Silvicultural Herbicides and Their Effects on Water Quality and Aquatic Organisms: An Overview

Forest Vegetation Management Conference, Wilsonville, Oregon

Ashley Coble, Forest Watershed Scientist, NCASI

NCASI

IMPACT. SCIENCE. SOLUTIONS.

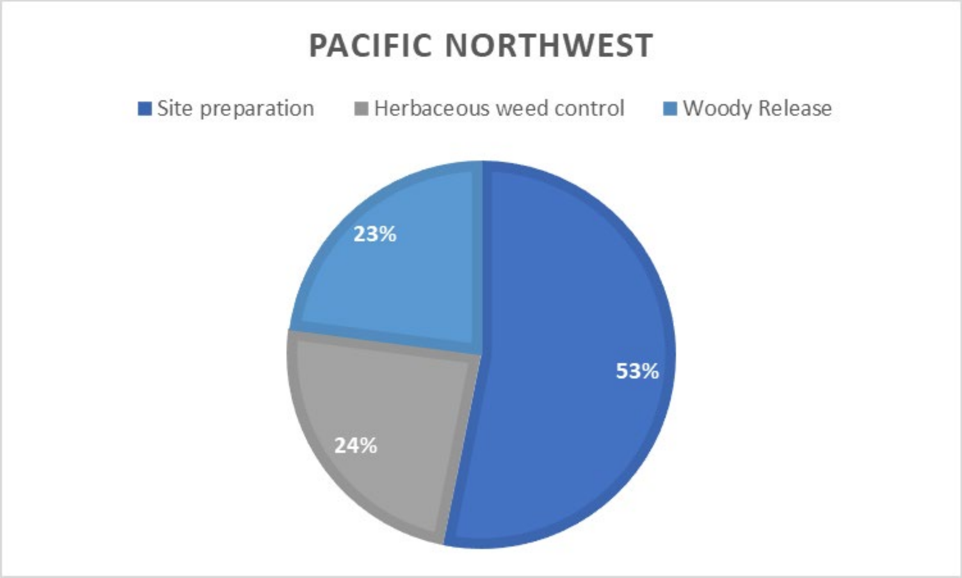
5 DECEMBER 2018

Herbicides: An Effective Forest Management Tool

- Effective tool to enhance seedling survival, early stand productivity, and control non-native invasive species

- Applied ≤ 3 times during a typical rotation (20 to 50 years) on private forestlands (Shepard et al. 2004; NCASI 2015)

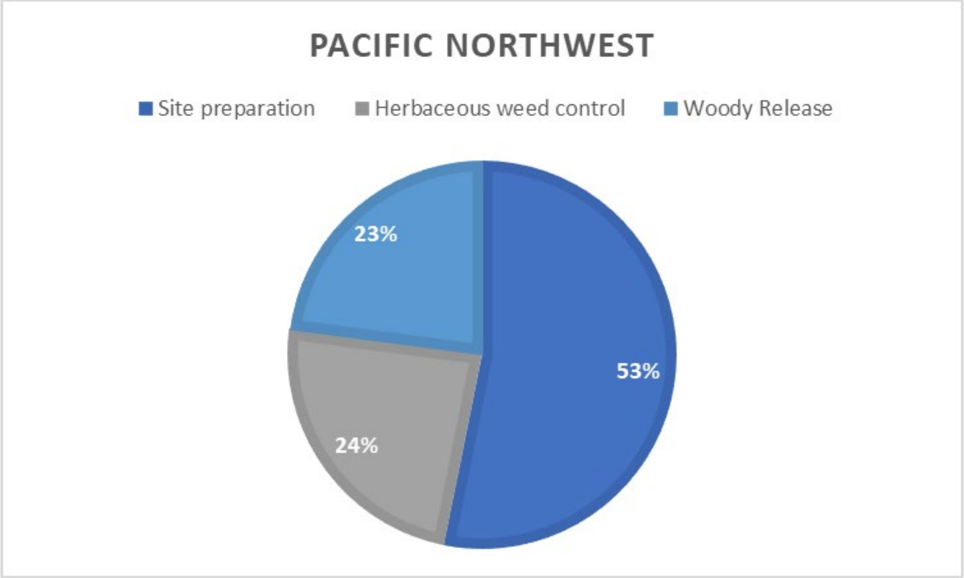
Purpose of herbicide application in 2011
(NCASI Survey, 2015)



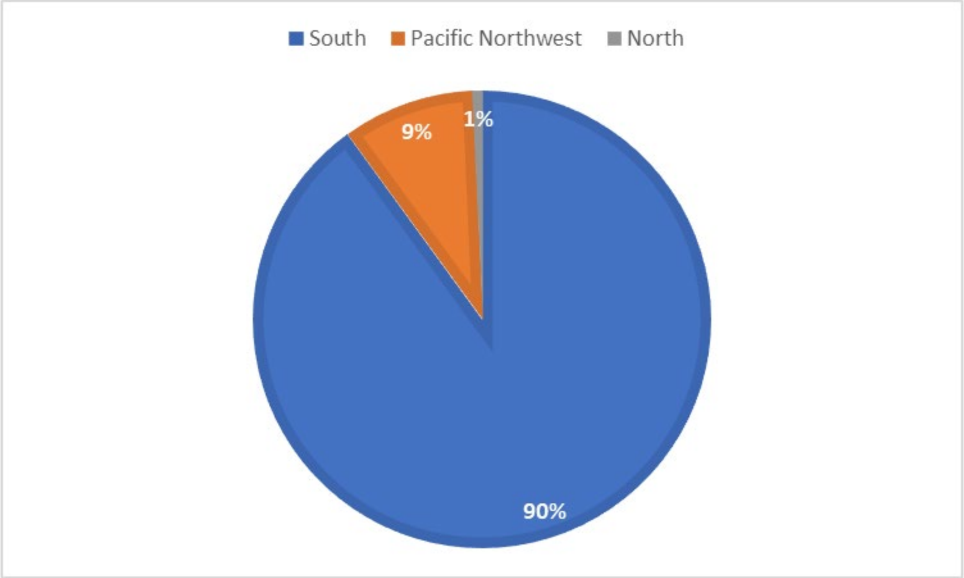
Herbicides: An Effective Forest Management Tool

- Effective tool to enhance seedling survival, early stand productivity, and control non-native invasive species
- Applied ≤ 3 times during a typical rotation (20 to 50 years) on private forestlands (Shepard et al. 2004; NCASI 2015)
- In 2011 herbicides were applied to 4.4% of the area under management on US private timberlands (NCASI 2015)

Purpose of herbicide application in 2011 (NCASI Survey, 2015)

