Effects of beetles on water resources in north-central Colorado

John D. Stednick, Ryan Jensen, Kelly McElwaine, Kate Condon, Ariann Blankenship, and Fred the Field Truck

Watershed Science

Colorado State University

Current Situation

- Approx. 95% of CO lodgepole pine infected
- Colorado River still in drought condition
- In-state and downstream users looking for more water, blame the beetle
- Effects of beetle-killed forest on water resources?

Not the first time in Colorado

- Beetle infestation in White River in 1939
- Moved into other areas but skipped Elk River
- Paired catchments: treatment vs control
- Significant increase in annual water yield
  - (50 and 40 mm: White and Yampa)
- Peakflow increases of 27% on White not Yampa
- Love 1955; Bethlahmy 1974

Water Resources Concerns

- Uncertain water yields over last decade
  - Beetles or GCV?
- Large openings and snow scour
- Peak flow increases modeled in BC
- Water quality changes
- Wildfire danger
- Erosion and sediment delivery

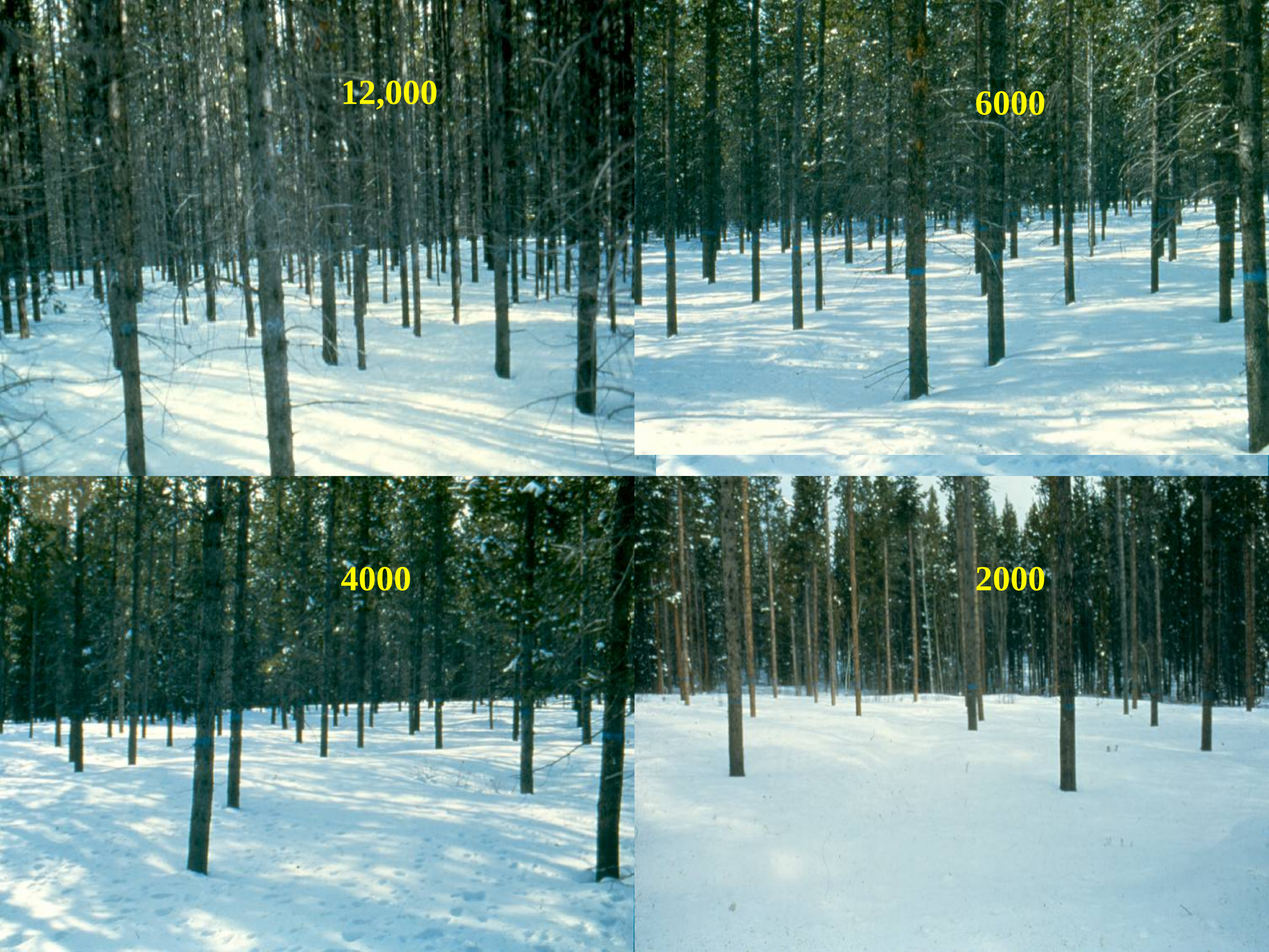
Quick Review

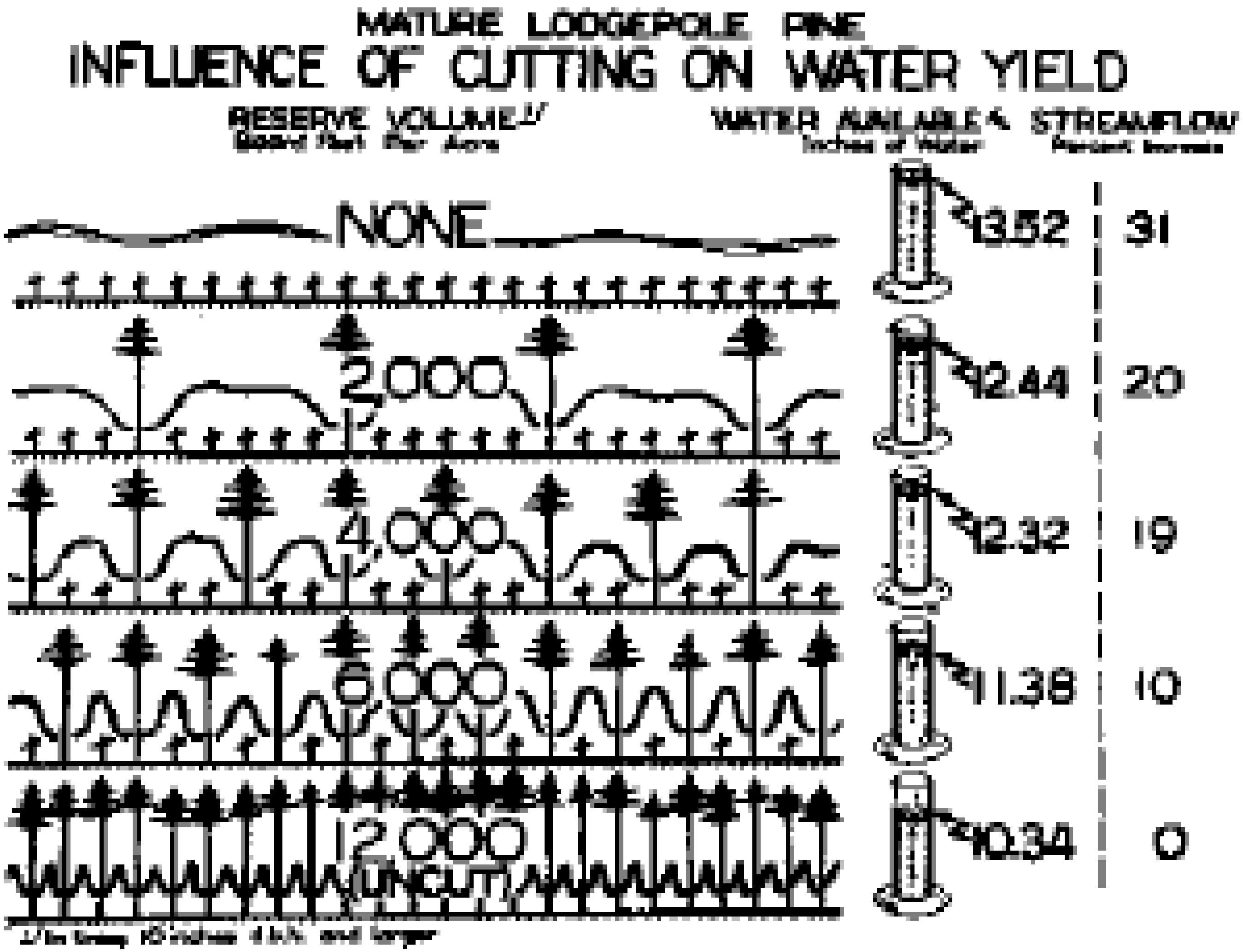
- Beetle-kill effects are similar to harvesting
- Timber harvesting will decrease interception and evapotranspiration
- Threshold of response is 20% basal area removal for measurable response
- Response is proportional to level harvested clearcut or thinning
- Increase yield on rising limb
- Downstream measurements of increased water yields are problematic

King Creek Plot Study

- Comparison of different harvest levels to increase SWE
- Established 5- 1 acre plots (4 replicates) in mature Lodgepole pine in 1938
- Snowpack accumulation, interception, throughfall, and soil moisture.
- Logged in 1940 leaving residual volumes of 0, 2000, 4000, and 6000 board feet/acre (fbm).


110 Year Old Stand
32 sq. m per ha BA


12,000
6000
4000
2000

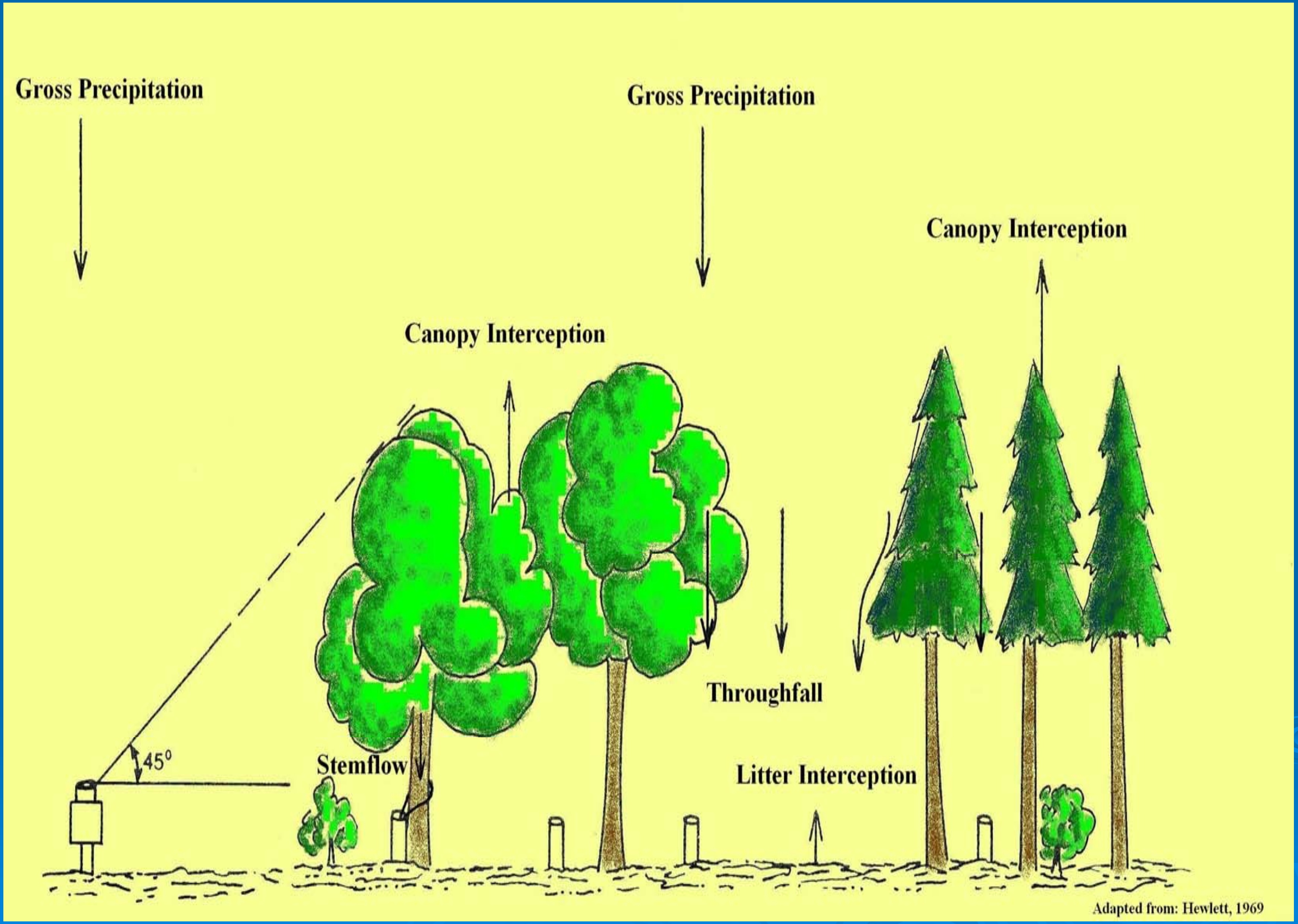


Wilm and Dunford, 1948

Results

- 26% increase in SWE on clearcut plots.
- Loss of trees (canopy cover):
  - Decreased canopy interception
  - Decreased sublimation loss.
  - Decreased ET loss during growing season.

