Linking Pollution Estimates to Water Quality Goals

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TETRA TECH

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I Want to Meet Pollutant Reduction Goals and Protect My Resources… How Do I Figure This Out?

- ► Understanding the pollutants of concern
- ► What are priorities?
  - TMDLs, monitoring data, stakeholder concerns
- ► What are the needed reductions?
  - Watershed scale
  - Field scale
- ► Which BMPs are acceptable and encouraged?
- ► What tools are available to help determine reductions?

Presentation Outline

- ► Pollutants of concern
- ► Model selection – when is simple OK?
- ► 2 approaches to determine watershed pollutant loads
  - Unit area load
  - Event mean concentrations
- ► BMP pollutant removal
  - Watershed
  - Streambank and gully erosion
- ► Comparisons to loading goals
- ► Hands-on exercises

Goals

- ► Familiarity with simple watershed loading and pollutant removal models
- ► Understanding of when to use them and when not
- ► Provide examples of tools for
  - Pollutant removal estimates: grant applications, tracking in eLink, project benefit comparisons, etc.
  - Checking estimates (others' estimates and our own)

Typical Pollutants of Concern

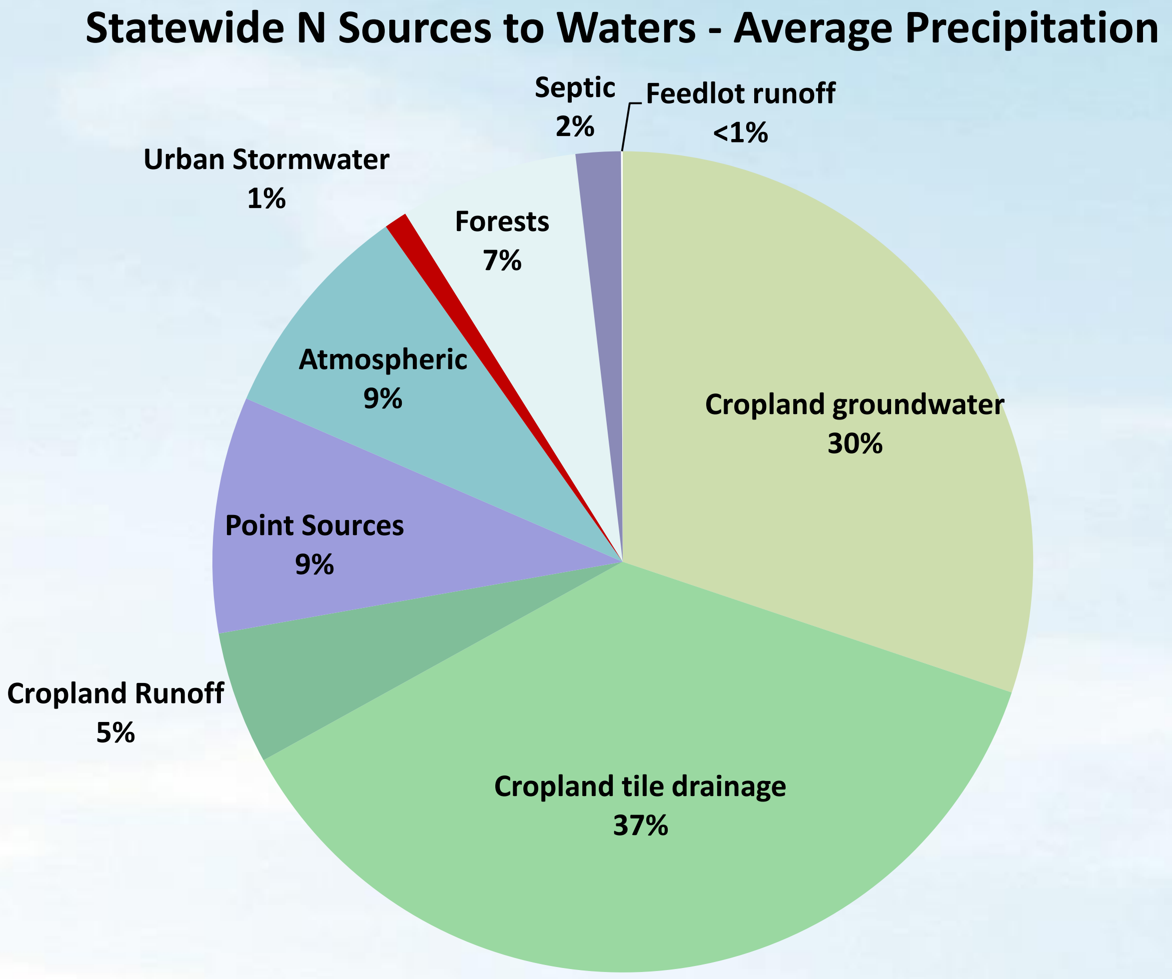
- ► Bacteria
- ► Nutrients – Phosphorus and Nitrogen
- ► Sediment
- ► Metals

Nitrogen in Minnesota

- MPCA currently working on nitrate standards for streams – to protect aquatic life
- Minnesota Nutrient Reduction Strategy – calls for reductions in nitrogen
- Focus on nitrogen for Gulf of Mexico restoration
  - Need <u>significant</u> basin-wide reductions to reduce hypoxia