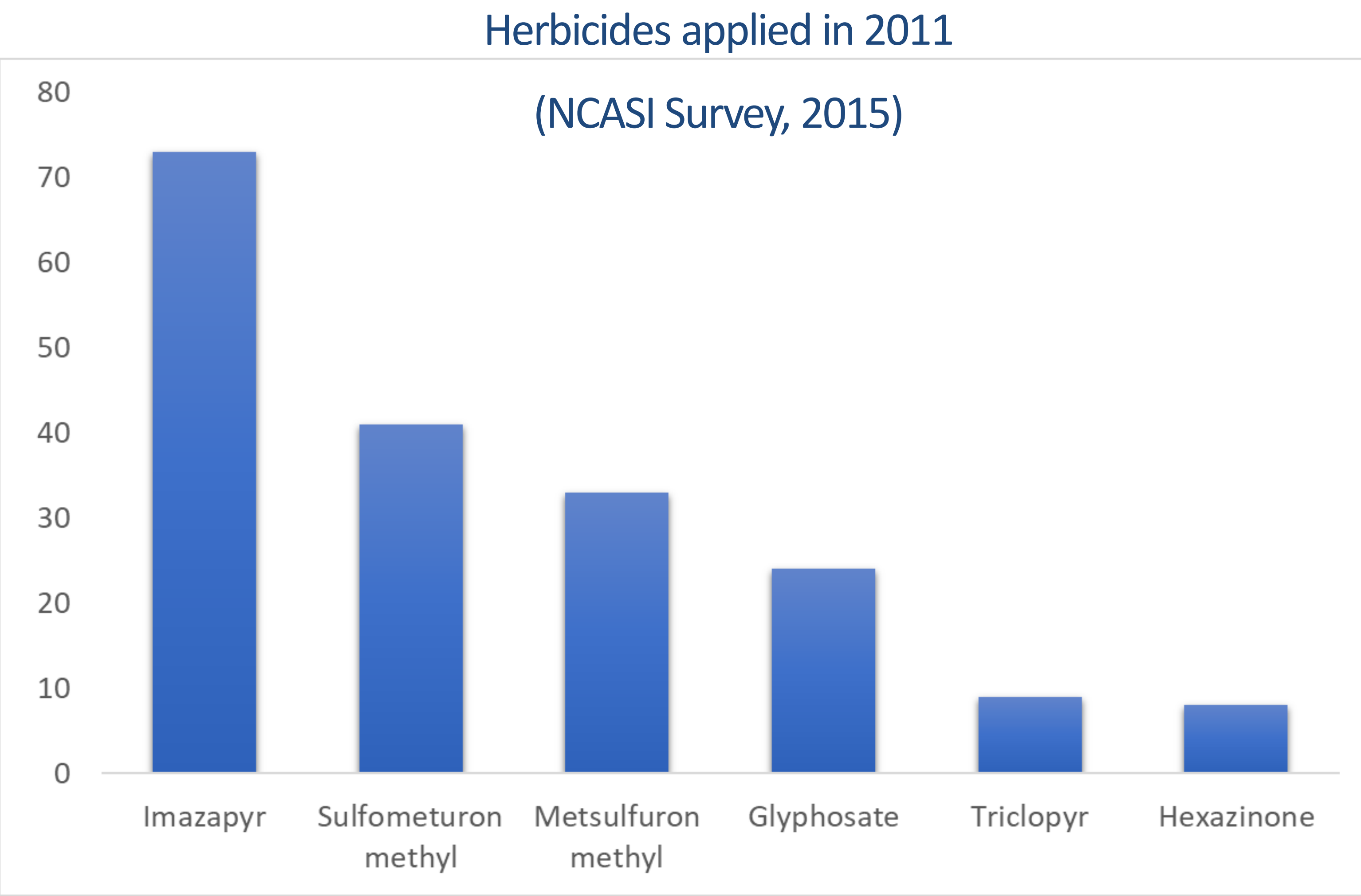


Distribution of herbicides applied in 2011 (NCASI Survey, 2015)



Commonly Applied Silvicultural Herbicides

- Percentages do not add up to 100% because applied in mixtures
- All other herbicides are negligible on a national basis
- Atrazine, which is used only in the PNW, was applied to ~16% of treated acreage



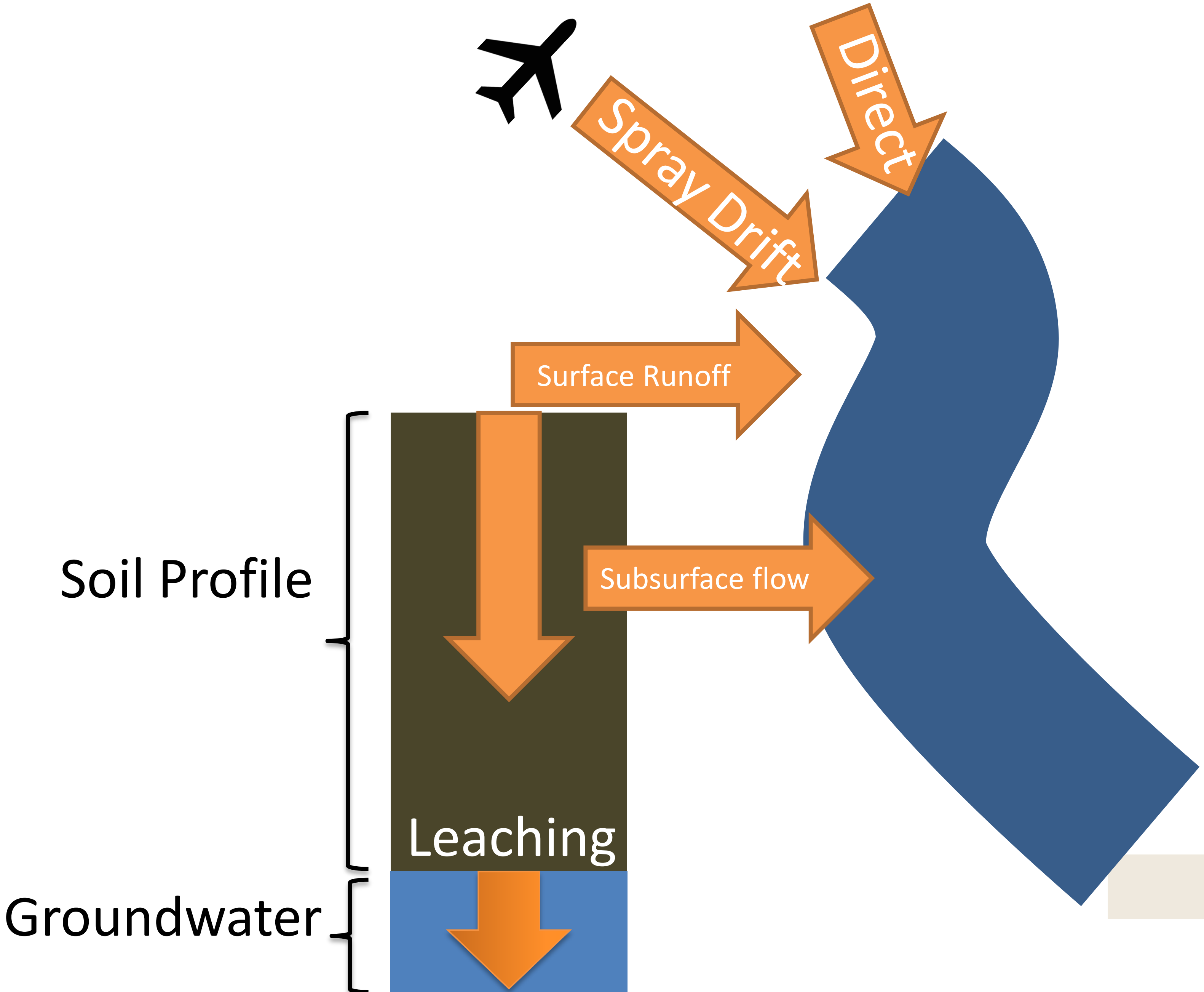
Research Questions

- Are BMPs effective at keeping herbicides out of surface water within and immediately outside the treated areas?
- If herbicides enter surface water are aquatic organisms at risk?