Minimal effect from redistribution of snow

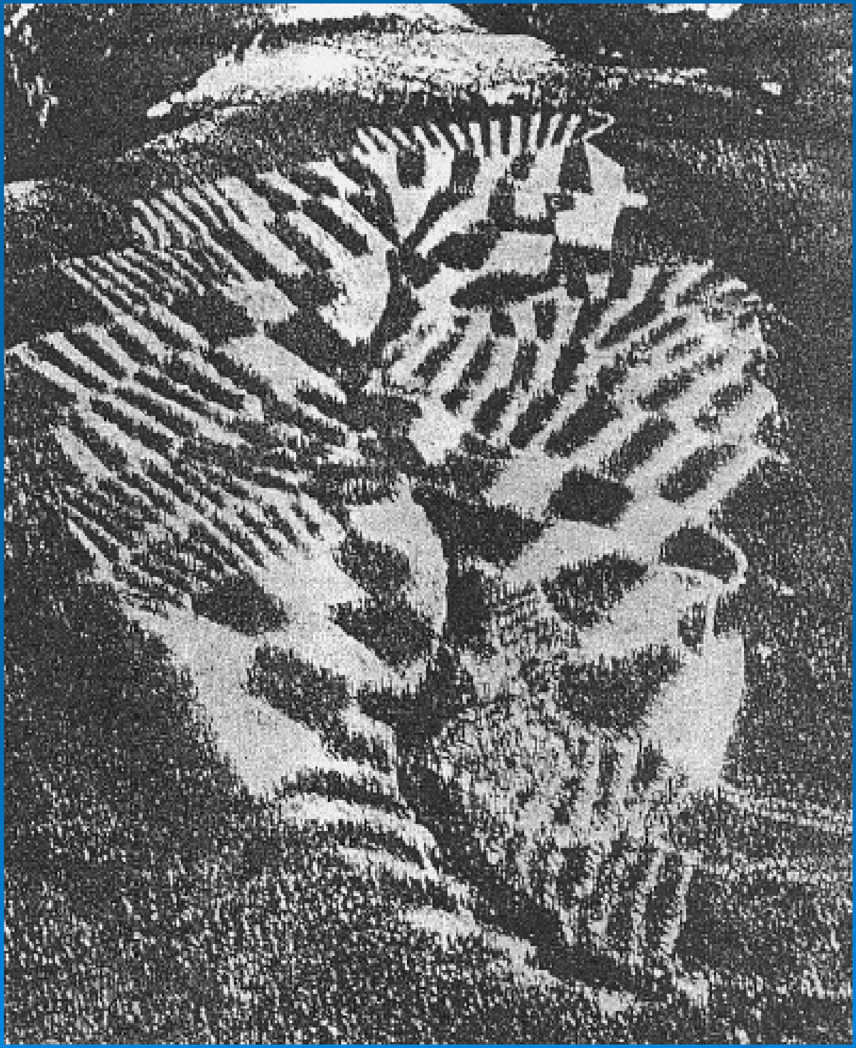

Gross Precipitation
Gross Precipitation
Canopy Interception
Canopy Interception
45°
Stemflow
Throughfall
Litter Interception
Adapted from: Hewlett, 1969

Paired Watershed Study: Fool Creek – E. St. Louis Creek

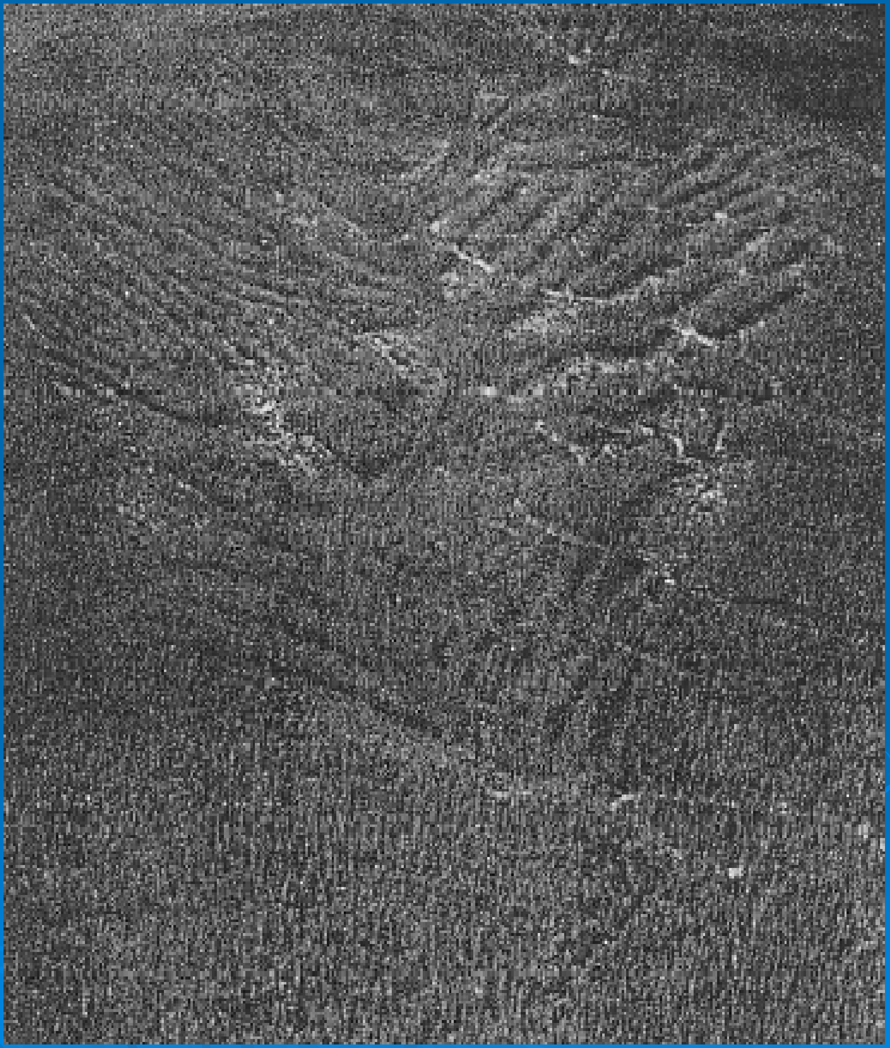
- To determine effect of timber harvest on streamflow
- Paired watershed study
- Control used to assess changes in streamflow from timber harvest after a 15-year pretreatment calibration period