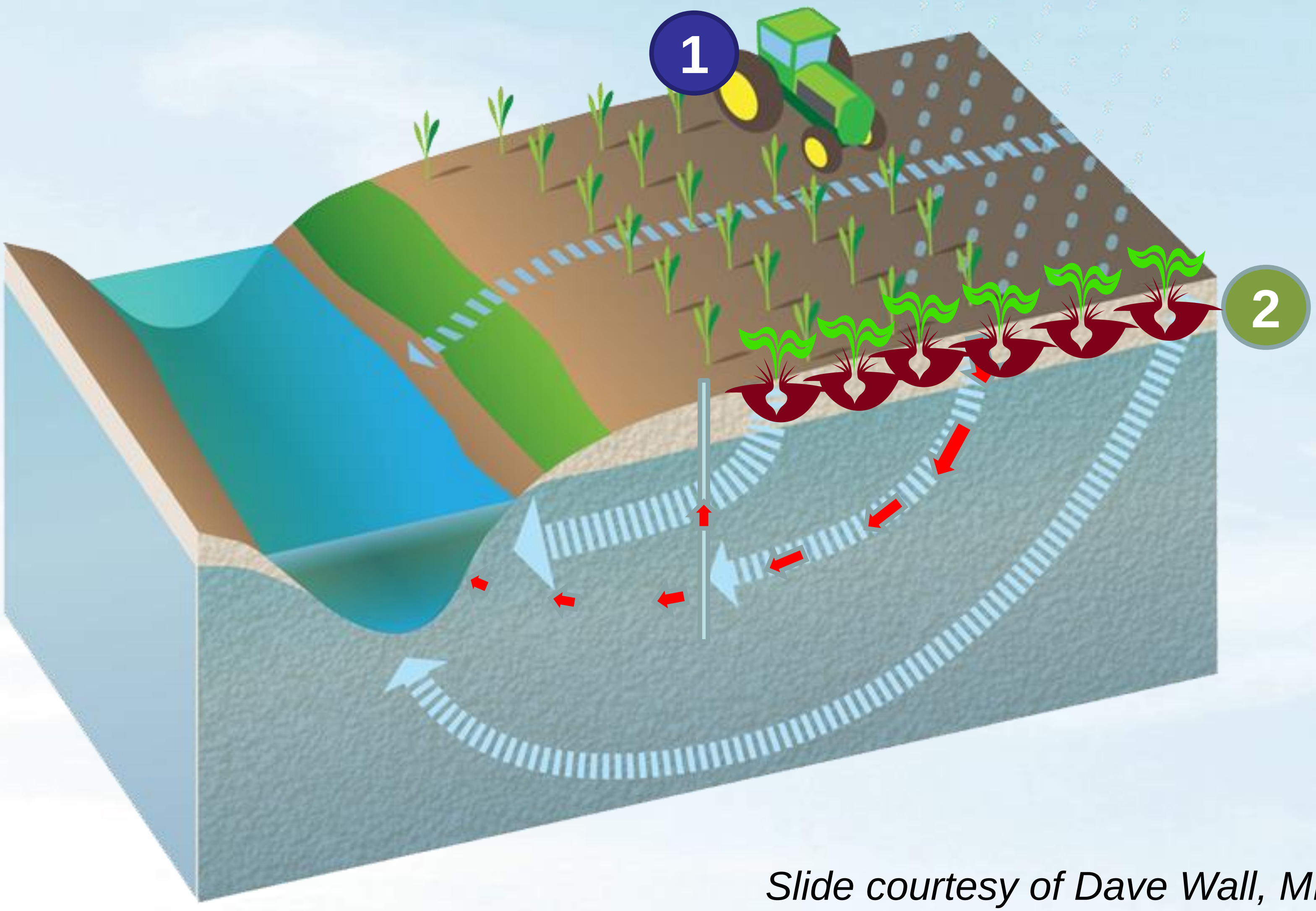
New publication by MPCA

Nitrogen in Minnesota



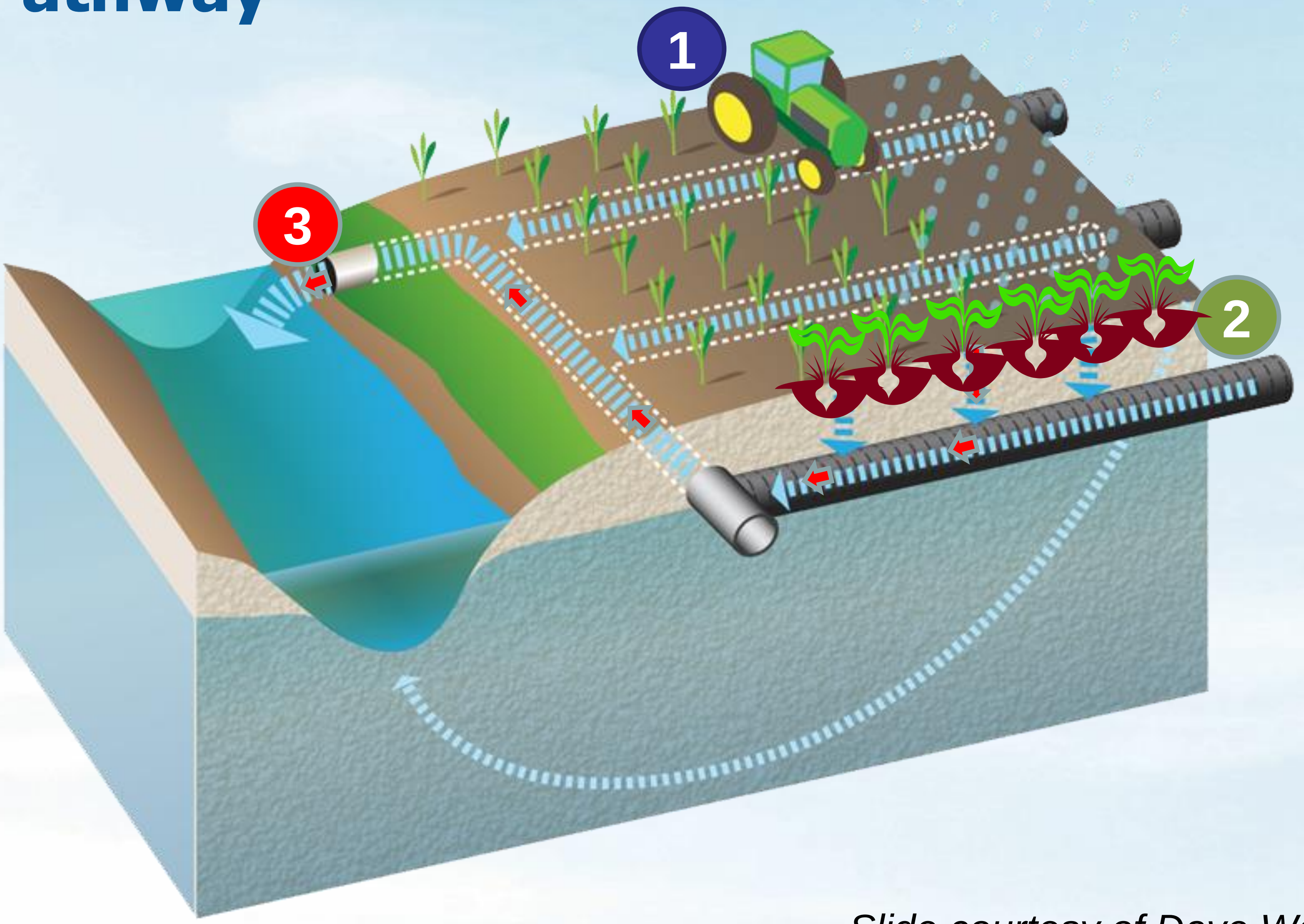
Summary provided by MPCA

