Fate of Herbicides in Carver Soil

Evaluation for Utility Rights-of-Way Herbicide Applications on Cape Cod Massachusetts

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Objective

- Evaluate the fate of herbicides used in utility rights-of-way: Process in upper part of soil!
- Address the specific situation in a common soil type on Cape Cod: Carver Soil
- Evaluate the effects on groundwater and surface water
  - Human health
  - Ecological (aquatic life) effects

Outline

- Herbicides used and their application rate
- Evaluate the fate in a Carver soil and exposure to underlying ground water
- Model simulations
  - Fate in soil
  - Groundwater exposure evaluation
  - Surface water exposure evaluation
- Comparison of simulated concentrations with:
  - Health-based standards
  - Aquatic life benchmarks

Herbicides and Methods Used

- Application method: Low-volume foliar
- Tank-mix with four herbicide products:
  - Arsenal (Imazapyr)
  - Accord (Glyphosate)
  - Krenite S (Fosamine)
  - Escort (Metsulfuron-methyl)
- Application rates (see Table on next slide)
  - Based on actual use data
  - Low application rates compared to maximum rates allowed under Massachusetts Rights-of-Way regulations

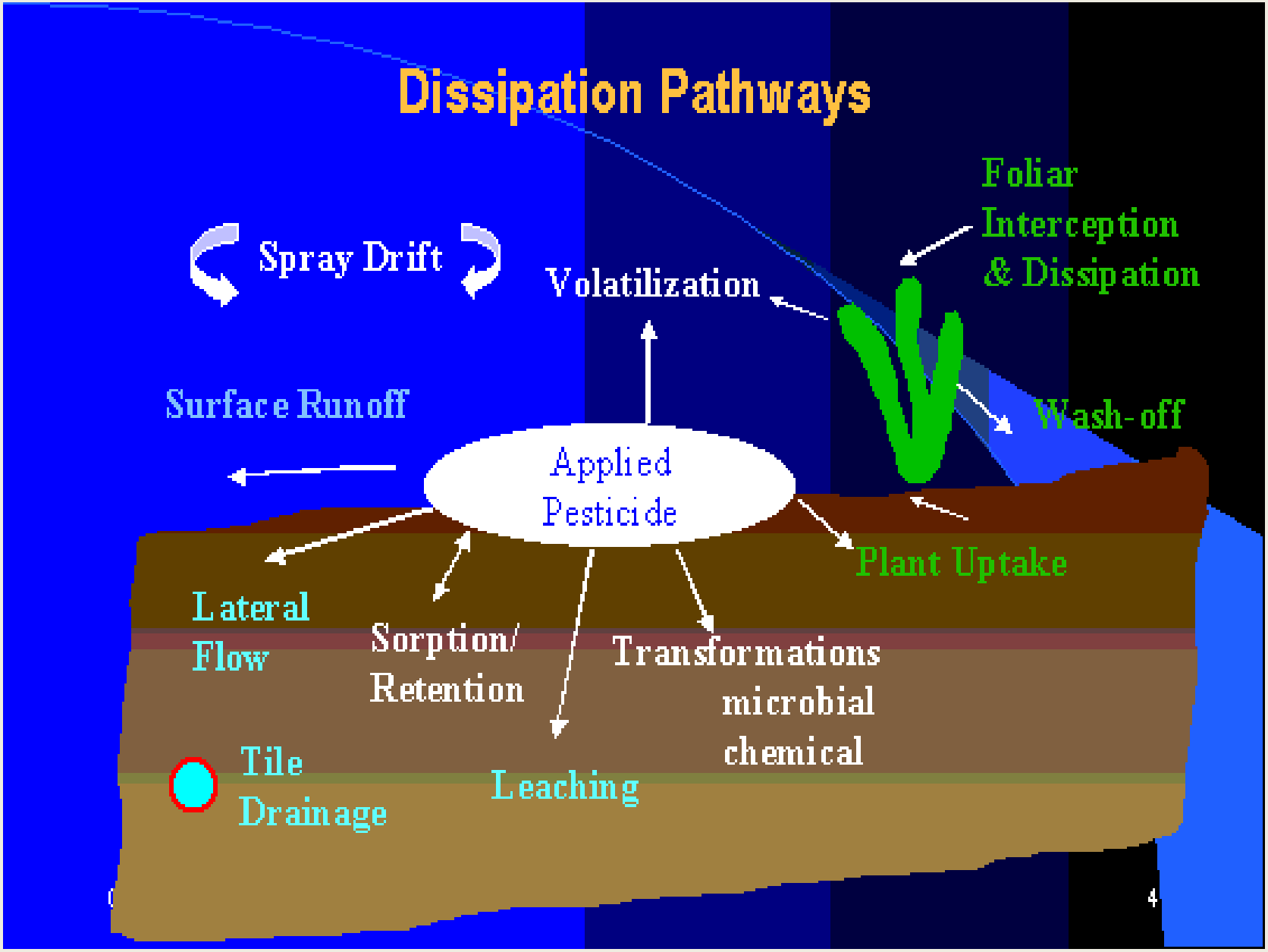
Herbicide Application Rates

Herbicide	Application rate (lb/acre)	Percentage of Maximum Rate
Imazapyr	0.01	2
Glyphosate	0.5	33
Fosamine	1.0	17
Metsulfuron-methyl	0.004	7

- Application rates are low compared to the maximum rates that are allowed by state regulations

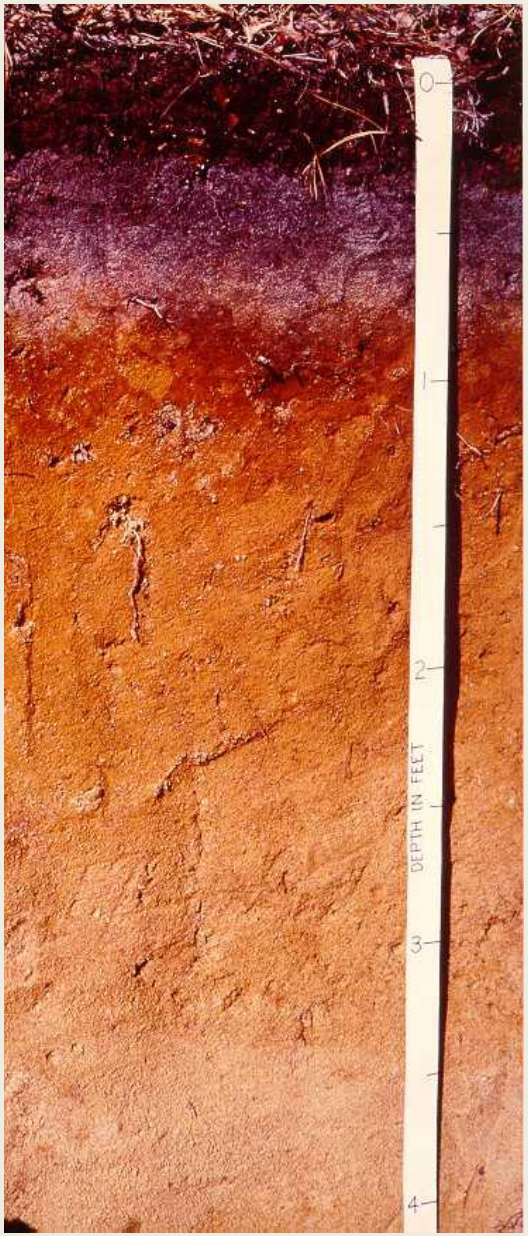
Low-volume Foliage Applications

Selective spraying of target vegetation


Dissipation Pathways
Foliar
Interception
& Dissipation
Spray Drift
Volatilization
Surface Runoff
Wash-off
Applied
Pesticide
Plant Uptake
Lateral
Flow
Sorption/
Retention
Transformations
microbial
chemical
Tile
Drainage
Leaching