Fool Creek Watershed

1958 – 2 years after harvest



1982 – 26 years after harvest



from Troendle and King, 1985

Changes in Discharge Pattern Over Time for Fool Creek

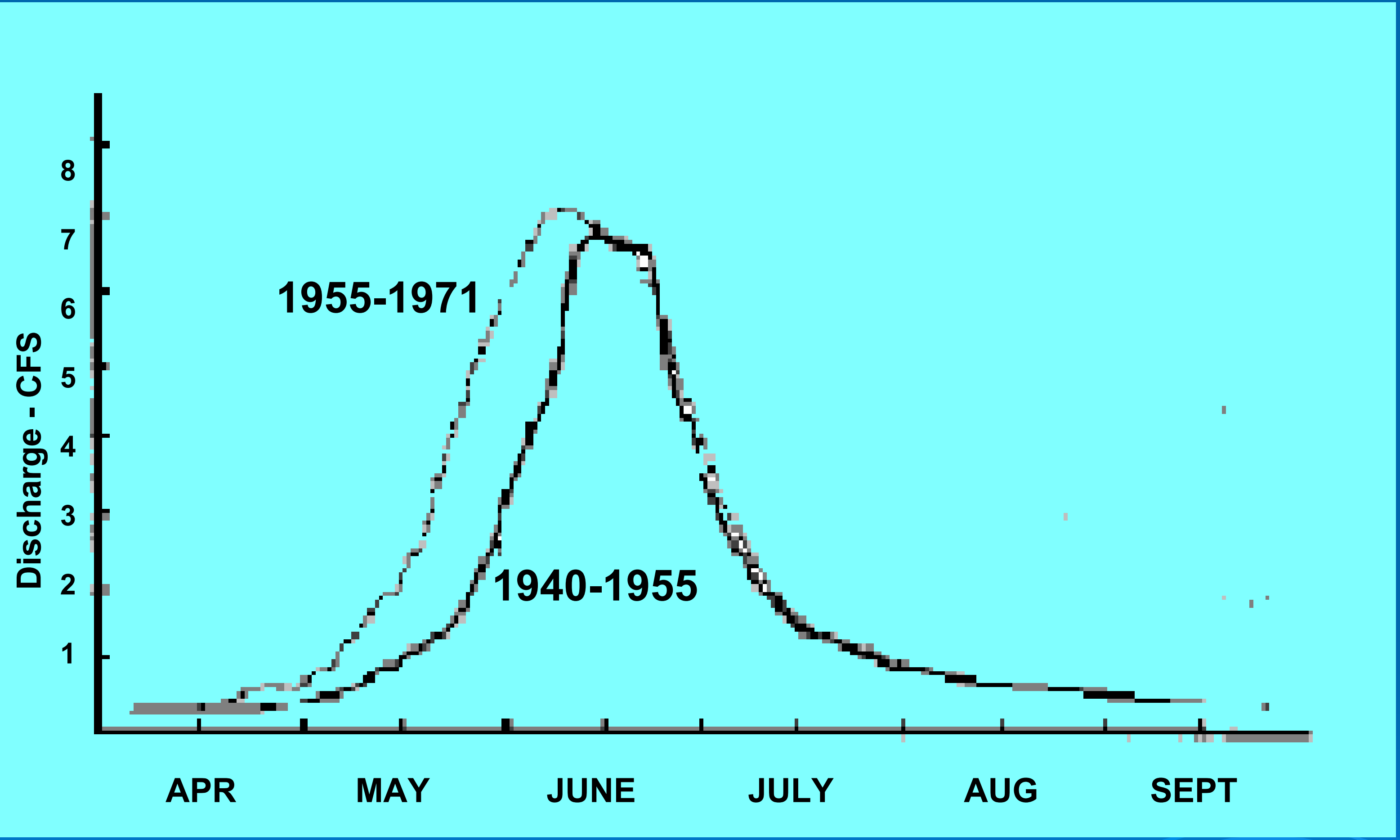


Chart adapted from Alexander, et al.,
General Technical Report RM-118

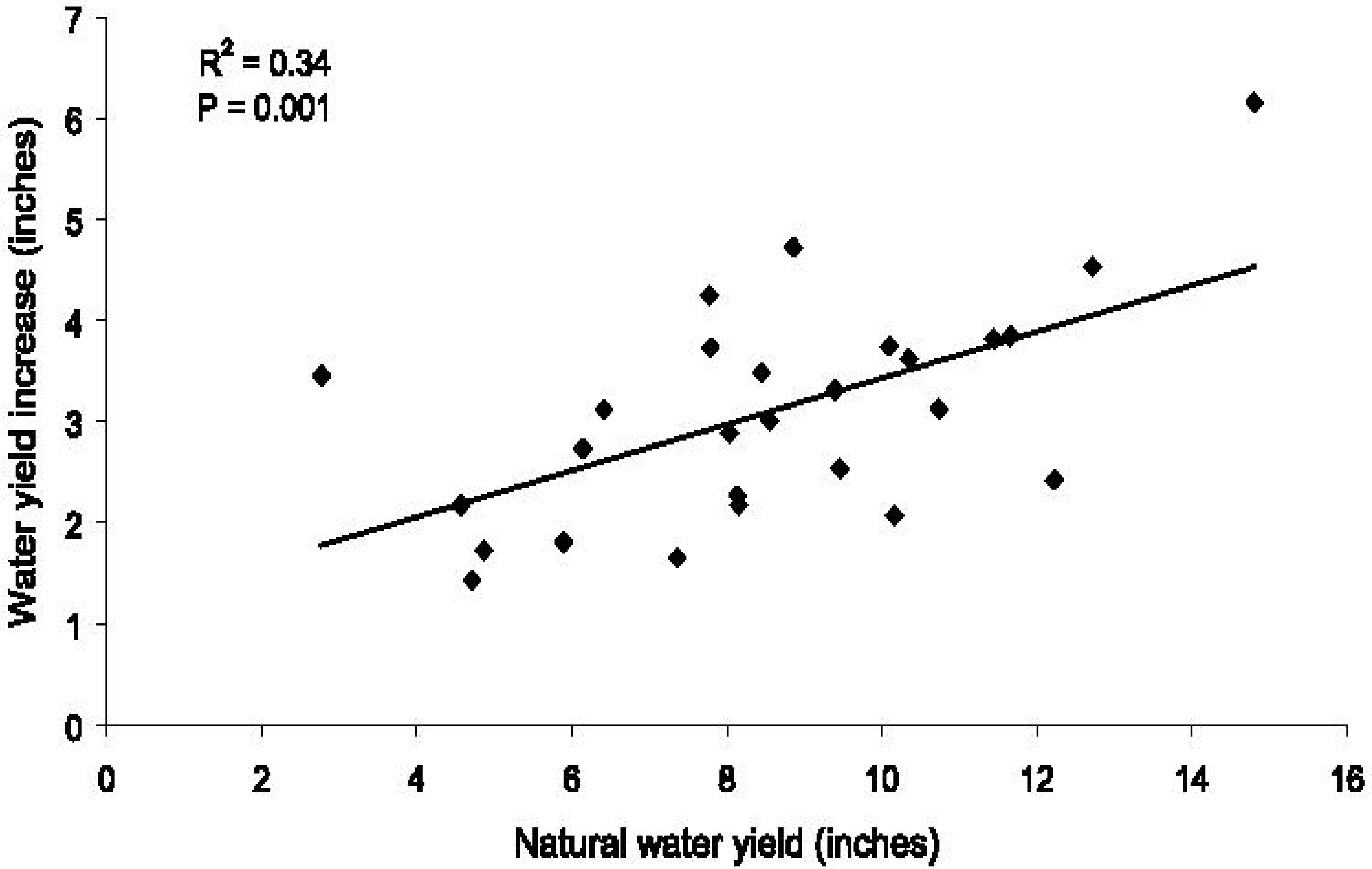
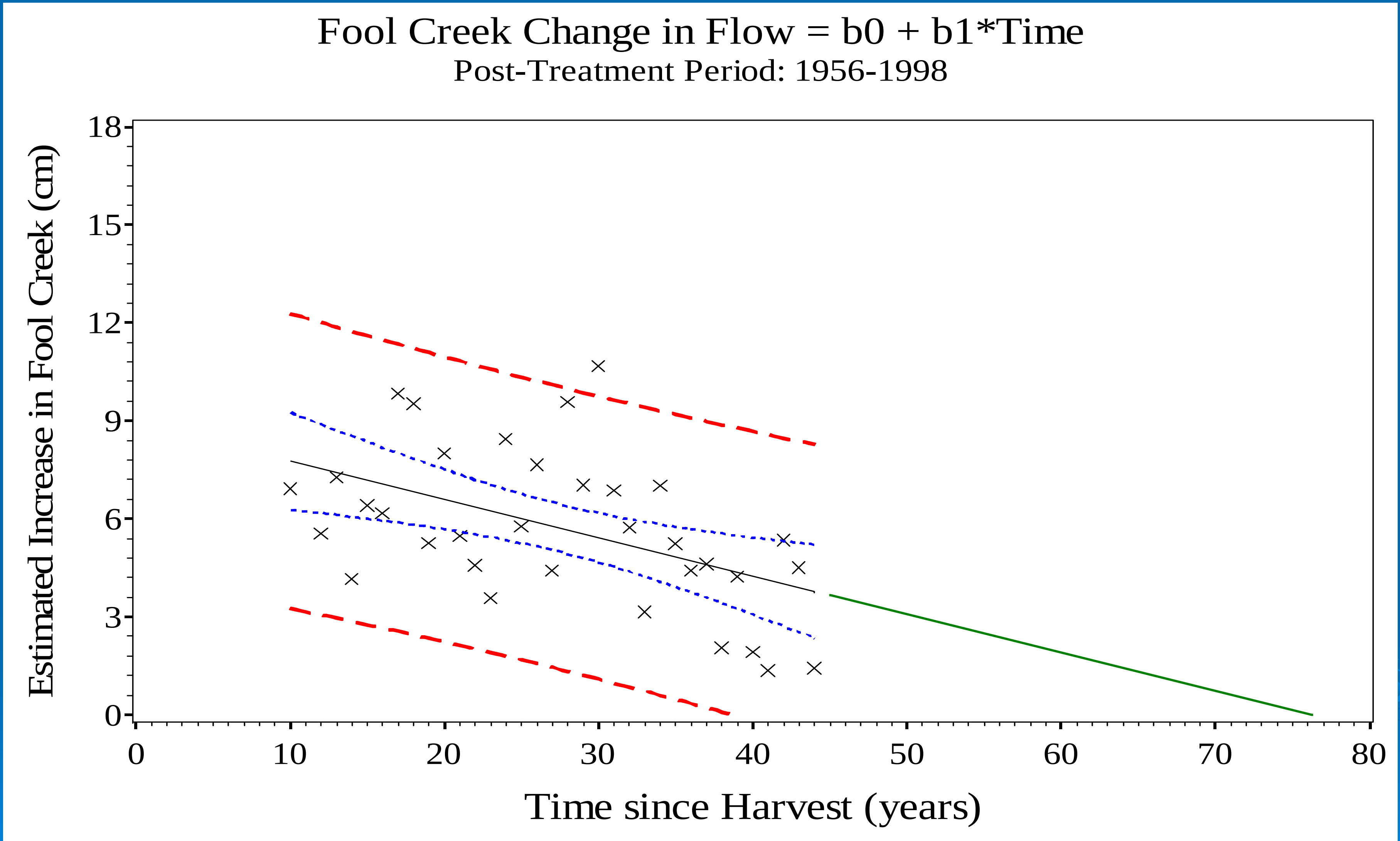


Figure 2.5. Harvest-induced increases in water yield from Fool Creek versus the predicted natural water yield in the absence of any forest harvest. Data are from 1956-1982.


Fool Creek Change in Flow = b0 + b1*Time
Post-Treatment Period: 1956-1998
Estimated Increase in Fool Creek (cm)
0
3
6
9
12
15
18
0
10
20
30
40
50
60
70
80
Time since Harvest (years)

Opening size and catch efficiency

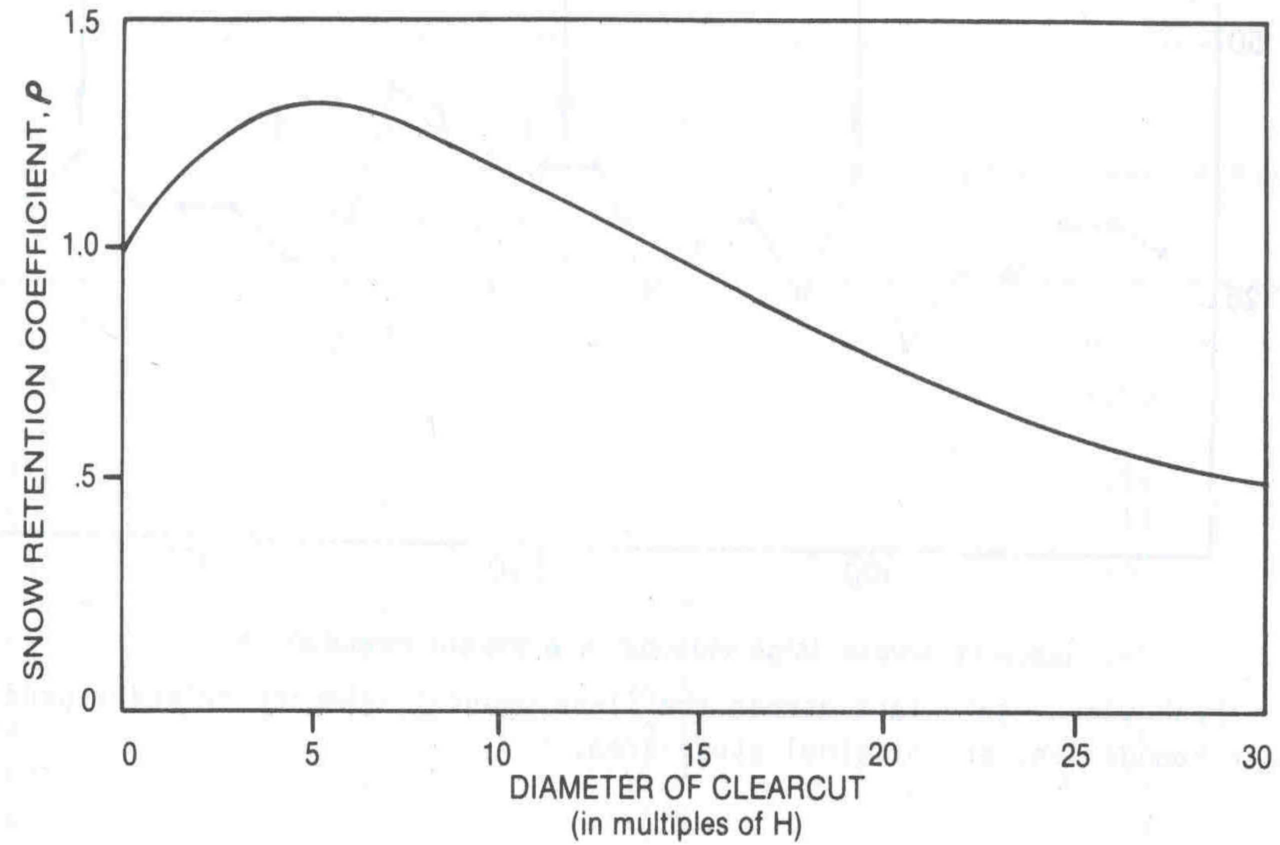


Figure 2.--Snow retention as a function of clearcut size. H is height of surrounding trees (Troendle and Leaf, 1980).

Source: Troendle and Meiman 1984

Interception

- Sublimation is greater from vegetation than from ground
  - Higher temperature on leaf surface
  - Greater surface area
  - Trees radiate longwave radiation
  - Higher air temperature surrounding snow
- Cut trees to decrease interception
  - Increase snowpack
  - Increase water yield

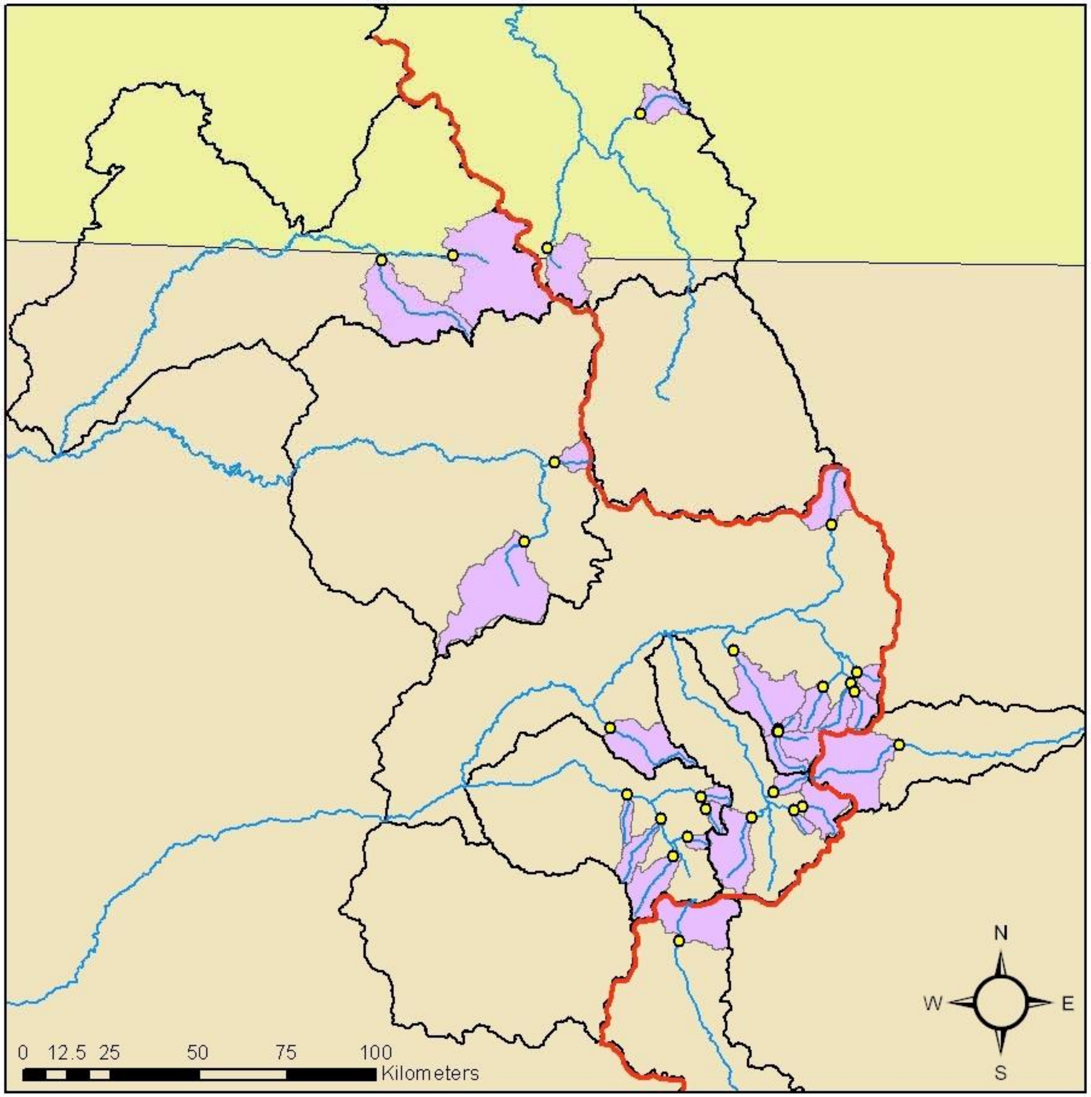
Research Objectives

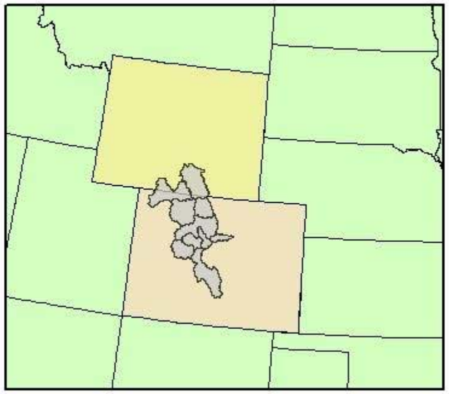
- Determine effects of beetle-killed forests on:
  - annual water yield
  - peak flows
  - water quality