Reducing Nitrate Losses: Groundwater Pathway



Slide courtesy of Dave Wall, MPCA

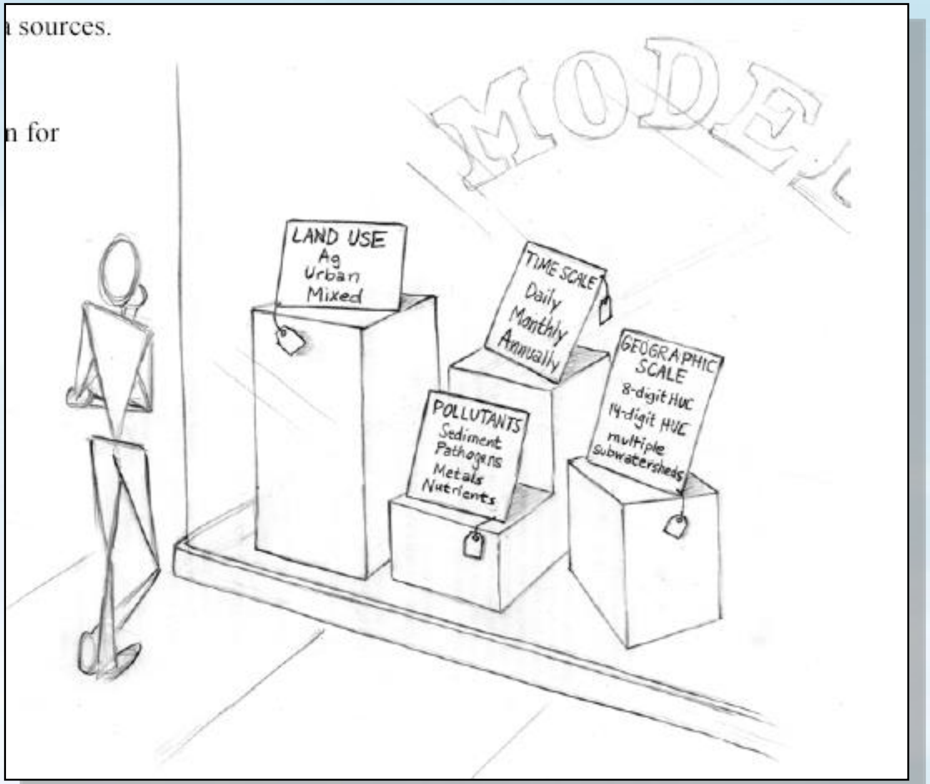
Reducing Nitrate Losses: Tile Drainage Pathway