Potential Pathways into Surface Water

- Inadvertent application to stream channels (Direct)
- Spray drift
- Surface runoff
- Leaching through the Soil Profile (subsurface connectivity)

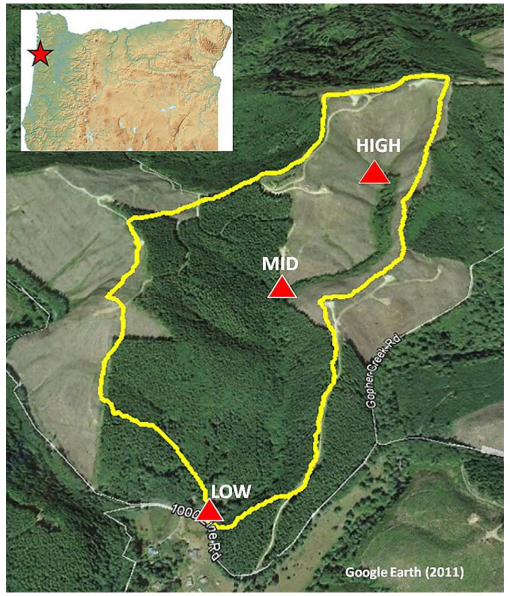
Potential Pathways for Chemicals to Enter Surface Water



Regulations to Prevent Herbicides from Entering Waterways

- Regulations on product labels (USEPA, FIFRA)
  - Prohibit application, mixing and loading with a certain distance of surface water
  - Specify weather conditions, and maximum application rates and heights

- Forestry best management practices (BMPs)
  - No-spray riparian buffer zones (RMAs, SMZs)
    - Vegetation intercepts drift
    - Slows/absorbs runoff
    - Protects streams from direct spray
    - Sediments and chemicals are retained in riparian zone

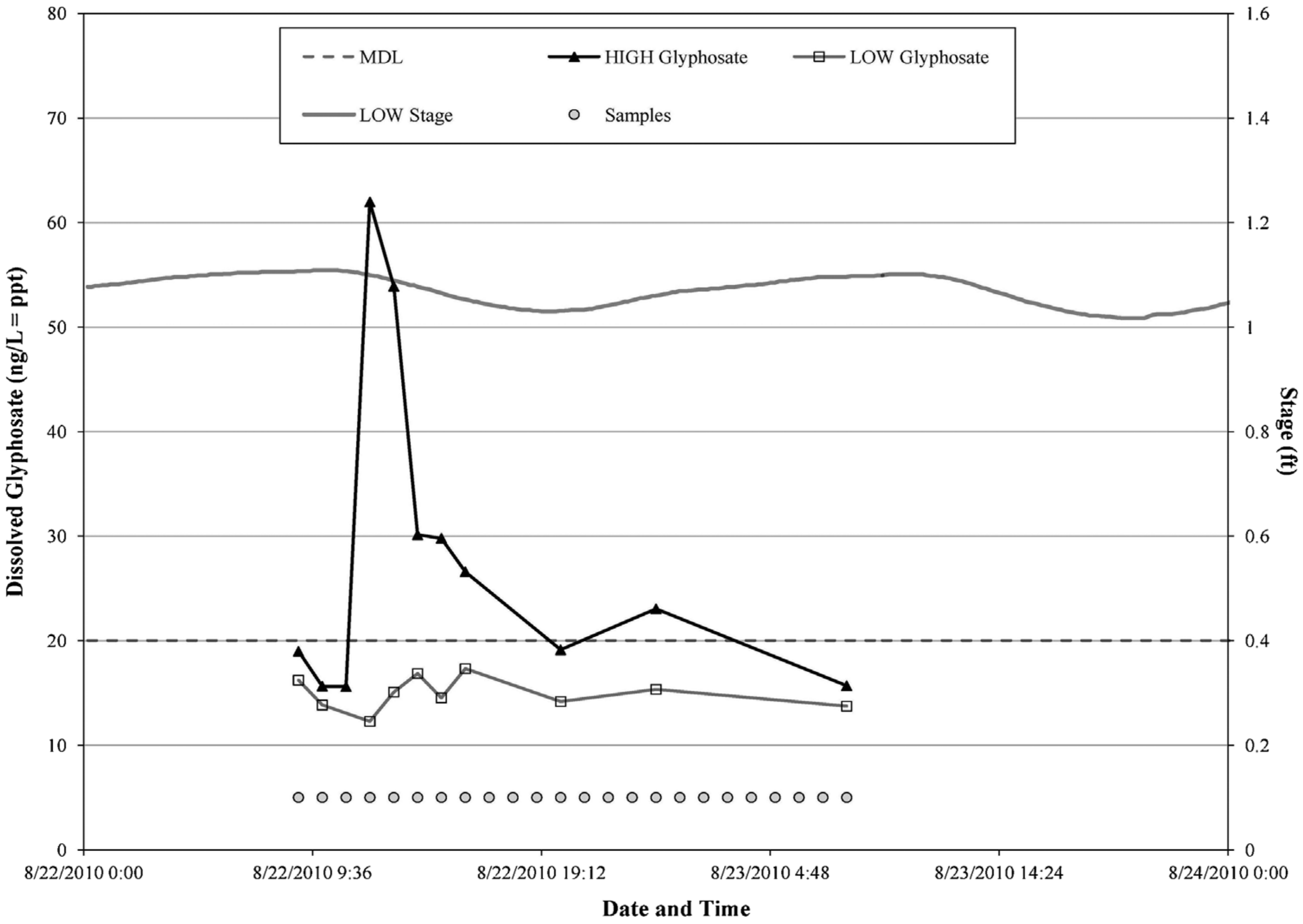


Louch et al. 2017

Direct Application or Spray Drift: Typical Observations

- Maximum herbicide concentrations in streams may occur during or immediately after application (prior to storm event)

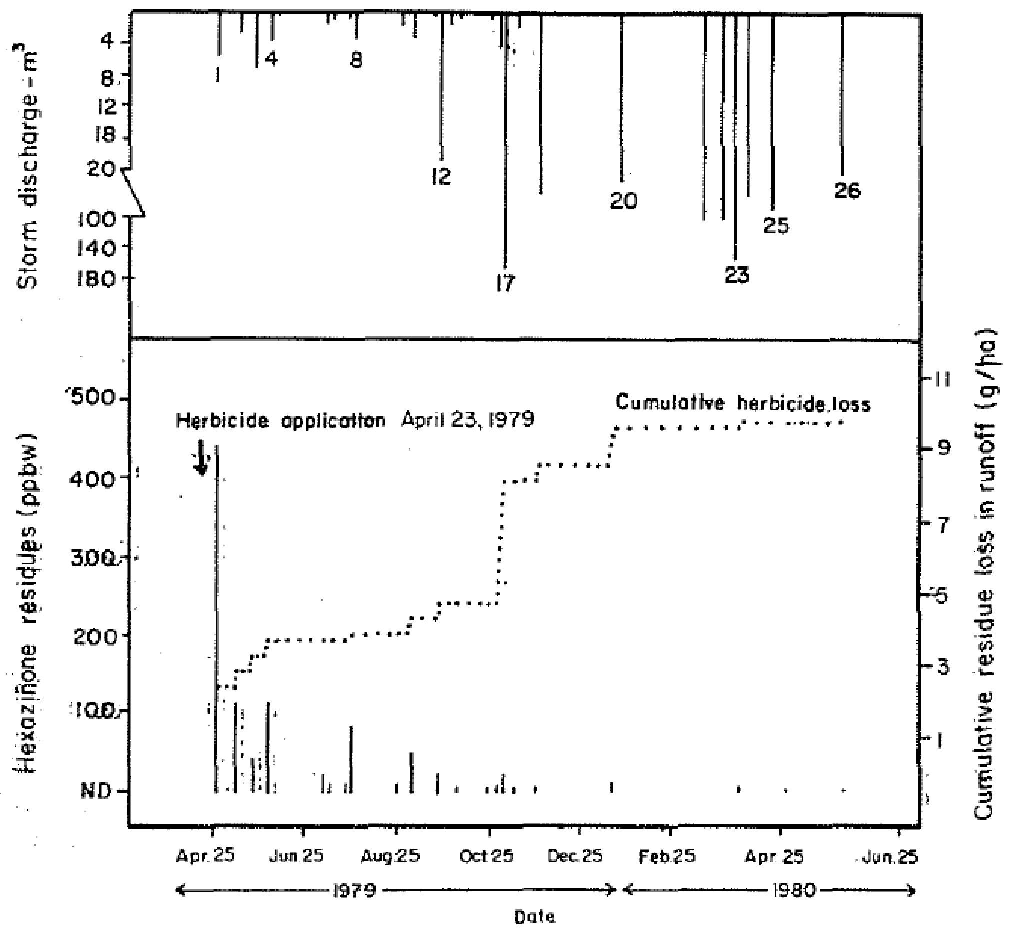
- In a review across 5 contemporary studies detectable levels of herbicide during or immediately after were found in 4 of 5 sites (Tatum et al. 2017)



Louch et al. 2017

Surface Runoff: Typical Observations

- Maximum herbicide concentrations in streams may also occur in the first storm event
- Concentrations decrease with each subsequent storm event until the 4th or 5th post-application event, when below detection