Research Methods

- Beetle area damage mapping by USDA Forest Service
- Using watersheds with USGS stations
- Determine beetle-killed area over time and space
- Using a paired watershed study approach
- Water quality sampling in select watersheds

Locations of Study Watersheds





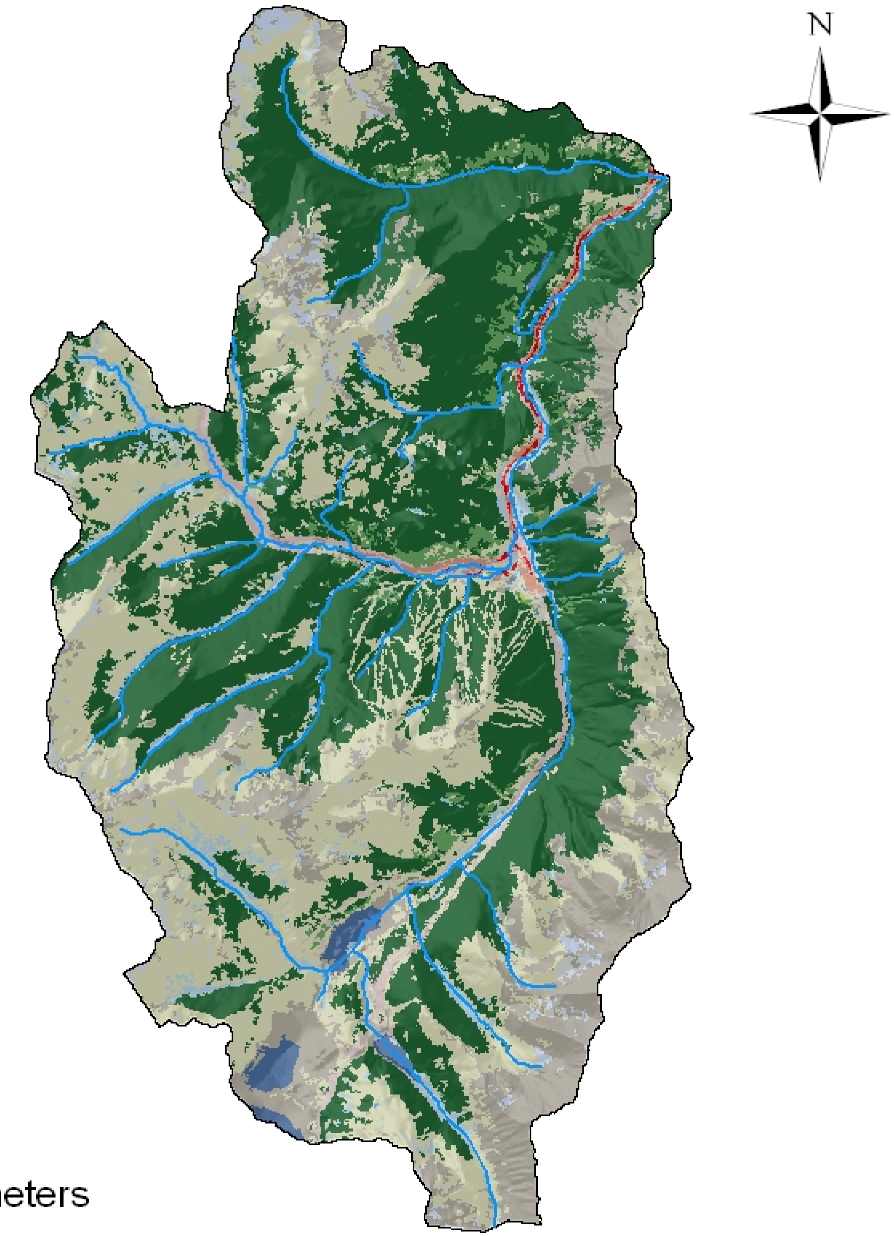
Legend

- Gauges
- Rivers
- Continental Divide
- 8-Digit Hydrologic Units
- Study Watersheds
- Colorado
- Wyoming

Sources:
- 8-digit HUC's and Rivers from USGS National Hydrography Dataset website, http://nhd.usgs.gov/data.html
- Gauge locations from USGS National Water Information System website, http://waterdata.usgs.gov/nwis

Tenmile Creek Watershed

USGS Gauge #: 09050100
Area: 93.3 square miles
Forested Area: 54.5 sqm (58%)
Aspect: NE
Mean Elevation: 11,190 ft
Elevation Range: 9,115 ft - 13,915 ft



- Open Water
- Perennial Ice/Snow
- Developed, Open Space
- Developed, Low Intensity
- Developed, Medium Intensity
- Developed, High Intensity
- Barren Land (Rock/Sand/Clay)
- Deciduous Forest
- Evergreen Forest
- Mixed Forest
- Shrub/Scrub
- Sedge/Herbaceous
- Pasture/Hay
- Woody Wetlands
- Emergent Herbaceous Wetlands
- Rivers, Streams
- Watershed Boundary

0 1.5 3 6 9 12 Kilometers

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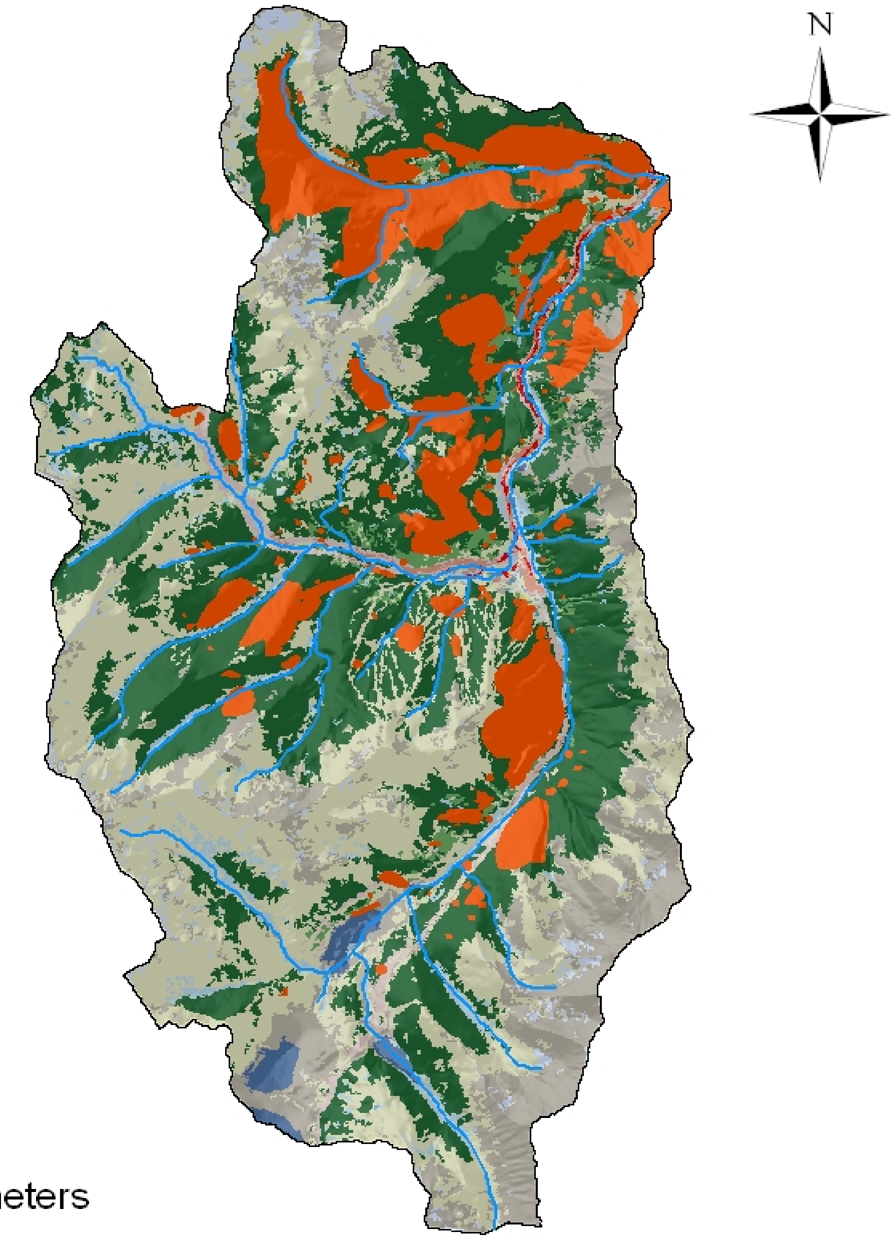
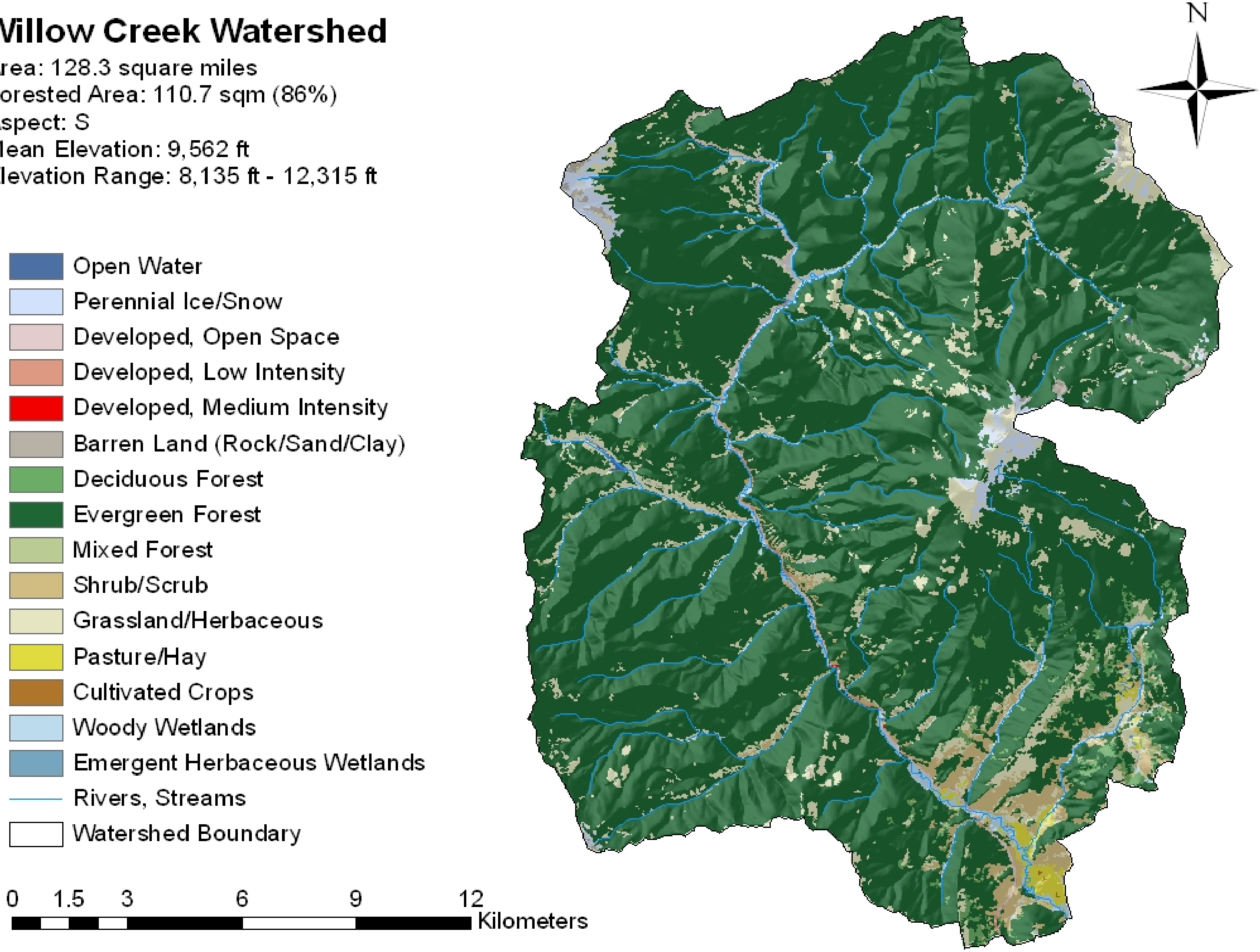


