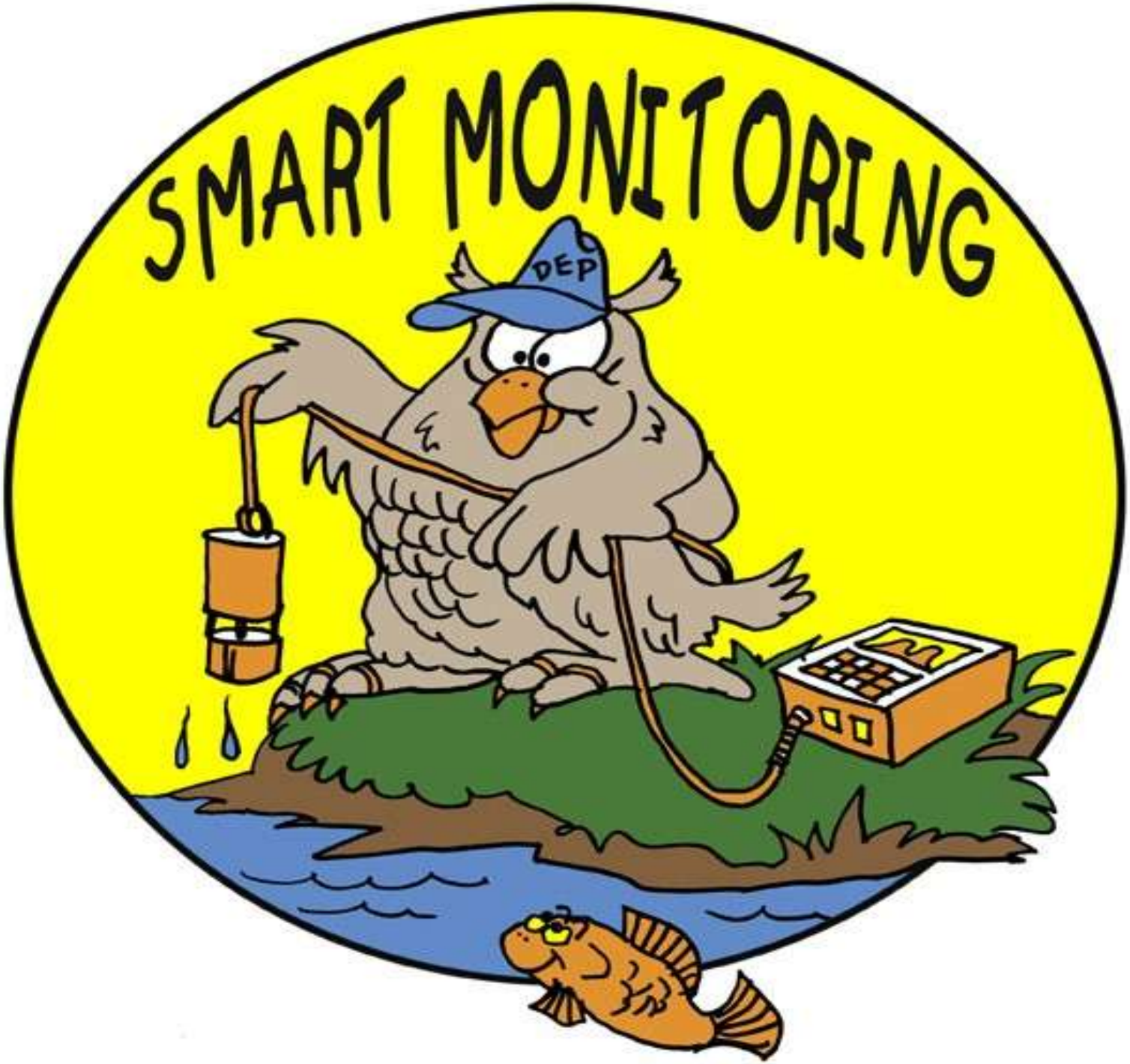

SMART MONITORING
DEP

Massachusetts Monitoring Program

- Traditional program
  - Gross pollution
  - Point Sources
- Emerging Program
  - Nonpoint Sources
  - Trends
  - More coverage

