BARR

Big Scale and Gradual Change, Using Models to Gain Perspective

Evan Christianson, Barr Engineering

Groundwater Response Can Be S L O W

Managing change that occurs at very large scales and over generations is difficult

The Problem of Generational Amnesia

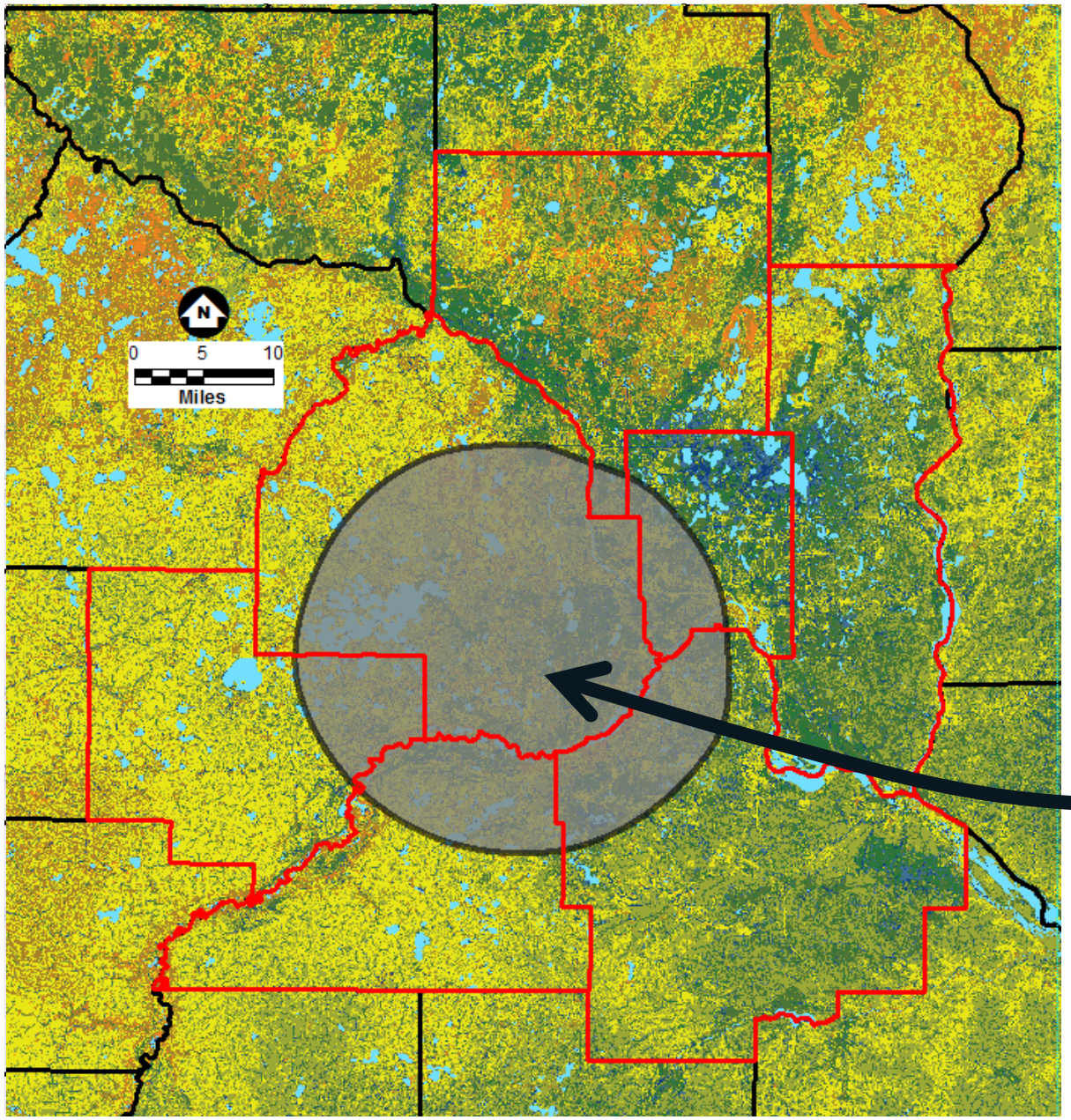
- Generation 1 – Pristine
- Generation 2 – Clean, good swimming and fishing
- Generation 3 – Recreate certain times of the year, limit fish consumption
- Generation 4 – It looks pretty, but that's about it
- Generation 5 – It looks nice..sometimes..when it doesn't smell

The Problem of Generational Amnesia

Generational change in groundwater is even more difficult

Max Pixel

Groundwater Pumping 7- County Metro Area



2012-2016 Avg. Infiltration (Recharge)