Cumulative Damage, 1995-2007
Rivers, Streams
Watershed Boundary

0 1.5 3 6 9 12 Kilometers

Willow Creek Watershed

Area: 128.3 square miles
Forested Area: 110.7 sqm (86%)
Aspect: S
Mean Elevation: 9,562 ft
Elevation Range: 8,135 ft - 12,315 ft



Willow Creek Watershed

Area: 128.3 square miles
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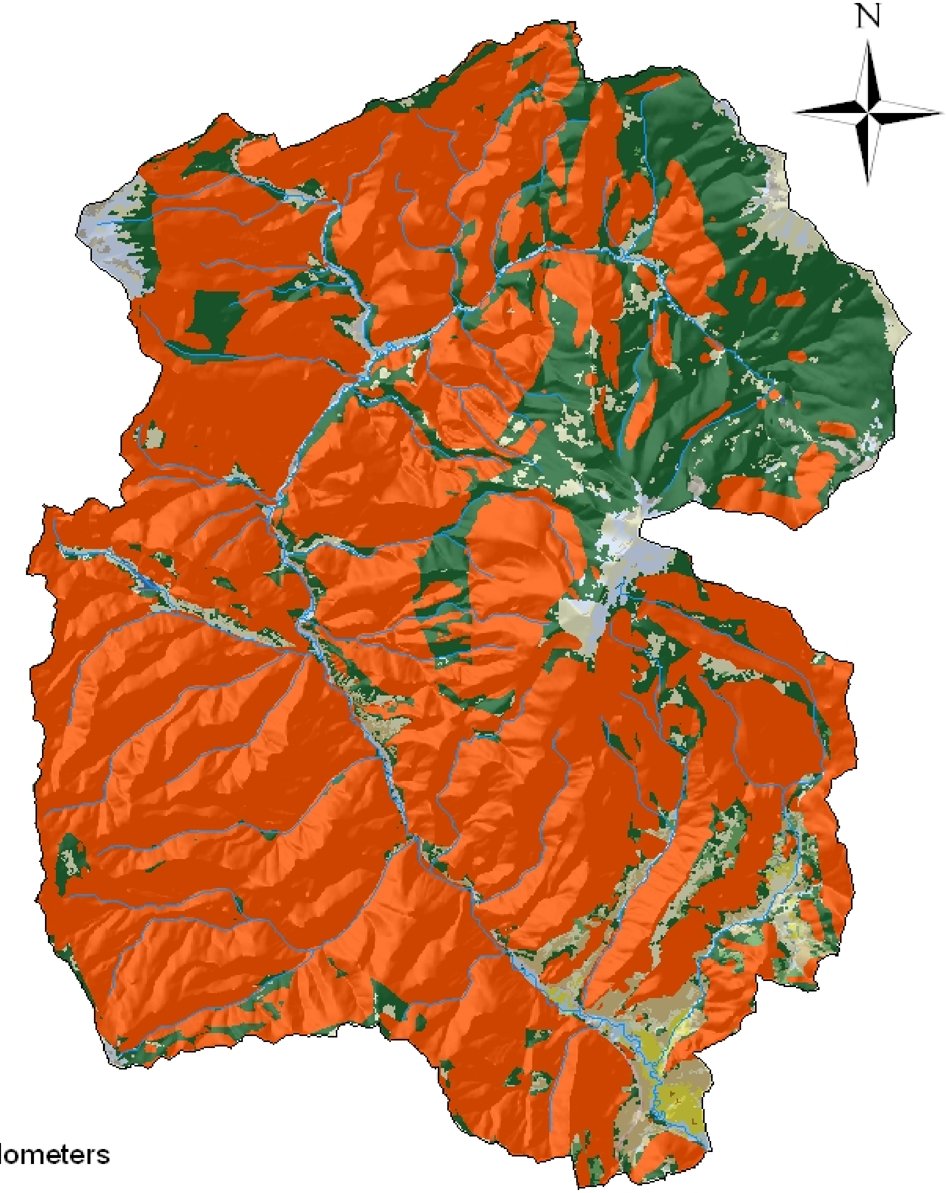
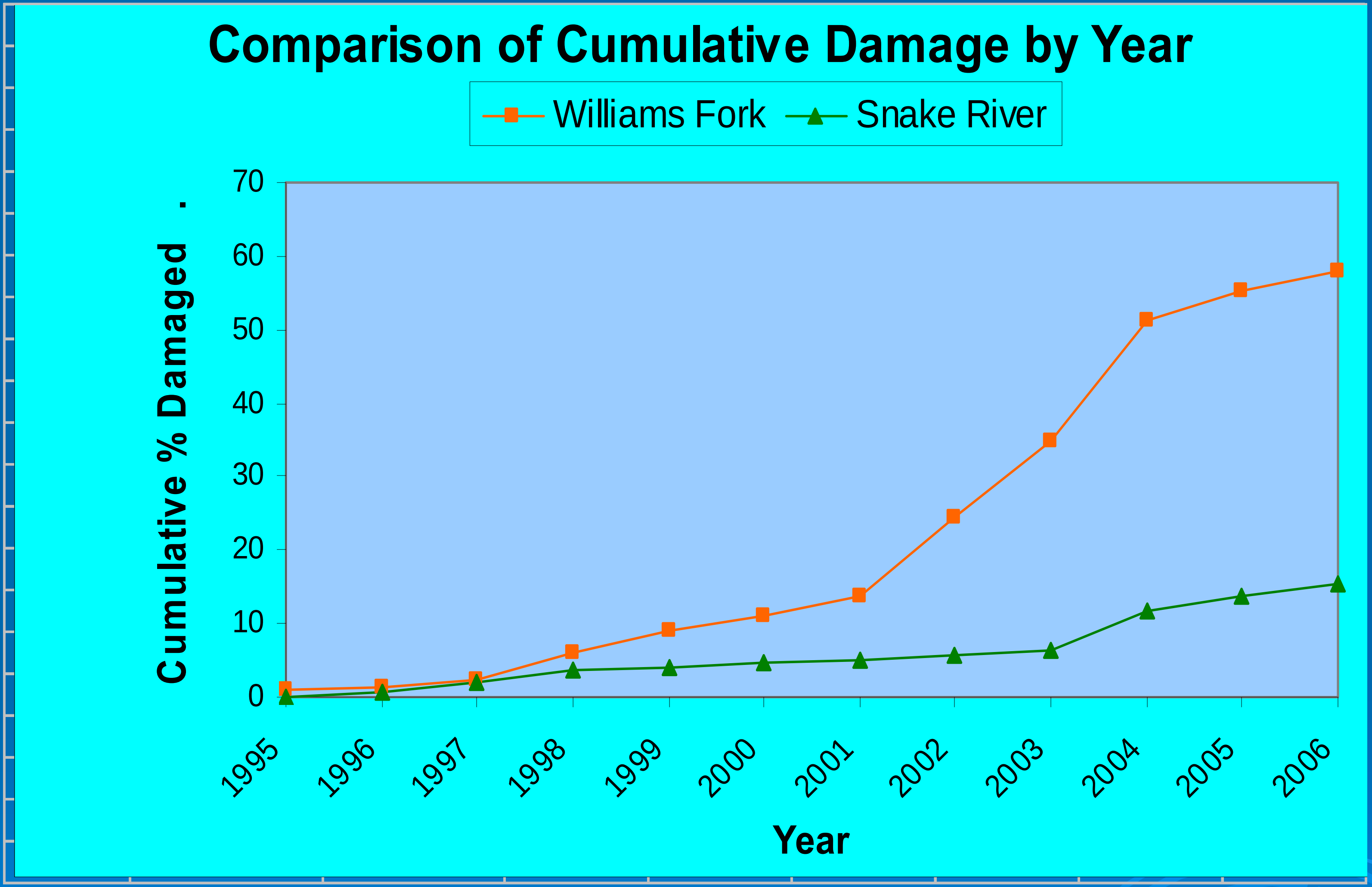
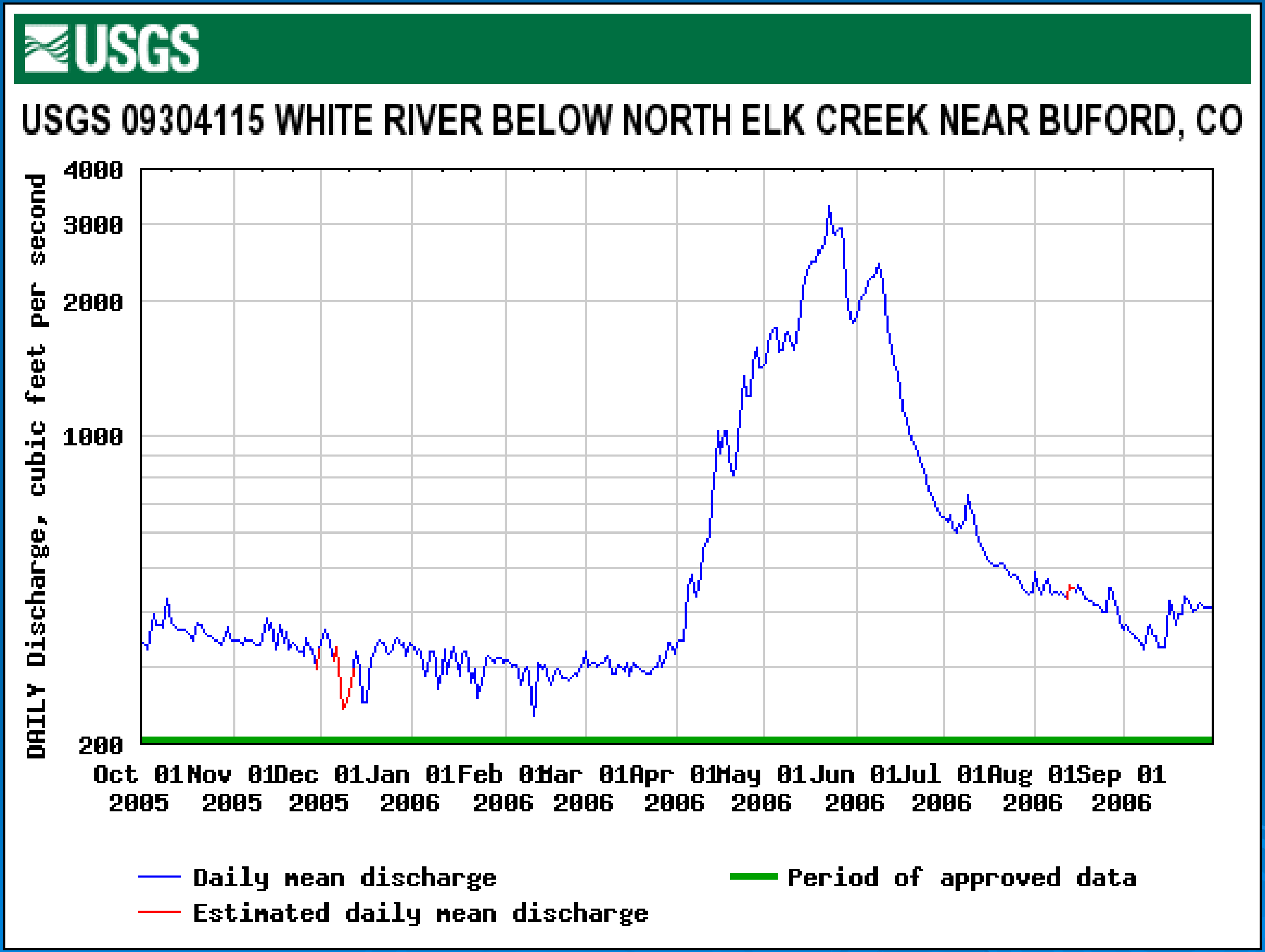