SMART Monitoring Networks

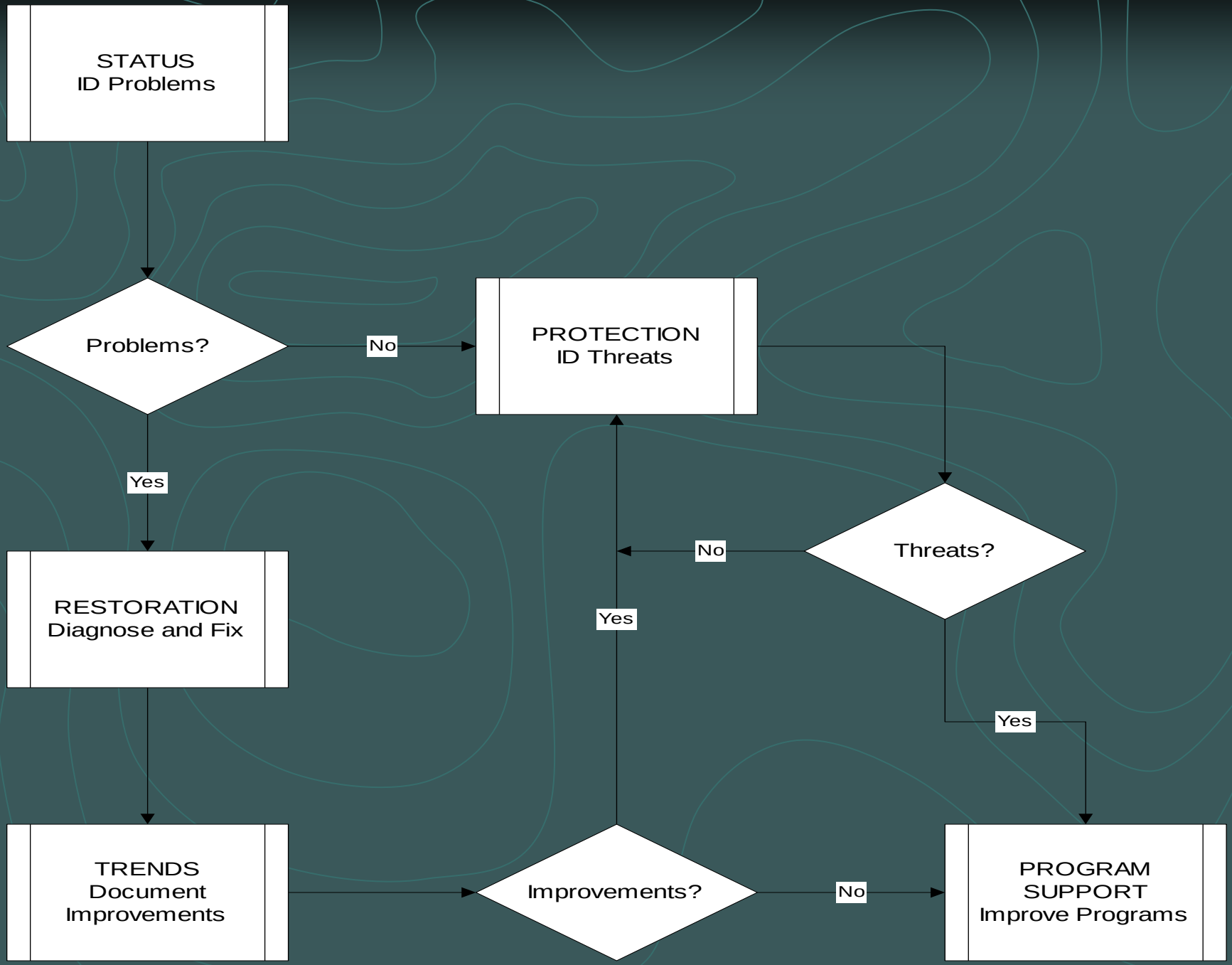
Tier	Schedule	Scale
Statewide	Continuous	Large scale Long term
Basins	Rotating Basin	NPDES Program
Local	Flexible	Small scale Rain events

Outline

- Goals
- Strategies
  - Sites
  - Frequency
  - Indicators
- Traditional program
  - Successes /failures
- Proposed SMART Program

Why We Monitor

Question	Goal
What is the condition of the resource?	Status
Is the condition changing over time?	Trends
How do we restore and enhance the resource?	Restoration
How do we protect and maintain the resource?	Protection
How do we improve our programs?	Program Support