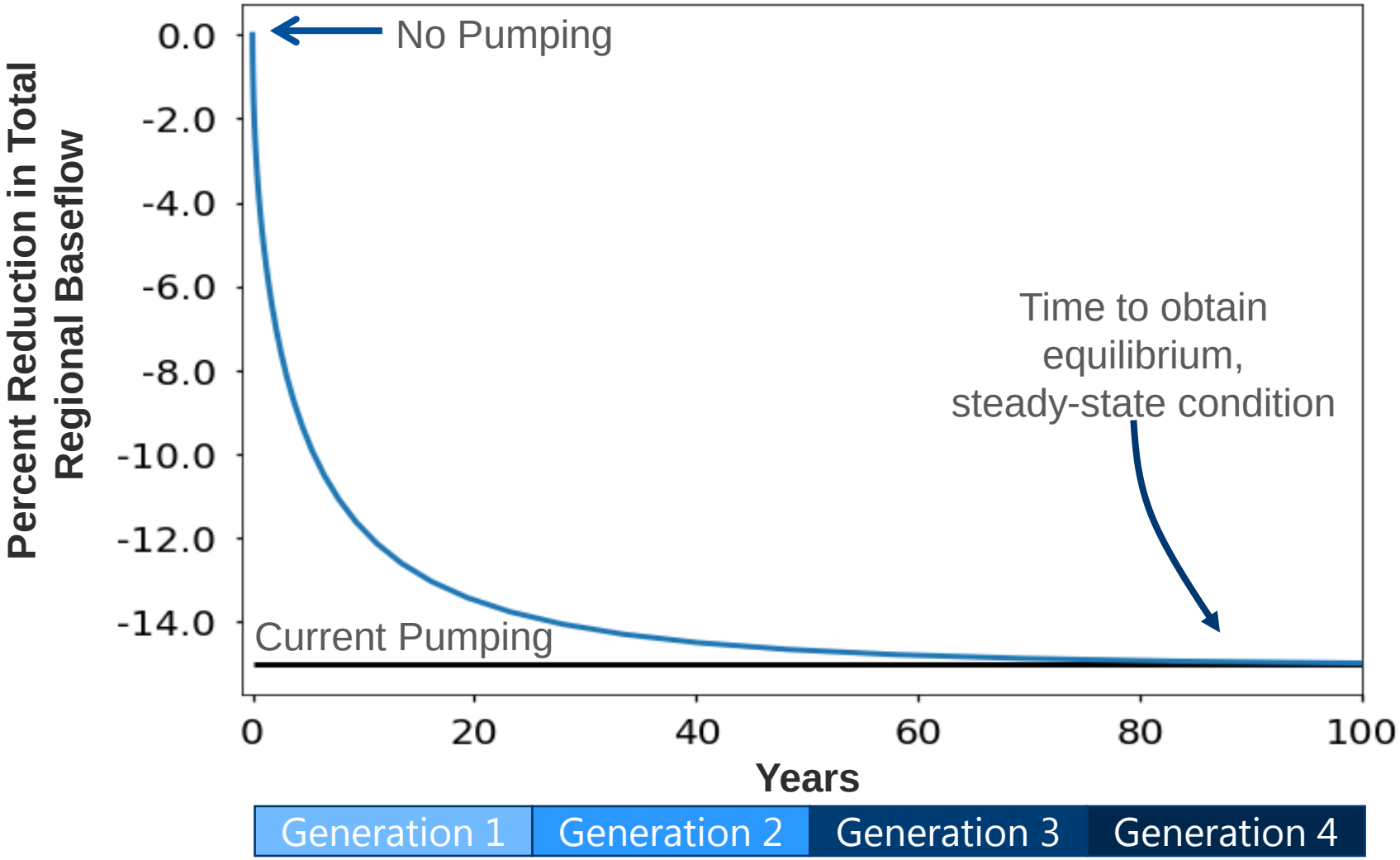
- 100,375,000,000 Gallons
  - (2012-2016 Avg.)
- 275,000,000 Gallons Per Day
- 191,000 gpm
- Equivalent to 1.9 inches per year across the 7-county metro
- Or 100% recharge in this area

Infiltration, inches per year

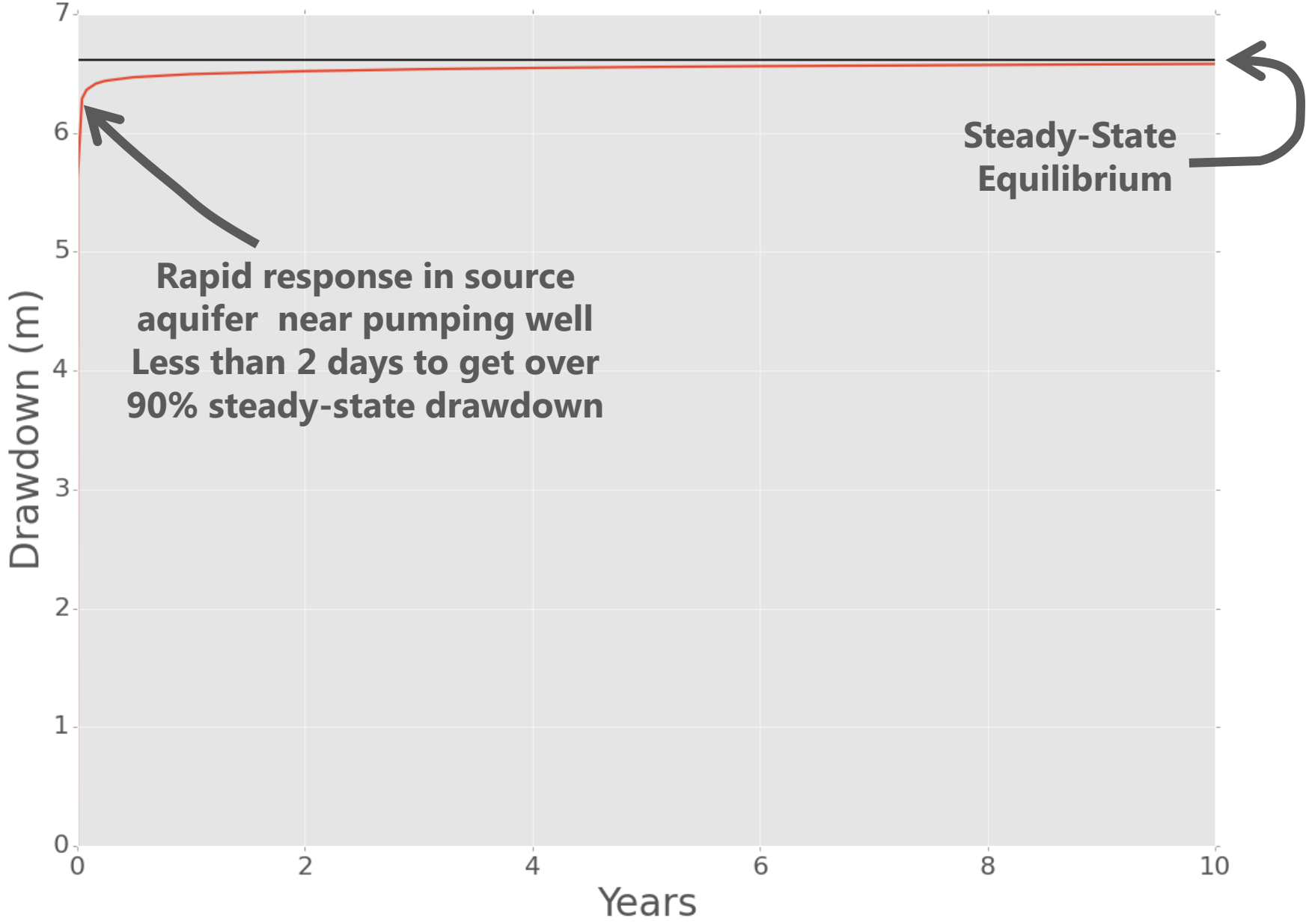
0.00 - 2.00	10.01 - 12.00
2.01 - 4.00	12.01 - 14.00
4.01 - 6.00	14.01 - 16.00
6.01 - 8.00	16.01 - 18.00
8.01 - 10.00	> 18.01
	Water Body