Cumulative Insect Damage, 1995-2007
Rivers, Streams
Watershed Boundary

0 1.5 3 6 9 12 Kilometers

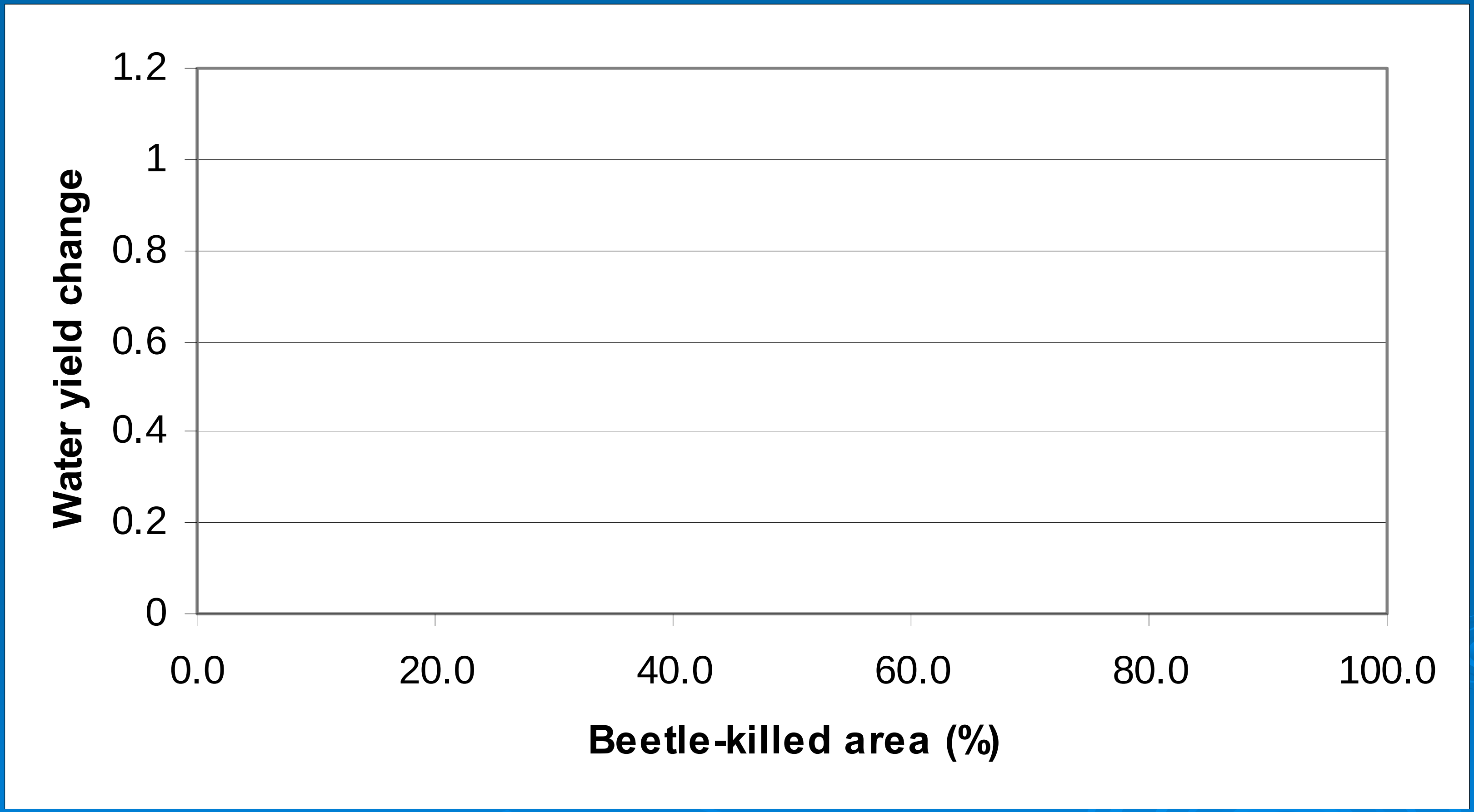


Comparison of Cumulative Damage by Year
Williams Fork
Snake River
Cumulative % Damaged .
0
10
20
30
40
50
60
70
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
Year

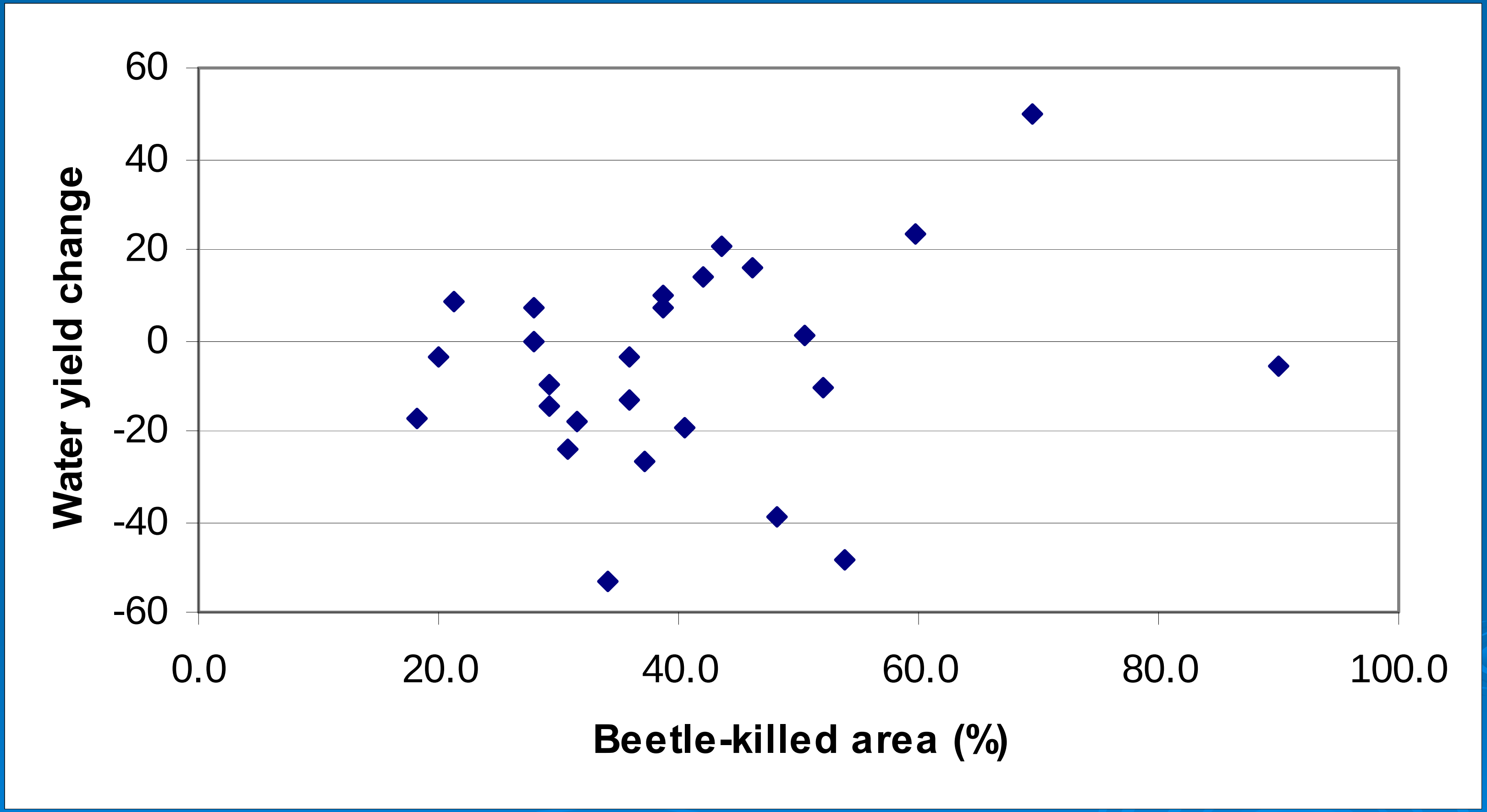


USGS
USGS 09304115 WHITE RIVER BELOW NORTH ELK CREEK NEAR BUFORD, CO
DAILY Discharge, cubic feet per second
4000
3000
2000
1000
200
Oct 01 2005
Nov 01 2005
Dec 01 2005
Jan 01 2006
Feb 01 2006
Mar 01 2006
Apr 01 2006
May 01 2006
Jun 01 2006
Jul 01 2006
Aug 01 2006
Sep 01 2006
Daily mean discharge
Estimated daily mean discharge
Period of approved data