STATUS
ID Problems
Problems?
No
PROTECTION
ID Threats
Yes
RESTORATION
Diagnose and Fix
Threats?
No
Yes
Yes
TRENDS
Document
Improvements
Improvements?
No
PROGRAM
SUPPORT
Improve Programs

Outline

- Goals
- Strategies
  - Sites
  - Frequency
  - Indicators
- Traditional program
  - Successes /failures
- Proposed SMART Program

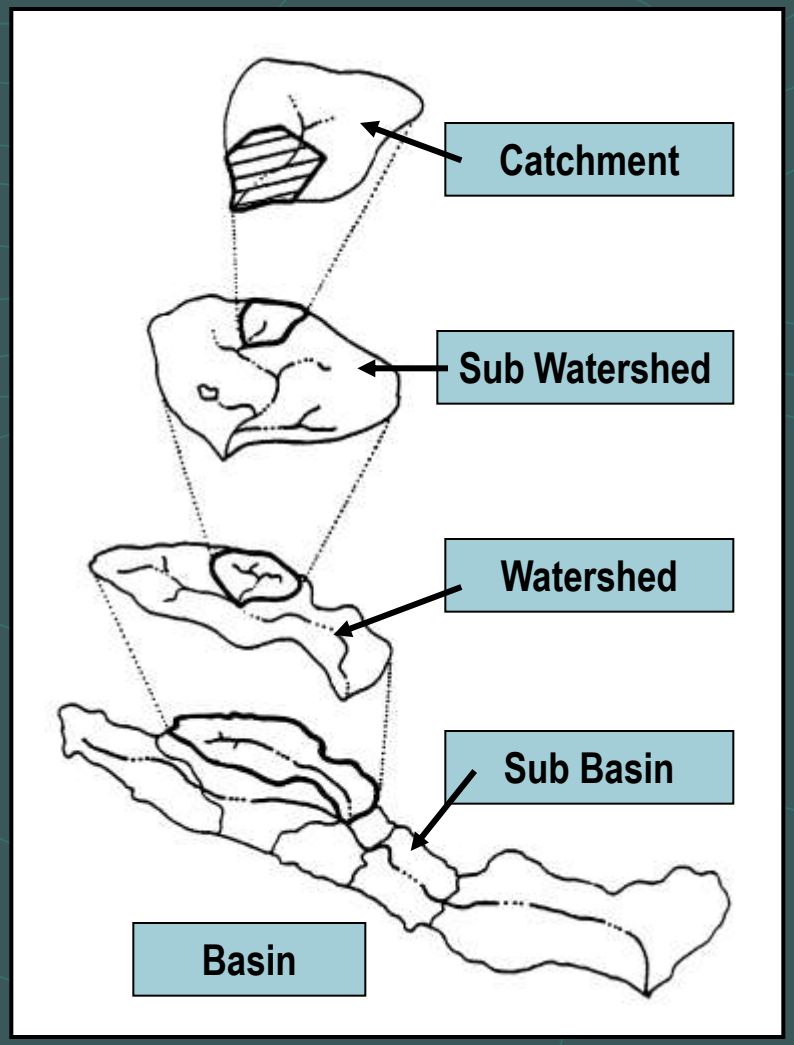
Monitoring Strategies

- Sampling sites
  - where
- Sampling frequency
  - when
- Indicators
  - what

Space Scales:

WHERE WE MONITOR

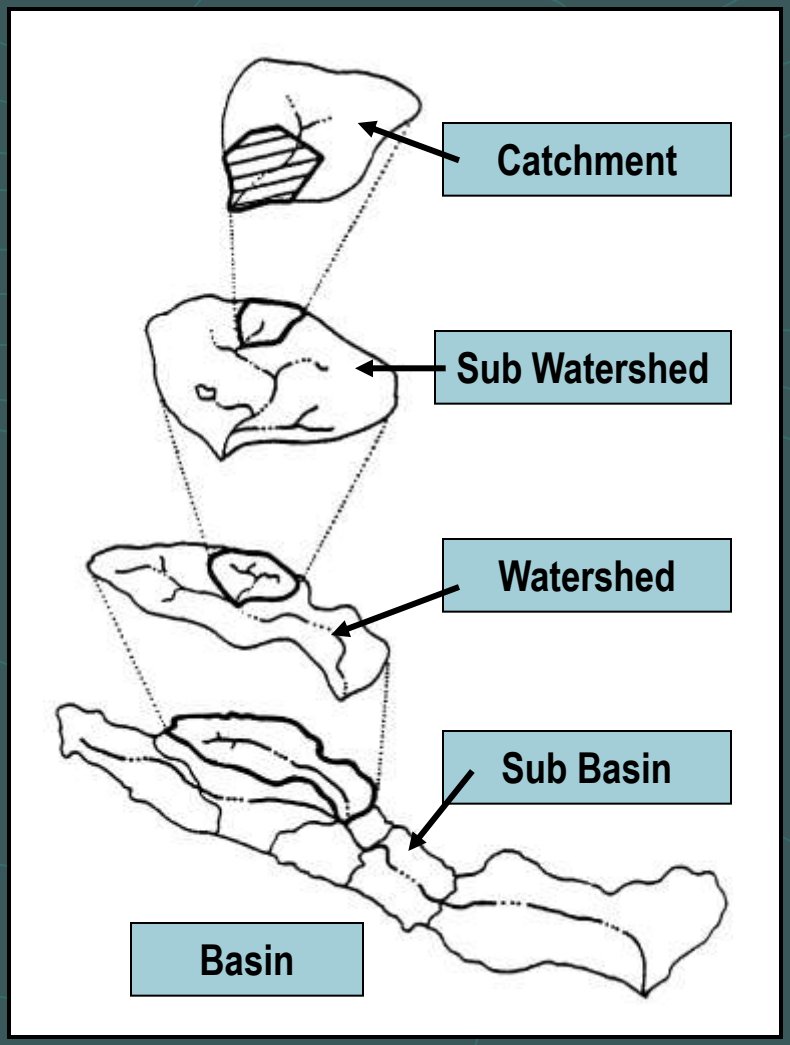
- Geology
- Soils
- Bioactivity
- Solar Radiation
- Human Activity



Pollution

Stream Size Categories:

Category	Stream Size
Headwaters	Intermittant and 1st Order
Tributaries	1st and 2nd Order
Mainstems	3rd and 4th Order
	5th and 6th Order
	Greater than 6th Order



River Continuum Concept

Headwaters (detritus)	Mid Reaches (photosynthesis)	Downstream (sediment)
Erosion	Transport	Deposition
Stony	Gravelly/Sandy	Muddy
Shady	Light	Turbid
Cold	Diurnal Swing	Warm
Shredders	Collectors/Grazers	Collectors/Large Predators

Stream Segments

	Mainstems	Tributaries	Headwaters
% Miles	15%	10%	75%
Total Miles	1,323	882	6,615
Segments	**250**	**350**	**> 4,000**

SMART Lesson #1

- It is useful to stratify your rivers by stream size
  - River Continuum Concept
  - 75% of river miles in headwaters
  - Increasing monitoring coverage = headwaters

Time Scales:

"You cannot step in the same river twice"

Time Scales:

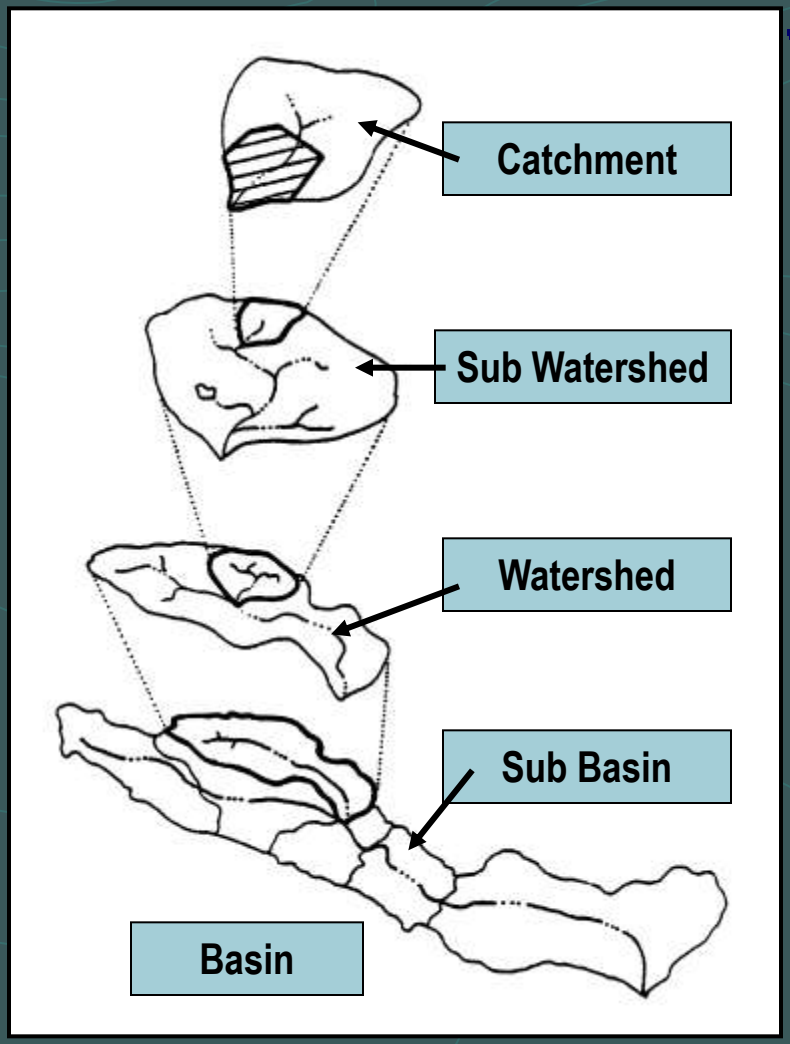
WHEN WE MONITOR

Day - Week

Rainfall

Month - Season

Hydrograph



Diurnal Effects

Day - Week

Climatic Effects

Year - Year

Capturing Variability

- Year to year
- Within the year
  - Seasonal
  - Daily
- Timing of variability

Massachusetts Bioperiods

Oct-Nov	Fall salmonid spawning
Dec-Feb	Overwintering
Mar-Apr	Spring flood
May	Migratory fish spawning
June	Resident spawning
July-Sept	Rearing and growth

