SECTION B.2

ECOLOGICAL RISK ASSESSMENT OF METALS AND ACID ROCK DRAINAGE

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ECOLOGICAL RISK ASSESSMENT OF METALS AND ACID ROCK DRAINAGE

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Scope of Presentation

- Brief recap of ERA Process
- Elements of ARD Risk Scenarios
- Modifying Factors of Risk to Aquatic Biota
- Tackling Wildlife Population Risk
- Canada's Fisheries Act and Risk Assessment

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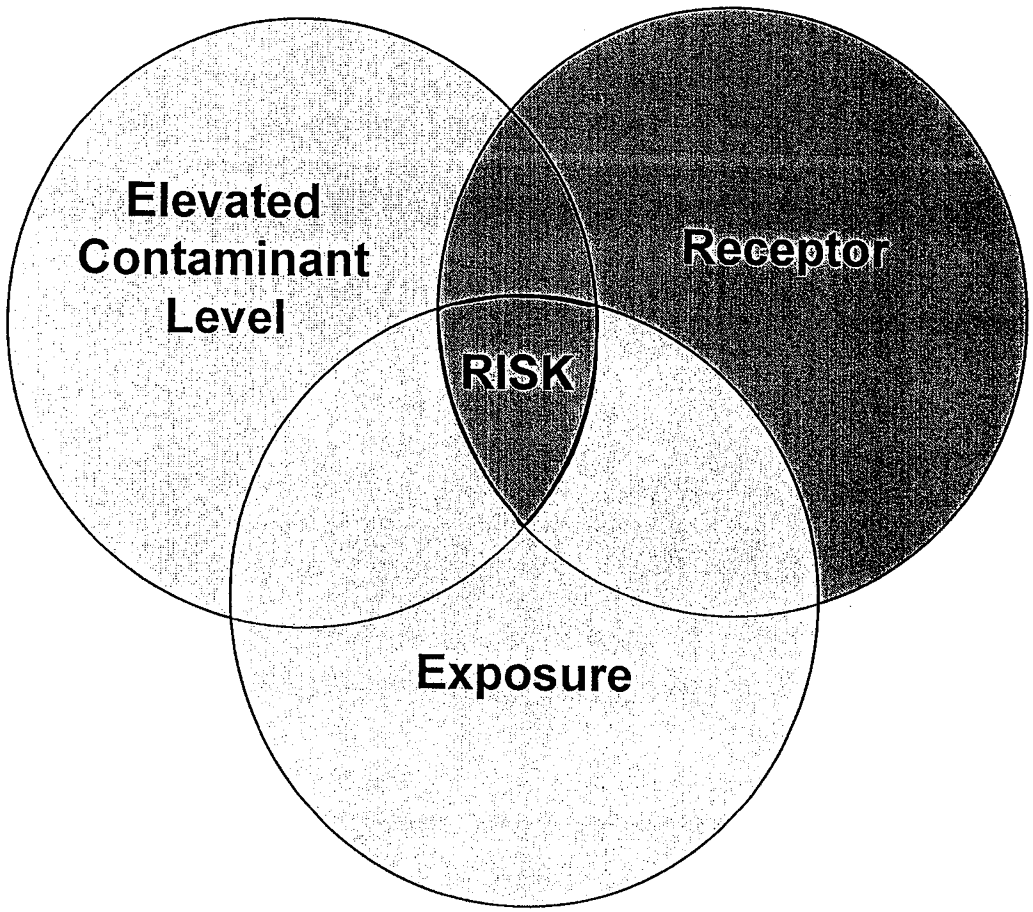
Requirements for Contaminant Health Risk



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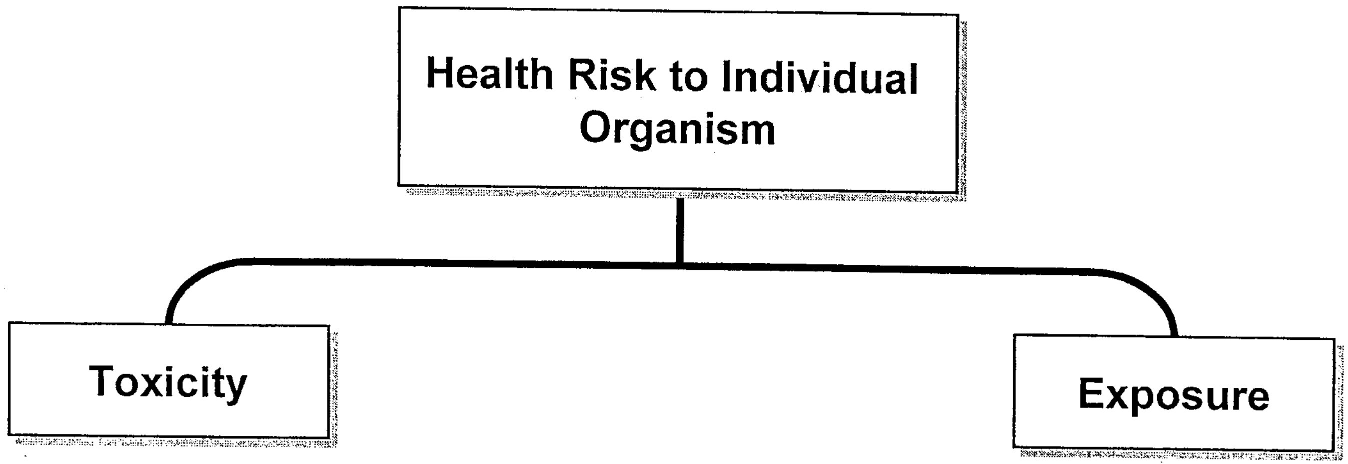
Elements of ARD Risk Scenarios

- Unconfined mine water drainage
- Tailings leachate
- Waste rock leachate
- Unconfined surface tailings
- Submerged shallow water tailings
- End pit lake
- Fish, benthic invertebrates, amphibians
- Water fowl, aquatic mammals
- Metals
- pH



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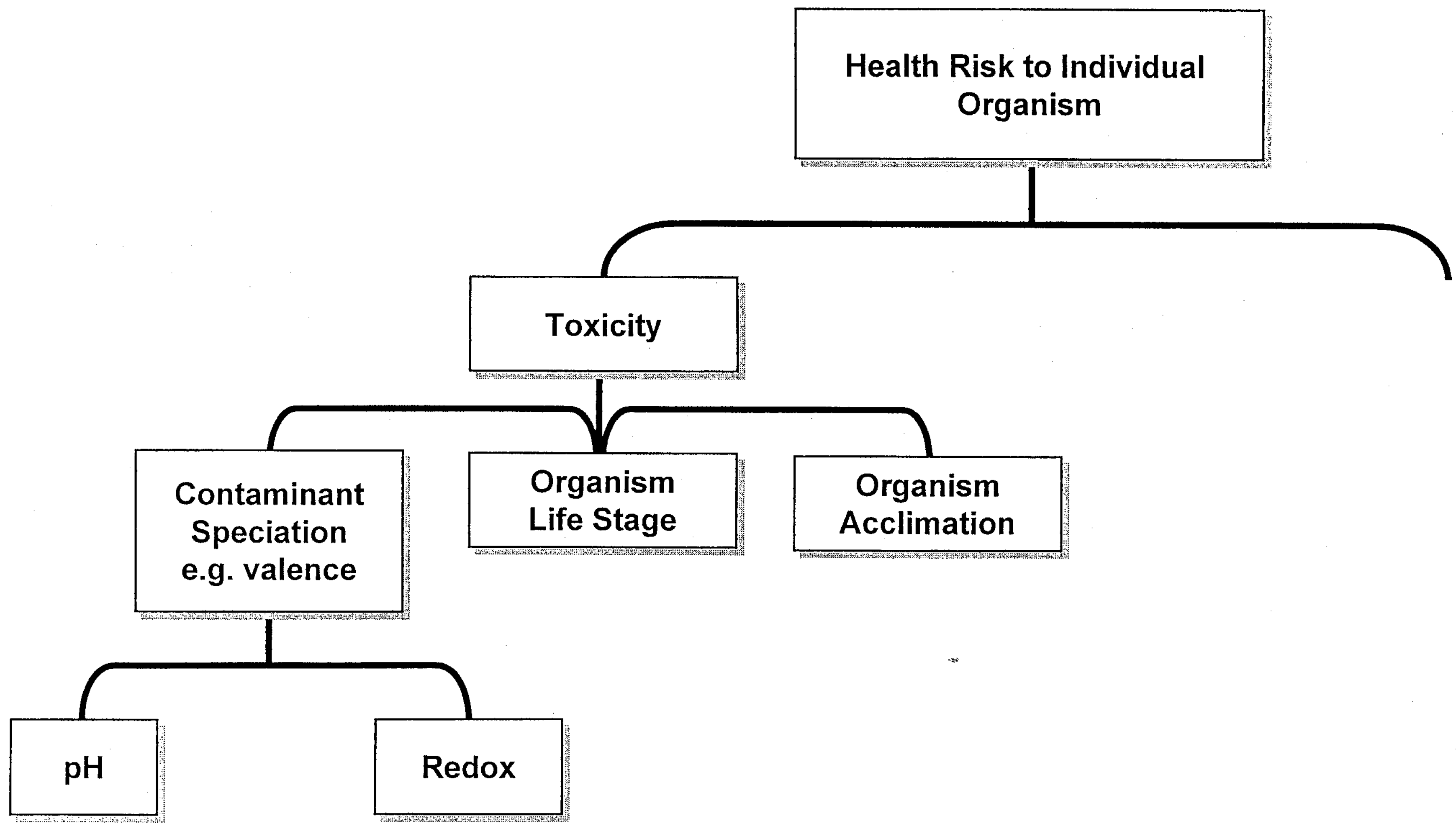

