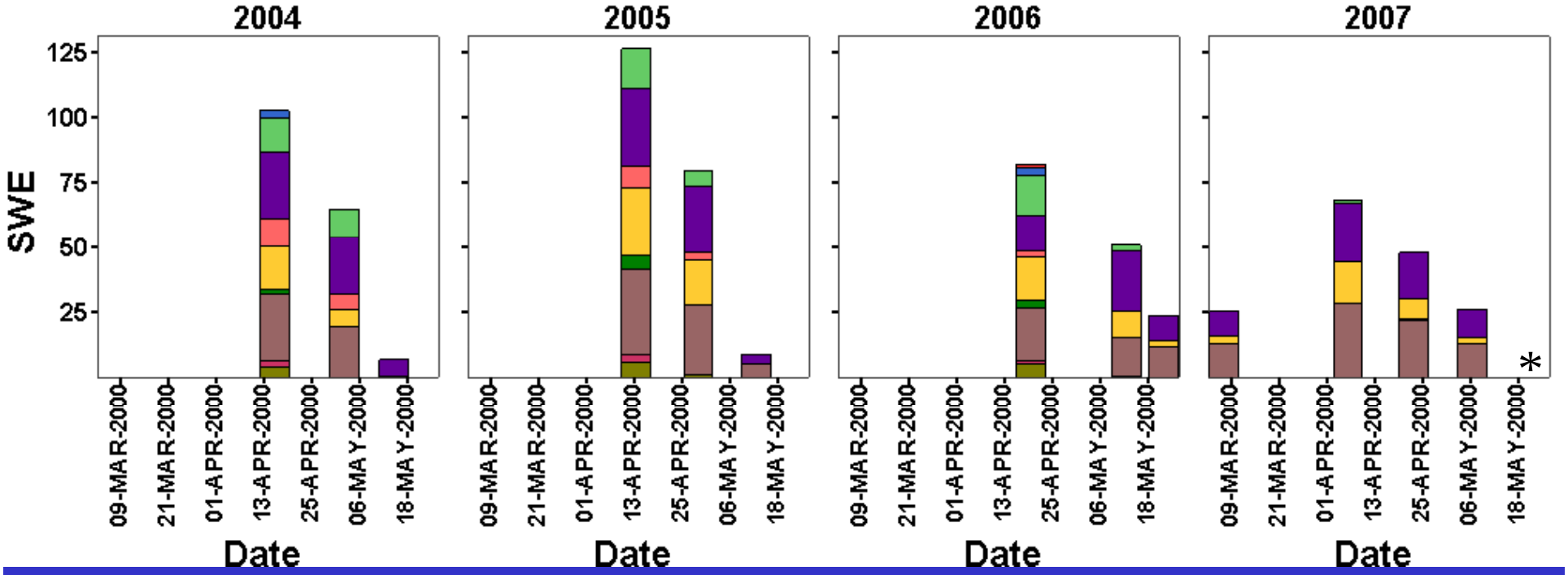
# Snow Course Summary

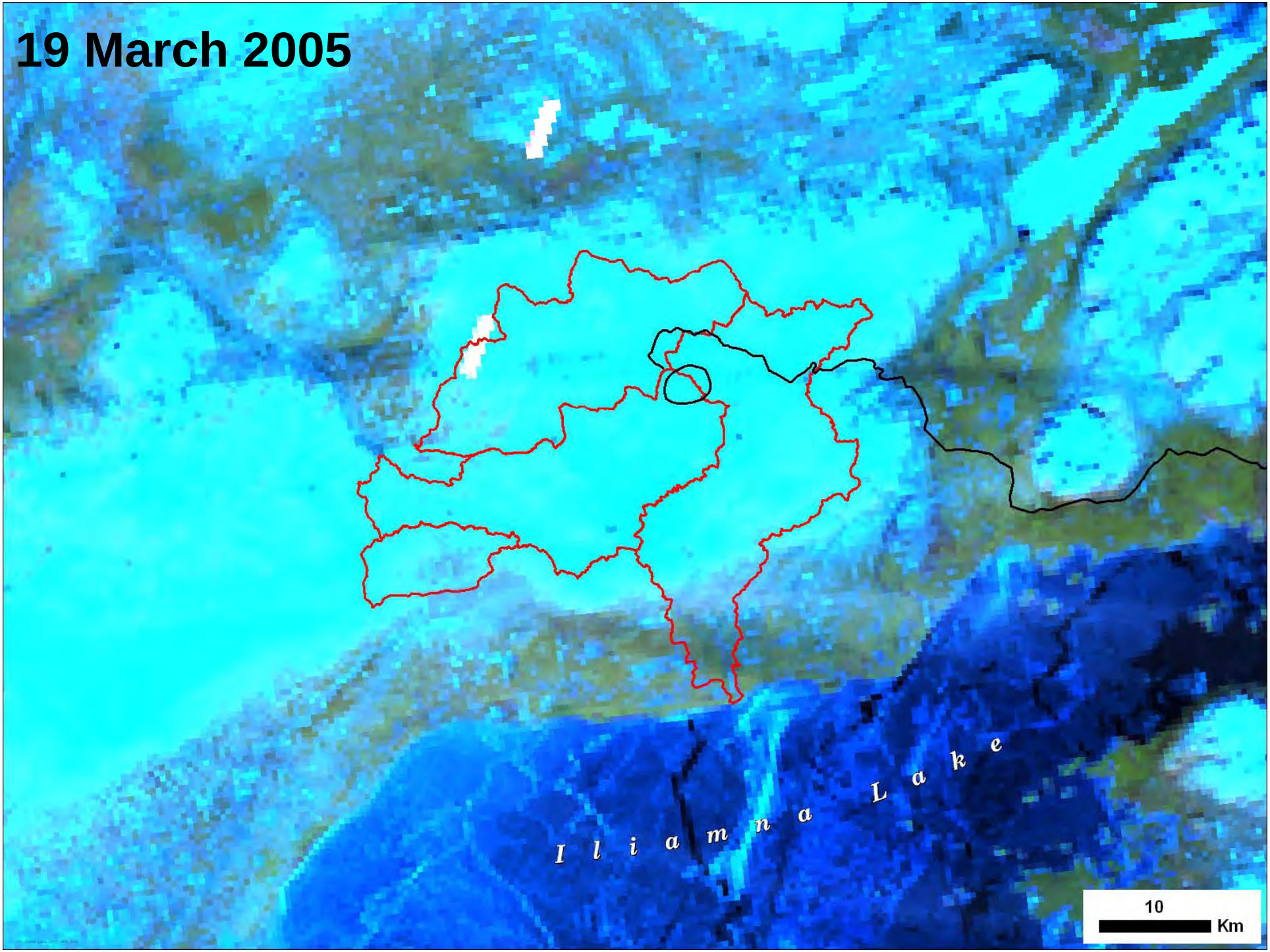
- Port Alsworth is not well correlated with nearby Pebble snow courses
- Based on three years of data, Fishtrap Lake appears to be the best NRCS snow course for comparisons
- Snow accumulation was above average at Fishtrap in 2005 (113% of average), but not near record levels (142% in 1993, 144% in 2001)
- 2007 snow accumulation was the lowest on record for Fishtrap Lake (47% of average)