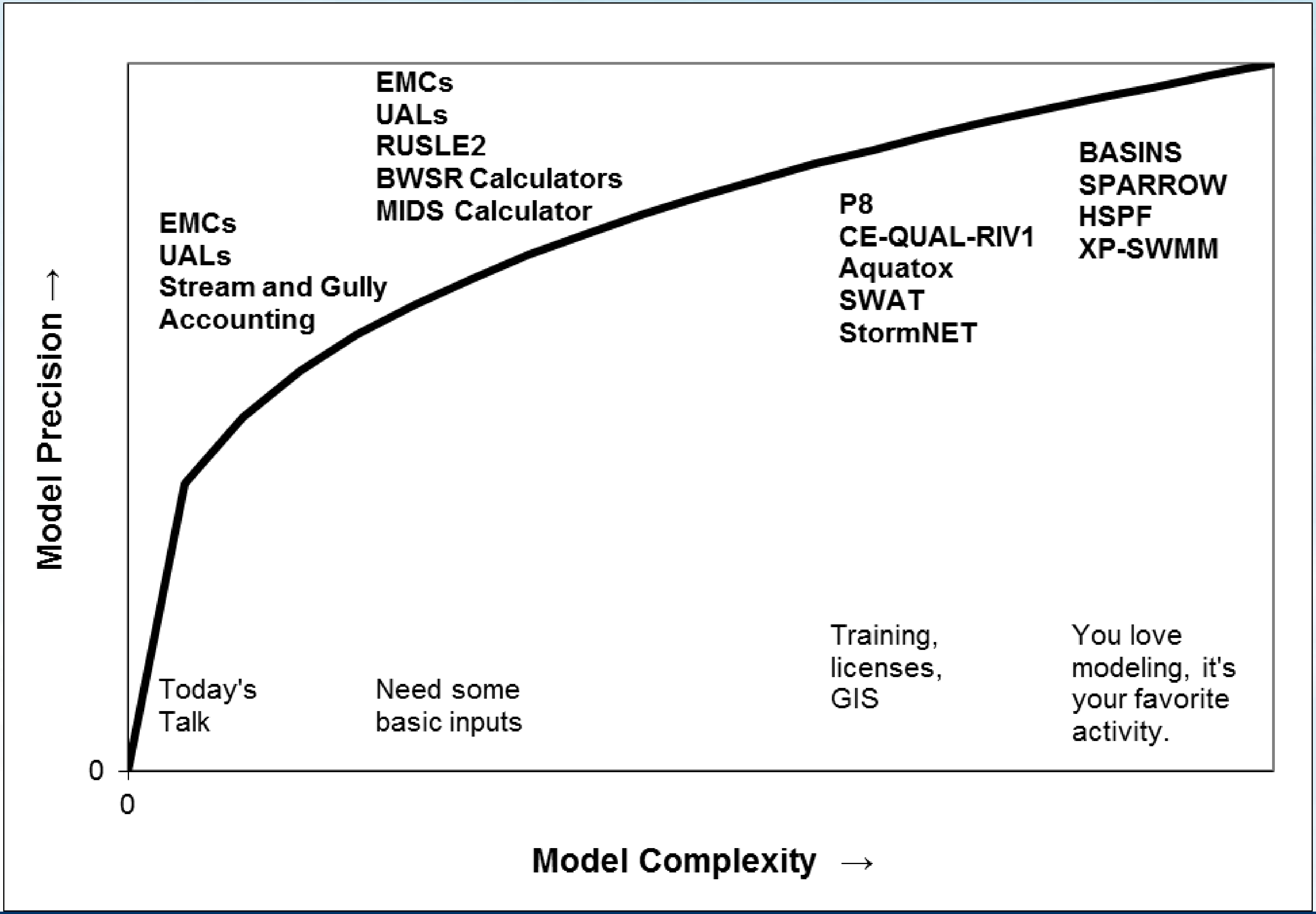
Slide courtesy of Dave Wall, MPCA

Model Selection

- ► What is the question you are trying to answer?
- ► Scale – watershed, field, BMP
- ► Available tools
- ► Level of complexity and required inputs



Model Complexity Spectrum



When is simple OK?

- OK
  - Comparing benefits
  - Grant applications
  - Planning
- Not OK
  - BMP design, sizing
  - Apples to oranges comparisons

TWO APPROACHES FOR POLLUTANT LOADS

Unit Area Loads and Event Mean Concentrations

Units and Percentages

- Units: Always keep track of your units
  - $3 \frac{lb}{ac-yr} \times 14\, ac = 42\, ?$
  - $3 \frac{lb}{\cancel{ac}-yr} \times 14\, \cancel{ac} = 42 \frac{lb}{yr}$
  - $1\, kg = 2.2\, lb$
    - $25 \frac{lb}{yr} \times \frac{1\, kg}{2.2\, lb} = 11 \frac{kg}{yr}$
    - $11 \frac{kg}{yr} \times \frac{2.2\, lb}{1\, kg} = 24 \frac{lb}{yr}$
- Percentages: Always divide by 100 before using in an equation
  - 83% of 13 $\rightarrow \frac{83}{100} \times 13 \rightarrow 0.83 \times 13 = 11$

Unit Area Loads (UALs)

Average loading rates (load per area) assigned based on land use or land cover

Land cover	Unit Area Load (UAL)		
	TP (lb/ac-yr)	TSS (T/ac-yr)	TN (lb/ac-yr)
Agriculture—row crops in sensitive areas (i.e., tiled, sandy soils, karst)	0.40	1.7-2.6	20-37
Agriculture—row crops in less sensitive areas			15-23
Mixed crops in less sensitive areas			5-10
Forest/grassland	0.08	0.10	2
Urban - high density	1.1	0.21	4
Urban - low density	0.80	0.10	4

Load (lb/yr) = Area (ac) x UAL (lb/ac-yr)

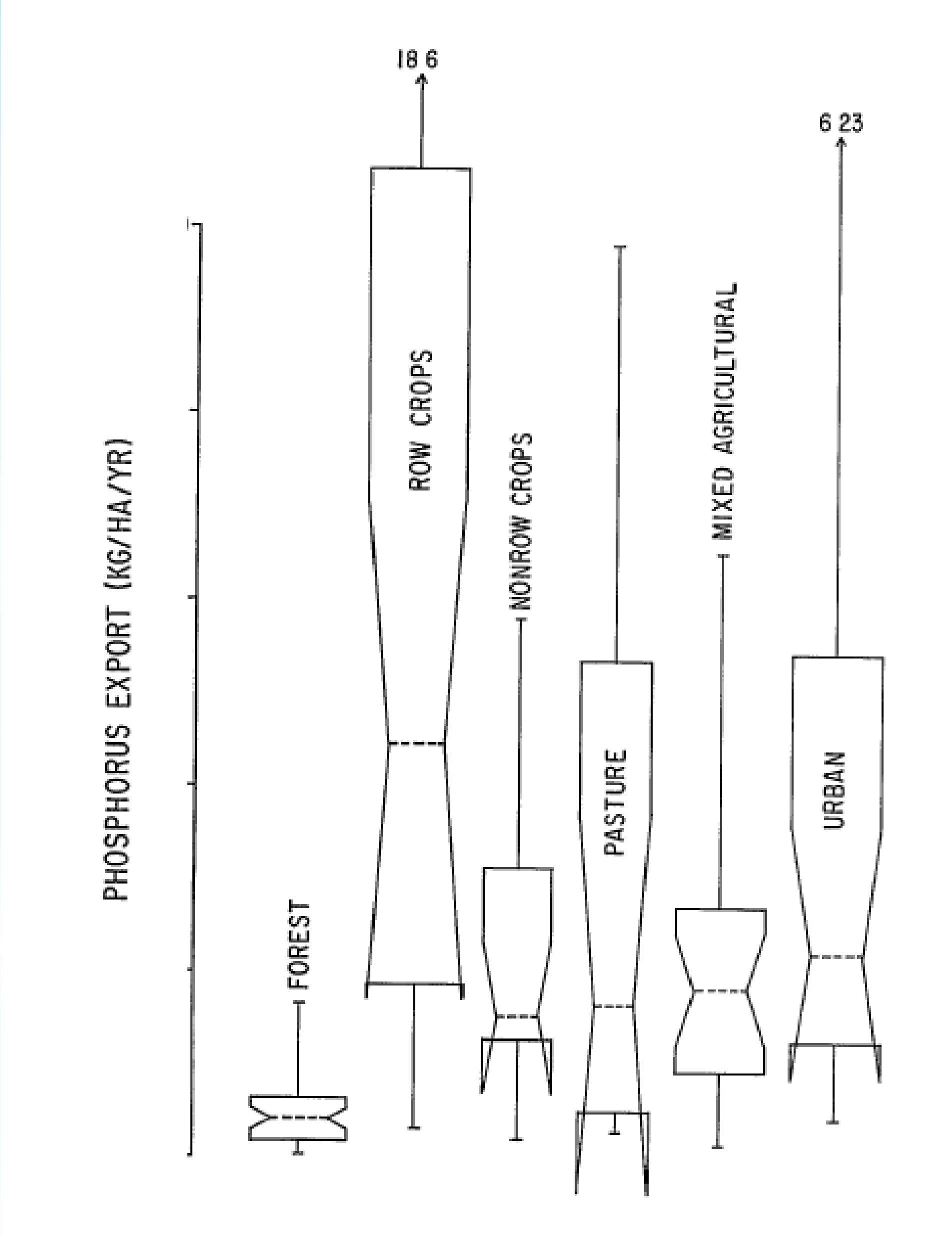
Unit Area Loads (UALs)