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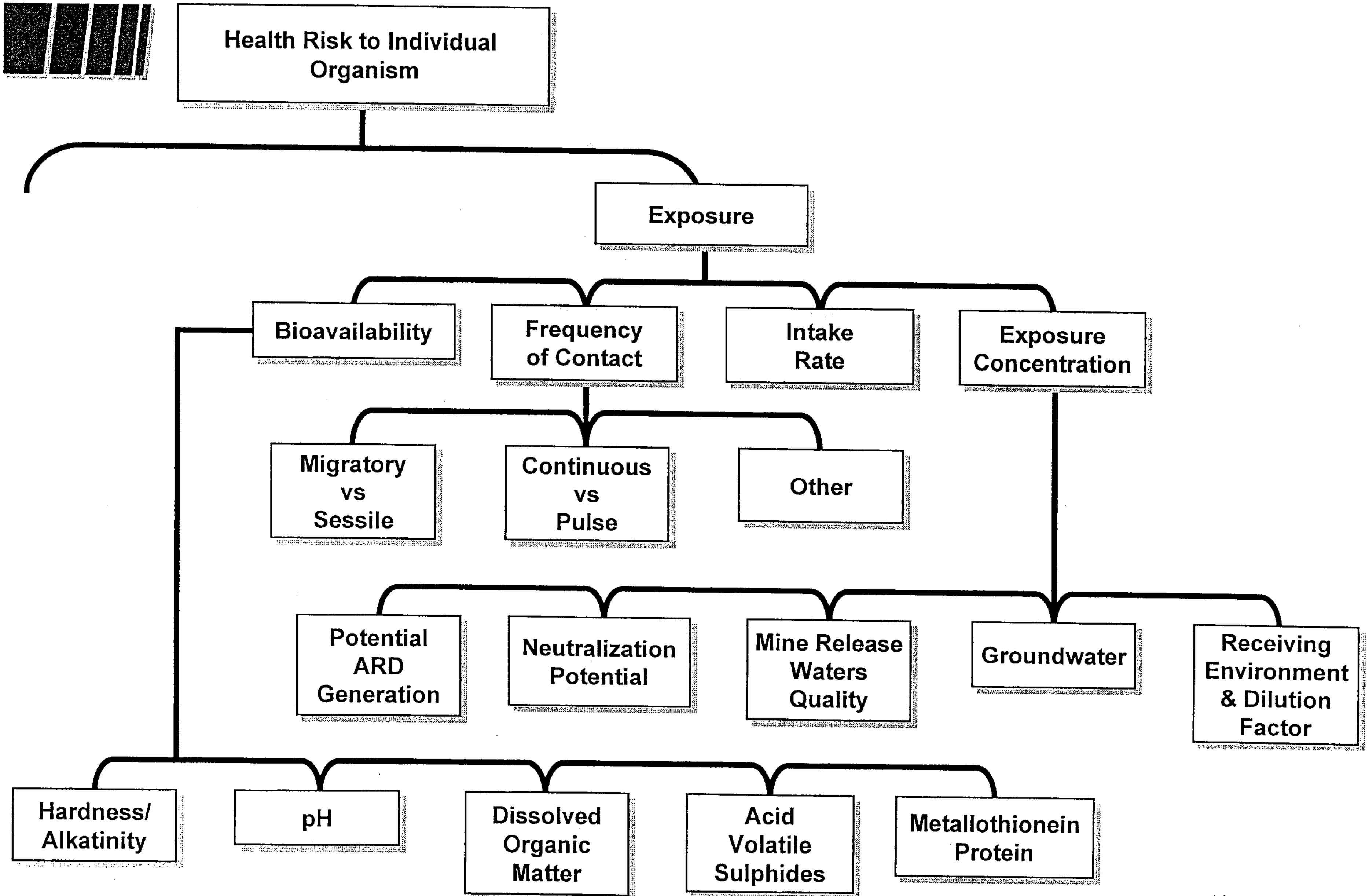

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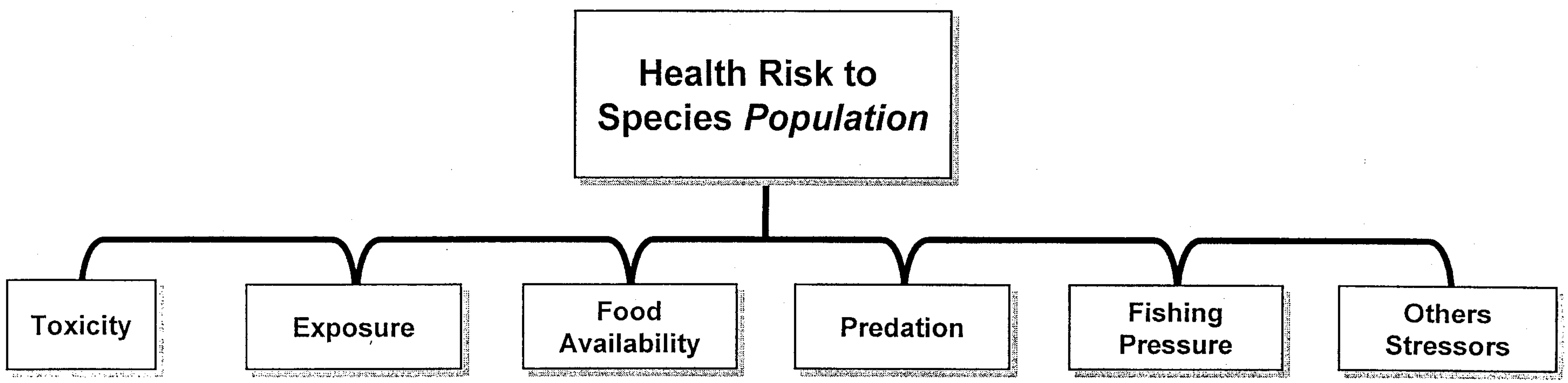

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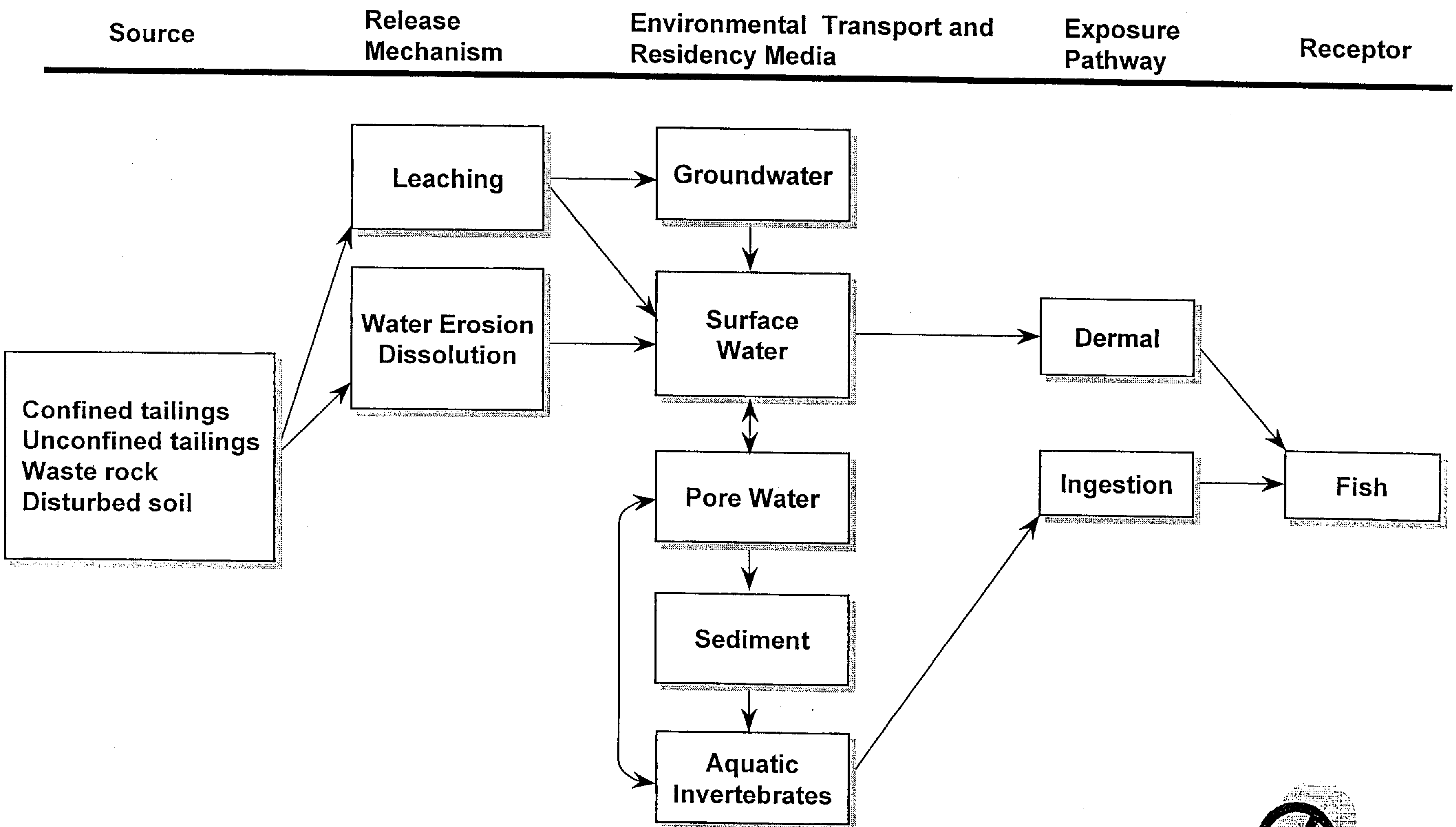
Conceptual Model for Aquatics



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Representative Aquatic EC_{20} (ug/l)

Metal	Fish EC_{20}(ug/l)	Invertebrates EC_{20}(ug/l)
Arsenic	1500 - 2130	633 - >930
Copper	5	0.2
Chromium	51 - 89	0.27 - 8.4
Lead	22	0.35
Zinc	47	21