Neary et al. 1983

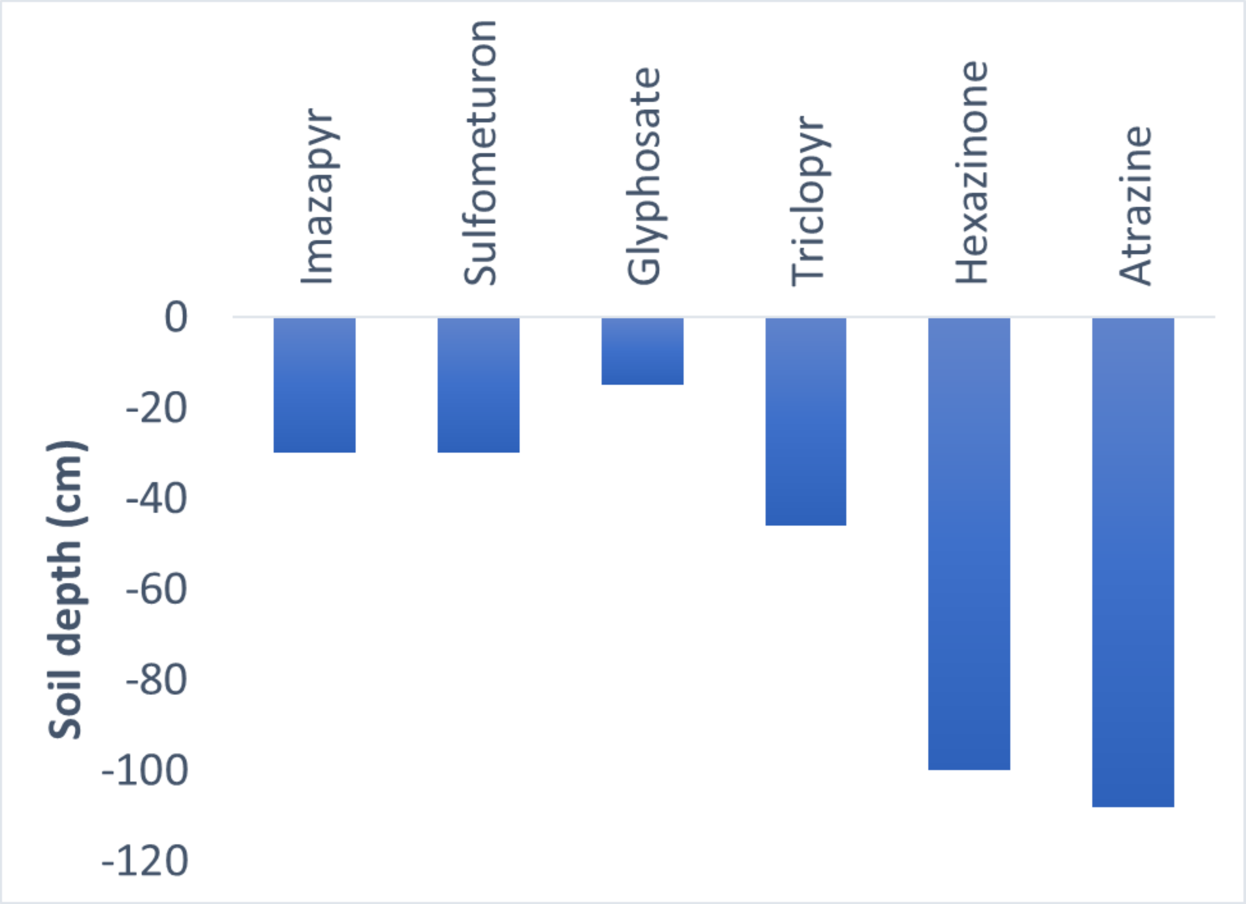
Leaching through Soil Profile & lateral movement (not typically observed in field)

- Majority of herbicide never reaches the mineral soil horizon (Newton et al. 1984, Newton et al. 1994, Thompson et al. 1997)

- When herbicides reach the soil surface do not penetrate deeply into soil profile or move laterally through soil profile (subsurface flow)

- During baseflow, herbicide concentration are typically near or below detection limits

Maximum Soil Depth Observed (in a single study)



Bartell et al. 1992, Newton et al. 1984, Roy et al. 1989, Feng and Thompson 1990, Thompson et al. 2000, Michael 1986, Michael 2003, USEPA 1998, Kookana et al. 2010, Neary et al. 1985, Feng et al. 1992

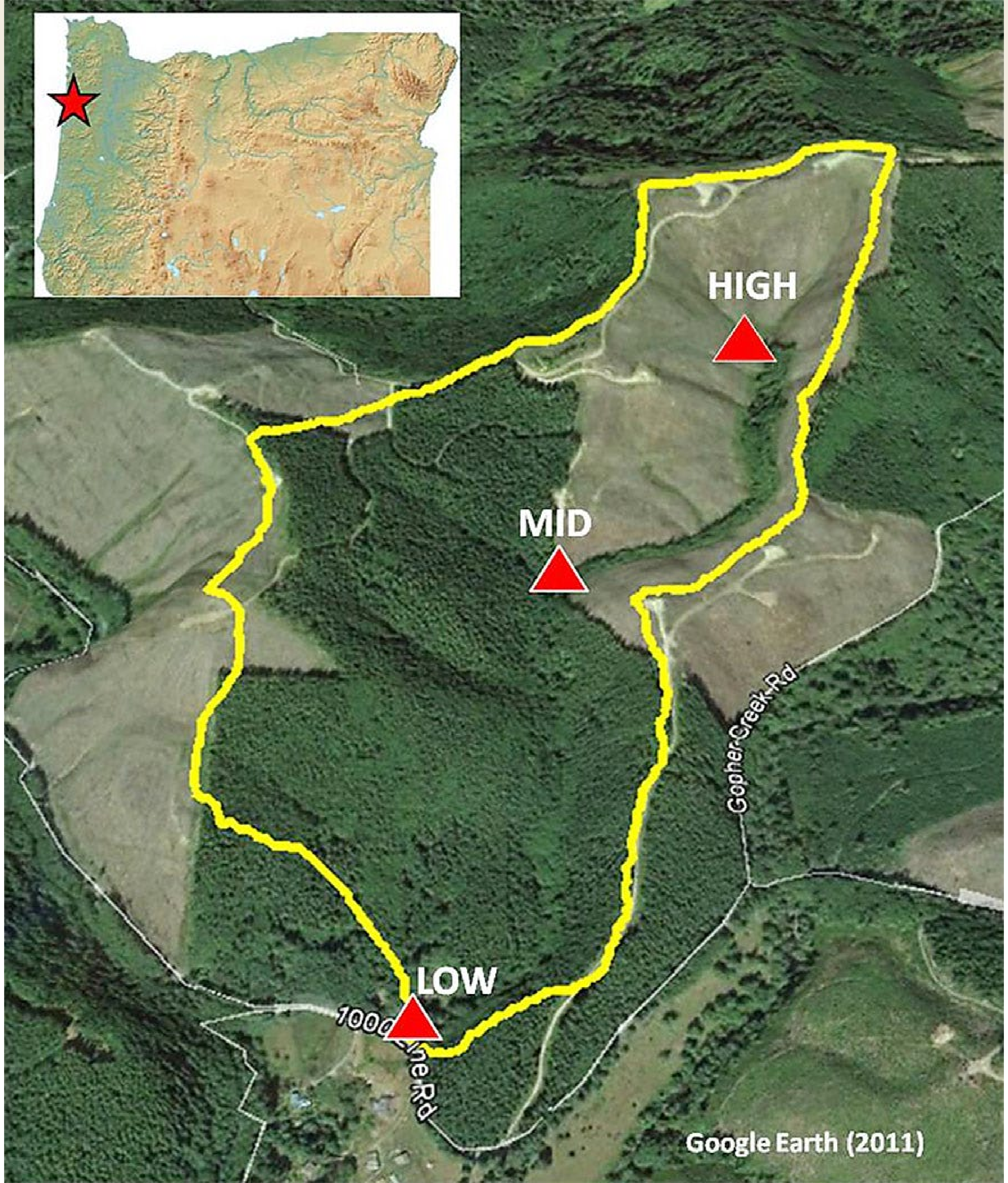
Silvicultural herbicides not likely to enter groundwater