Metro-Wide Thought Experiment

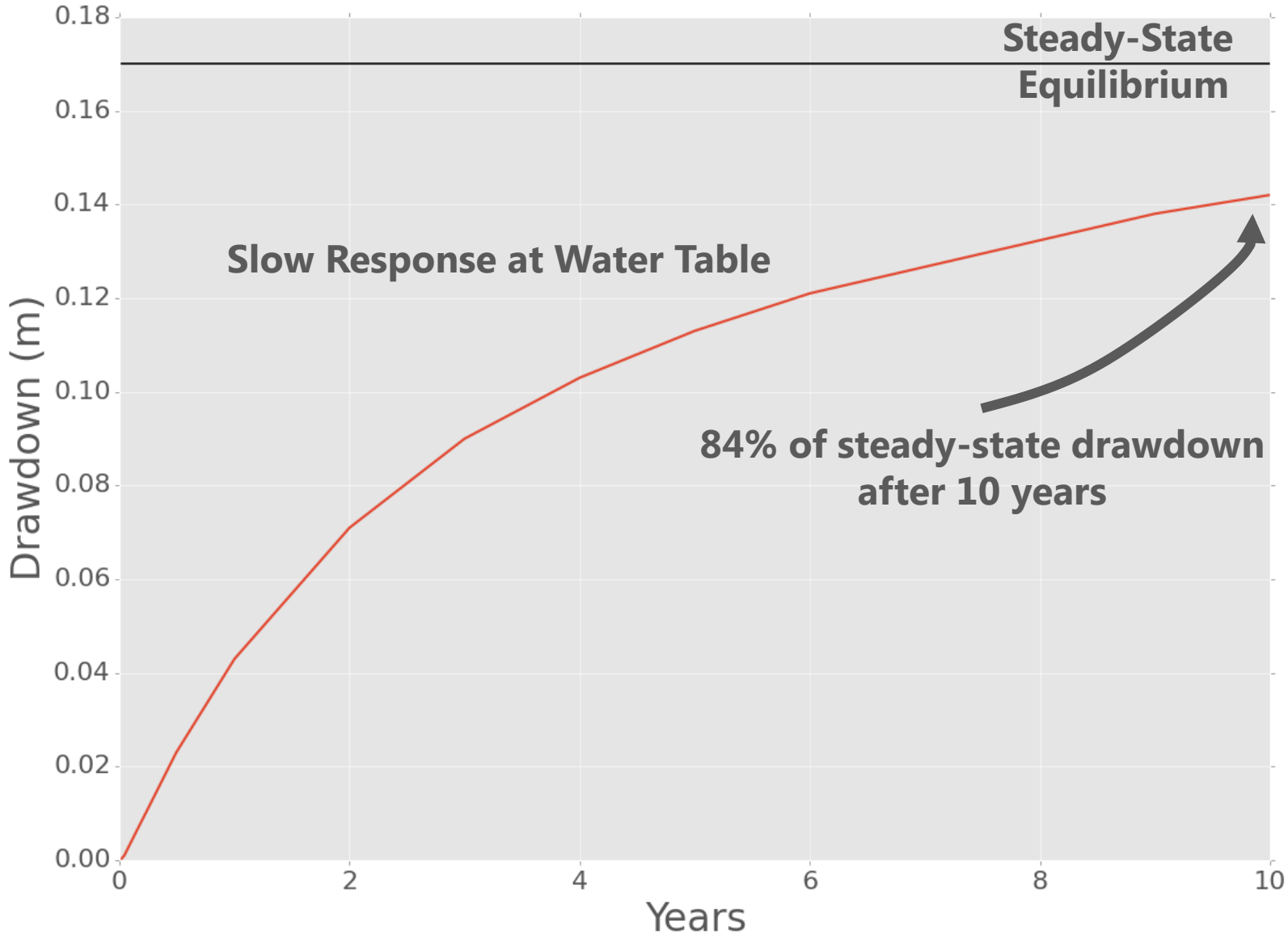
Go from no-pumping to current conditions
How long for changes in baseflow to equilibrate?



Drawdown in Jordan Aquifer Near Pumping Well



At Water Table Near Pumping Well



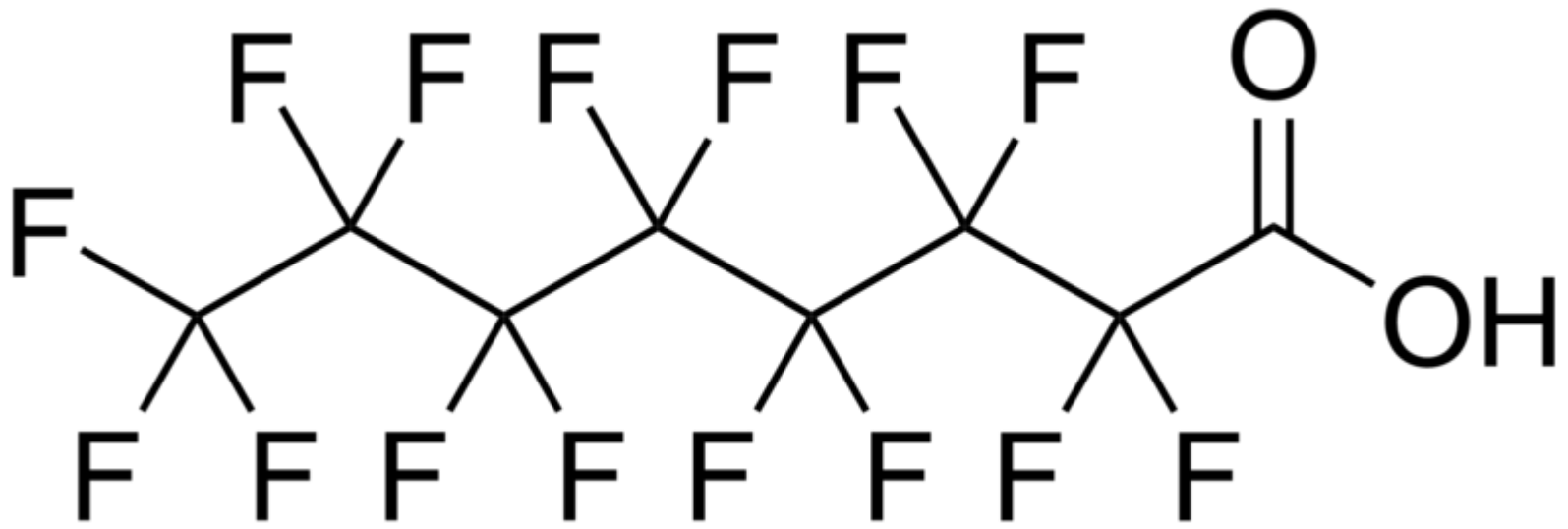
Non Point Source Groundwater Contamination