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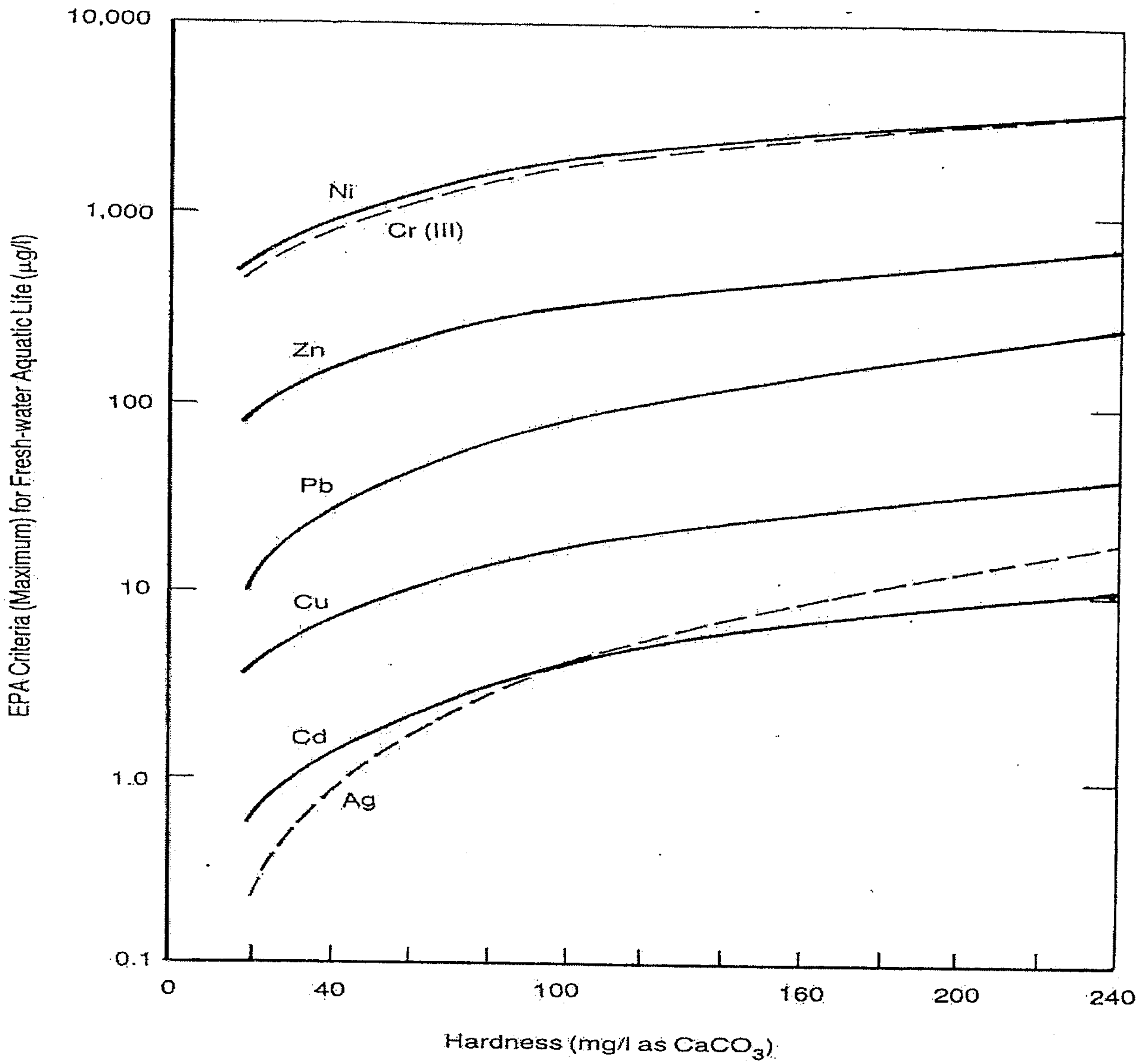

Note: Curves were derived from equations given in Table D-3 of Appendix D. For Ag, Ni, and Zn, criteria are maximum concentrations not to be exceeded at any one time. For Cd, Cr, Cu and Pb, criteria are one-hour average concentrations, not to be exceeded more than once every three years on the average.

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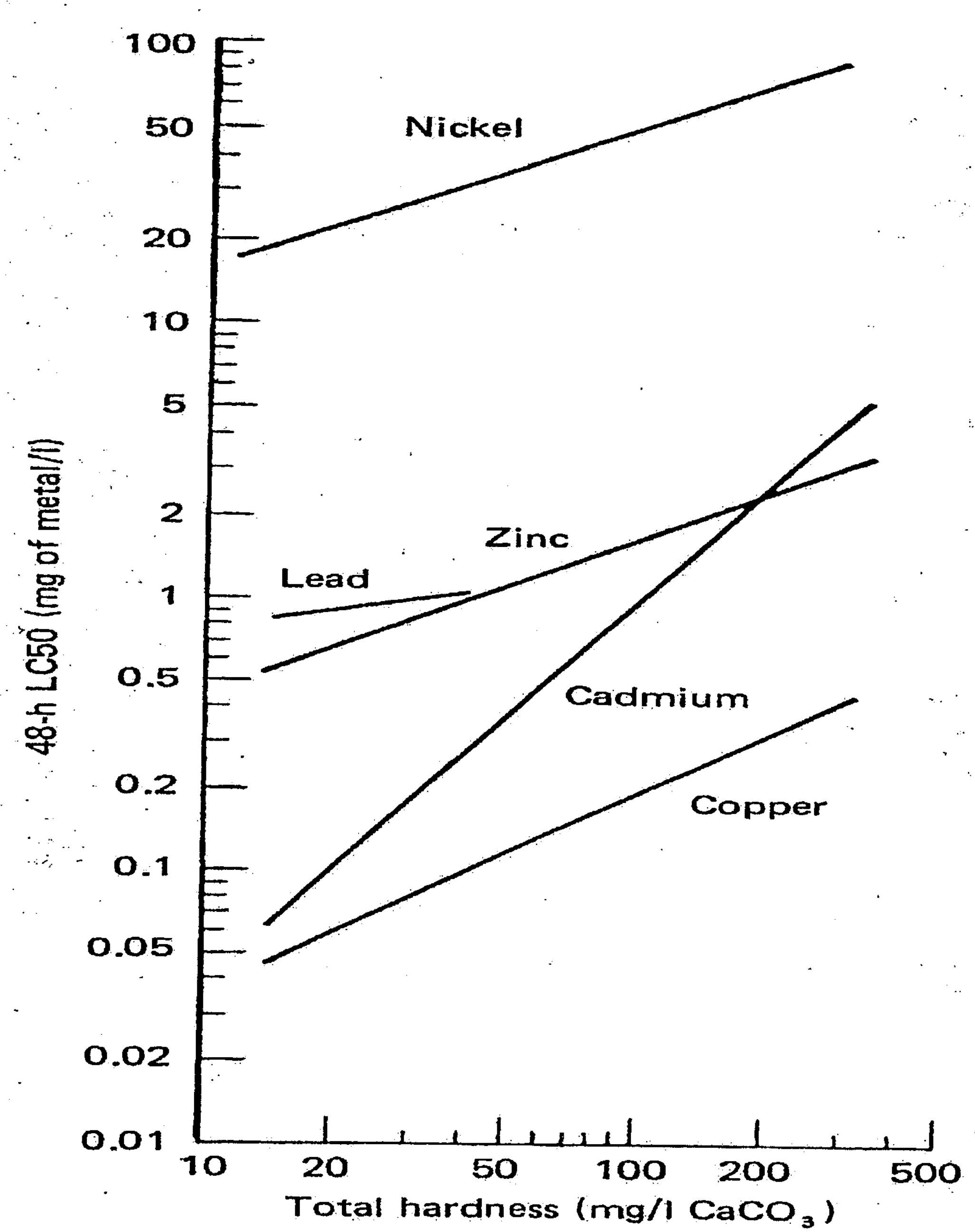

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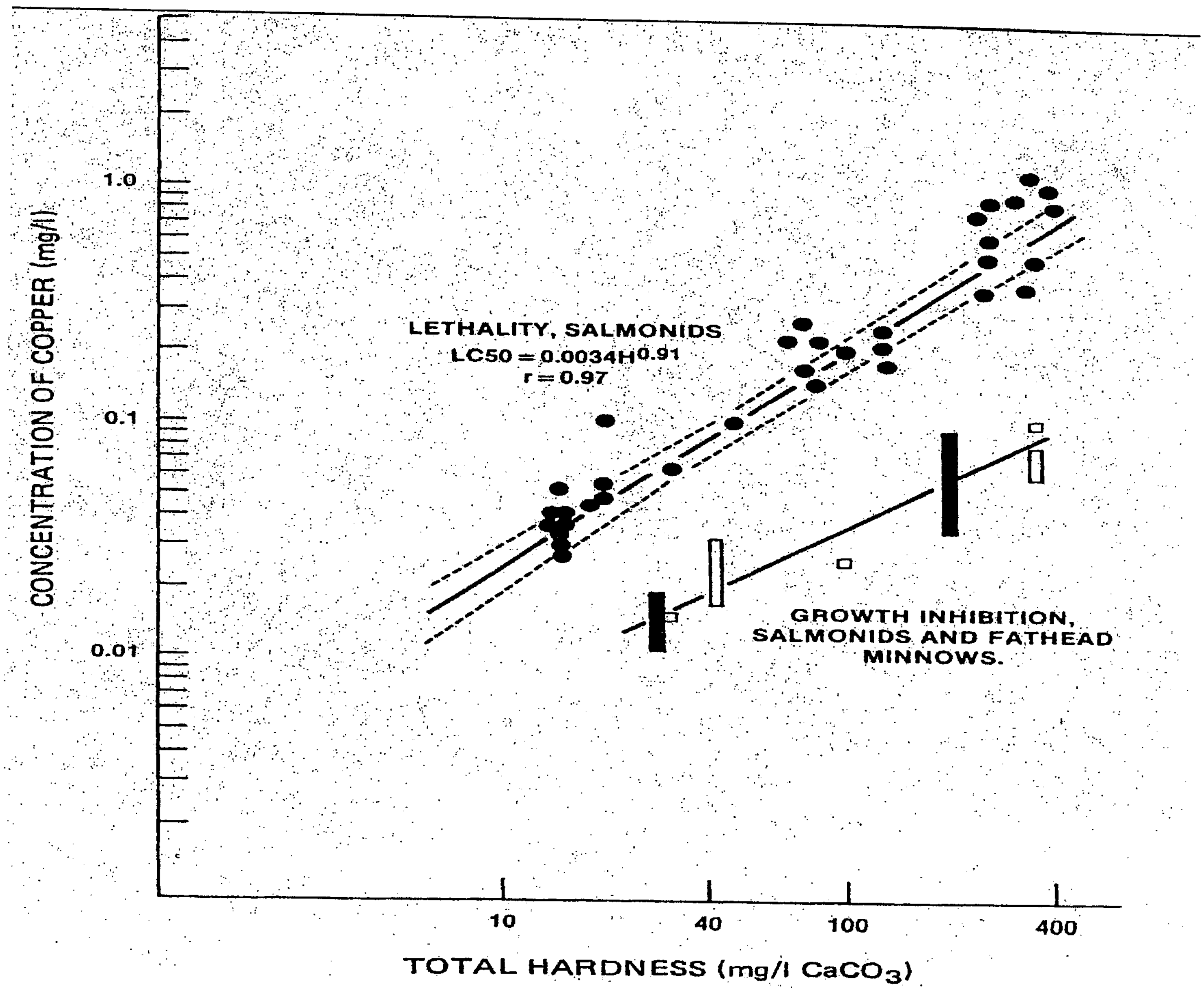