Carver Soil Profile:

- **O Horizon**: Organic layer consisting of partly to moderately decomposed organic matter (>80% organic)
- **A Horizon**: Mineral horizon with an accumulation of humified organic matter (1-3%), usually up to 3 inches thick and acidic in nature.
- **E Horizon**: A mineral subsurface layer where iron, aluminum and organic matter have been removed , in Carver soils often mixed with the A horizon.
- **B Horizon**: A mineral subsurface horizon which is characterized by chemical weathering of iron, an accumulation of iron, aluminum or clay and structural development. Organic matter content 0.1-1%. Strongly acidic.
- **C Horizon**: The unweathered geologic material the soil formed in. Carver soils formed in sandy glacial fluvial deposits.



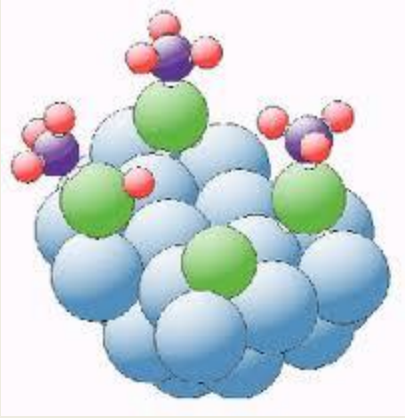
Important Properties for Fate of Herbicides in Carver Soil

- Organic matter in top layer
  - Important factor for sorption of all pesticides
  - Microbiological activity: Biodegradation
- Abundance of Iron and other metal oxides in subsurface
  - Important for adsorption of ionizable compounds
- Acidic character of soil profile
  - Favors the sorption of acidic compounds

Herbicide Fate in Soil

- Herbicides in soil are subject to:
  - Plant uptake
  - Degradation processes
  - Adsorption to soil materials

- Adsorption processes/interactions:
  - Hydrophobic partitioning
  - Electron donor-acceptor
  - Hydrogen-bonding
  - Ionic and electrostatic
  - Ligand-exchange



Some Adsorption interactions of an ionizable organic compound with natural solids

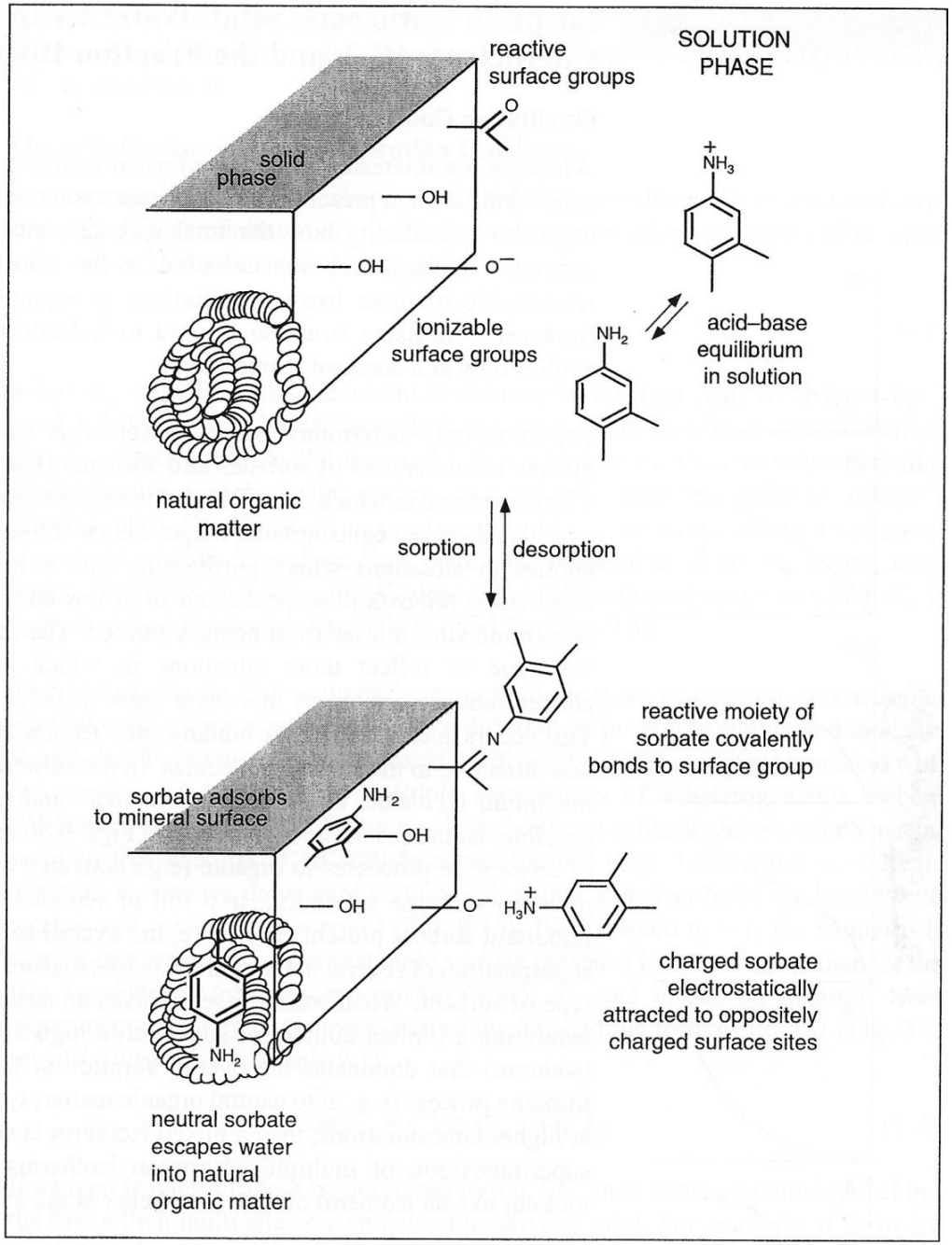
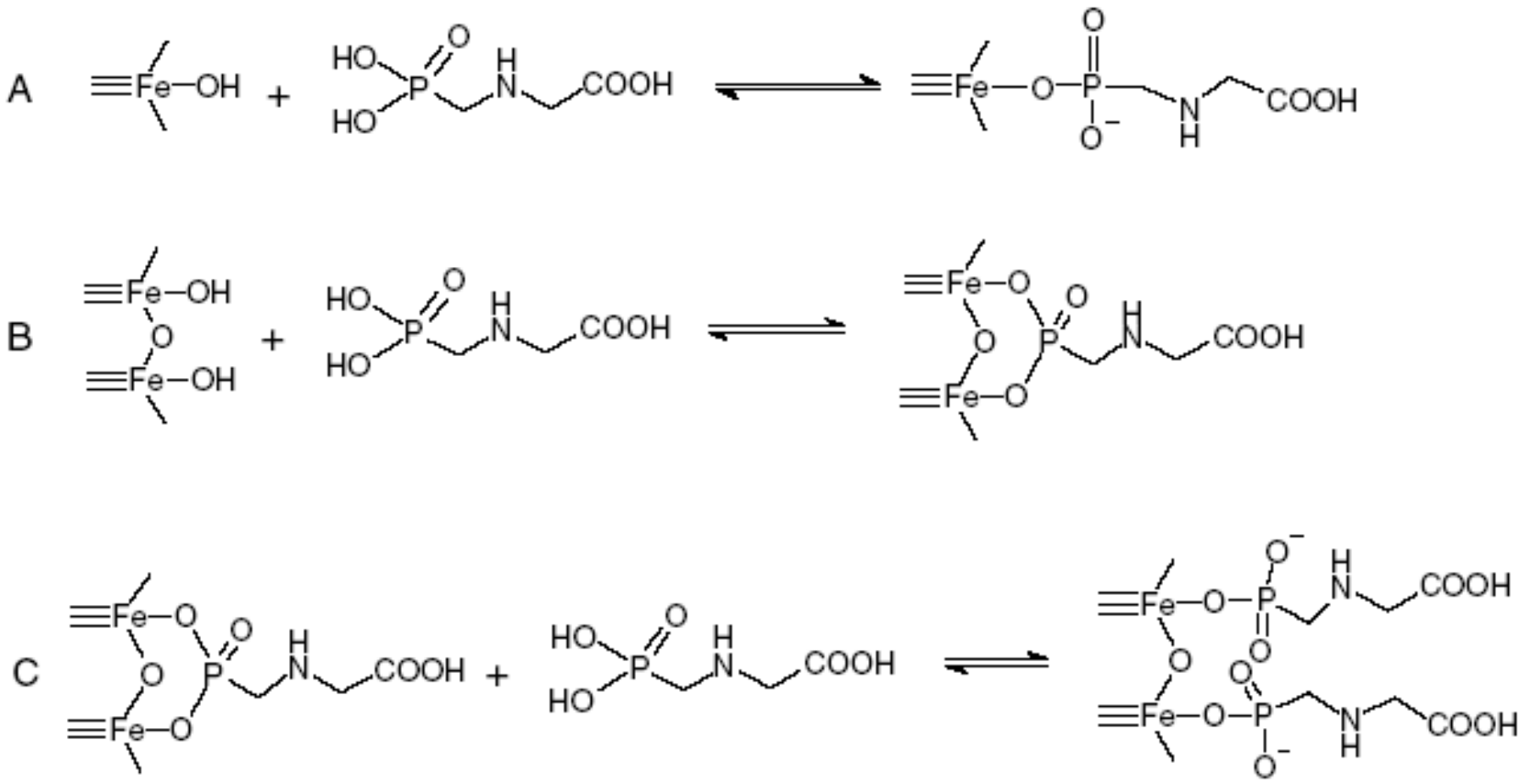