- For commonly applied herbicides most studies have failed to detect herbicide residues in groundwater (Neary and Michael 1989, Bush et al. 1990, Neary et al. 1993, Griffiths et al. 2017)

- On occasion some highly soluble herbicides have been observed following application to forest lands including hexazinone, atrazine, and picloram.
  - Of these only hexazinone is commonly applied across the US

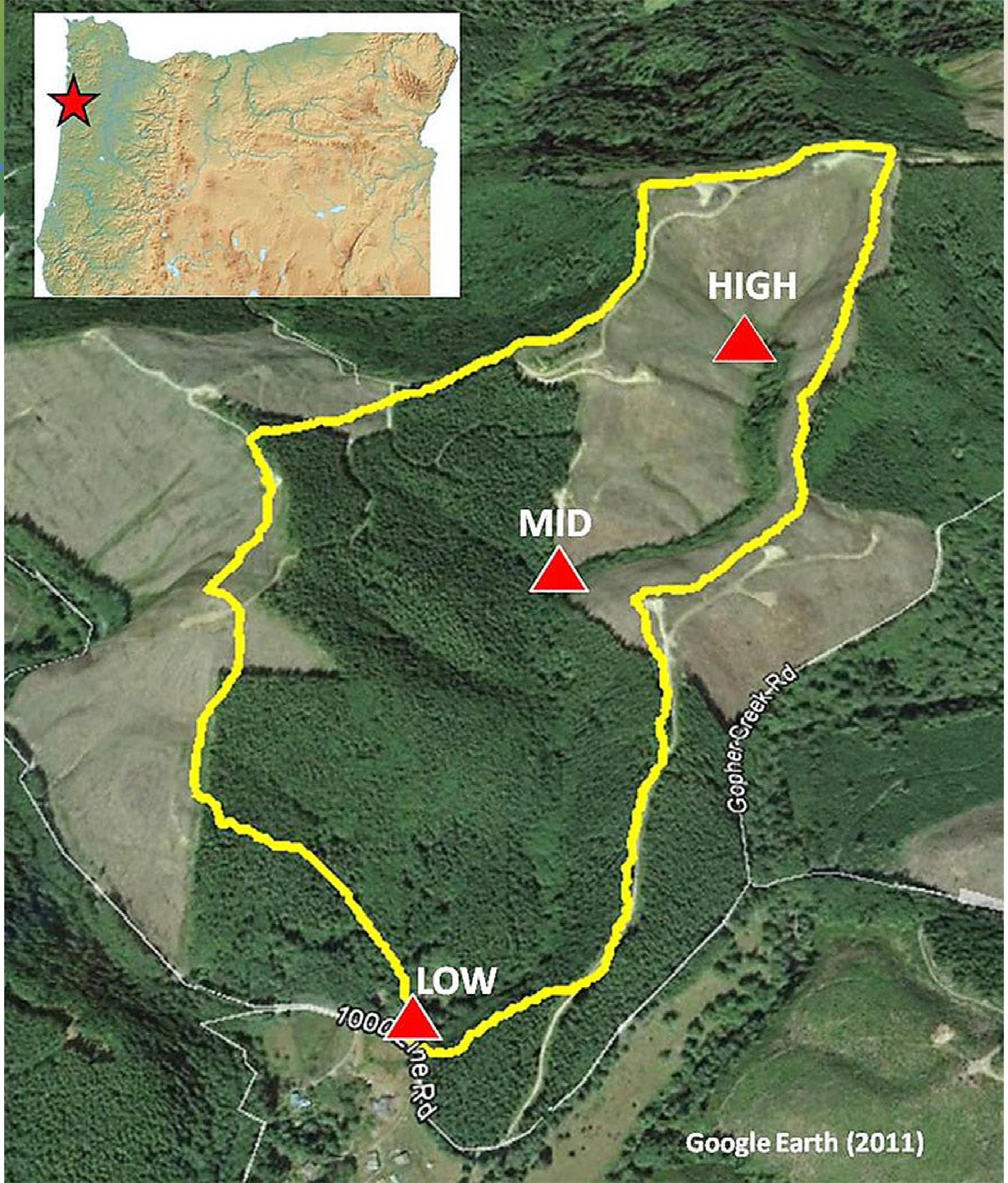
Needle Branch Study Oregon Coast

Triangles indicate locations of stream gauges



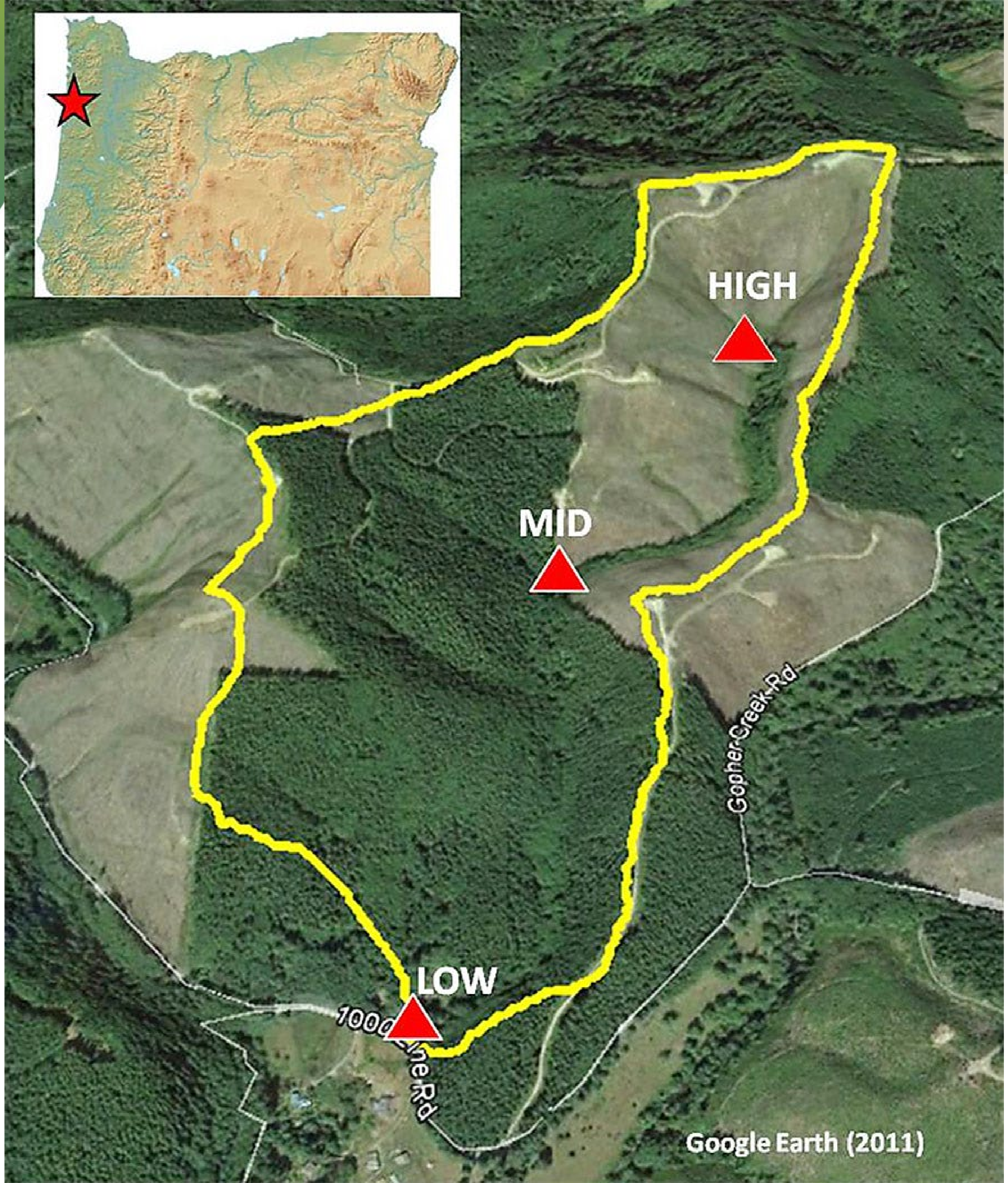
Needle Branch Study Site

- Louch, J., Tatum, V., Allen, G., Hale, V. C., McDonnell, J., Danehy, R. J., & Ice, G. (2017). Potential risks to freshwater aquatic organisms following a silvicultural application of herbicides in Oregon's Coast Range. *Integrated environmental assessment and management*, 13(2), 396-409.