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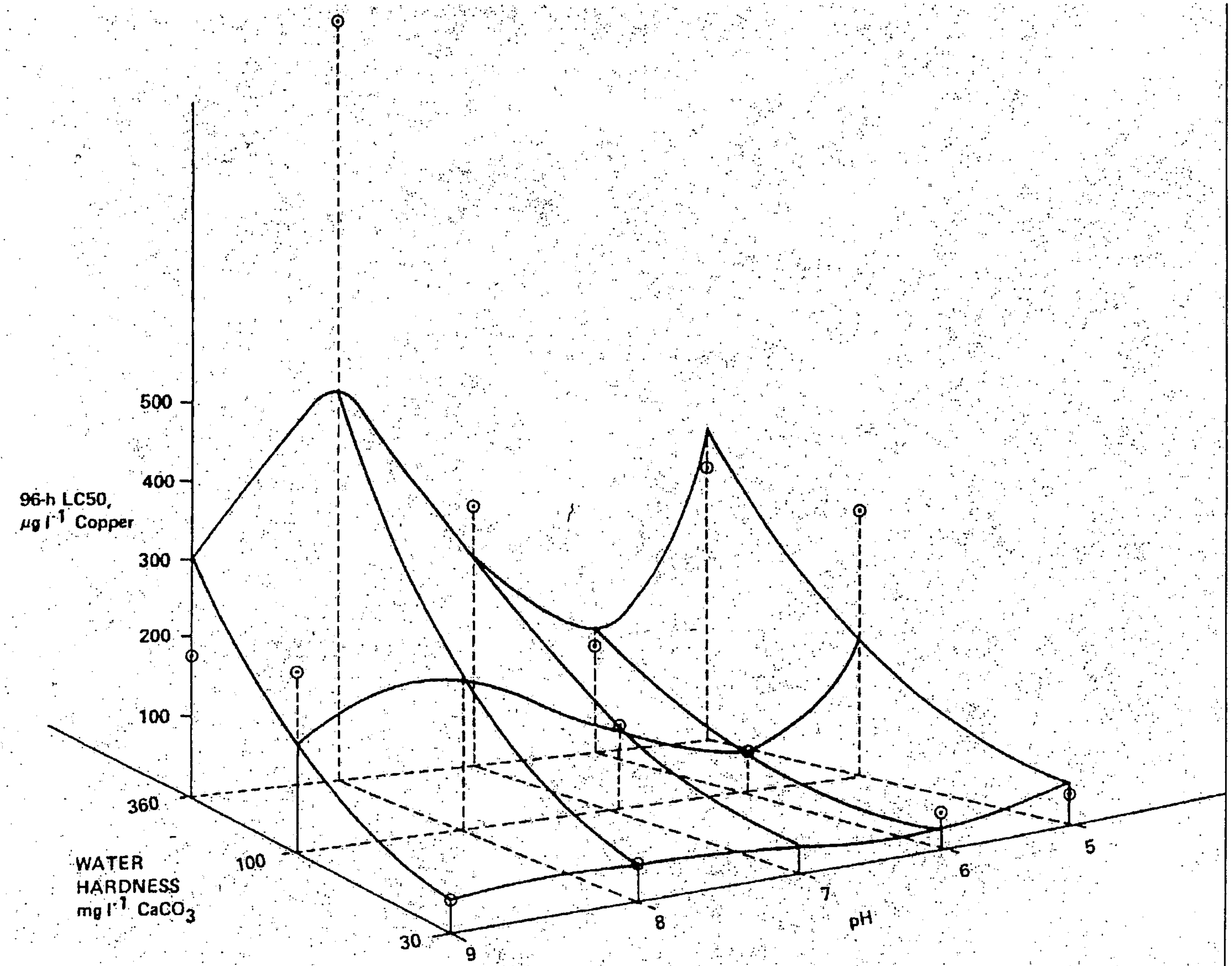

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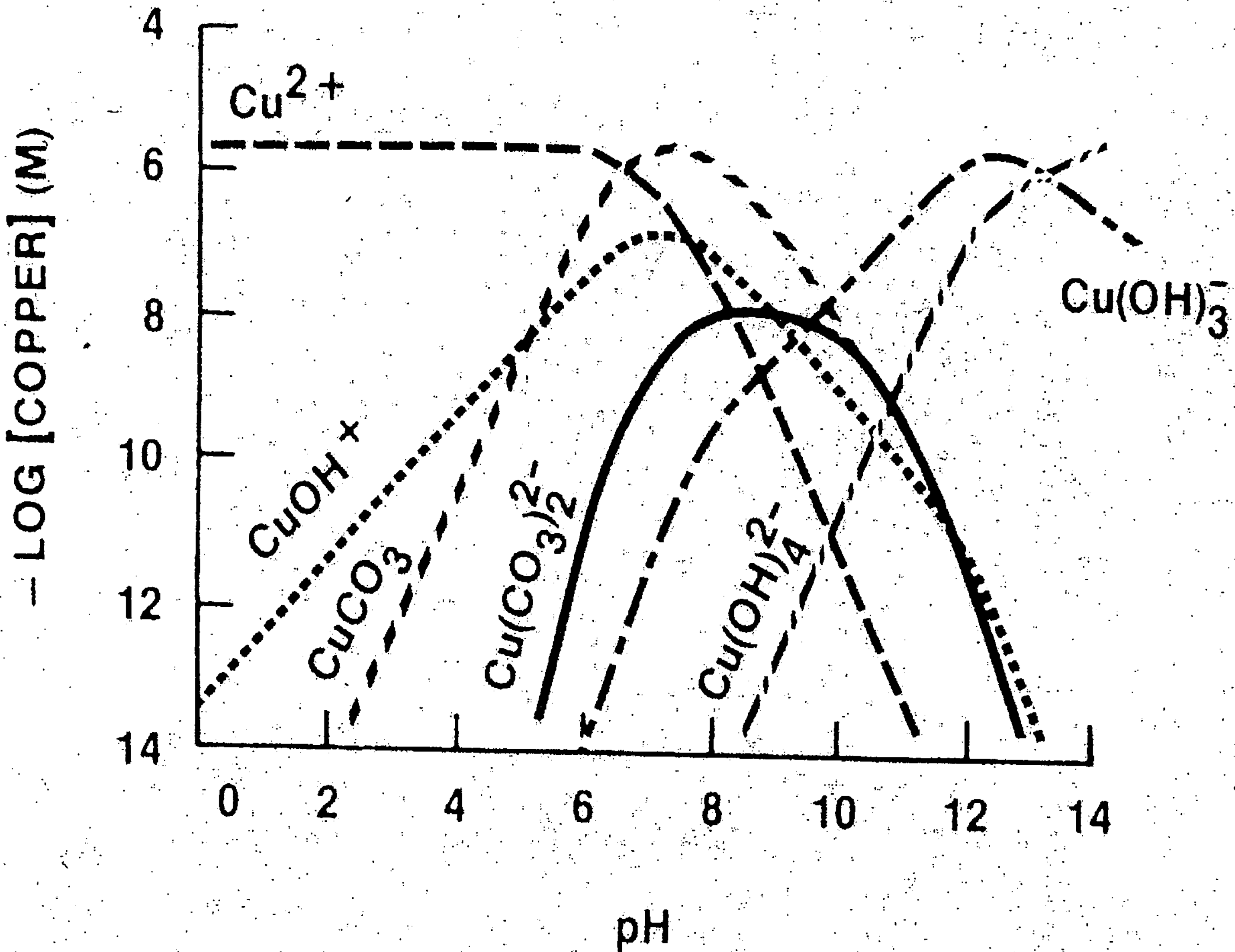