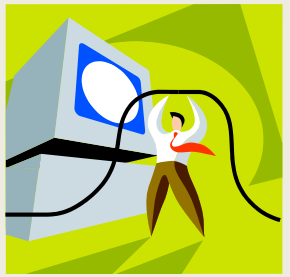
Figure 9.2 Some sorbent–sorbate interactions possibly controlling the association of a chemical, (3,4-dimethylaniline) with natural solids.

Adsorption Processes
Example Glyphosate on Iron Oxide Surfaces



Modeling of Pesticide Fate in Soils

- Fate in soil was simulated by EPA's Pesticide Root Zone Model (PRZM)
- Input parameters include:
  - Application rate, chemical and environmental fate properties, soil and vegetation characteristics, meteorological data
- Output includes:
  - Herbicide concentration profile in soil



Model Input Considerations

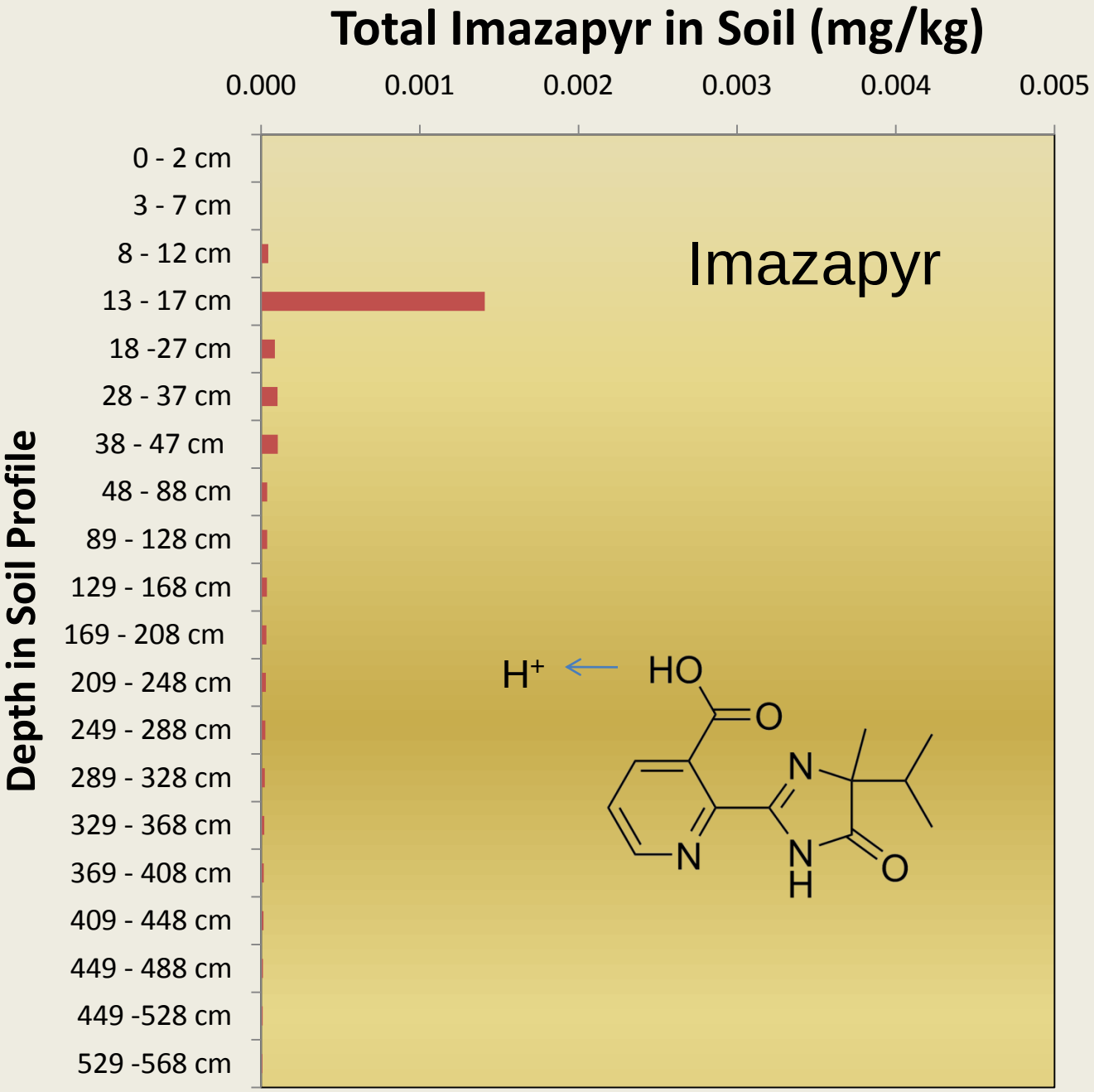
- Disturbed top layer of Carver soil: considered soil with thinner organic top layer