NO_3^-

Cl^-

PFAS

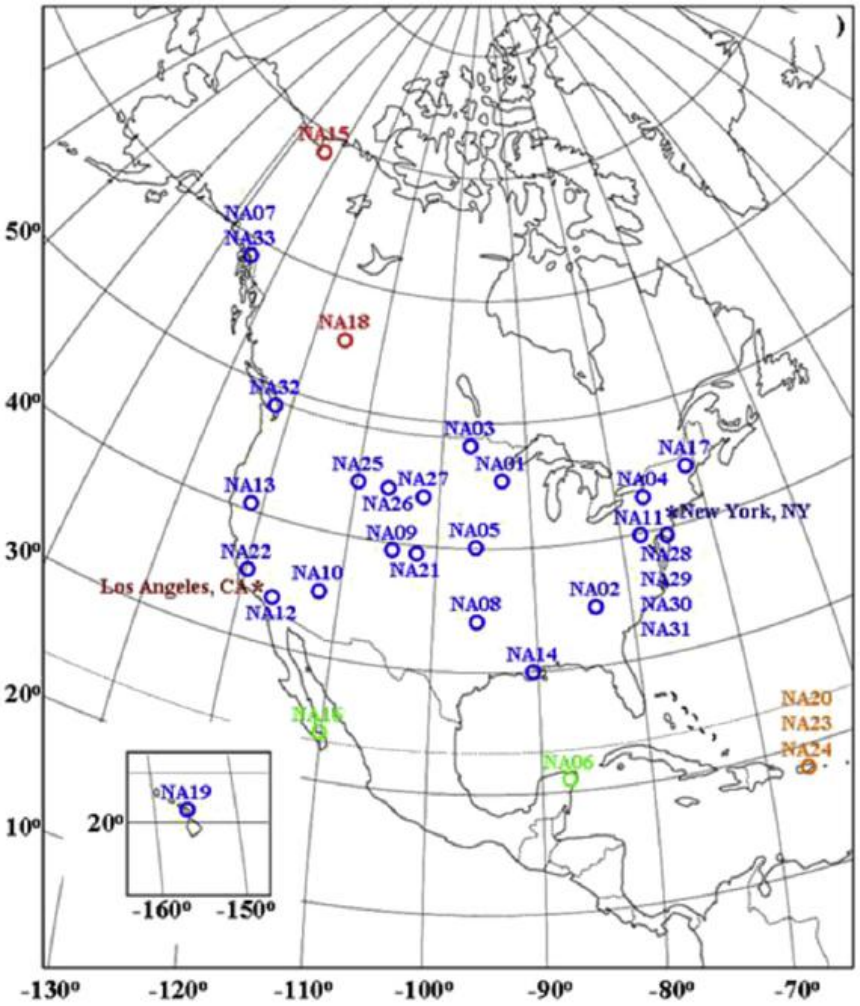
PFOA



Wikimedia Commons

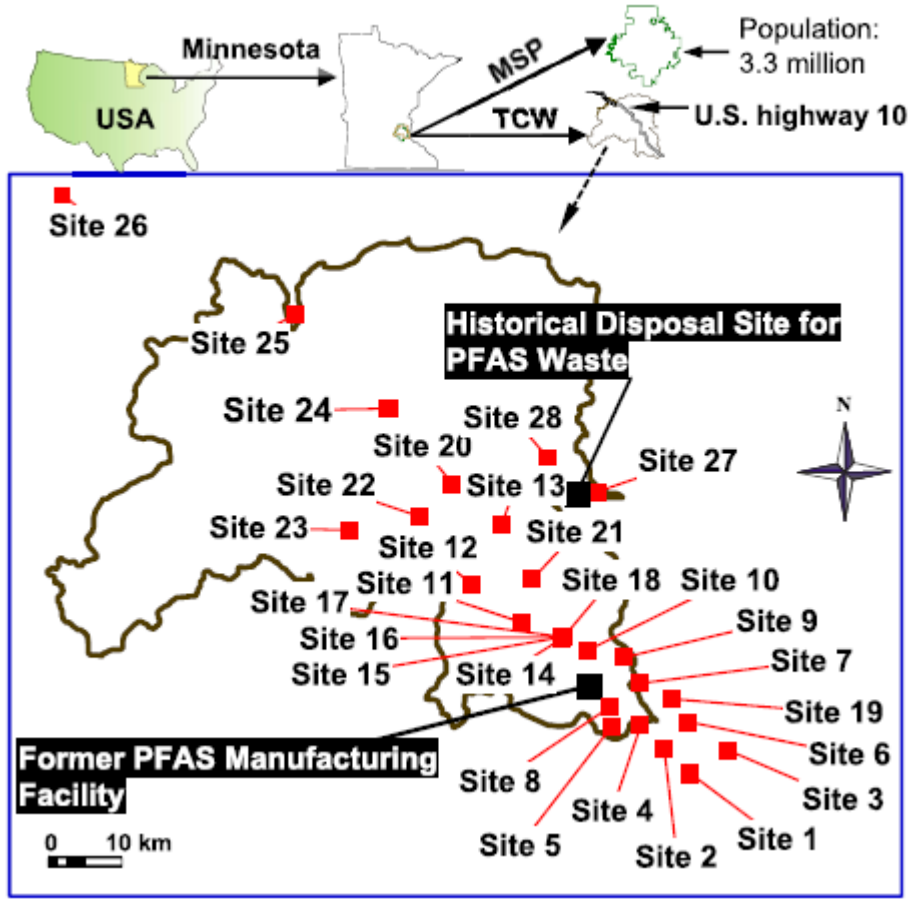
Rankin et. al., 2016

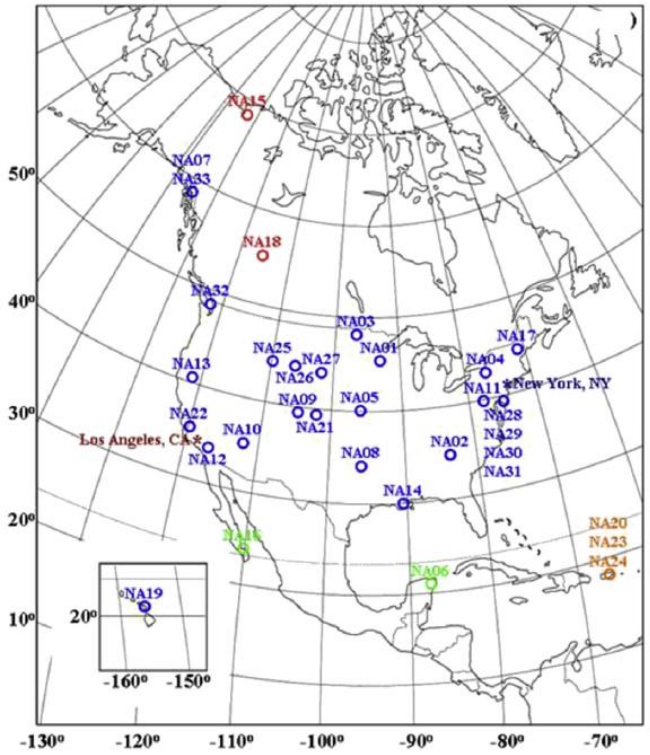
A North American and global survey of perfluoroalkyl substances in surface soils: Distribution patterns and mode of occurrence; Chemosphere