BMPs employed

"HIGH" at fish/no fish interface. No riparian buffer above this point but spray boom on stream side turned off during herbicide application
(half-boom spraying)



BMPs employed

"MID" at base of harvest area, stream is fish-bearing below HIGH. Riparian buffer of 50 ft and no-spray buffer of 60 ft between MID & HIGH

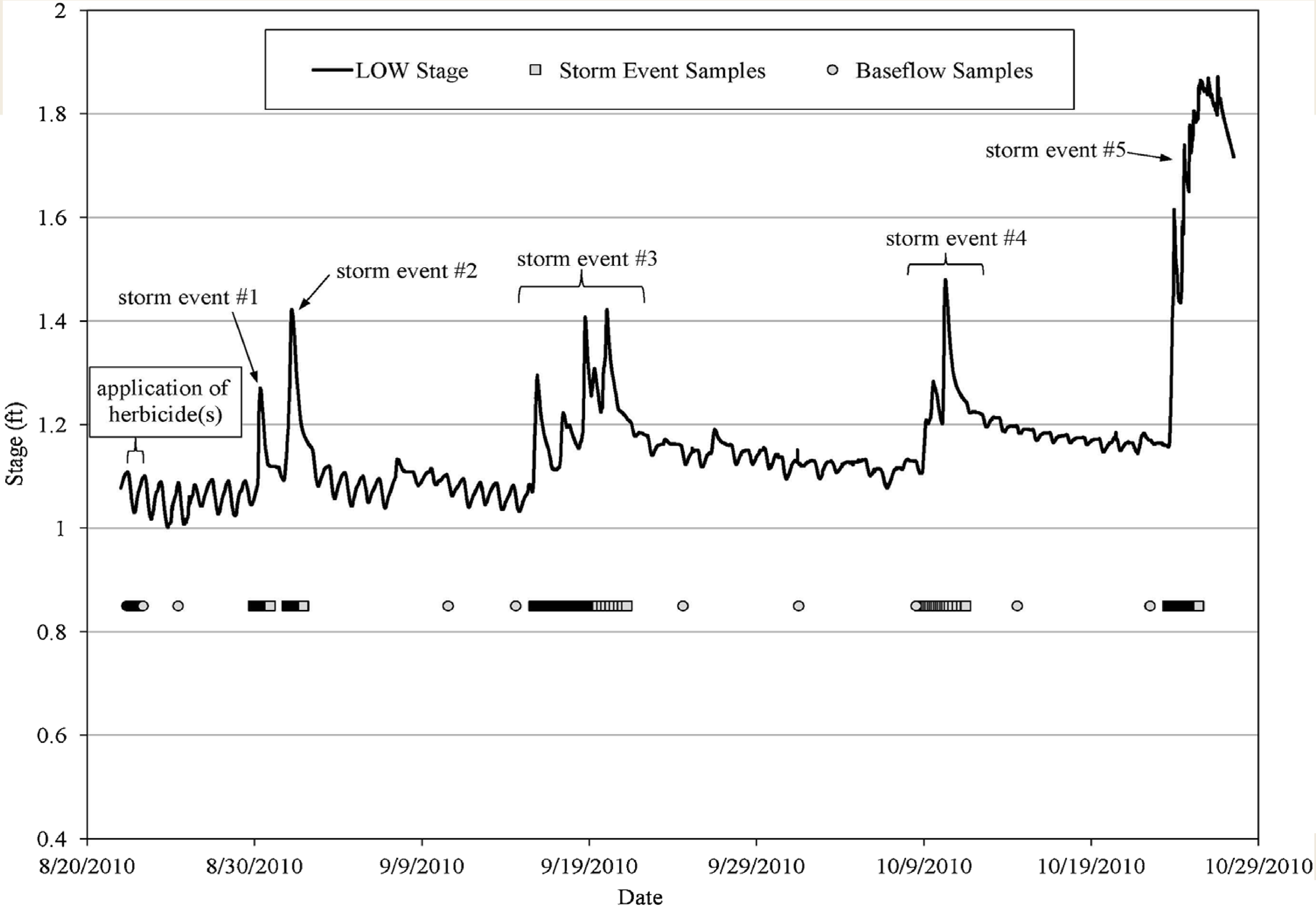
Needle Branch Herbicide Application

- Site prep application made in August, 2010
  - 48 oz/acre Accord® XRT II (a.i. glyphosate)
  - 12 oz/acre Chopper® Gen 2 (a.i. imazapyr)
  - 4 oz/acre Sulfomet® Extra (a.i. sulfometuron methyl & metsulfuron methyl

Water Sample Collection

- Day of Application
  - Application started11:38 am, finished 1:18 pm
  - Samplers programmed to collect one sample/hour from 9 am to 8 am next morning
- Storm events
  - Samplers manually triggered when predicted
    - Sampling frequency set based on predicted storm intensity and duration
- Baseflow
  - Grab samples collected about once/week

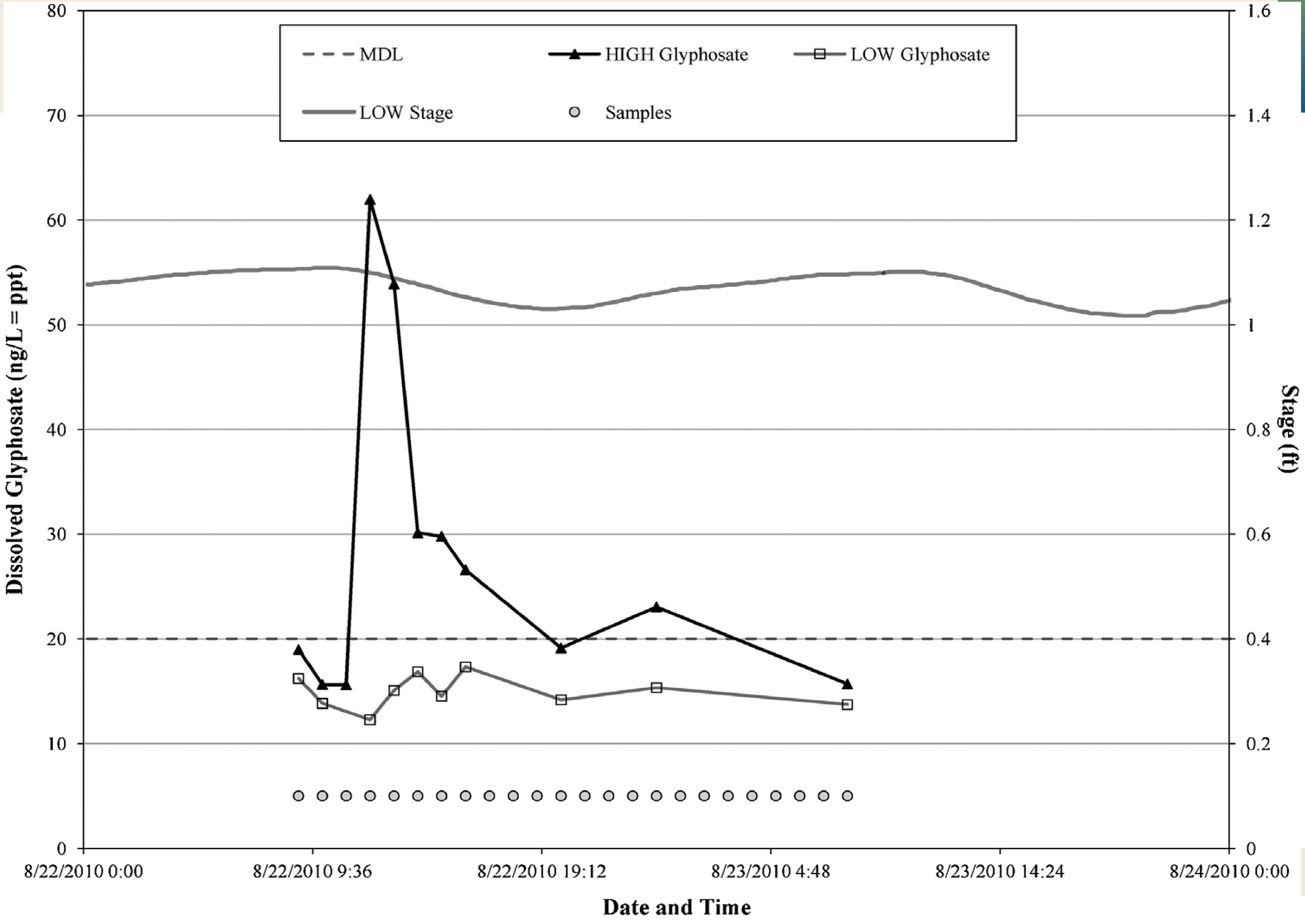
NCASI
IMPACT. SCIENCE. SOLUTIONS.