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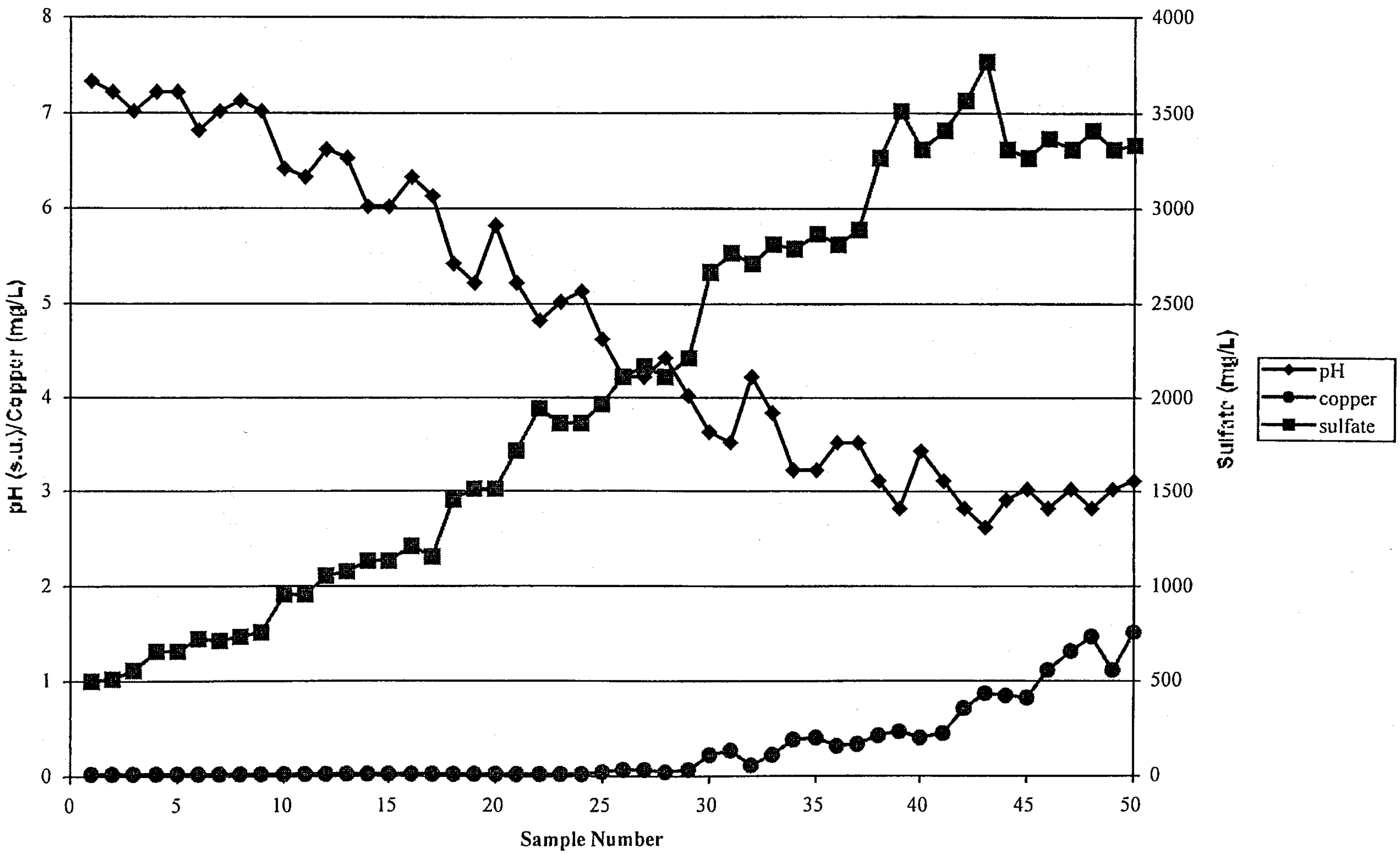
Evolution of Acid Rock Drainage



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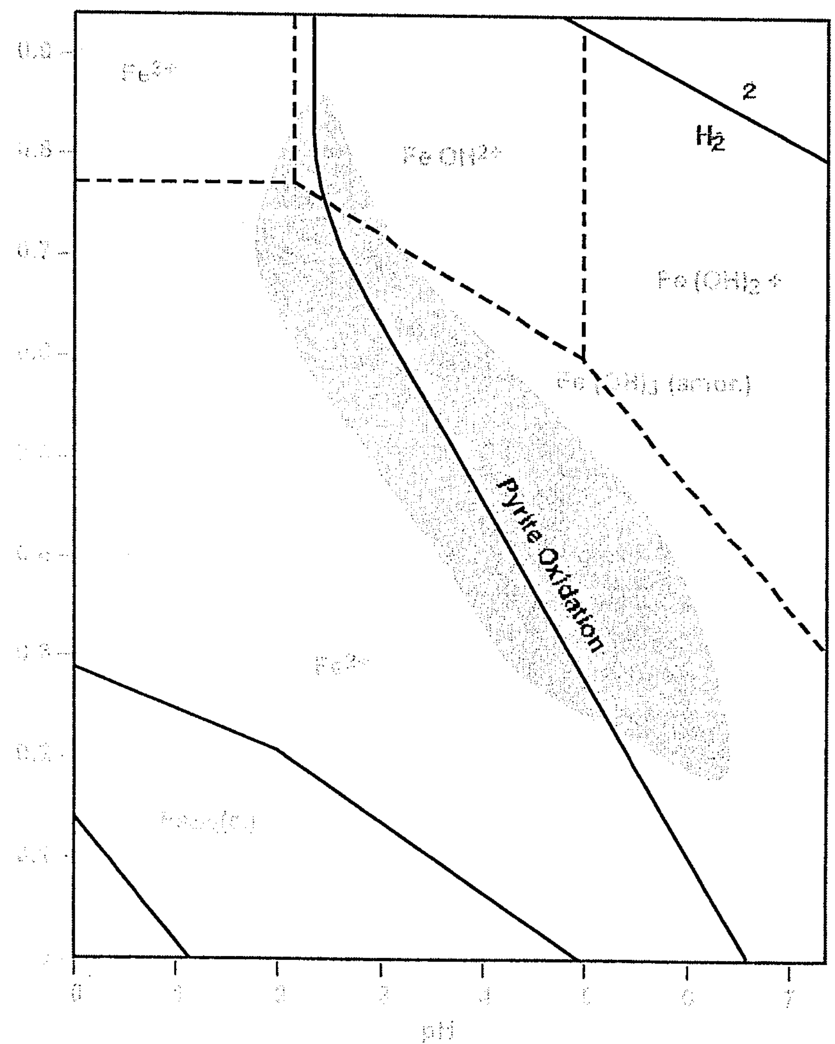
Eh-pH Diagram for the Oxidation of Pyrite



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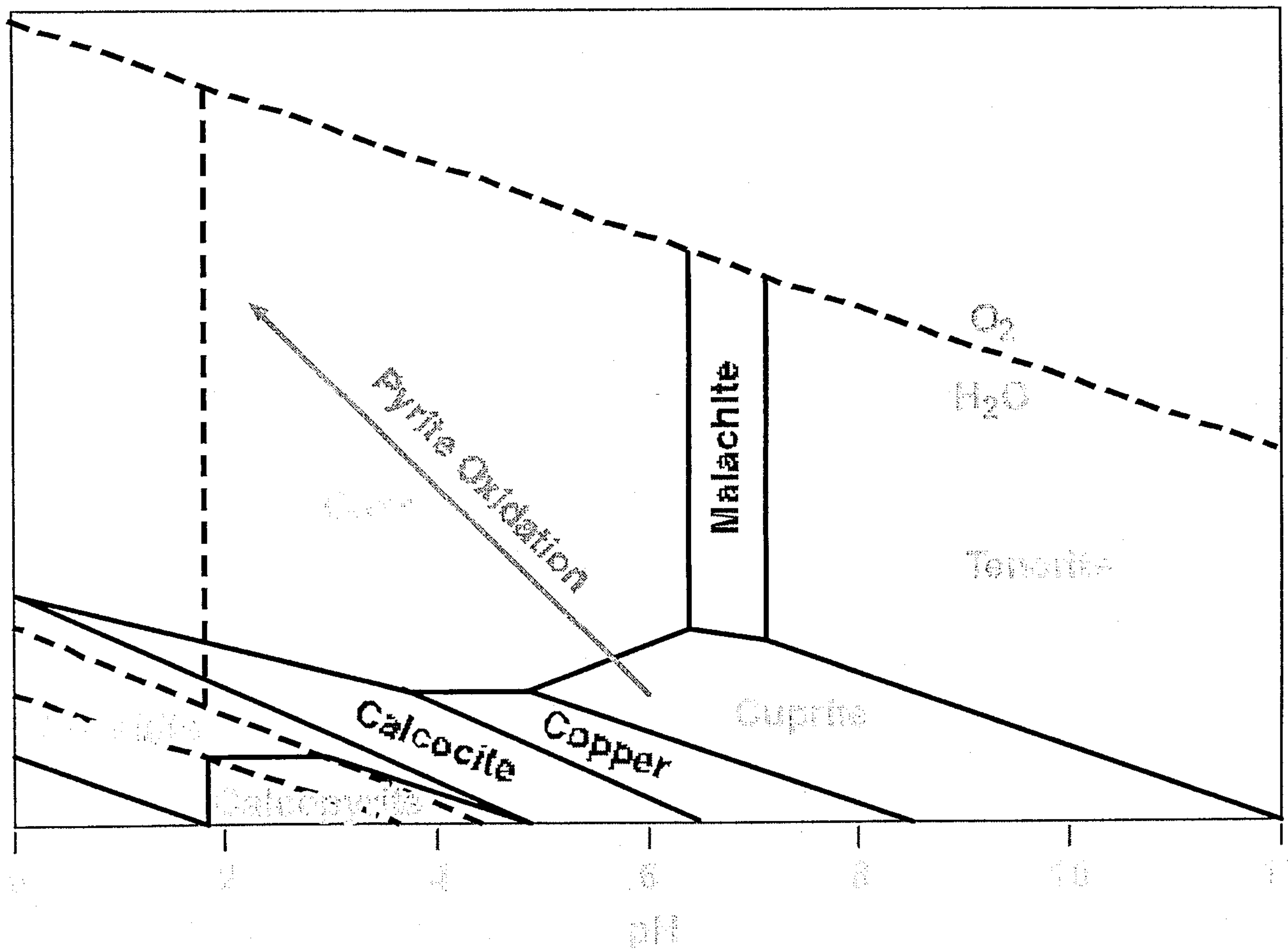
Eh-pH Diagram for Copper