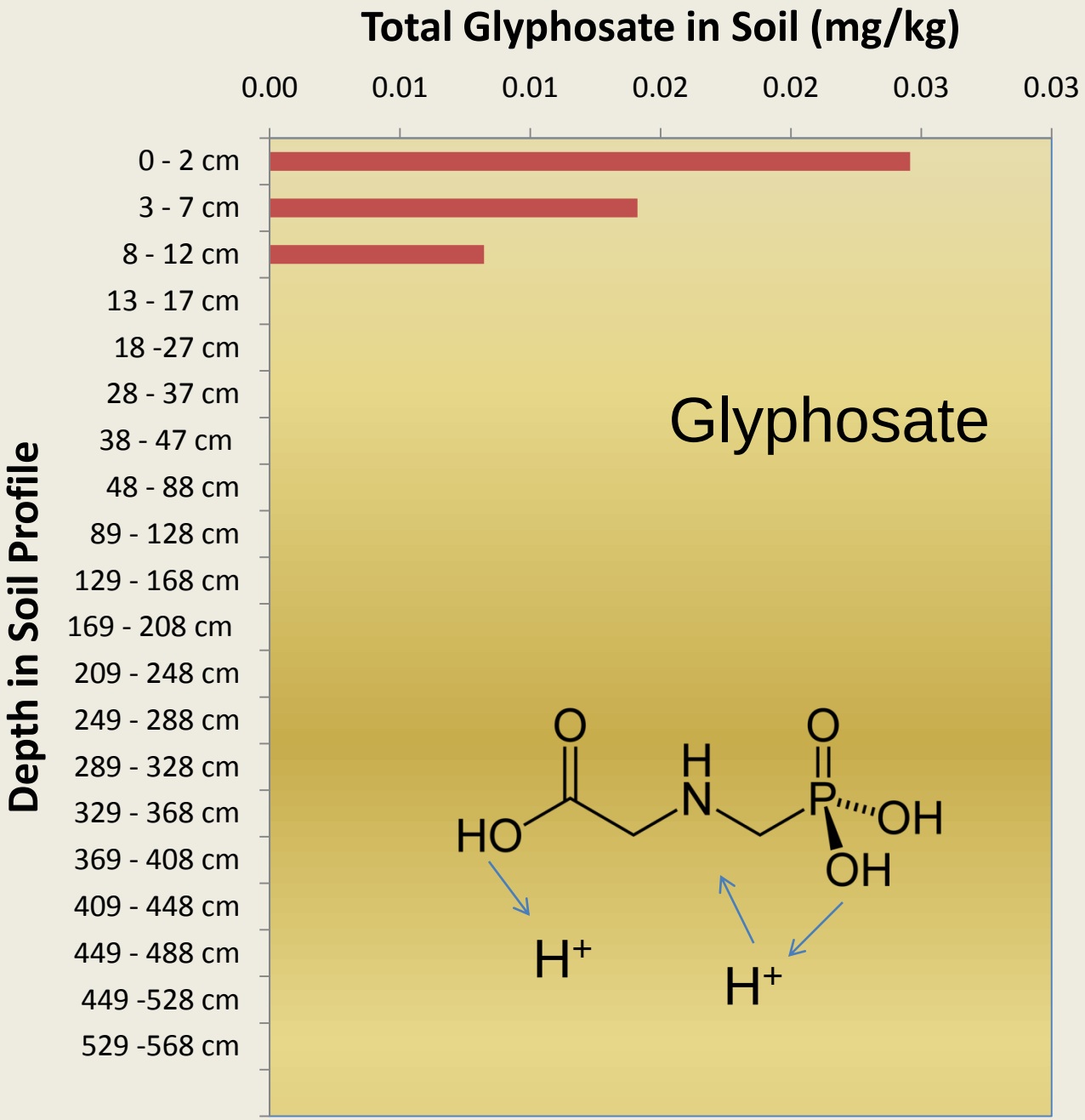
- Consideration of adsorption on metal oxides in subsurface (B-horizon)

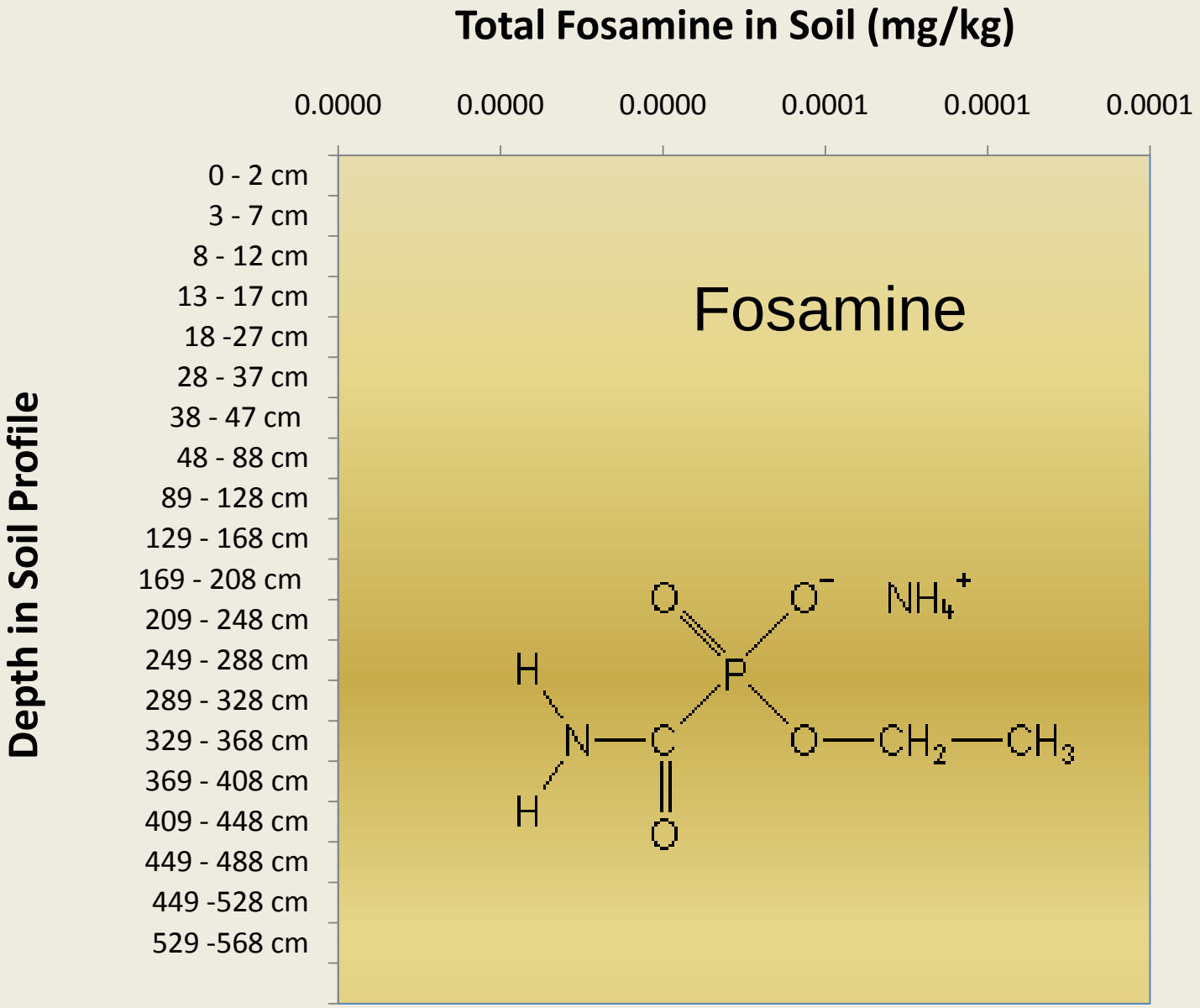
- Acidic character of promotes adsorption of acidic herbicides