Annual water yield change

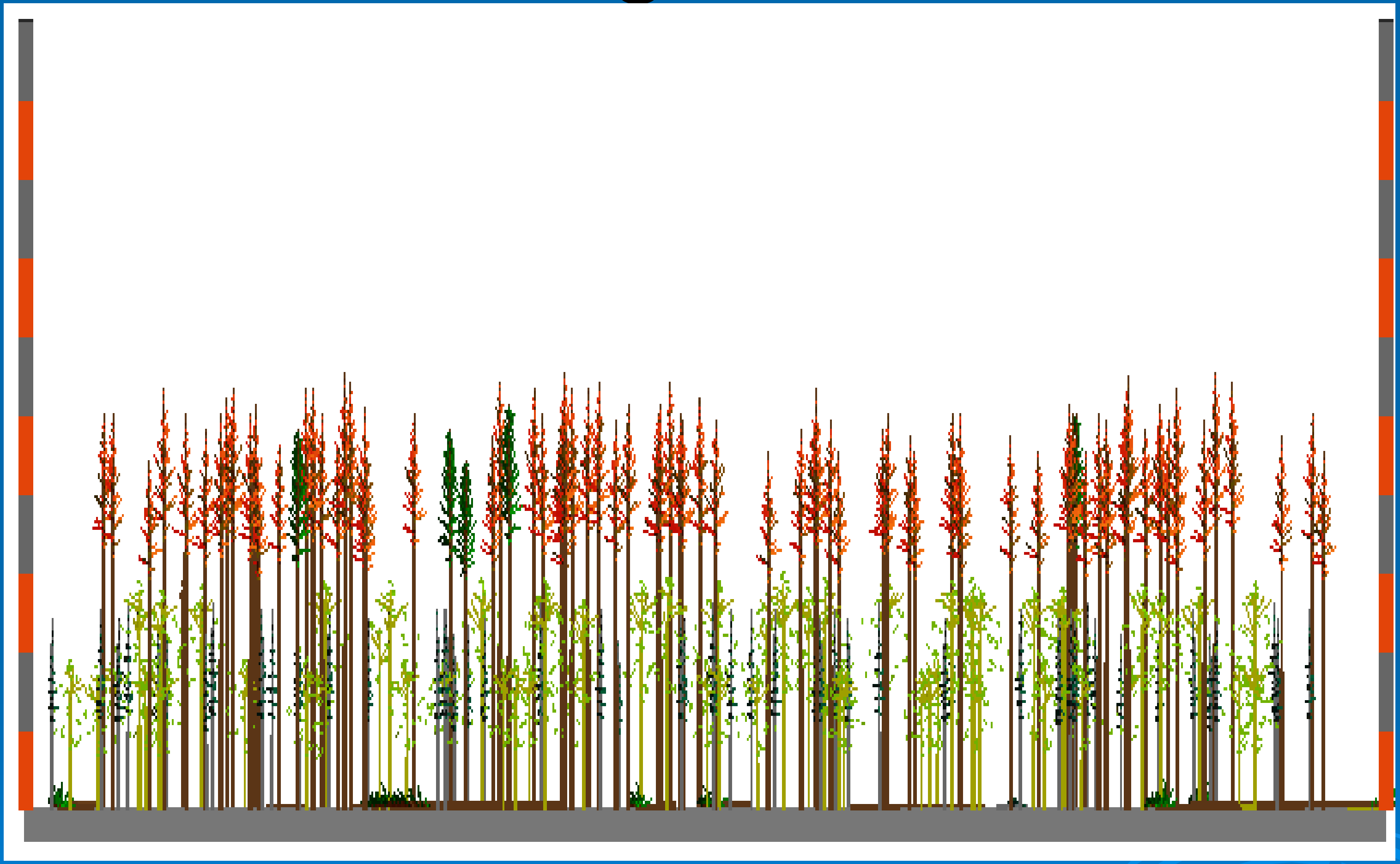


Annual water yield change



Even-aged forest

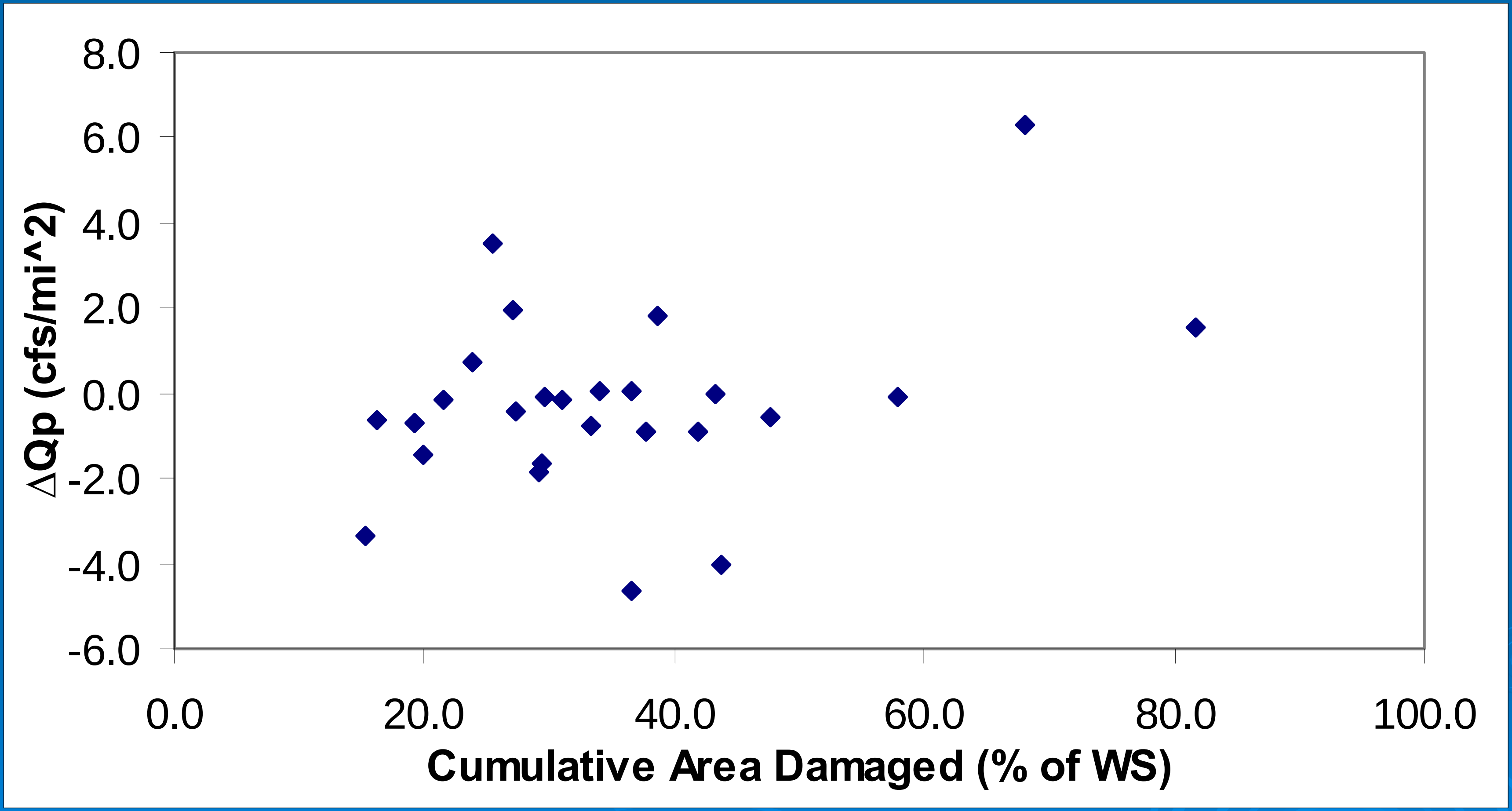
Uneven-aged forest



Water yield increases

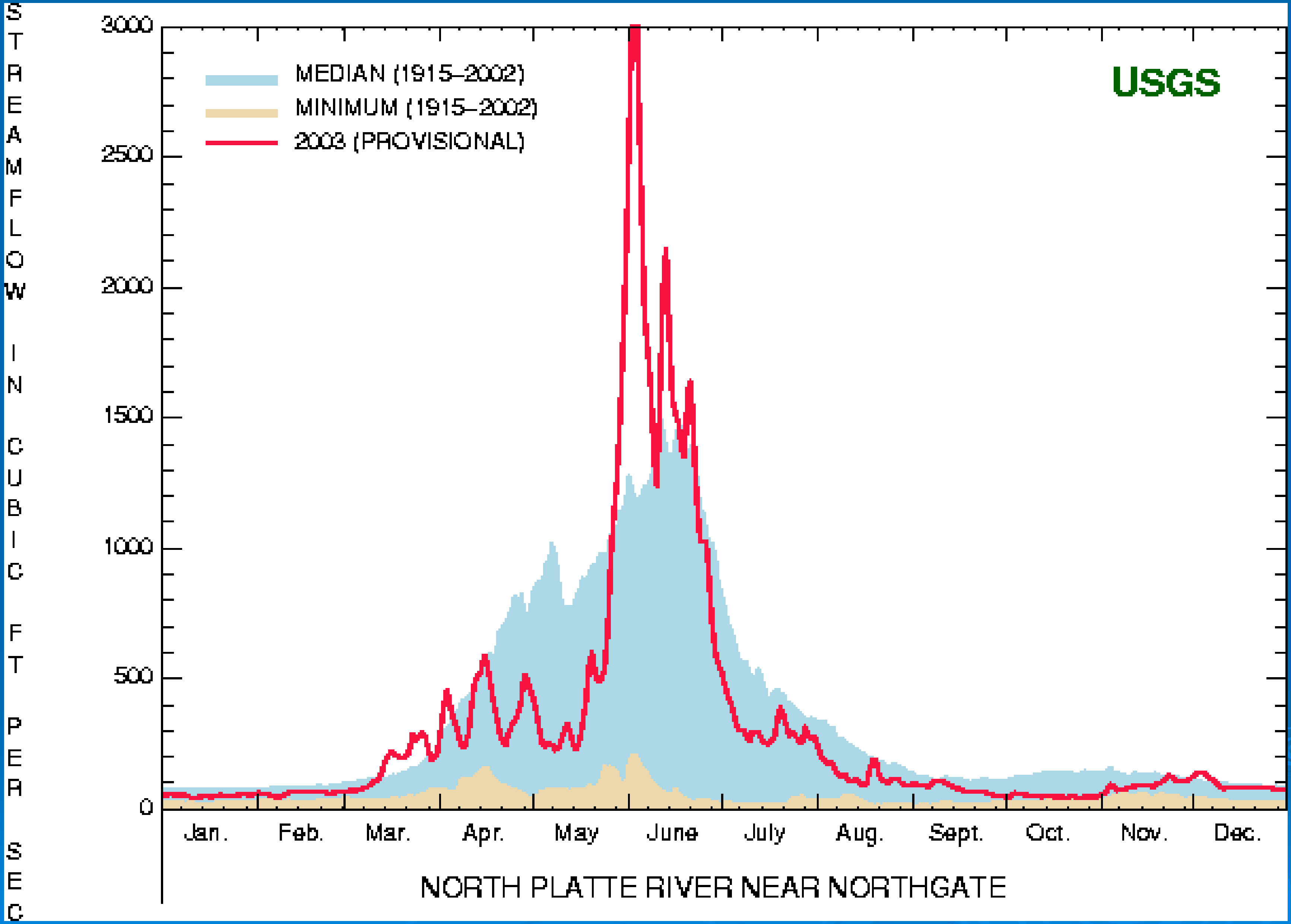
- Even-aged stands
  - Decreased interception and evapotranspiration
  - Increased water yield
- Uneven aged stands
  - Regeneration or release of understory
  - No change in net precipitation
  - No increase in water yield

Change in peak flow

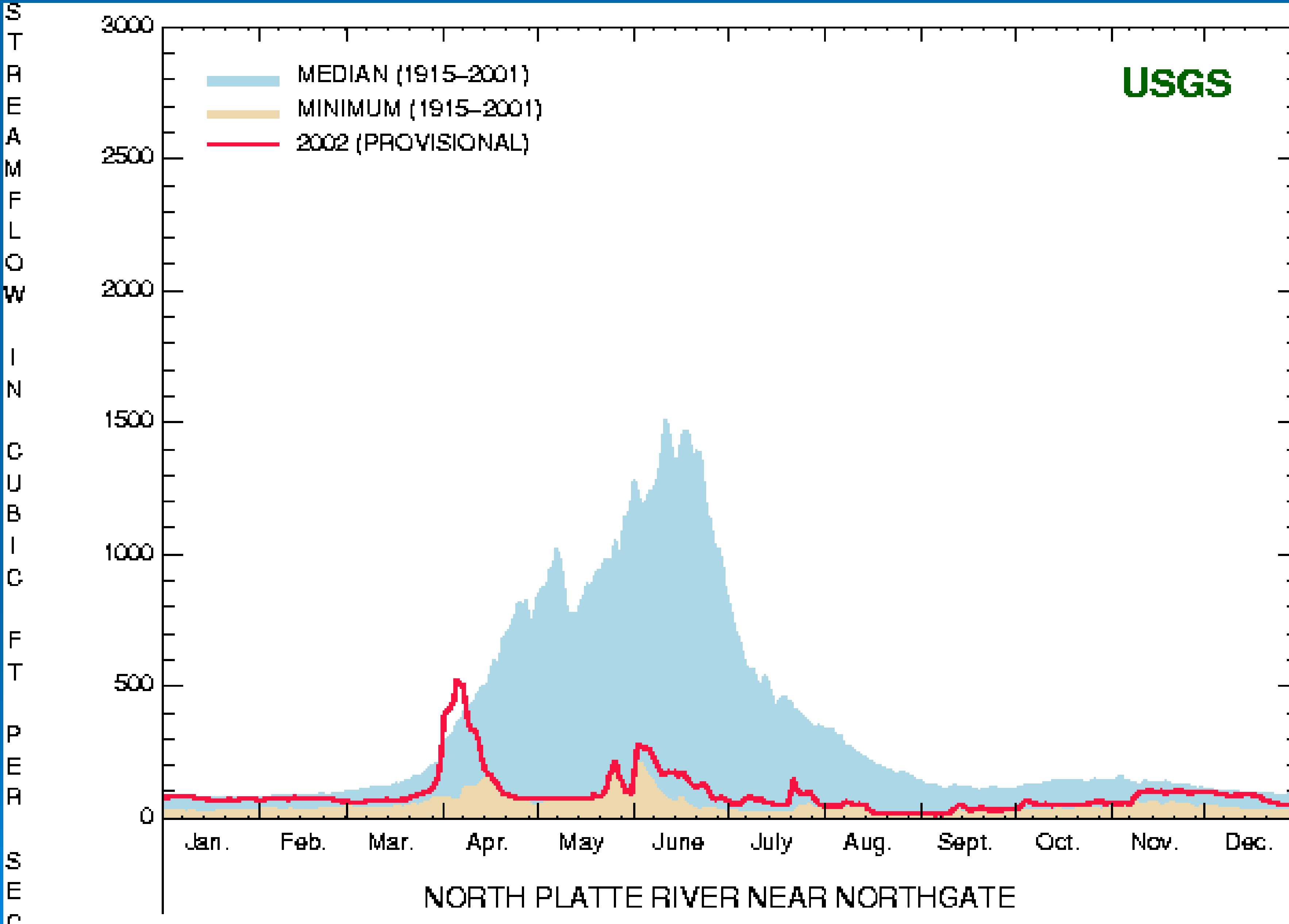


Water yield change detection

- Recognize significant changes in annual hydrograph in Rocky Mountains
- Precipitation is lower (slightly)
- Runoff is earlier
- Runoff peaks are higher, lower, or stay the same
- Changes in all hydrograph metrics



STREAMFLOW IN CUBIC FT PER SEC
3000
2500
2000
1500
1000
500
0
MEDIAN (1915–2002)
MINIMUM (1915–2002)
2003 (PROVISIONAL)
USGS
Jan.
Feb.
Mar.
Apr.
May
June
July
Aug.
Sept.
Oct.
Nov.
Dec.
NORTH PLATTE RIVER NEAR NORTHGATE



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Jan.
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Sept.
Oct.
Nov.
Dec.
NORTH PLATTE RIVER NEAR NORTHGATE

Move to plot level studies

- Water resources response at watershed level too variable
- Move to plot or stand level
  - Measure snow pack accumulation
  - Thermal properties
  - SWE and snowmelt generation