Example:

Land use or land cover	Area (ac)	UAL (lb P/ac-yr)	Load (lb P/yr)
Grassland	**50**	**0.08**	**4**
Agriculture	**25**	**0.4**	**10**
Low density developed	**8**	**0.8**	**6.4**
Total	***83***		***20***

*Tip: round numbers

Variability in UALs



EMCs and Runoff Volume

- ► Average loading rates (load per runoff volume) assigned based on land use or land cover
- ► Takes into account runoff volume

Land cover	Event Mean Concentration (EMC)			Runoff Factor
	TP (mg/l)	TSS (mg/l)	TN (mg/l)	
Agriculture—row crops in sensitive areas (i.e., tiled, sandy soils, karst)	0.32	1,362	--	30
Agriculture—row crops in less sensitive areas				
Mixed crops in less sensitive areas				
Forest/grassland	0.04	11	0.6	4
Urban - high density	0.3	81	2.4	80
Urban - low density	0.3	27	2.0	35

*For areas with imperviousness, runoff factor = % impervious. For areas without imperviousness, runoff factor is related to CN.

EMCs and Runoff Volume

- Input needs
  - Annual precipitation (inches) = precip
  - Runoff factor
  - Pollutant concentration, or event mean concentration (mg/l) = EMC
  - Area (ac) = A

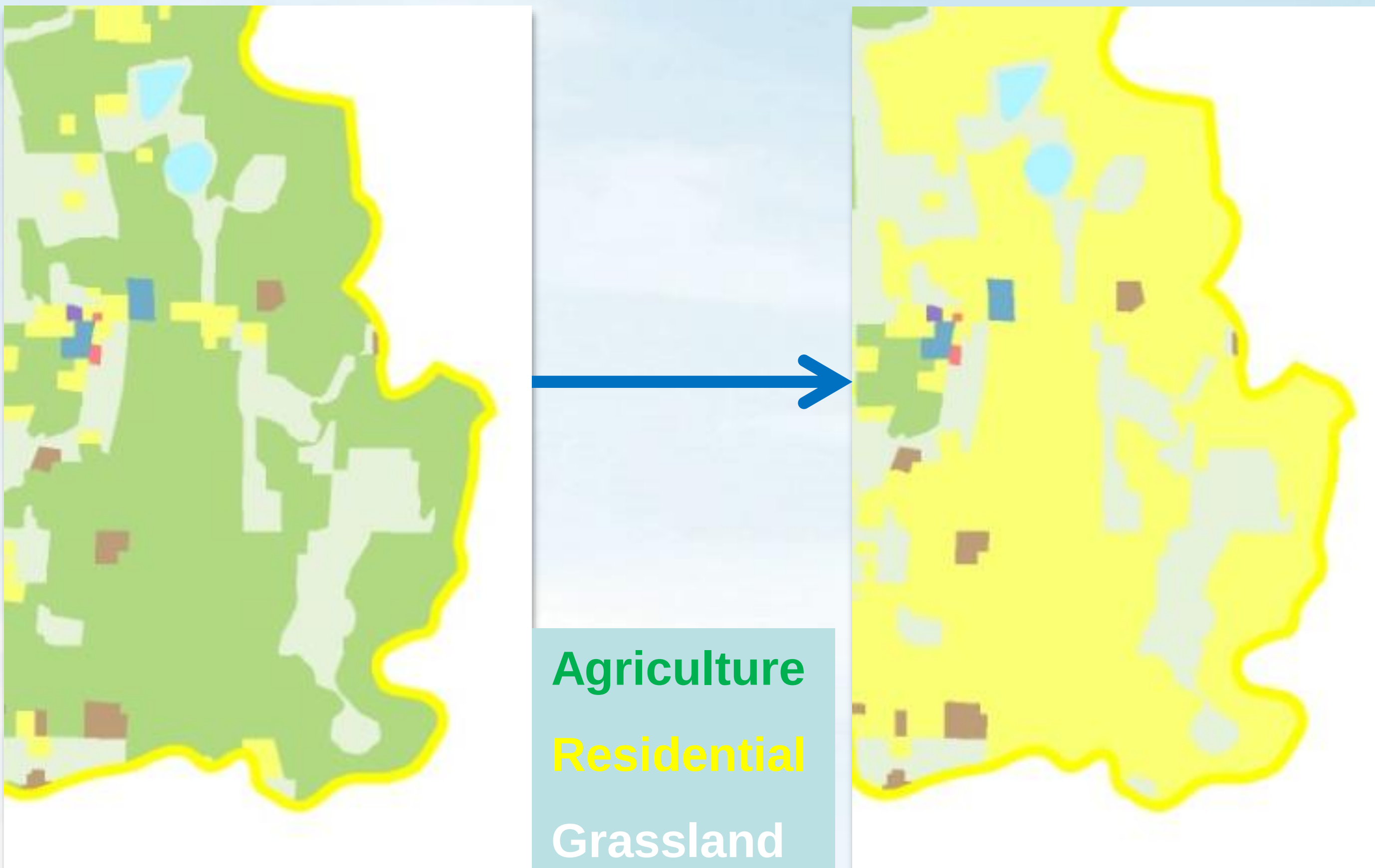
Land use or land cover	Precip (in)	Runoff Factor	EMC (mg/l P)	Area (ac)	Load (lb P/yr)
Grassland	32	4	0.04	50	1.1
Agriculture	32	30	0.32	25	16.4
Low density developed	32	35	0.30	8	5.6
Total				*83*	*23*

L (lb/yr) = precip x [0.05+(0.009 x runoff factor)] x EMC x area x 0.20

POLLUTANT REMOVALS– EFFECT OF LAND USE AND BMPS

What if all ag lands were converted to developed and grassland?