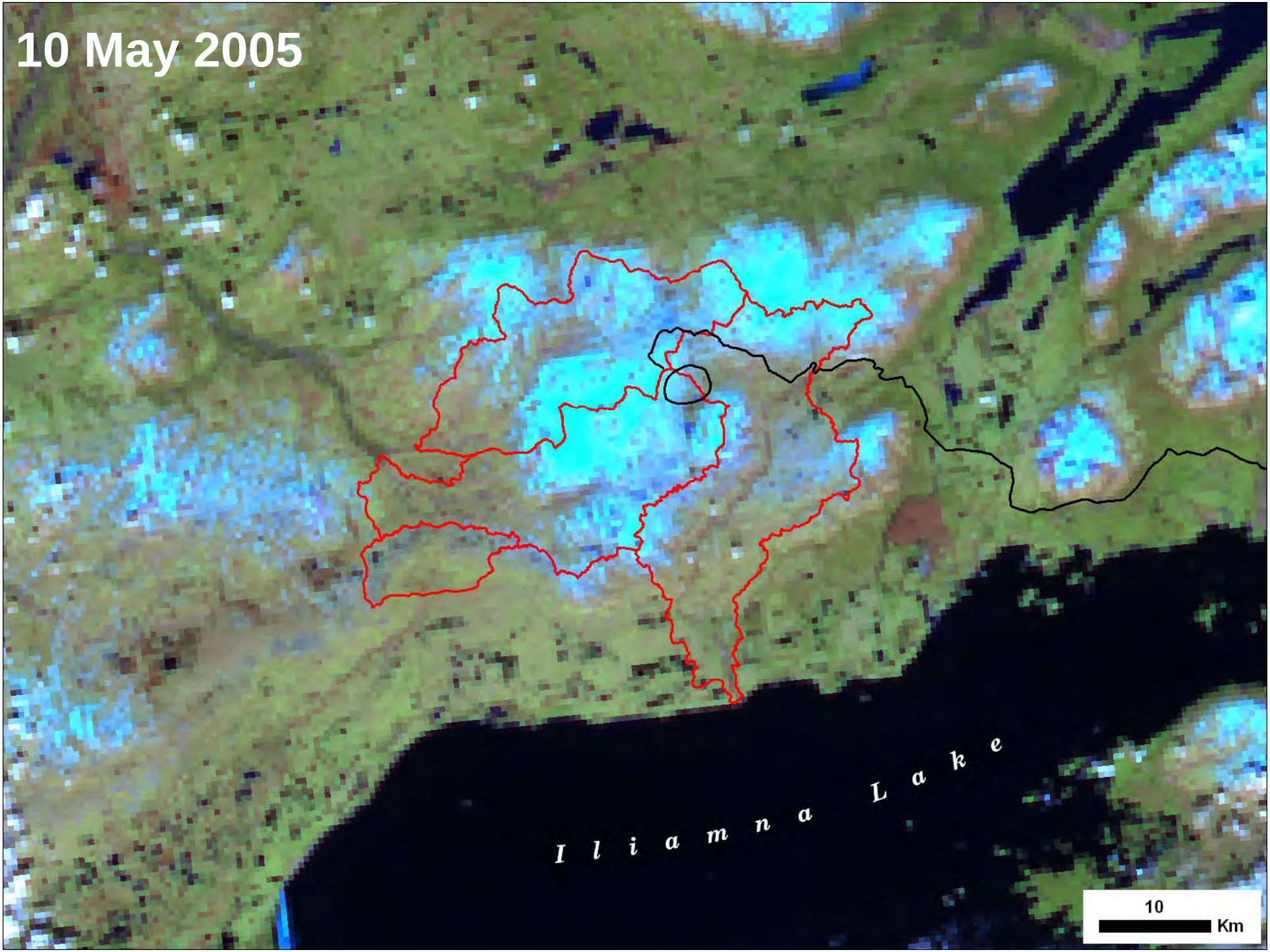
# Spring Snowpack Ablation

- Ablation is a combination of melting, evaporation and sublimation of the snowpack.
- Ablation rates were measured in the field by biweekly repeat visits to fixed survey stations (2004–2007).
- MODIS imagery combined with on-site meteorological data and SWE distribution map is being evaluated as a method of estimating ablation rates during spring breakup.