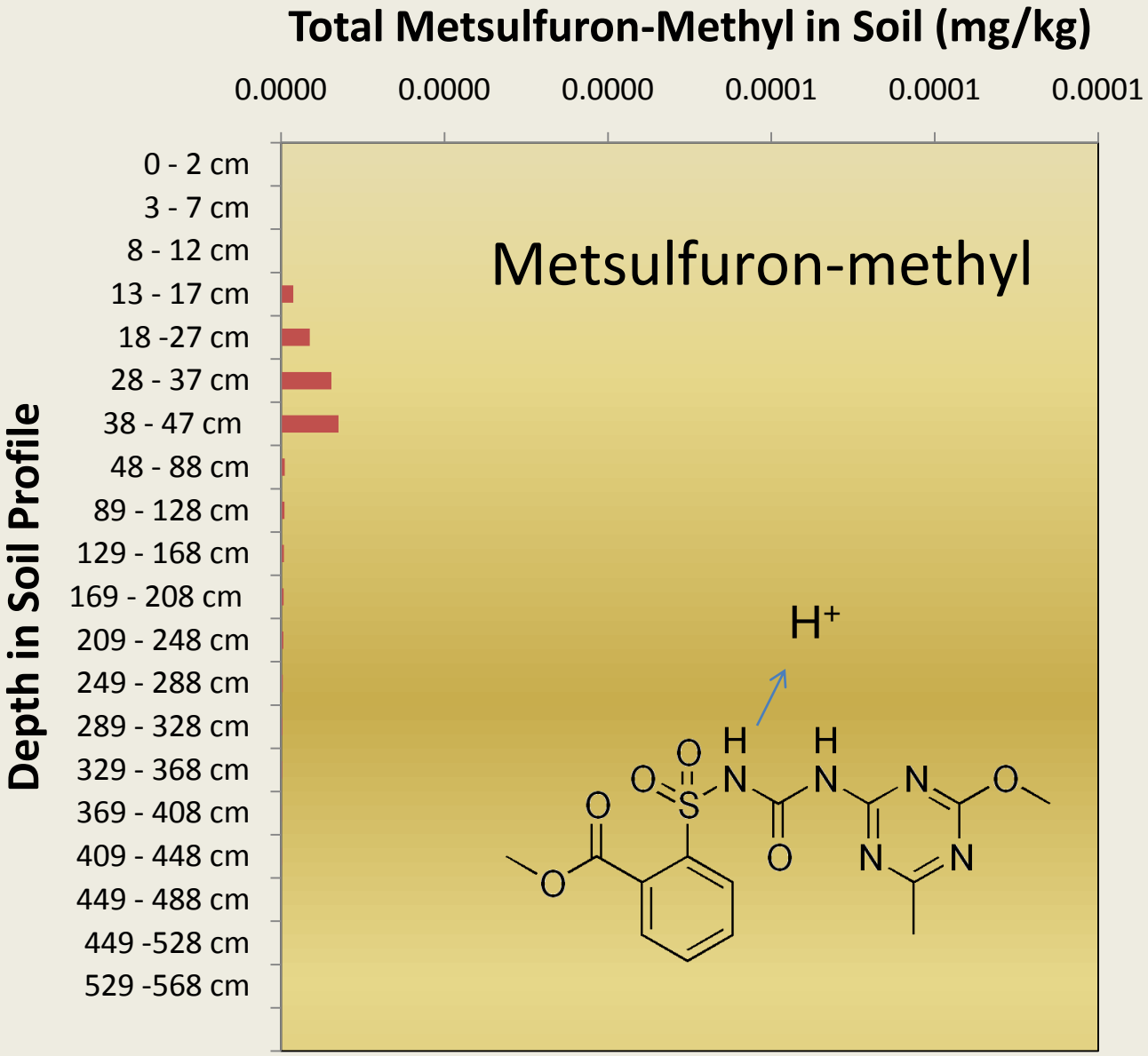
Model Output

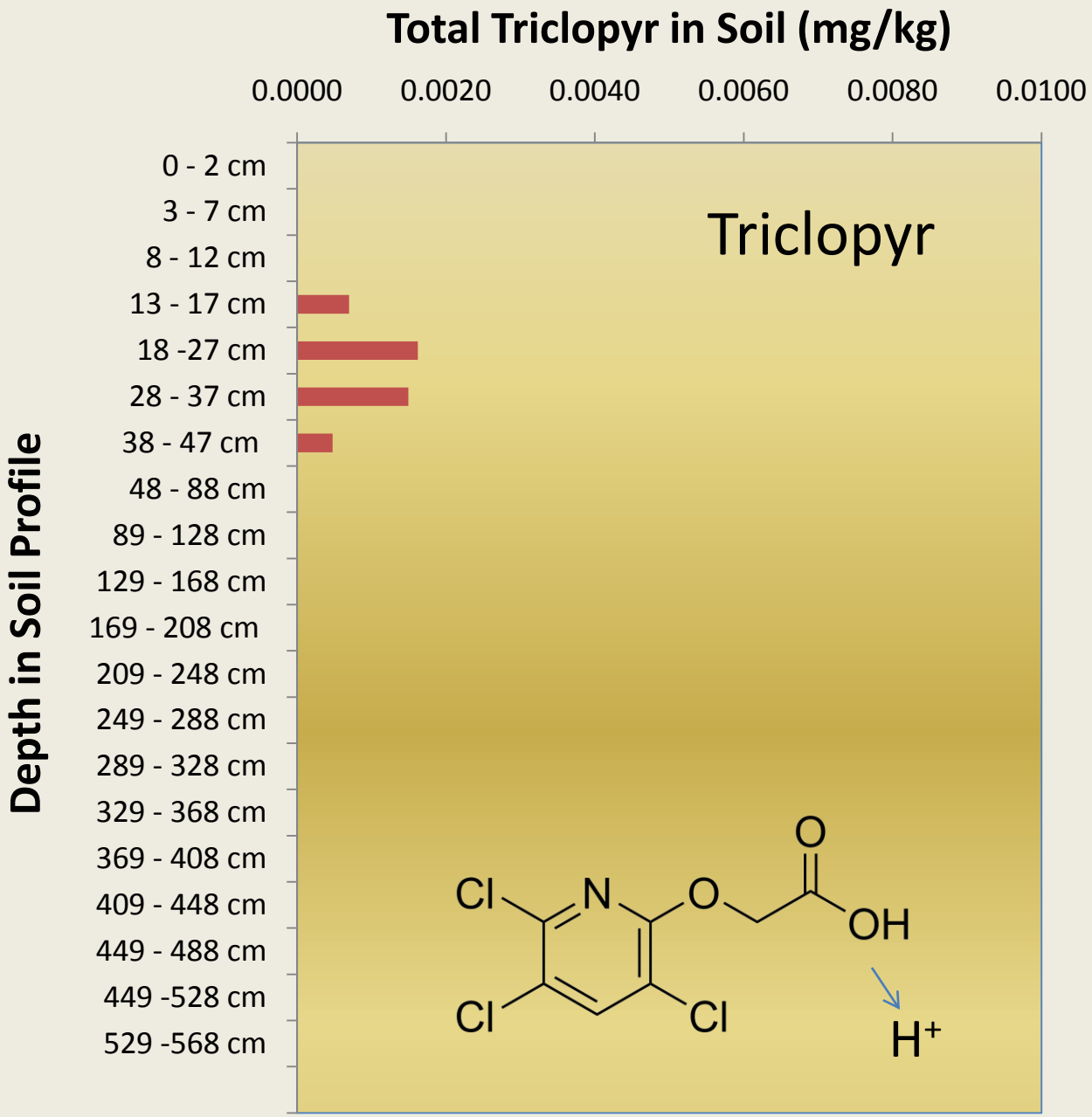
- Concentration profiles for a 17 ft-deep profile
- Groundwater levels are generally deeper, up to 60 ft deep
- Profiles shown for situation after 3 consecutive years of applications