► Different land uses have different loads



What if all ag lands were converted to developed and grassland?

Land use or land cover	Area (ac)	UAL (lb P/ac-yr)	Load (lb P/yr)
Grassland	50	0.08	4
Agriculture	25	0.4	10
Low density developed	8	0.8	6.4
Total	*83*		*20*

Land use or land cover	Area (ac)	UAL (lb P/ac-yr)	Load (lb P/yr)
Grassland	60	0.08	4.8
Agriculture	0	0.4	0
Low density developed	23	0.8	18.4
Total	*83*		*23*

Best Management Practice Pollutant Removal

- Local monitoring data
- Literature percent removals
- Models and tools
  - Calculator
  - Spreadsheets
  - MIDS
  - Watershed and BMP models – HSPF, P8, SWAT, others

Conservation Tillage, NRCS

Stillwater Rain Garden

Pollutant Removals by BMP

BMP	TP Reduction (%)	TSS Reduction (%)	TN Reduction (%)
Developed Land Use BMPs			
Bioretention	100 (for infiltrated water)	85	50
Dry swale	50	40-80	35
Stormwater pond	34-73	60-90	30
Infiltration practices	100 (for infiltrated water)	--	--
Permeable pavement	65	95	83
Cropland BMPs			
Conservation tillage	63	30	0
Continuous no-till		70	
Cover crops	29	--	51
Perennial buffer (P and N removal rates assume a 100-foot buffer)	58	40-60	0
Water and sediment control basin	85	--	0
Constructed wetlands	--	--	50
Controlled drainage	0	0	33-44
Bioreactors	0	0	13

Design Elements Influence Performance

High performance

	Outflow concentration	Removal
Exceeds water quality volume by more than 50%; wet extended detention	TSS = 11 mg/L TP = 0.08 mg/L	TSS = 90% TP = 73%
Exceeds water quality volume by more than 25%; flowpath greater than 1.5:1; sediment forebay at major inflows; wetland elements cover at least 10% of pond surface area	TSS = 15 mg/L TP = 0.12 mg/L	TSS = 84% TP = 50%
Single cell design; flow path less than 1:1; on-line design		
Pond surface area to contributing area is less than 2%; does not provide full water quality storage volume; intersects groundwater	TSS = 30 mg/L TP = 0.19 mg/L	TSS = 60% TP = 34%

Low performance

Minnesota Stormwater Manual

Pollutant Removal

- Portion of residential development drains to wet pond
  - 10 acre watershed
  - 60% P removal