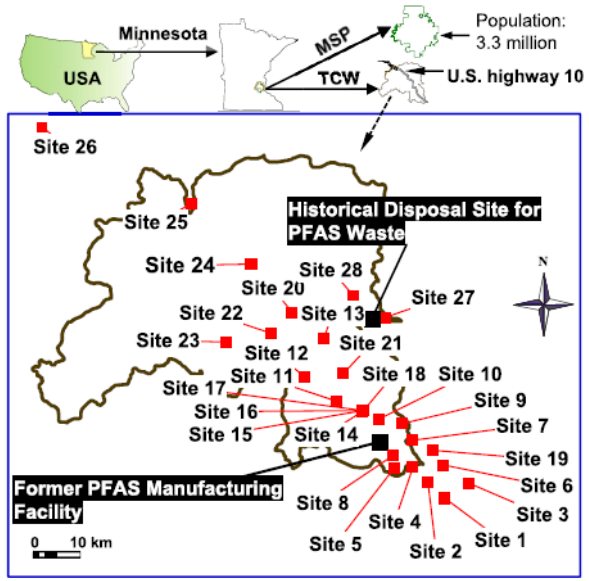


Xiao et. al., 2015

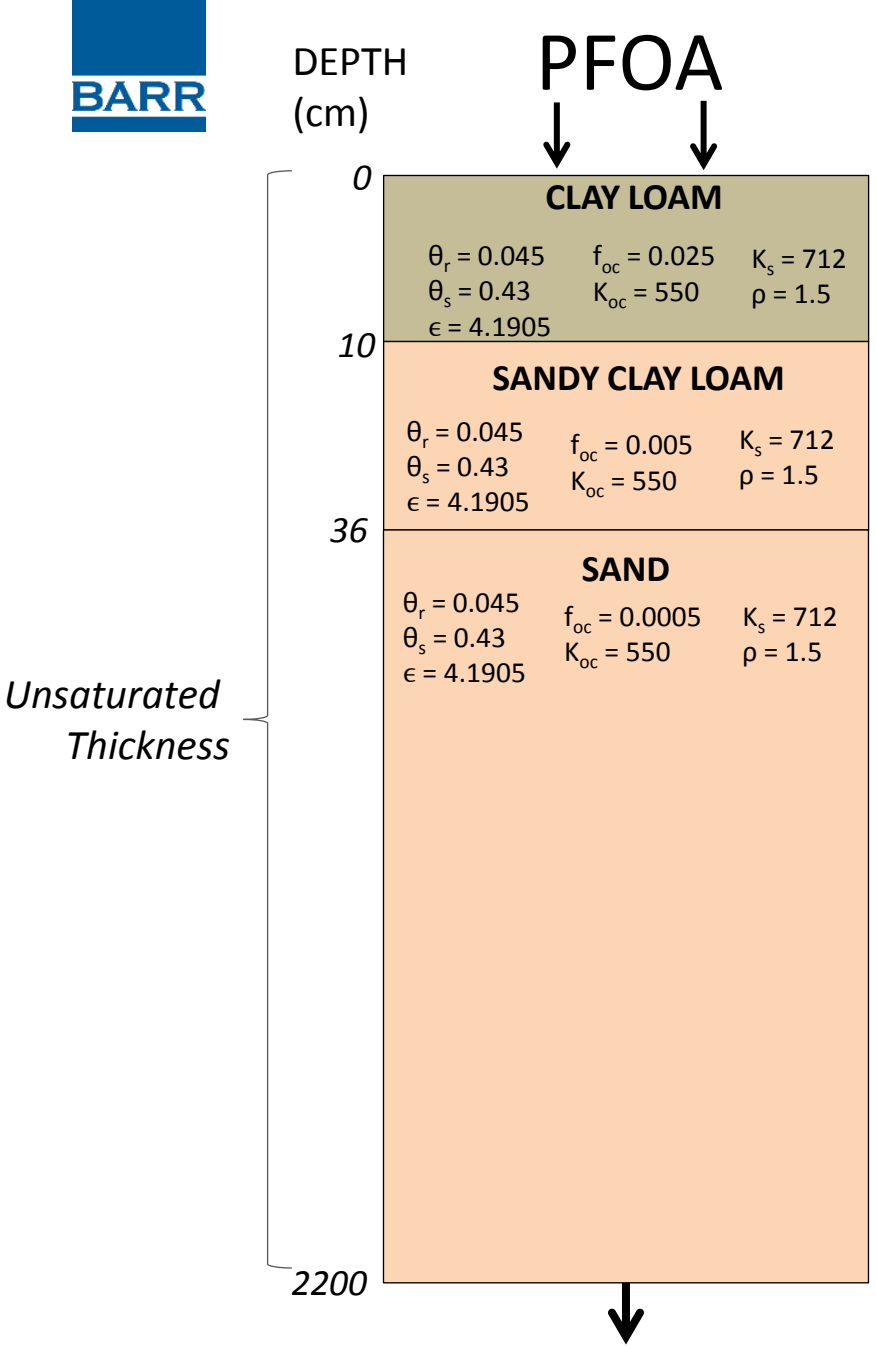
Perflurooctane sulfonate (PFOS) and perflurooctanoate (PFOA) in soils and groundwater of a U.S. metropolitan area: Migration and implications for human exposure; Water Research