Total Imazapyr in Soil (mg/kg)
0.000
0.001
0.002
0.003
0.004
0.005
Depth in Soil Profile
0 - 2 cm
3 - 7 cm
8 - 12 cm
13 - 17 cm
18 -27 cm
28 - 37 cm
38 - 47 cm
48 - 88 cm
89 - 128 cm
129 - 168 cm
169 - 208 cm
209 - 248 cm
249 - 288 cm
289 - 328 cm
329 - 368 cm
369 - 408 cm
409 - 448 cm
449 - 488 cm
449 -528 cm
529 -568 cm
Imazapyr
H+
HO
O
N
N
N
H
O


Total Glyphosate in Soil (mg/kg)
0.00
0.01
0.01
0.02
0.02
0.03
0.03
Depth in Soil Profile
0 - 2 cm
3 - 7 cm
8 - 12 cm
13 - 17 cm
18 -27 cm
28 - 37 cm
38 - 47 cm
48 - 88 cm
89 - 128 cm
129 - 168 cm
169 - 208 cm
209 - 248 cm
249 - 288 cm
289 - 328 cm
329 - 368 cm
369 - 408 cm
409 - 448 cm
449 - 488 cm
449 -528 cm
529 -568 cm
Glyphosate
O
HO
H
N
O
P
OH
OH
H+
H+


Total Fosamine in Soil (mg/kg)
0.0000
0.0000
0.0000
0.0001
0.0001
0.0001
Depth in Soil Profile
0 - 2 cm
3 - 7 cm
8 - 12 cm
13 - 17 cm
18 -27 cm
28 - 37 cm
38 - 47 cm
48 - 88 cm
89 - 128 cm
129 - 168 cm
169 - 208 cm
209 - 248 cm
249 - 288 cm
289 - 328 cm
329 - 368 cm
369 - 408 cm
409 - 448 cm
449 - 488 cm
449 -528 cm
529 -568 cm
Fosamine


Total Metsulfuron-Methyl in Soil (mg/kg)
0.0000
0.0000
0.0000
0.0001
0.0001
0.0001
Depth in Soil Profile
0 - 2 cm
3 - 7 cm
8 - 12 cm
13 - 17 cm
18 -27 cm
28 - 37 cm
38 - 47 cm
48 - 88 cm
89 - 128 cm
129 - 168 cm
169 - 208 cm
209 - 248 cm
249 - 288 cm
289 - 328 cm
329 - 368 cm
369 - 408 cm
409 - 448 cm
449 - 488 cm
449 -528 cm
529 -568 cm
Metsulfuron-methyl
H+


Total Triclopyr in Soil (mg/kg)
0.0000
0.0020
0.0040
0.0060
0.0080
0.0100
Depth in Soil Profile
0 - 2 cm
3 - 7 cm
8 - 12 cm
13 - 17 cm
18 -27 cm
28 - 37 cm
38 - 47 cm
48 - 88 cm
89 - 128 cm
129 - 168 cm
169 - 208 cm
209 - 248 cm
249 - 288 cm
289 - 328 cm
329 - 368 cm
369 - 408 cm
409 - 448 cm
449 - 488 cm
449 -528 cm
529 -568 cm
Triclopyr
Cl
N
O
O
OH
Cl
Cl
H+

Herbicide Concentration Profiles in Soil

- No significant downward migration beyond the upper horizons
- Can be attributed to the organic matter in the top horizon and metal oxides in subsurface
- Low mobility indicates low potential for migration to groundwater
- Herbicides in the top horizons will be subject to degradation

Groundwater Evaluation

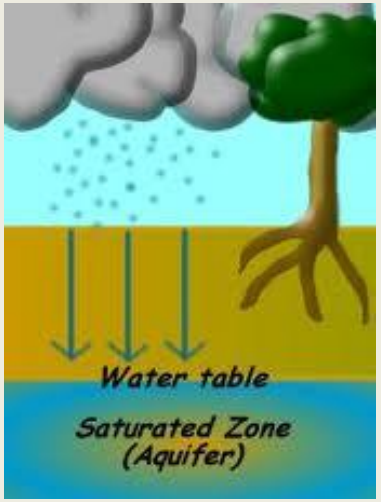
- Exposure of herbicides to groundwater was simulated with SCI-GROW model

- EPA-approved generic screening level model
  - Simulates high-end estimates for groundwater concentration levels

- Simulates behavior on a vulnerable site:
  - Sandy soils
  - Low organic content (<1%)
  - Shallow groundwater (avg. 14 ft)

SCI-GROW Model

- **S**creening **C**oncentration **I**n **GRO**und **W**ater
- Input parameters include:
  - Annual application rate (maximum) and frequency
  - Dissipation rate in soil (half-life value)
  - Mobility parameter K_{OC}
- Output:
  - Simulated herbicide concentration in underlying aquifer