Area (ac)	UAL (lb P/ac-yr)	Load to Pond (lb/yr)	60 % Removal (lb/yr)
10	0.8	8	5

Streambank Erosion

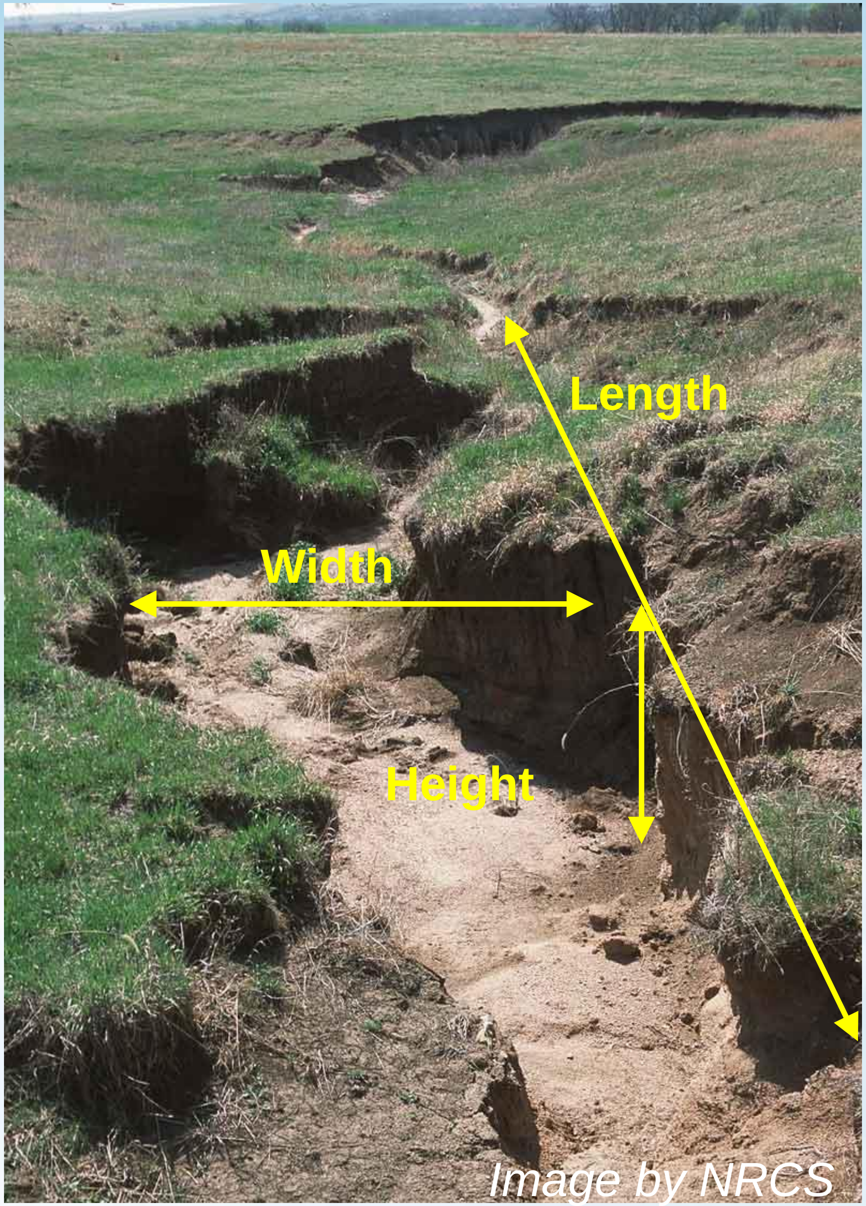
Streambank Erosion

Streambank erosion

Row	Description	Notes	Example Values
A	Height (ft)	Height of erosion	*12*
B	Width (ft/year)	Lateral recession rate	*1.2*
C	Length (ft)	Length of erosion	*279*
D	Annual Volume Lost (cf/year)	A x B x C	*4,018*
E	Annual mass lost (tons/year)	D x soil density (assumes silt soil at 85 lb/cf)	*171*
H	Phosphorus loss (lbs/year)	Assume 1 lb P per ton of soil	*171*

Lateral Recession Rate (ft/yr)	Category	Description
0.5 +	Very severe	Bank is bare with gullies and severe vegetative overhang. Many fallen trees, drains and culverts eroding out and changes in cultural features as above. Massive slips or washouts common. Channel cross-section is U-shaped and streamcourse or gully may be meandering.

Gully erosion



Gully erosion

Gully erosion

Row	Description	Notes	Example Values
A	Height (ft)	Height of erosion	*12*
B	Width (ft)	Width of erosion	*20*
C	Length (ft)	Length of erosion	*279*
D	Volume (cf)	A x B x C	*66,960*
E	Total mass lost (tons)	D x soil density (assumes silt soil at 85 lb/cf)	*2,846*
F	Time (years)	Estimated time erosion has been occurring	*17*
G	Soil loss (tons/year)	E / F	*167*
H	Phosphorus loss (lbs/year)	Assume 1 lb P per ton of soil	*167*

COMPARISON TO LOADING GOALS

Comparisons to Loading Goals

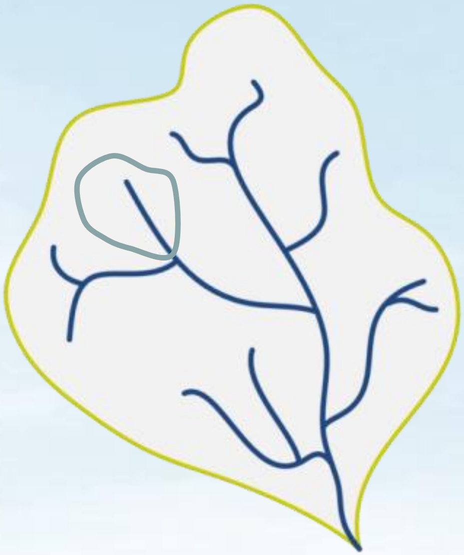
$$\frac{load\ reduction\ achieved\ in\ proposed\ project}{watershed\ load\ reduction\ goal}$$