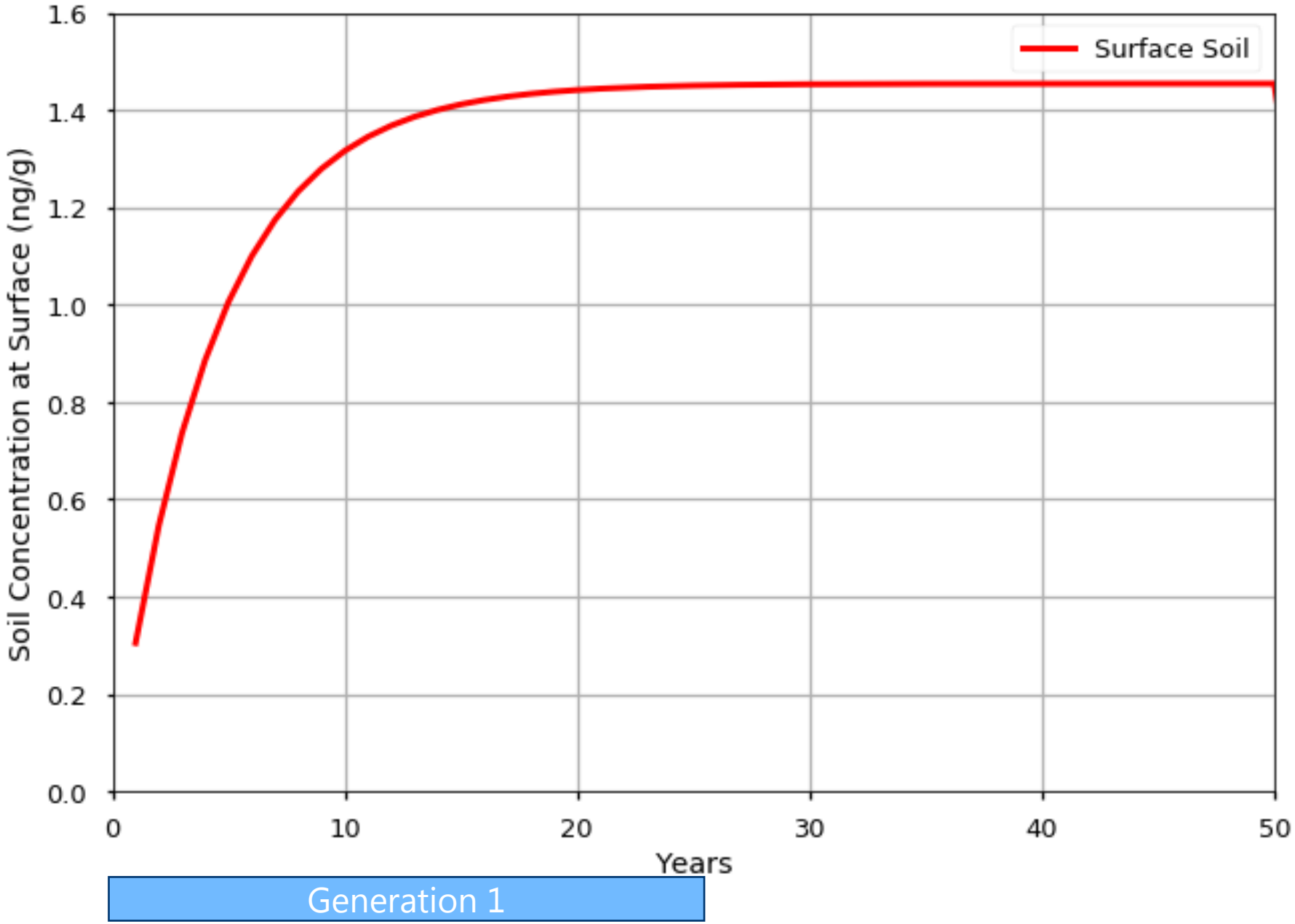
- Both studies found PFOA in all soil samples
- Concentrations ranged from:
  - Xiao et al: 0.2 to 28.2 ng/g
  - Rankin et al: 0.02 to 1.8 ng/g
- Dependent on TOC



MODEL INPUTS

θ_r = Residual Soil Water Content [cm^3/cm^3]
θ_s = Saturated Soil Water Content [cm^3/cm^3]
ϵ = Brooks-Corey Exponent
f_{oc} = Fraction Organic Carbon [unitless]
K_{oc} = Organic Carbon Partition Coefficient [cm^3/g]
K_s = Saturated Hydraulic Conductivity [cm/day]
ρ = Bulk Density [g/cm^3]

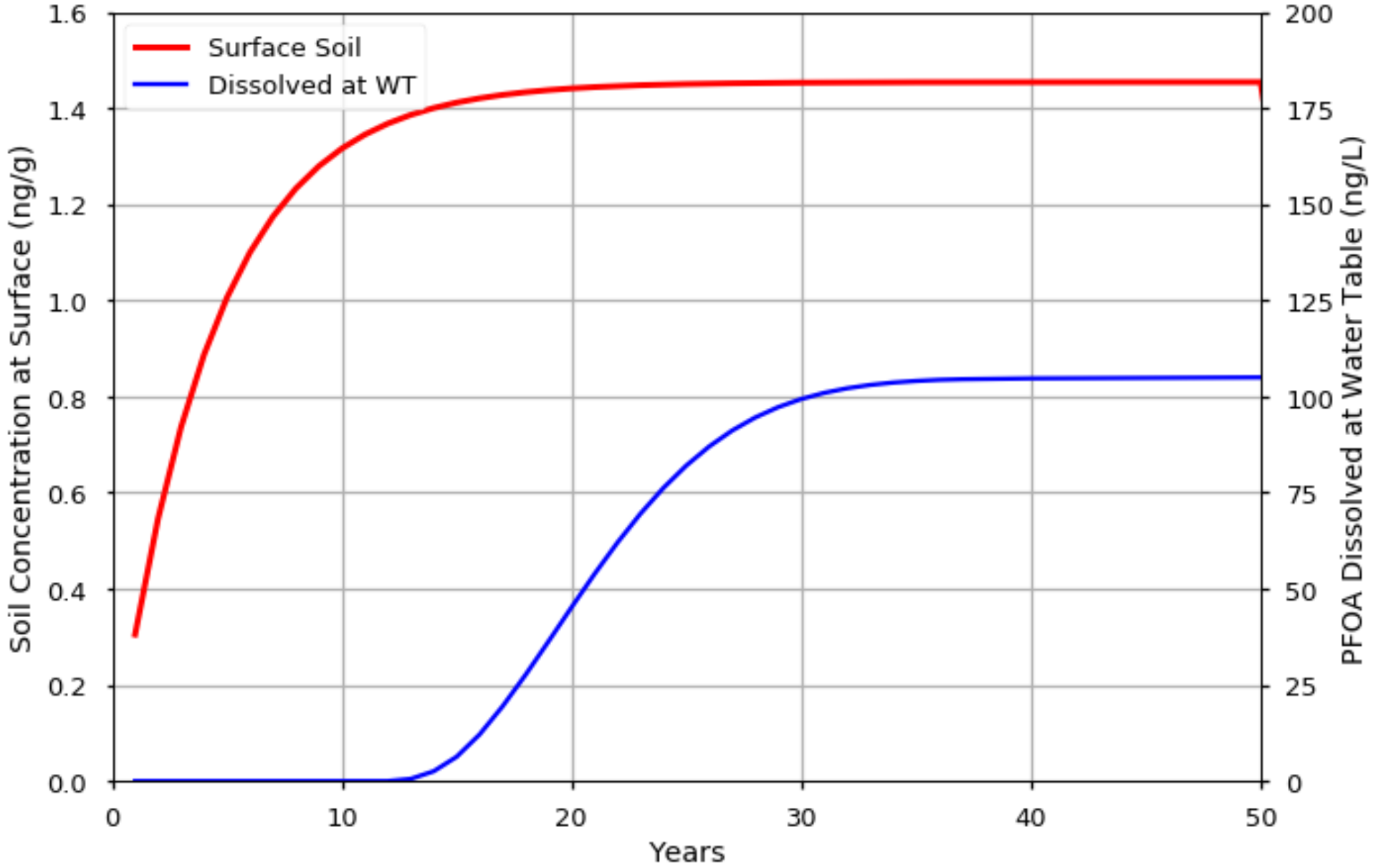
Load soil so that concentration at surface reaches equilibrium at 1.46 ng/g