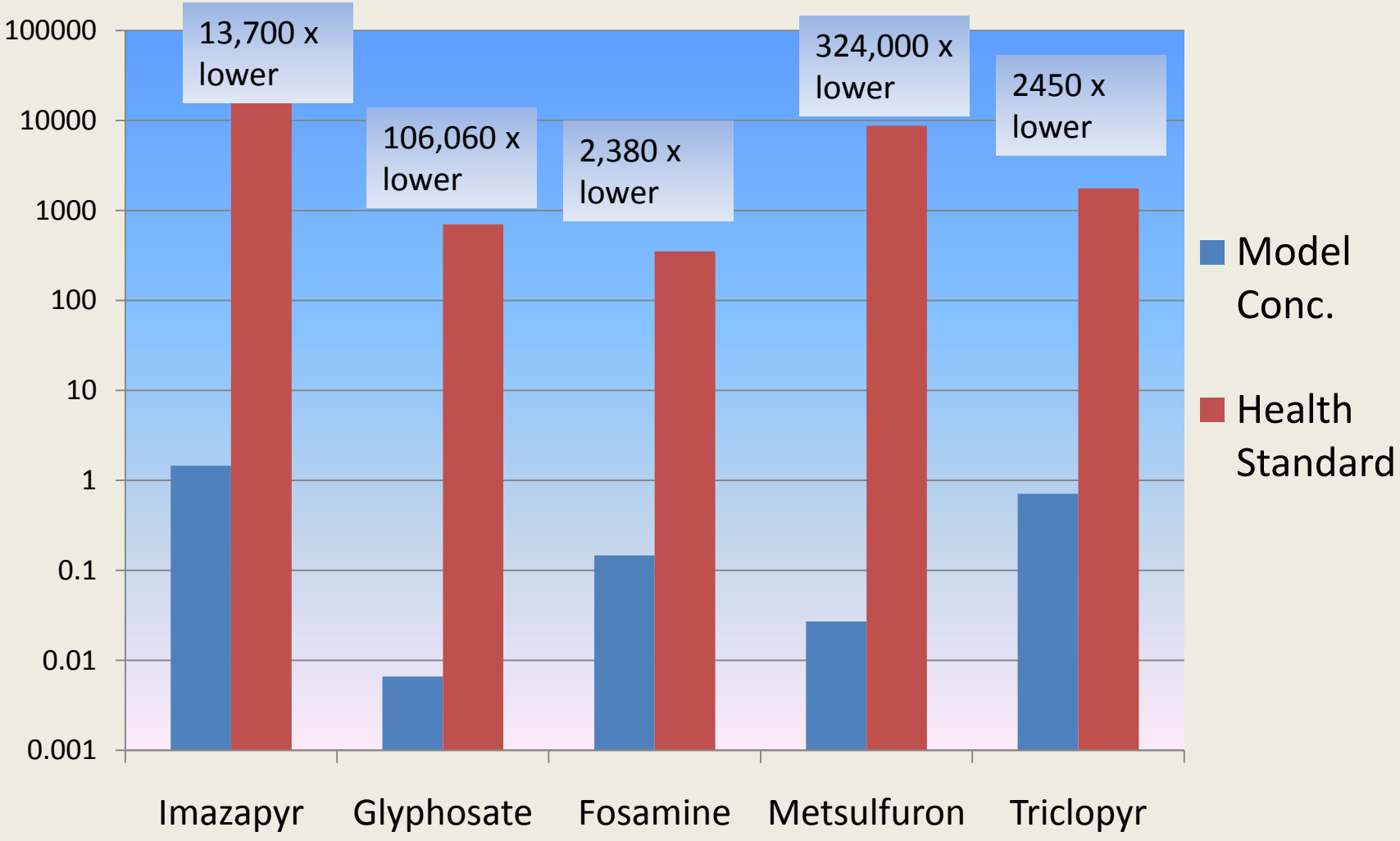


Simulated Groundwater Concentrations

Herbicide	Simulated Concentration (parts-per-billion, ppb)	Health-Based Standard [1] or Health Value[2] (ppb)
Imazapyr	1.46	20000
Glyphosate	0.0066	700
Fosamine	0.147	350
Metsulfuron-methyl	0. 027	8750
Triclopyr	0.713	1750

[1] Health-based standards represent concentrations at which a lifetime of exposure does not result in adverse effect to human health; [2] Health value calculated based on RfD value.

Comparison with Health-Based Standards



Note the Y-axis is expressed on a **log-based** scale!!

Simulated Groundwater Concentrations

- Simulated values are conservative:
  - Conservative design of model based on highly vulnerable site
  - Model does not consider set-back values
  - ROW application scenario on a relatively narrow strip of land

vs.

  - Field-area-wide application assumed in model

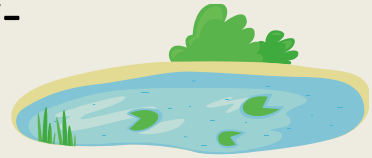
Calibration of SCI-GROW model

- Monitoring data for Chlorothalonil (Cape Cod Commission, 1990)
  - Measured concentration in groundwater:
    - 0.34 ppb
  - SCI-GROW-simulated value:
    - 4 to 6 ppb

- Indicates conservative simulation

Surface Water Evaluation

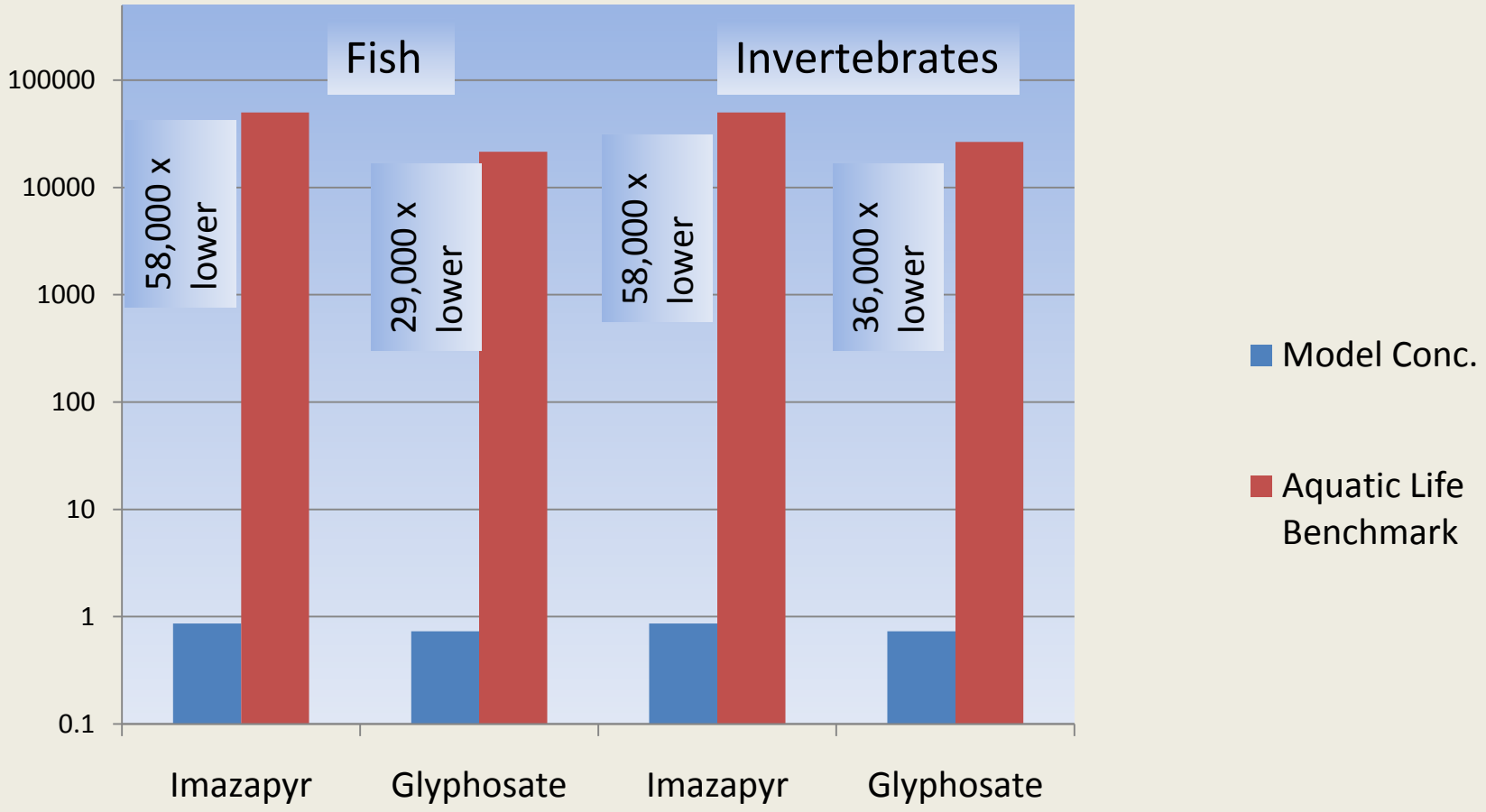
- Exposure of herbicides to surface water was simulated with PRZM-EXAMS
- The field-scale runoff/leaching model that simulates:
  - Runoff, erosion, plant uptake, leaching, decay, foliar wash off, and volatilization; selected value for off-site drift
  - Input includes soil, vegetation and local climate data
  - Does not consider buffer zone
- Output includes simulated herbicide concentrations at various time intervals:
  - From initial peak concentration up to 90 day-concentration