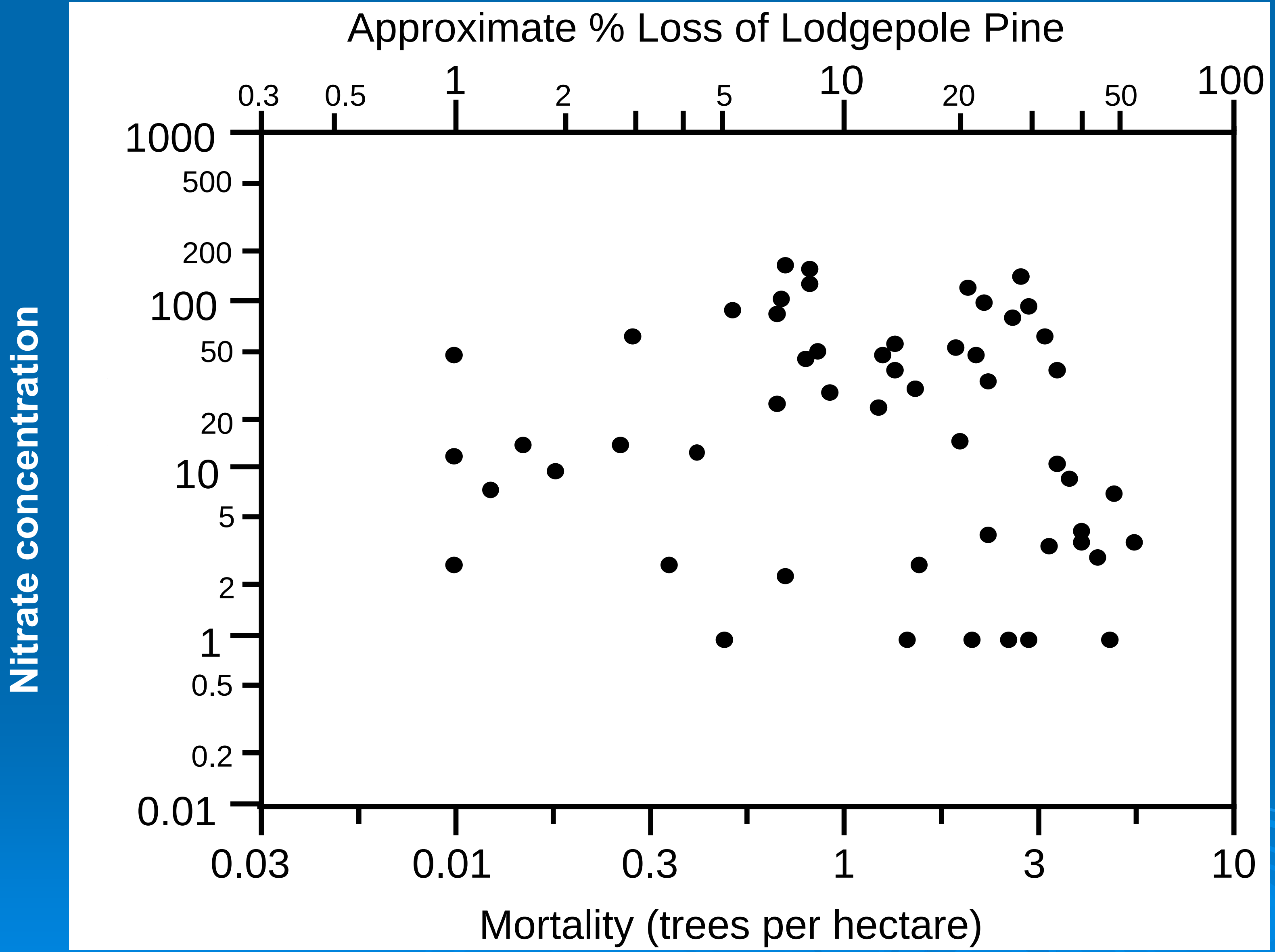
Water quality effects

- Few studies of beetle kill on water quality
- Previous efforts suggest a nitrogen response
- Nitrogen response may be from lack of processing atmospheric inputs

- Can use the effect of timber harvesting on water quality as analogue?

Water quality

- Background concentrations of nitrate are low, rarely above 10 ueq L^{-1}
- A 15-20 tree gap increased soil water nitrogen – nitrification
- Nitrogen responses to timber harvesting
- Plot increases often not measured at watershed level



Rhoades, McCutchan, et al., in prep.

Water quality

- Large addition of litter (leaf fall)
- Increased litter decomposition rates
- Foliage leaching, both on tree and forest floor
- Increased organic compound flux
- Potential increase in metal migration

Water quality concerns

- Increased primary productivity
- Increased color
- Aesthetic issue
- Increased water treatment costs
- Increased organics may result in TTHM precursors

Beetle Management Plan

- Timber salvage sales
- Hazardous fuel reduction
- Forest health spraying
- Hazard tree reduction

Timber harvesting

- Hydrologic responses
  - Decreased interception
  - Increased water yield
  - Increased snowmelt rates
  - Soil compaction - roads and tractor trails – surface runoff
  - Management activities >beetles?

Timber harvesting

- Institutional constraints
  - Congressional designation
  - Roadless areas
  - Harvest unit size nte 16 ha
  - Wildlife habitat
    - Federally threatened Canada lynx
- Economics
- Physical constraints
  - Slopes >35%
  - Wetlands

Opening size and catch efficiency

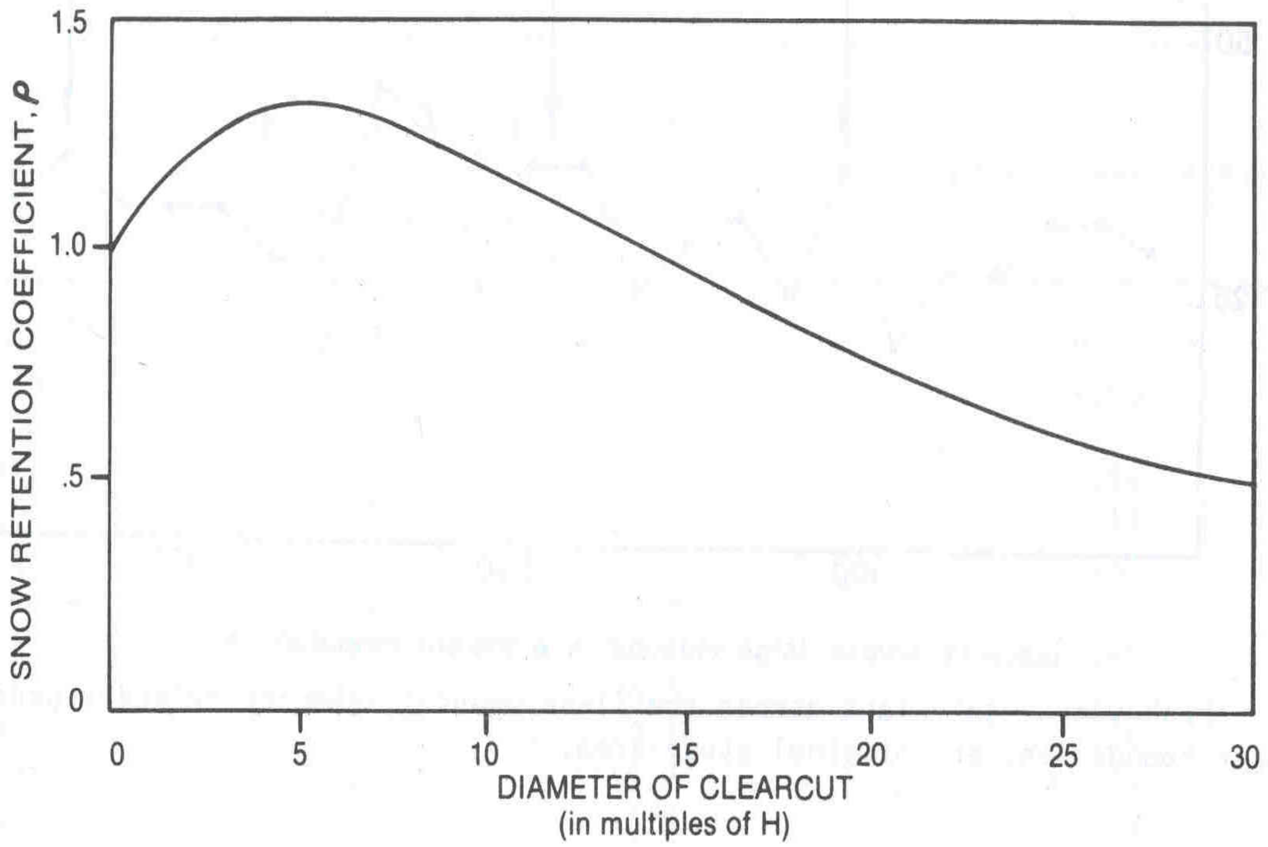


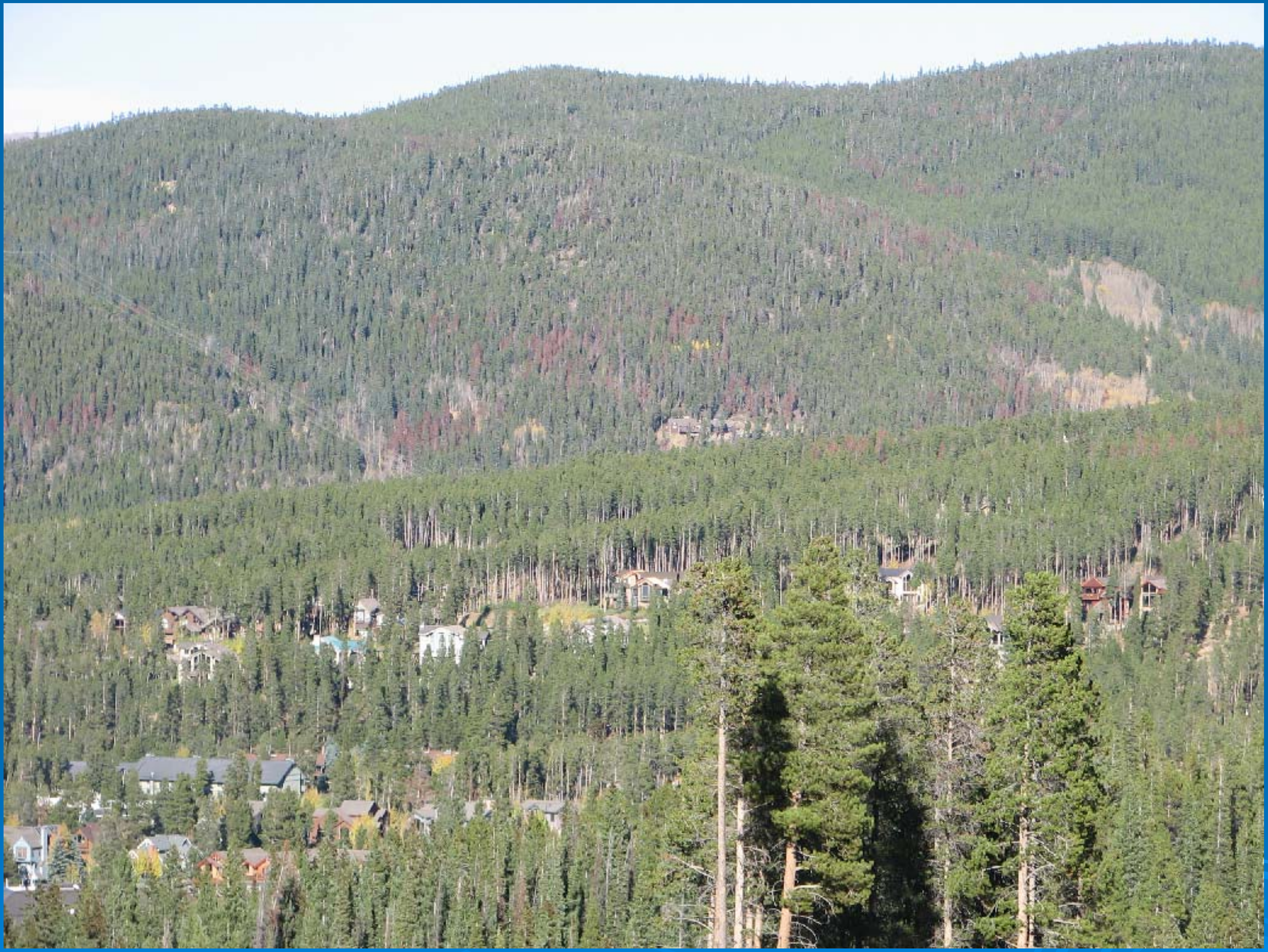
Figure 2.--Snow retention as a function of clearcut size. H is height of surrounding trees (Troendle and Leaf, 1980).

Source: Troendle and Meiman 1984


Slash piles

Hazardous Fuel Reduction

- Wildland urban interface
  - Mechanical treatment
  - Timber harvesting
  - Aggressive treatments on private property
  - Increased fire risk after beetle kill not supported by literature



Forest Health Spraying

- On the ground spraying
  - Carbaryl or Permethrin
- High value areas
  - Campgrounds, picnic areas, trailheads, scenic corridors, power lines
- Insecticide is expensive to apply
- More excursions found in surface waters


UGA2252036

Hazard tree reduction

- Improve public safety
- Too little to have an effect on beetles
- Too little to have an effect on water resources

Summary

- Water resource responses are variable
- Efforts to control outbreaks have failed
- Socio-economic not ecological crisis
- Retain or create diverse forest structure include areas of dead trees
- Not always harvest as large clearcut
- Adaptive management

Recommendations

- Better mapping of forest regeneration with and without timber harvesting
- Assess fire risk for various forest conditions
- Measure on-site meteorological conditions
- Use nested gauges to quantify streamflow changes and cumulative effects
- Increase water quality sampling