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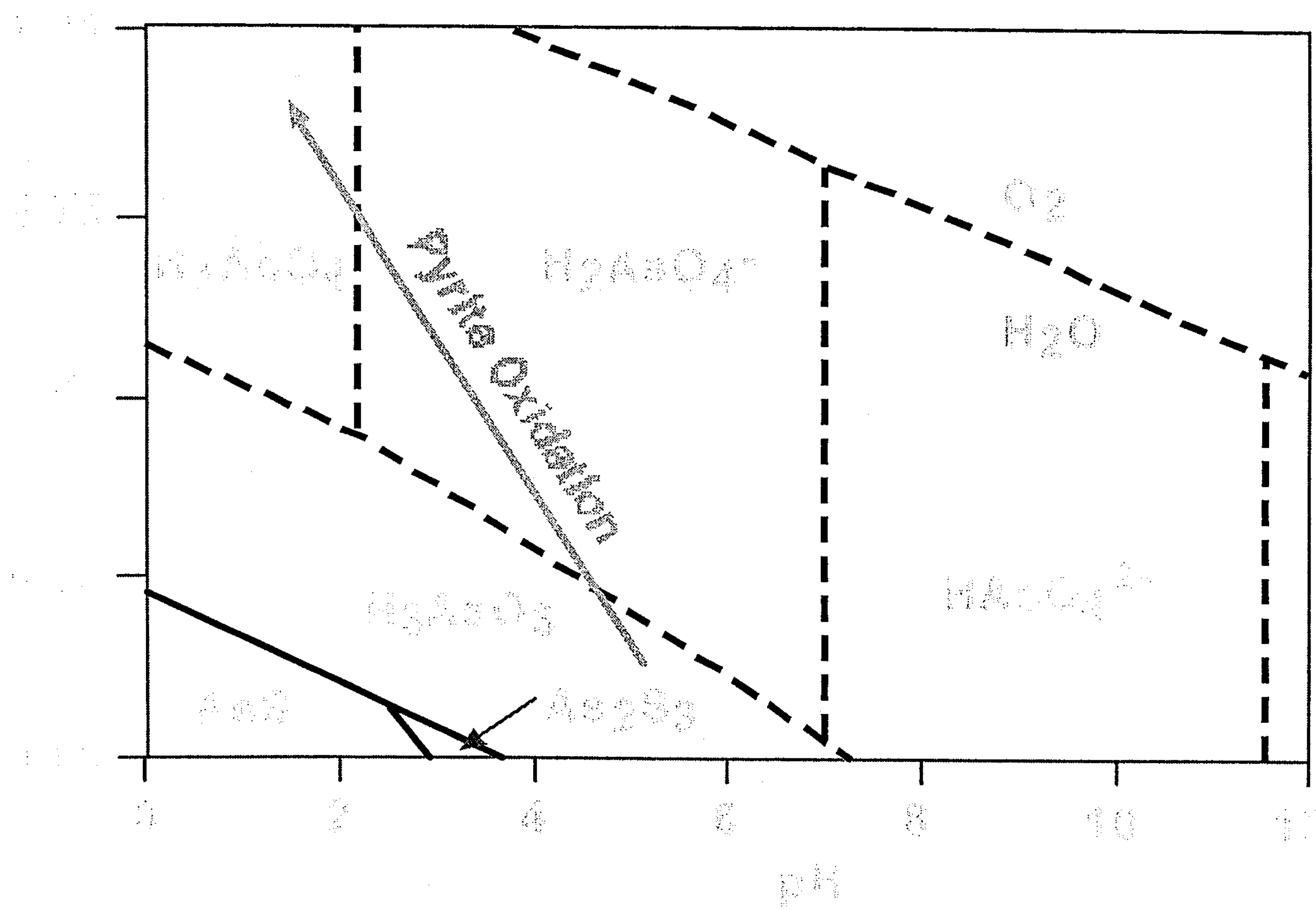
Eh-pH Diagram for Arsenic



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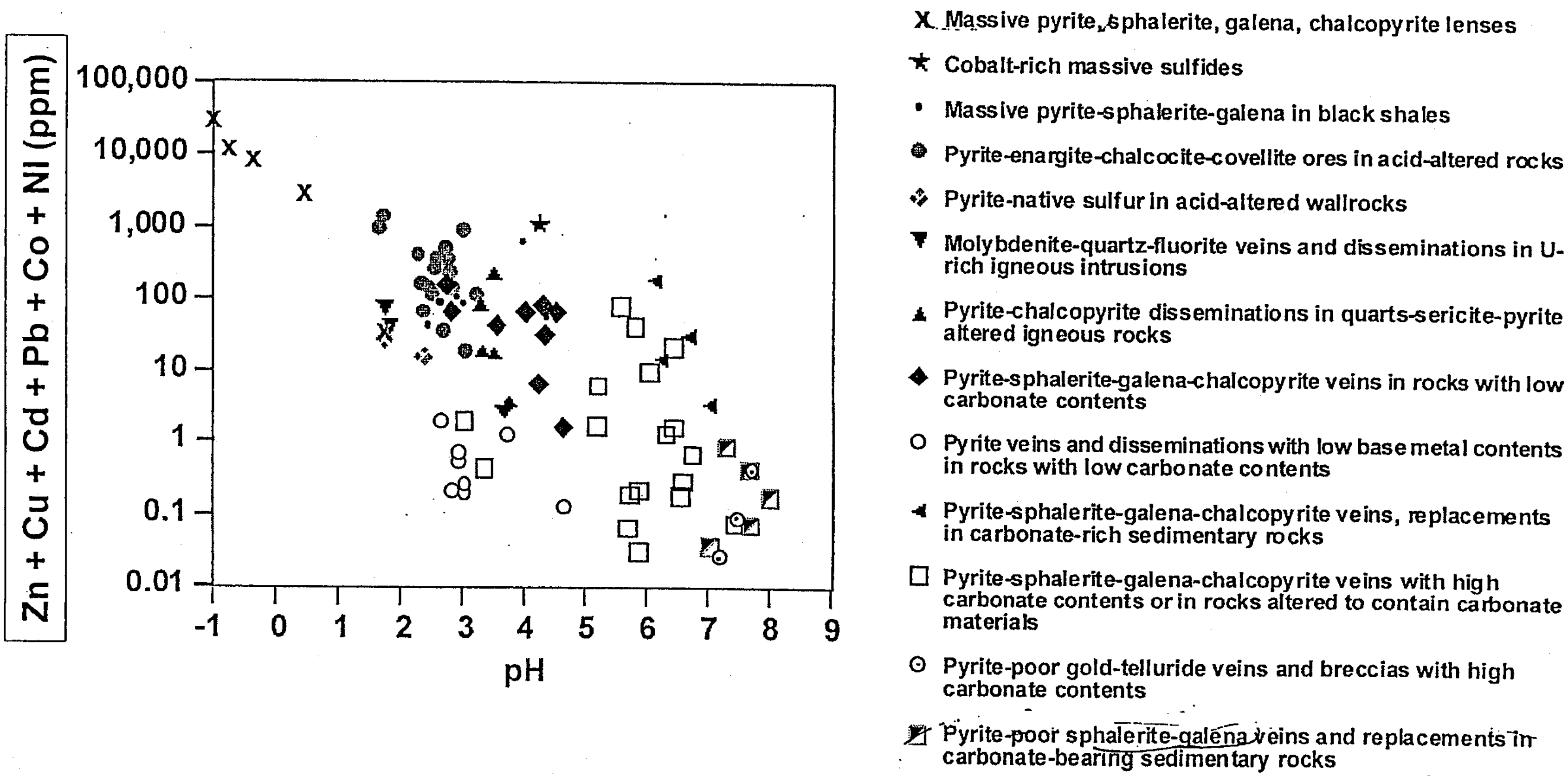
Variation in Aqueous Base Metal Concentrations with pH for Water Draining Various Mineralized Rock in Diverse Sites in Colorado, USA



After Plumlee and Nash, 1995

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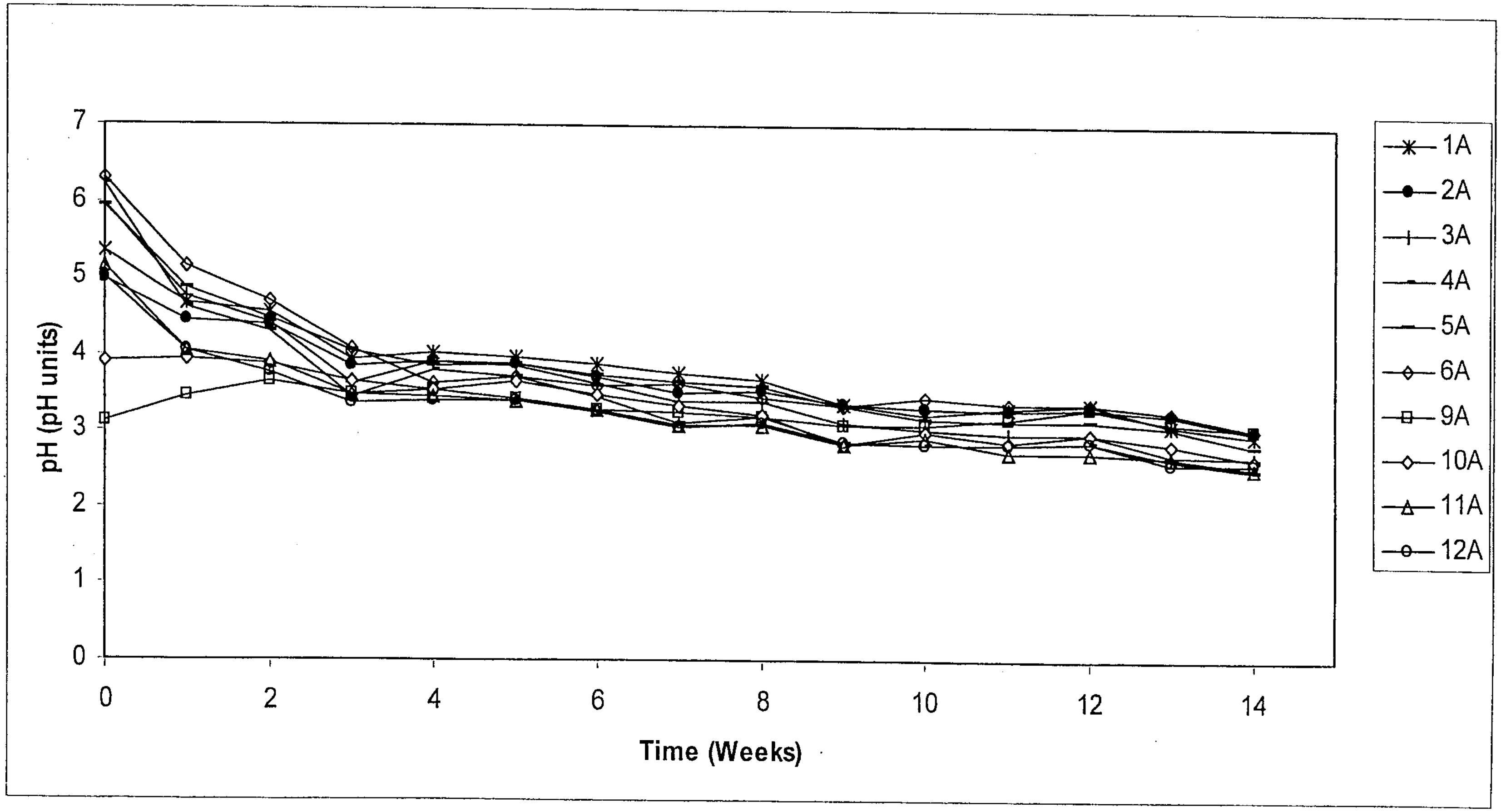
Summary of pH in Humidity Cell Testing of Tailings