$$x\ 100$$

$$=\%\ of\ loading\ goal\ achieved$$

Defined Watershed Load Reduction Goal

Watershed load reduction goal = 20 lb/yr



Proposed project: riparian buffers

Estimated reduction = 3 lb/yr

(3/20) x 100 = 15%

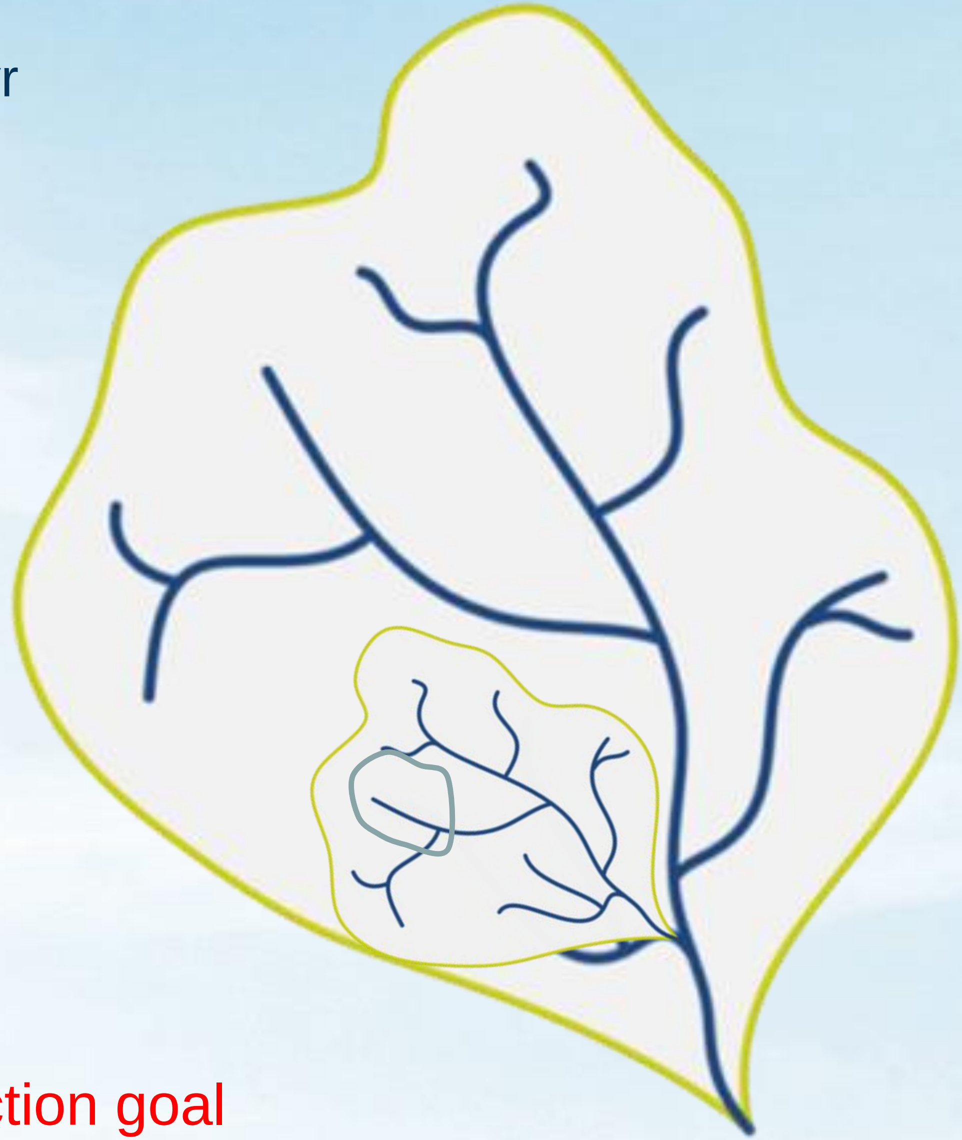
of load reduction goal achieved

Relate to Larger Watershed Goals

HUC8 load reduction goal = 800 lb/yr

HUC8 existing load = 3000 lb/yr

800 / 3000 = 27% reduction goal



Estimated reduction from proposed project(s) = 3 lb/yr

Existing load of project site = 8 lb/yr

3 / 8 = 38% reduction

Achieving load reduction goal

Comparisons to Loading Goals: Attenuation

$$\frac{load\ reduction\ in\ proposed\ project \times (100\% - \%\ attenuation\ rate)}{watershed\ load\ reduction\ goal}$$

Pomme de Terre: 2.8% attenuation

$$\frac{3\,\frac{lb}{yr} \times (1 - 0.028)}{800\,\frac{lb}{yr}} = \frac{\frac{3\ \mathrm{lb}}{\mathrm{yr}} \times 0.972}{800\,\frac{lb}{yr}} = \frac{2.9\,\frac{lb}{yr}}{800\,\frac{lb}{yr}} = 0.004 = 0.4\%$$

No Defined Loading Goals

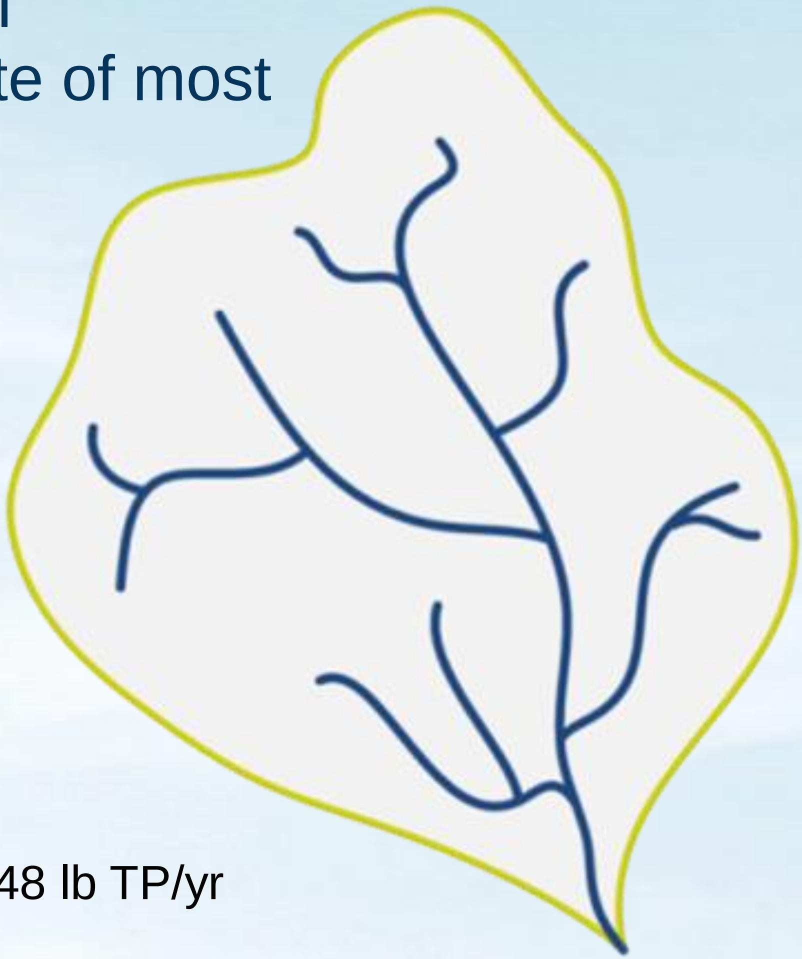
- Compare watershed load based on existing land use to watershed load based on all forest/grassland—provides estimate of most aggressive load reduction goal

600 ac forest
50 ac developed
350 ac agriculture

228 lb TP/yr

1000 ac forest

80 lb TP/yr



Aggressive load reduction goal = 228 – 80 = 148 lb TP/yr

Lakes: Annual vs. Daily Loading Goals

- EPA requires total maximum daily loads
- Lake managers typically evaluate lake loads on an annual or seasonal basis

Load Component	TP existing (lb/yr)	TMDL Allocation (lb/yr)	TMDL Allocation (lb/day)	TP Reduction (lb/yr)
WLA	2.6	2.6	0.0072	0
LA	6,122	4,862	13	1,260
MOS		541	1.5	
Total	6,125	5,405	15	1,260

Lakes: Annual vs. Daily Loading Goals

$$Annual\ Load = Daily\ Load\ x\ 365$$

Load Component	TP existing (lb/day)	TMDL Allocation (lb/day)	TP Reduction (lb/day)
WLA	0.0072	0.0072	0
LA	17	13	4
MOS		1.5	
Total	17	15	4

$$annual\ load = 4\frac{lb}{day}\ x\ 365\frac{day}{yr} = 1460\frac{lb}{yr}$$

Double Check Your Numbers!

- ► Use other tools available (e.g., RUSLE, BWSR calculators)
- ► Check your results with methods discussed today

1,300 tons / yr of sediment removed !!!

Too good to be true?

Use these simplified methods as a check.

HANDS-ON EXERCISES

Exercises

- Work in groups to solve problems
  - Use any method provided today
- Reconvene to review examples