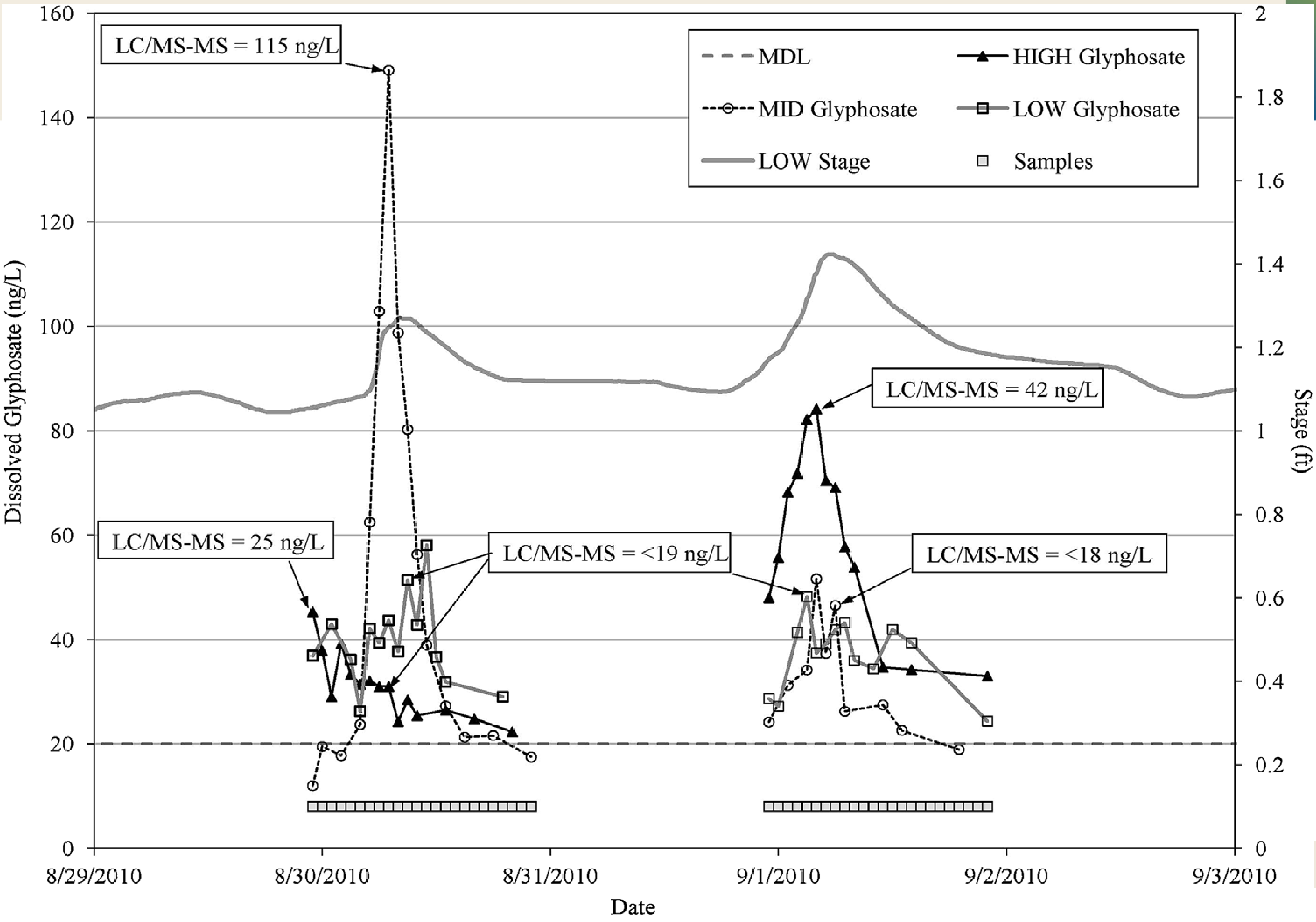
Measured Herbicide Concentrations

- Imazapyr, sulfometuron methyl, metsulfuron methyl never detected in any sample at concentration above the minimum detection limit
  - Imazapyr – 0.6 µg/L
  - SM – 0.5 µg/L
  - MM – 1.0 µg/L
- Maximum glyphosate concentration detected was 0.115 µg/L at MID during first post-application storm event