Generation 1

BARR

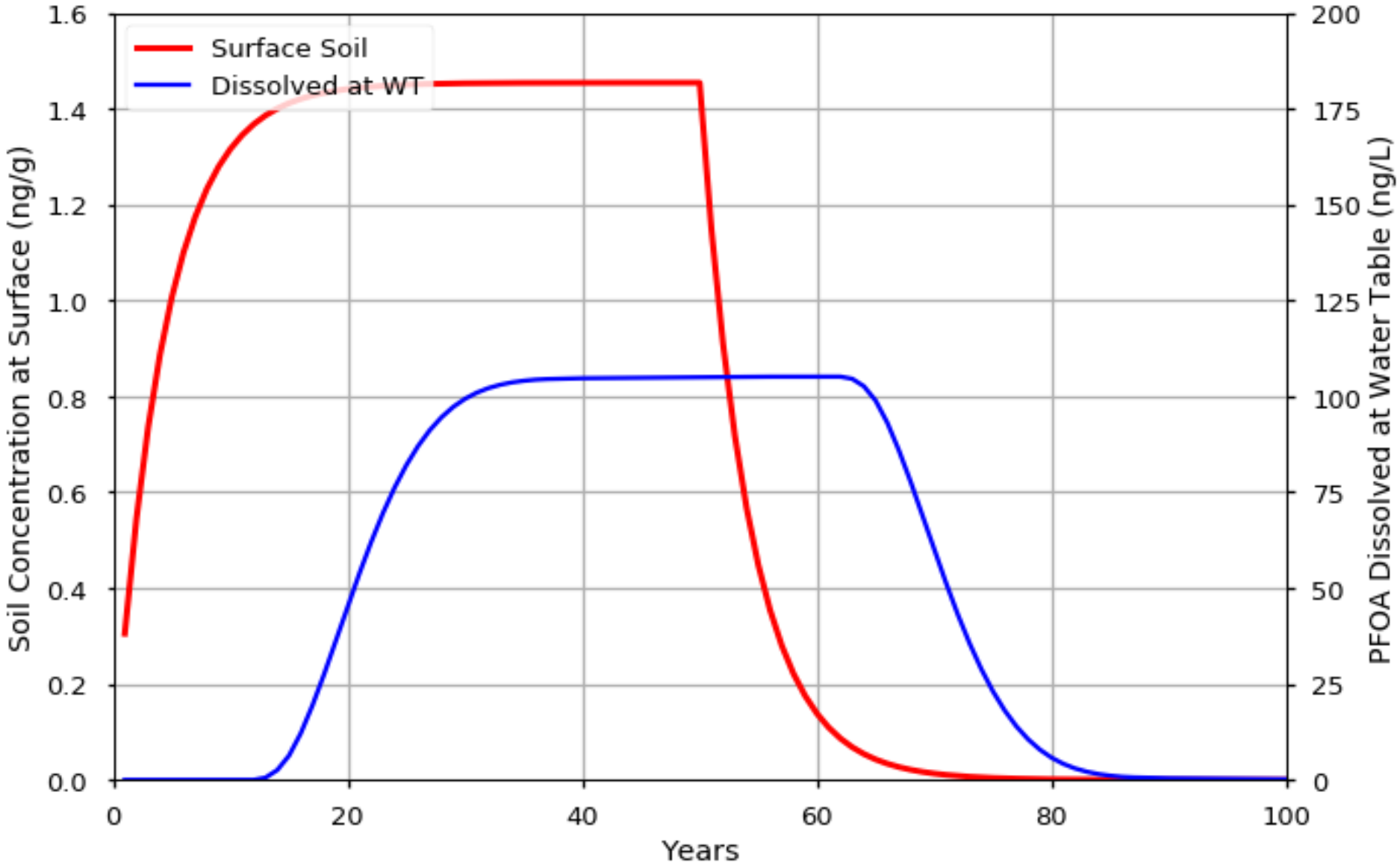
MN HBV for Groundwater= 35 ng/L



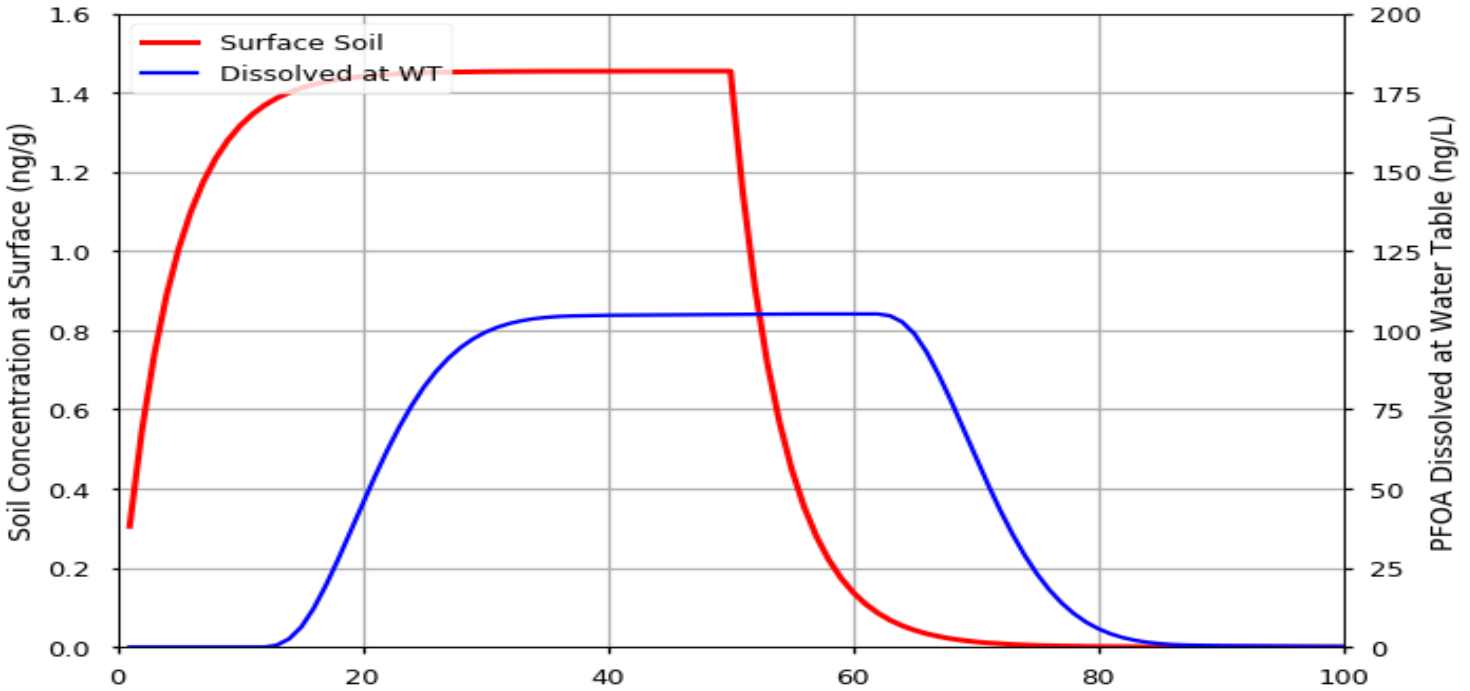
Generation 1 | Generation 2

BARR

MN HBV for Groundwater= 35 ng/L

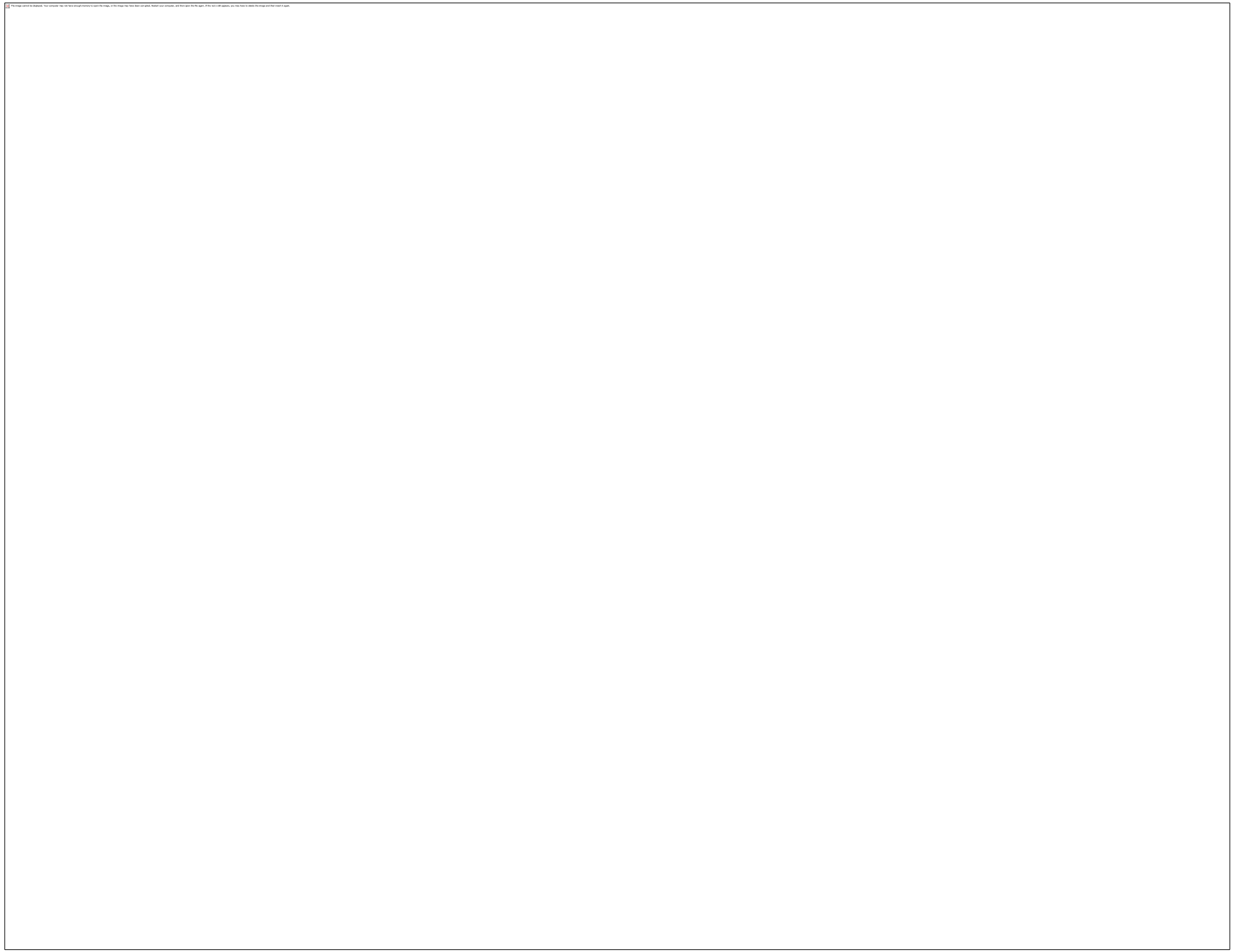


Generation 1 | Generation 2 | Generation 3 | Generation 4



Deep f_{oc} = 0.0005

Deep f_{oc} = 0.001


The image cannot be displayed. Your computer has not have enough memory to open the image, or the image may have been corrupted. Restart your computer, and then open the file again. If the red x still appears, you may have to delete the image and then insert it again.