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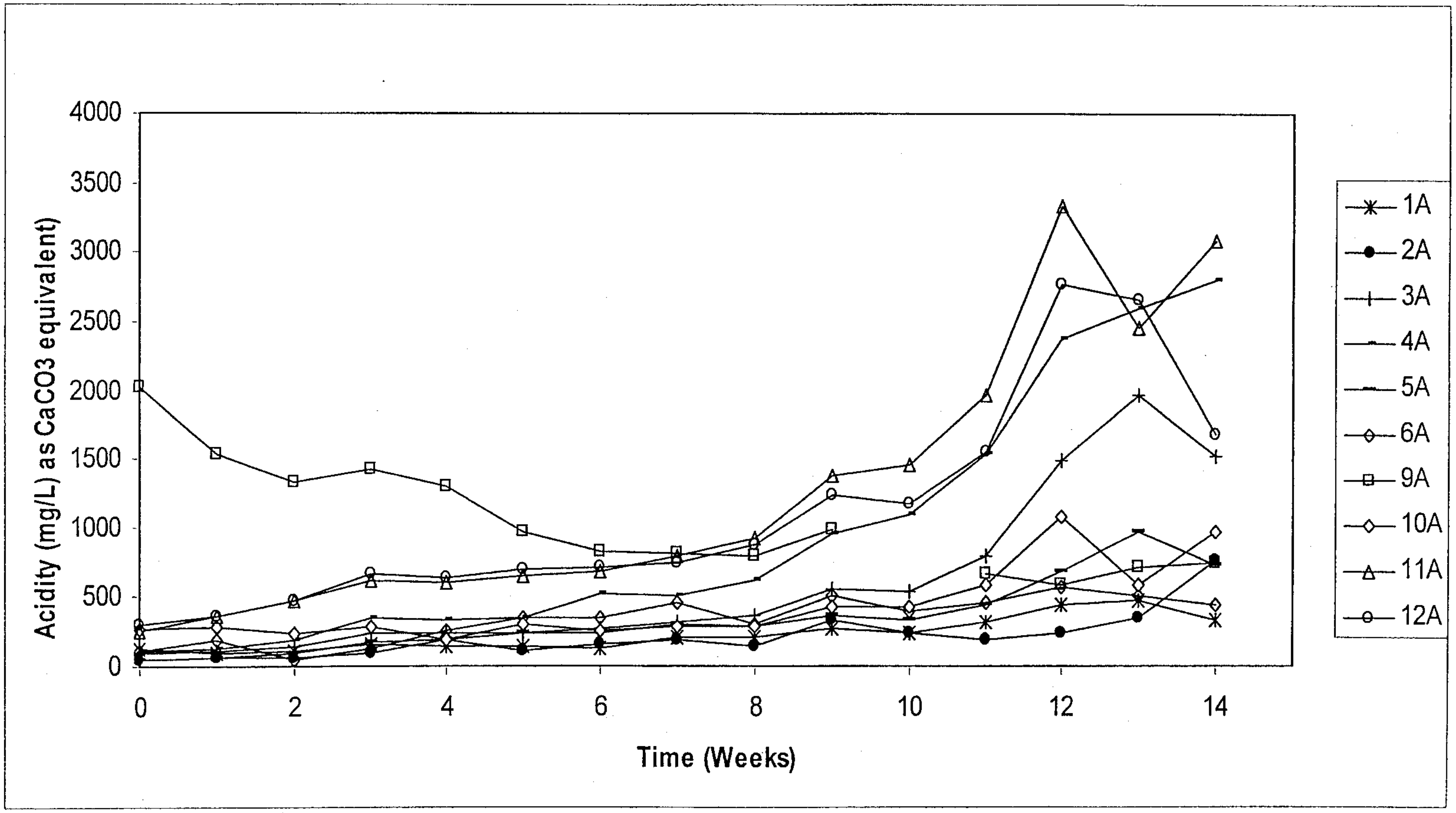
Summary of Acidity in Humidity Cell Testing of Tailings



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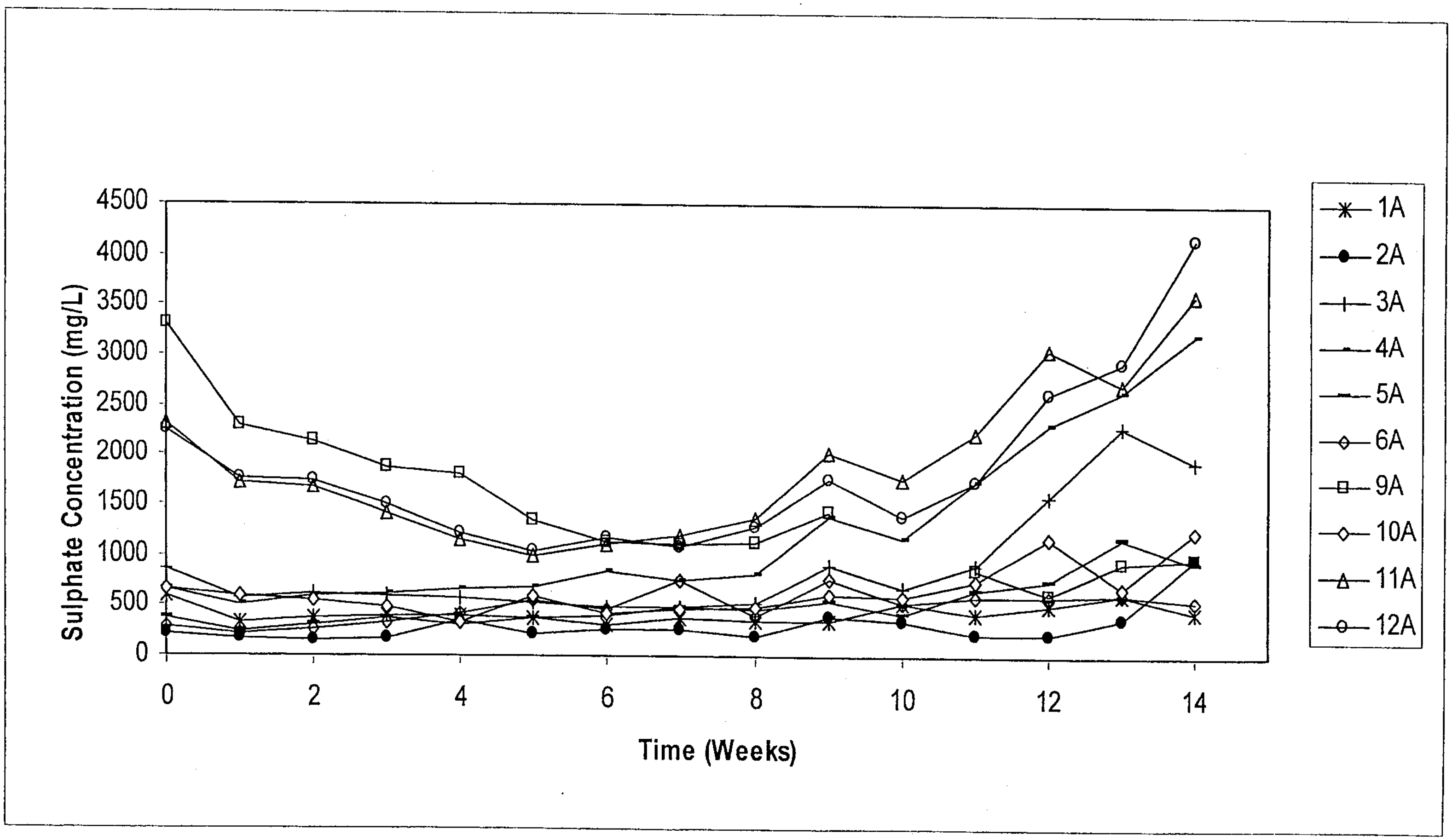
Summary of Sulphate Concentration in Humidity Cell Testing of Tailings



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Effect of Modifying Factors on Aquatic Risk

❖ Hardness	~ 2 - 10 x
❖ pH (direct)	~ 2 - 4 x
❖ eH	~ 2 - 5 x
❖ Alkalinity	~ 2 - 4 x
❖ Dissolved Organic Matter	~ 2 - 10 x
❖ Organism Acclimation	~ 2 - 3 x
	Product ?
❖ Acid Volatile Sulphides	~ 2 - 20