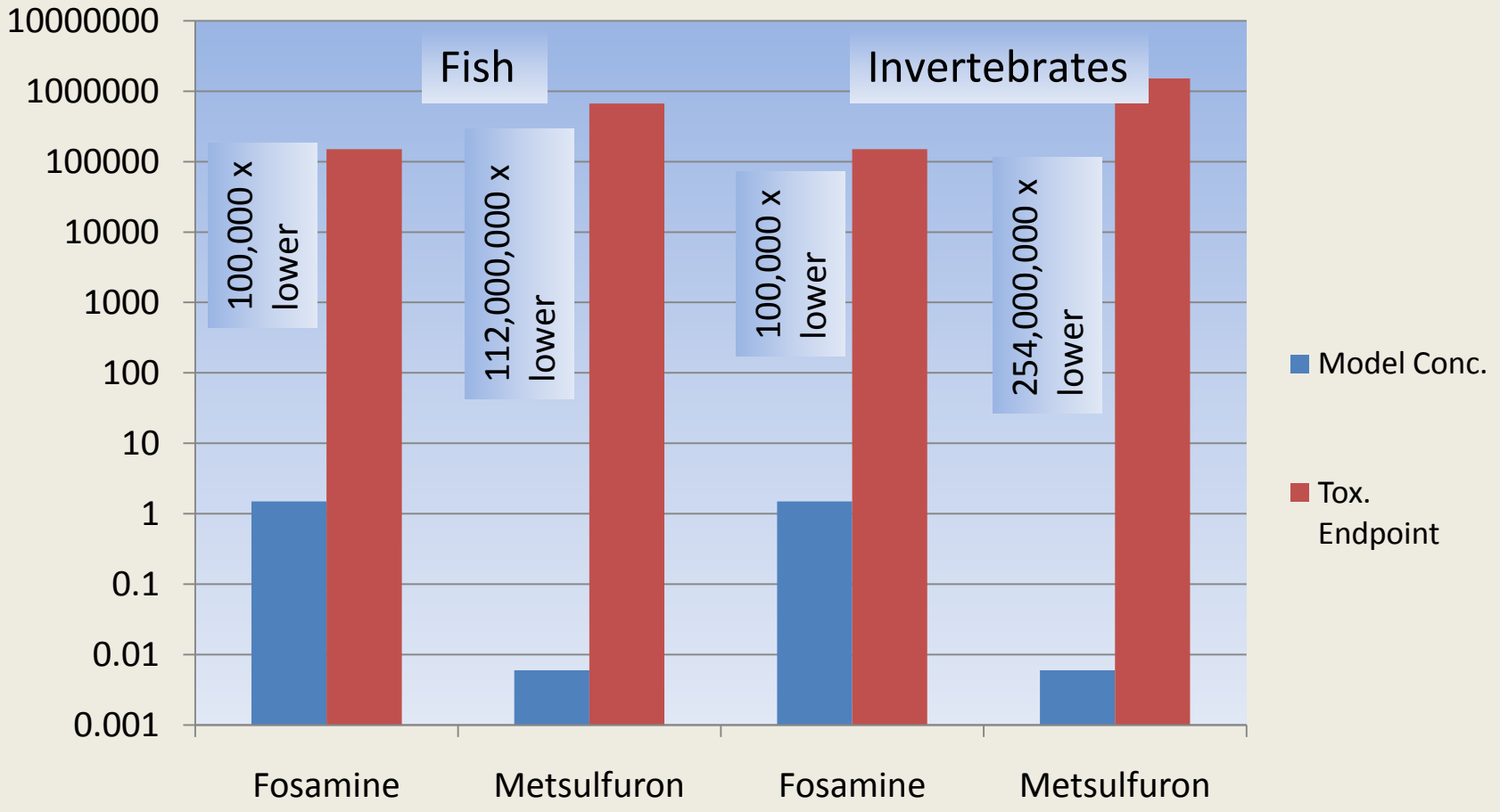
Simulated Surface Water Concentrations

Herbicide	Simulated Concentration (parts-per-billion, ppb)	Ecological Benchmark[1] or Toxicological Endpoint[2] (ppb) (Fish, acute effects)
Imazapyr	0.86	>50,000[1]
Glyphosate	0.73	21,500[1]
Fosamine-ammonium	1.5	>150,000[2]
Metsulfuron-methyl	0.006	670,000[2]

Comparison with Aquatic Life Benchmarks Acute Effects for Imazapyr and Glyphosate

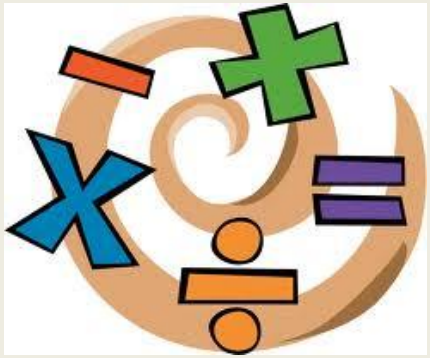


Comparison of Surface Water with Toxicological Endpoints, Acute Effects, for Fosamine and Metsulfuron



Conclusions

- ROW herbicide are applied at relatively low rates
- Simulated concentrations in ground- and surface water are well below health-based and ecological standards
- These low exposure levels indicate minimal risk to human health and non-target organisms



Further Reduction of Exposure

- Simulations represent worst-case scenario or high-end of exposure potential
- Exposure is reduced by limited-spray zones and no-spray zones
- No-spray zones include:
  - 50 ft from private well
  - 10 ft from surface water or wetland

Conclusion

At the rate and with the method of application, the herbicides used in the rights-of-way area in Eastham will not result in herbicide concentrations in ground and surface water that would cause harm to humans and aquatic wildlife.

Support from Existing Monitoring Studies

- Monitoring studies on golf courses

  (Cape Cod Commission, 1990; Cohen et al., 1990)

  – Show infrequent detections of pesticides used on golf courses (episodic nature)
  – If detected, pesticide levels in groundwater were low and below levels of concern
  – Intensively managed systems with proper management practices do not cause unreasonable risk to human health and the environment

Modeling and Monitoring

- EPA guidance suggests:
- Conservative screening-level modeling assessment:
  - If low exposures levels and no exceedance of levels of concern
  - Then no refined assessment and/or monitoring suggested
- As part of a cautious approach, a monitoring study is being developed to *complement* the model-based assessment.