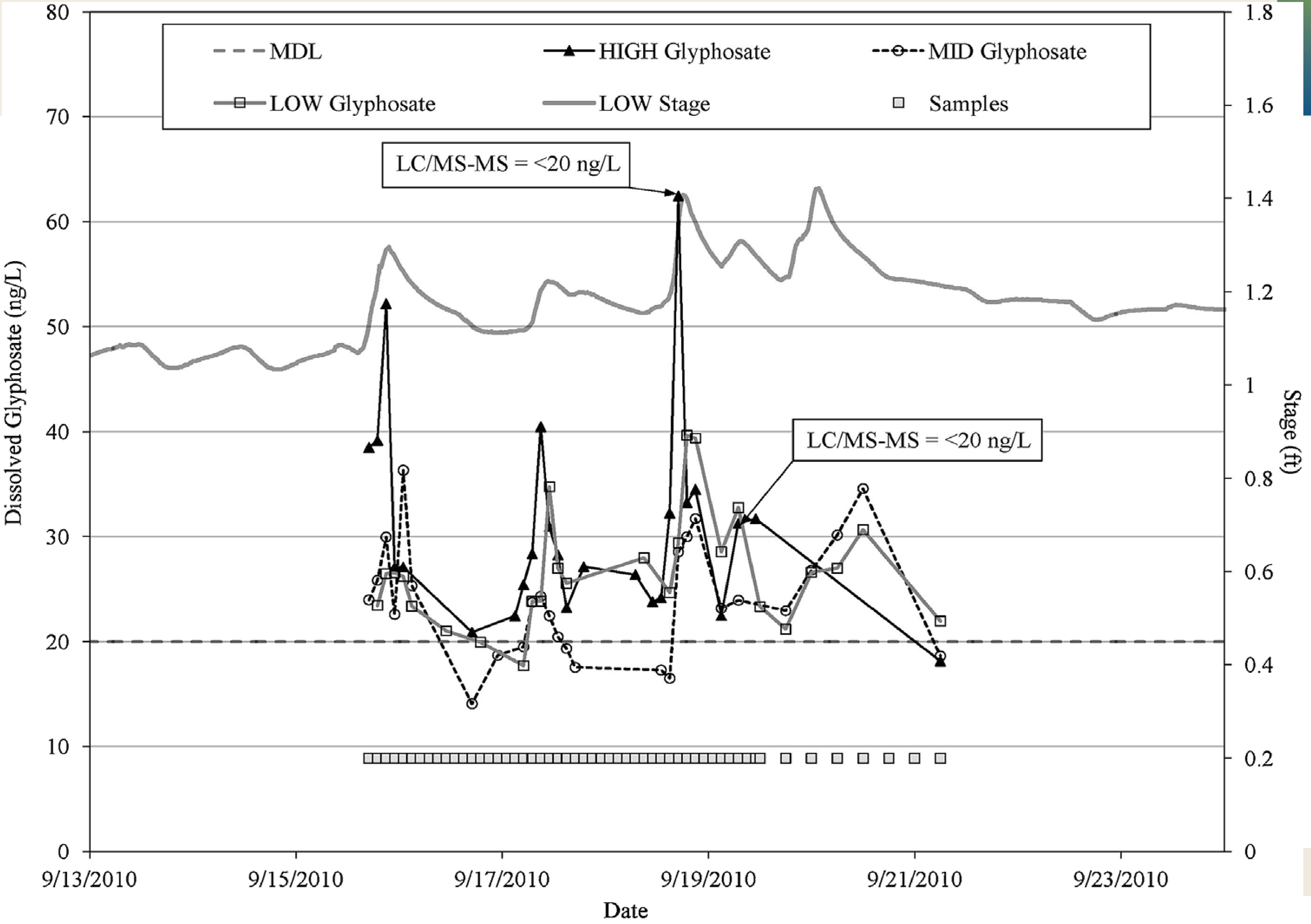
During and immediately post-application



First two post-app storm events



Third post-application storm event



Maximum single-sample concentrations of herbicides in stream water across 5 contemporary field studies

	Herbicide Concentration (µg/L)				
Herbicide	**Needle Branch**	**Alto**	**Dry Creek**	**Bay of Plenty - Pekepeke**	**Eastern Bay of Plenty**
	Oregon, USA	Texas, USA	Georgia, USA	New Zealand	New Zealand
Glyphosate	0.149	10.0	Not applied	Not applied	Not applied
Hexazinone	Not applied	29.9	7.7	230	5.3
Imazapyr	Below detection	39.3	7.3	Not applied	Not applied
Metsulfuron Methyl	Below detection	Not applied	Not applied	Not applied	Not applied
Sulfometuron Methyl	Below detection	2.5	1.24	Not applied	Not applied

Tatum et al. 2017

How long did elevated concentrations persist?

- Typically elevated concentrations were short-lived: < 24 hours across studies
- Storm triggered sample collection often ended before herbicide concentrations returned to background levels – data gaps

	Needle Branch	**Alto**	**Dry Creek**	**Bay of Plenty - Pekepeke**	**Eastern Bay of Plenty**
	Oregon, USA	Texas, USA	Georgia, USA	New Zealand	New Zealand
Time (h)	10-12 h	<24 h	12-24 h	<8 h	<8 h

Are these levels a concern for aquatic organisms?

Using Risk Quotients (RQs)

- RQs are used by EPA for screening level risk assessments in the pesticide registration and registration review processes.
  •Screening level assessments are conservative, first-step assessments
  - If potential issues are identified, then there is additional assessment and analysis

Site Specific RQs (Modified from typical EPA methods)

- Instead of using modeled peak concentrations to calculate RQs, use actual herbicide concentrations in stream water from forestry field studies
- Still a conservative assessment
  - Use maximum single-sample concentrations
  - Peak exposure duration in “real life” much shorter than exposures used in toxicity testing from which toxicity values are derived

NCASI
IMPACT. SCIENCE. SOLUTIONS.

Imazapyr Risk Quotient across US studies

Imazapyr RQs calculated using toxicity values for the most sensitive species and the peak imazapyr concentration reported in the Alto study

LOC = level of concern

RQ Type	RQ	RQ value that reaches a LOC
Acute – aquatic animals	0.0019 (fish) 0.0051 (amphibian) 0.0006 (aquatic invertebrate)	>0.5
Acute endangered species – aquatic animals	0.0019 (fish) 0.0051 (amphibian) 0.0006 (aquatic invertebrate)	>0.05
Chronic – all animals	0.00033 (fish) 0.00040 (aquatic invertebrate)	>1
Acute/Chronic Non-endangered or Endangered Plants	0.0034 (algae) **3.97 (macrophyte)**	>1

Sulfometuron Risk Quotient across US studies

Sulfometuron RQs calculated using toxicity values for the most sensitive species and the peak sulfometuron concentration reported in the Alto study and, for aquatic plants, the peak concentration reported in the Dry Creek study

RQ Type	RQ	RQ value that reaches a LOC
Acute – aquatic animals	0.00034 (fish) 0.00025 (amphibian) 0.0000042 (aquatic invertebrate)	>0.5
Acute endangered species – aquatic animals	0.00034 (fish) 0.00025 (amphibian) 0.0000042 (aquatic invertebrate)	>0.05
Chronic – all animals	0.0021 (fish) 0.000026 (aquatic invertebrate)	>1
Acute/Chronic Non-endangered or Endangered Plants	0.54 (algae - Alto) 0.27 (algae – Dry Creek) **20.83 (macrophyte - Alto)** **10.33 (macrophyte – Dry Creek)**	>1

LOC = level of concern

NCASI
IMPACT. SCIENCE. SOLUTIONS.

Glyphosate Risk Quotient across US studies

Glyphosate RQs calculated using toxicity values for the most sensitive species and the peak glyphosate concentration reported in the Alto study

LOC = level of concern

RQ Type	RQ	RQ value that reaches a LOC
Acute – aquatic animals	0.010 (fish) 0.013 (amphibian) 0.0067 (aquatic invertebrate)	>0.5
Acute endangered species – aquatic animals	0.010 (fish) 0.013 (amphibian) 0.0067 (aquatic invertebrate)	>0.05
Chronic – all animals	0.00039 (fish) 0.0002 (aquatic invertebrate)	>1
Acute/Chronic Non-endangered or Endangered Plants	0.083 (algae) 0.012 (macrophyte)	>1

Hexazinone Risk Quotient across US studies

Hexazinone RQs calculated using toxicity values for the most sensitive species and the peak hexazinone concentration reported in the Alto study

LOC = level of concern

RQ Type	RQ	RQ value that reaches a LOC
Acute – aquatic animals	0.00013 (fish) 0.00030 (amphibian) 0.00032 (aquatic invertebrate)	>0.5
Acute endangered species – aquatic animals	0.00013 (fish) 0.00030 (amphibian) 0.00032 (aquatic invertebrate)	>0.05
Chronic – all animals	0.0018 (fish) 0.0015 (aquatic invertebrate)	>1
Acute/Chronic Non-endangered or Endangered Plants	**4.40 (algae)** 0.427 (macrophyte)	>1

Site-Specific RQ Summary

- No risks to aquatic invertebrates, fish, or amphibians were identified, but the RQs indicate that potential risks to aquatic plants do exist

Is toxicity to aquatic plants likely to be an issue in actual practice?

- Are sensitive plants present in areas of streams where peak herbicide values are found?
  - Currently collecting data on this
- Toxicity tests from which toxicity values are derived use 5-14 days of continuous exposure.
  - Peak exposures in streams measured in hours, not days
  - Studies have shown that short exposures to very high concentrations can be tolerated
    - A study exploring this is ongoing
- Toxicity endpoint most commonly used is growth inhibition
  - Studies have shown that as long as the plant is not killed, growth generally rebounds rapidly once herbicide exposure ends

Questions?

Vickie Tatum, vtatum@ncasi.org

Ashley Coble, Forest Watershed Scientist

(541)752-8801
ext. 303

www.ncasi.org

acoble@ncasi.org

NCASI

IMPACT. SCIENCE. SOLUTIONS.