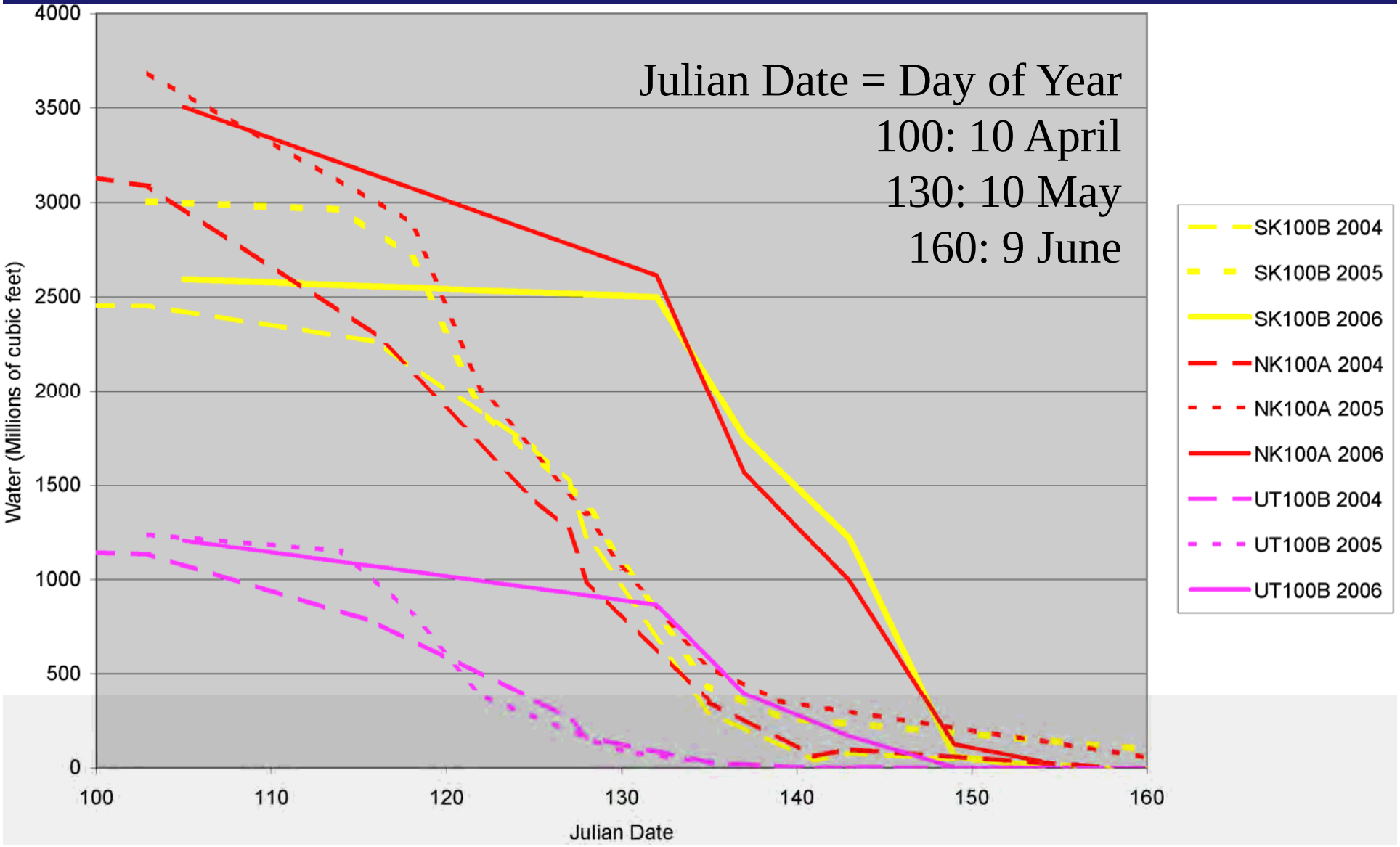
# Ablation Field Survey Data, 2004–2007 (Pebble Snow Course 2)

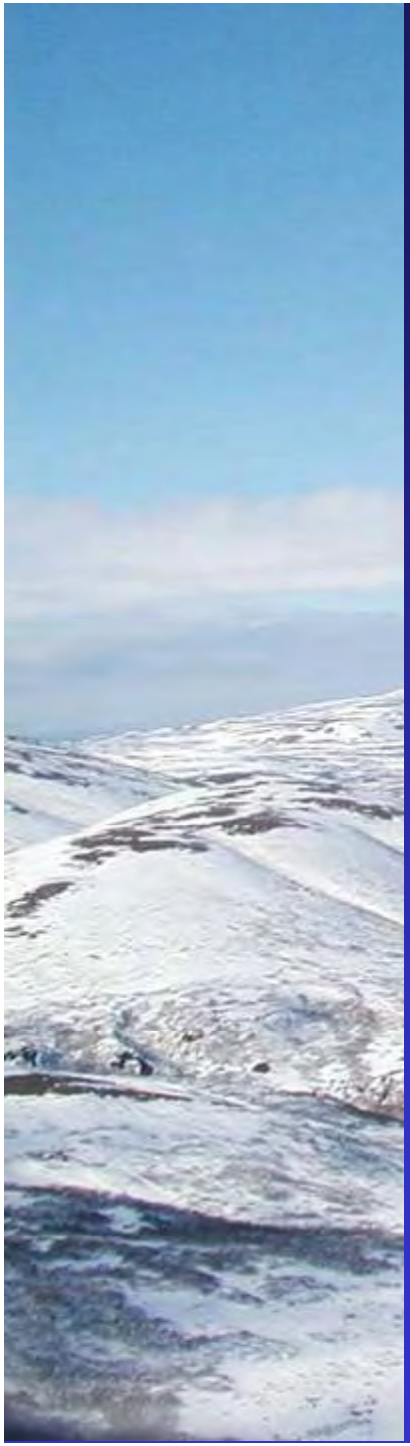



19 March 2005
Iliamna Lake
10
Km


10 May 2005
Iliamna Lake
10
Km

# Ablation Curves, 2004–2006





# Snow Survey–Summary

- A terrain modeling approach eventually will allow accurate spatial estimates of SWE from meteorological data and limited field surveys.
- Basin and sub-basin snow inputs can be easily determined from the resulting SWE grid of the mine area for any area of local interest.
- The use of the terrain modeling approach allows us to evaluate the effect of mine development scenarios on spring snow distribution and local water balance.