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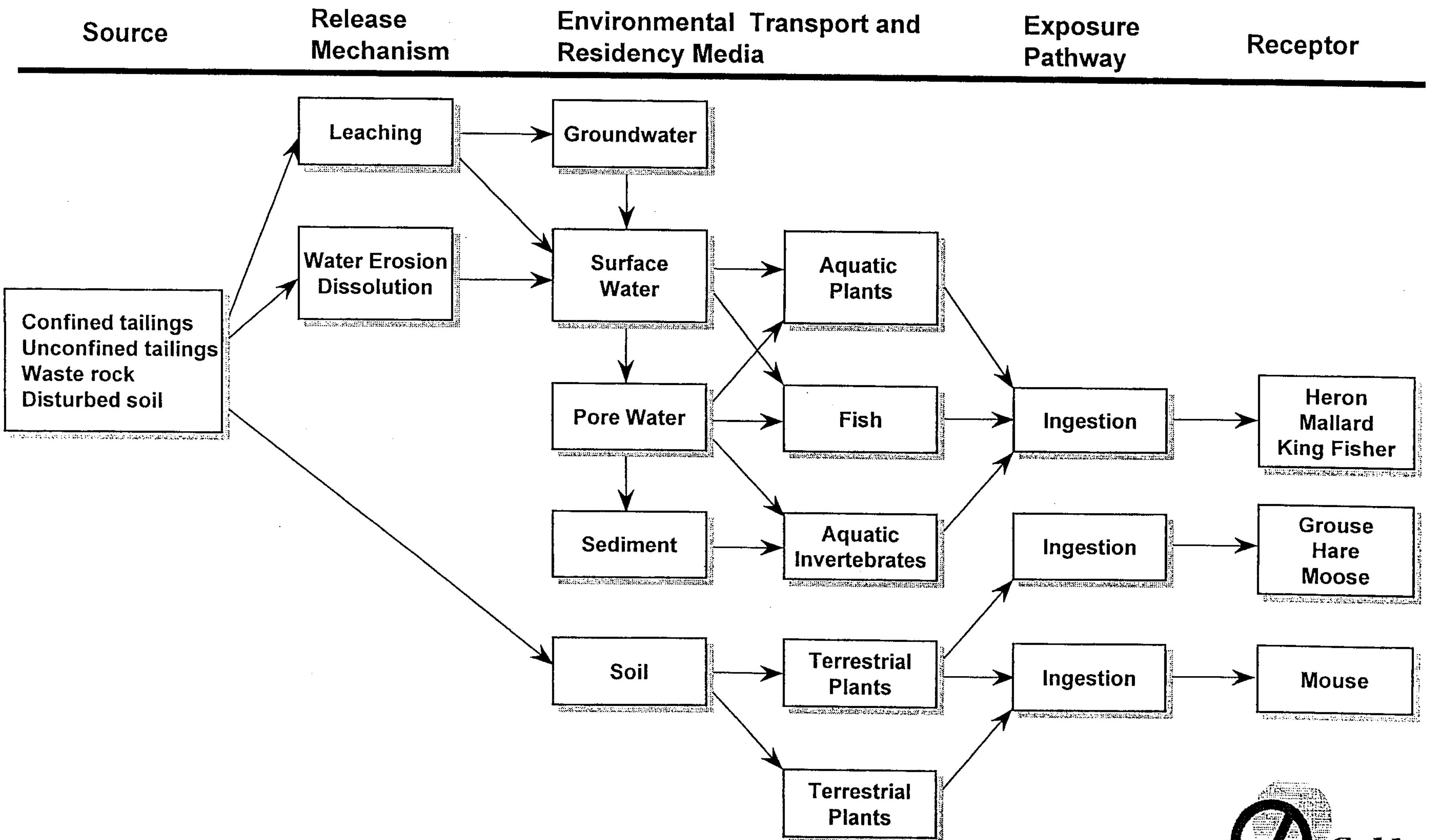
Conceptual Model for Wildlife



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Wildlife Health Risk Assessment

- Risk Characterization:
  - *calculate Exposure Ratio (ER)*

    $$ER = \frac{\text{predicted exposure}}{\text{toxicity reference value}}$$

  - *ER<1: no health risks identified*
  - *ER>1: potential health risks identified*

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Wildlife Health Risk Assessment

- **Exposure Assessment:**
  - *predict exposures likely to be received by each species, based on foraging preferences, food and water ingestion rates, etc.*

- **Let's Get Real!**
  - *hypothetical individual versus population*
  - *integrate habitat variability and habitat range with exposure*

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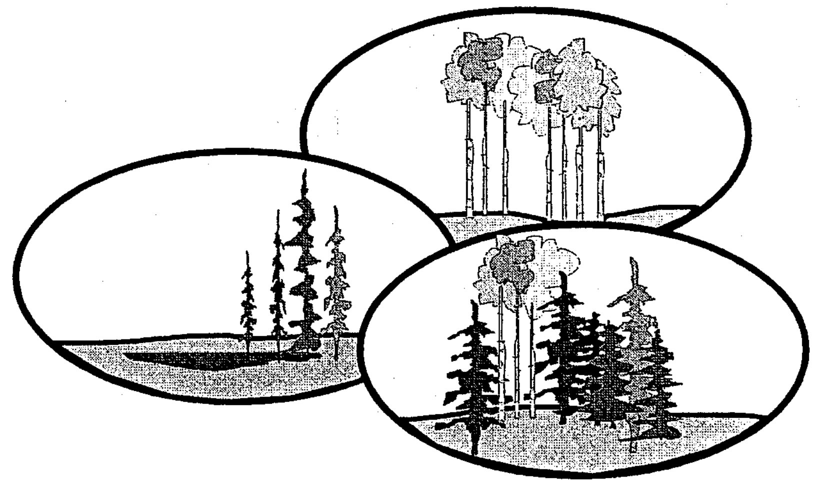
Wildlife Health Population Model

- ELC areas are determined by GIS mapping
- different soil types
- site is divided into areas defined by ELC and soil type
- plant concentrations in each ELC calculated based on soil type or measured data
- habitat preferences determine where animal may forage



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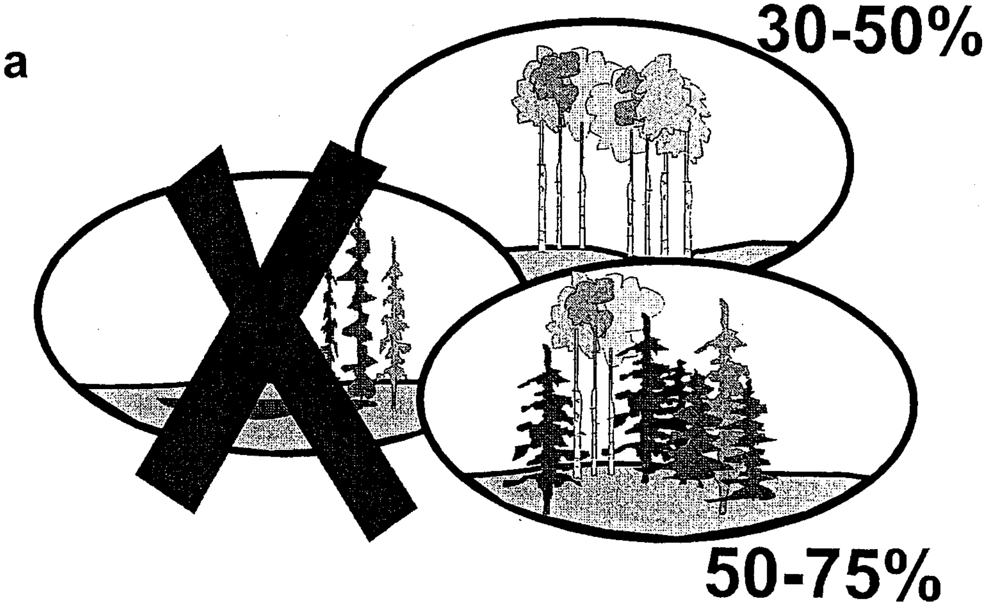
Receptor Habitat Preferences

- preference for ELC types determined by expert assessment
- preference modelled as a likelihood of selection



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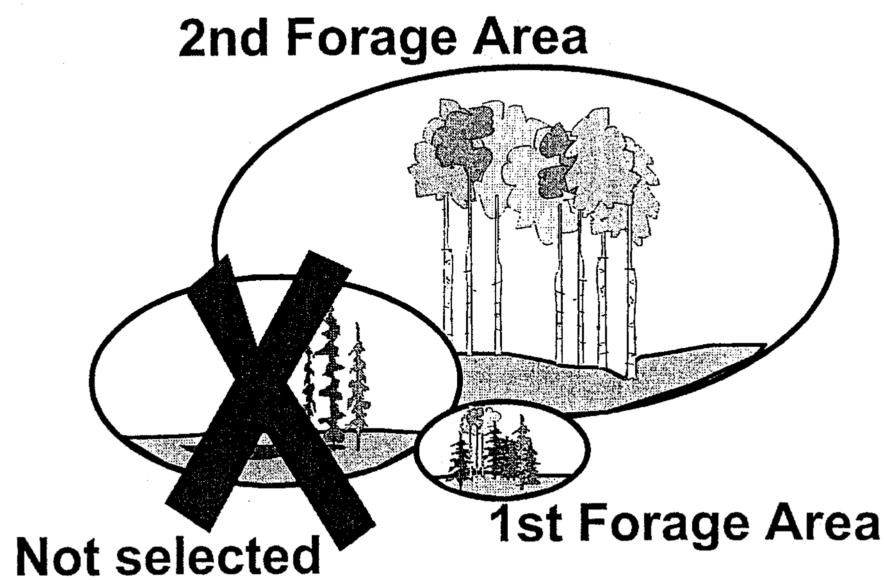
Receptor Dose Sampling

- forage ELC areas are randomly drawn based on preference
- the available forage areas are sampled in random order
- the number of ELC areas sampled depends on size of area and receptor forage area desired



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Wildlife Health Exposure Equations

Pathway	Equation and Equation Parameters
Water Ingestion	$EDI_{water} = \frac{IR \times BA \times C_{water} \times EF}{BW}$
	EDI_{water} = incidental water consumption while swimming (mg chemical/kg body weight/day) IR = ingestion rate (L/day) BA = oral bioavailability of compound (chemical-specific, unitless) C_{water} = chemical concentration in water (mg/L) EF = frequency of exposure (days/year) BW = receptor body weight (kg)

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Wildlife Health Exposure Equations

Pathway	Equation and Equation Parameters
Meat/Plant Ingestion	$EDI_{meat/plant} = \frac{IR \times BA \times C_{meat/plant} \times ED}{BW}$
	$EDI_{meat/plant}$ = estimated daily intake from plant/meat ingestion (mg chemical/kg body weight/day) IR = ingestion rate (kg/day) BA = oral bioavailability of compound (chemical-specific, unitless) $C_{meat/plant}$ = chemical concentration in meat/plant (mg/kg) ED = duration of exposure (days) BW = receptor body weight (kg)

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Population Exposure

- **Each iteration**
  - *produces an estimate of dose for a single individual in the region's sub-population*
- **Entire simulation**
  - *produces an estimate of risk for the region's sub-population*

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ERA vs Canada Fisheries Act

- Federal and Provincial Policy support ERA
- CFA 36 (3) prohibits the deposit of a deleterious substance of any type in water frequented by fish
- Definition of deleterious is not defined by exposure, in contrast to risk
- "1 drop in the ocean is deleterious"
- ERA results may contradict CFA at times, raising conflict