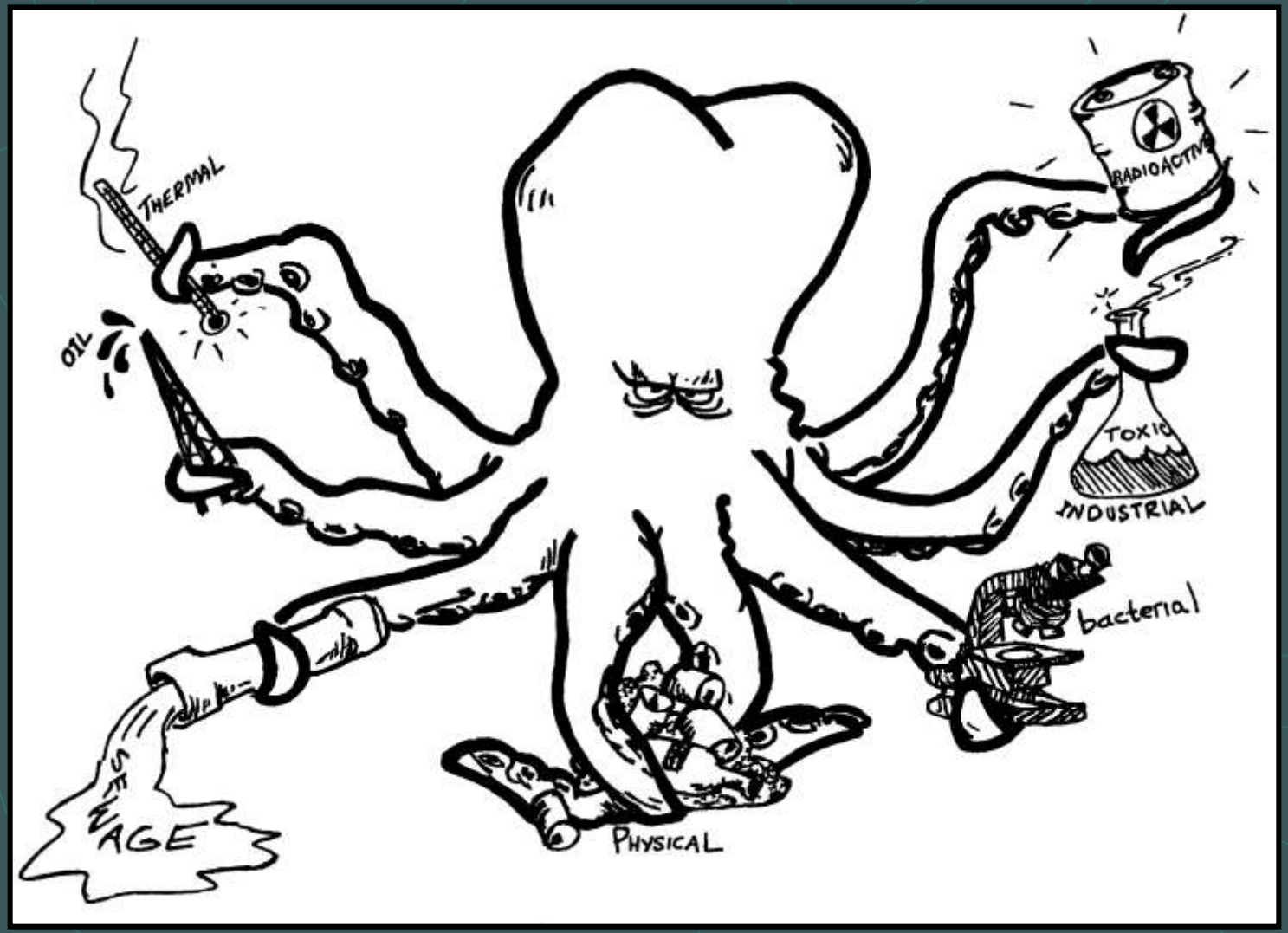
Sampling Frequency

	Mainstems	Tributaries	Headwaters
Year to Year	X		
Annual Cycle	X	X	X
Diurnal Cycle	X	X	
Rain Events		X	XX
Visits/Year	**6-12**	**12-24**	**> 24**

SMART Lesson #2

- Sampling frequency increases as stream size decreases (capturing variability):
  - It is unrealistic to hand sample headwater streams
  - 4000 segments x 24 visits/segment= 96,000 visits

What We Monitor: Indicators



Indicators

Response	Biota Bacteria
Exposure	Water Chemistry Sediment Chemistry Flow Regime Physical Habitat Fish Tissue
Stressor	Land Use Loadings
Administrative	Permits WWTF Construction

SMART Lesson #3

- Response Indicators -status
- Exposure Indicators- diagnose and fix
- Exposure Indicators- trends and protection
  - Catch threats before they become problems
  - Measure progress by causes not uses

Nashua River Watershed Water Quality 1973	Above Clinton WWTP	Below Clinton WWTP	Above Leominster WWTP	Below Leominster WWTP	Above Pepperell Pond	Below Pepperell Pond	Pepperell Pond	Nissitissit and Squannacook
I. Ecological Health	35	35	20	35	30	35	35	90
A. Biology	NS	NS	NS	NS	NS	NS	NS	S
B. Chemistry	NS	NS	NS	NS	NS	NS	NS	S
Baseline	NS	NS	NS	NS	NS	NS	NS	S
Nutrients	NS	NS	NS	NS	NS	NS	NS	S
Toxics	NS	NS	NS	NS	NS	NS	NS	S
C. Sediments	NA	NA	NA	NA	NA	NA	NS	NA
D. Hydrology	S	S	S	S	S	S	S	S
E. Habitat	NS	NS	NS	NS	NS	NS	NS	S
II. Public Health	65	65	30	30	30	50	40	80
A. Bacteria	NS	NS	NS	NS	NS	NS	NS	P
Swimming	NS	NS	NS	NS	NS	NS	NS	P
Boating	NS	NS	NS	NS	NS	NS	NS	S
B. Aesthetics	S	S	NS	NS	NS	P	NS	S
C. Toxics in Fish	NA	NA	NA	NA	NA	NA	NA	NA

Water Quality 1993	Above Clinton WWTP	Below Clinton WWTP	Above Leominster WWTP	Below Leominster WWTP	Above Pepperell Pond	Below Pepperell Pond	Pepperell Pond	Nissitissit and Squannacook
I. Ecological Health	90	75	65	70	70	90	90	85
A. Biology	S	P	NS	NA	NS	S	NA	S
B. Chemistry	S	P	NS	NA	NS	S	S	S
Baseline	S	S	S	S	S	S	S	T(pH)
Nutrients	S	P	S	S	S	S	S	S
Toxics	?	P	NS	NA	NS	S	S	S
C. Sediments	NA	NA	NA	NA	NA	NA	NA	NA
D. Hydrology	S	S	S	S	S	S	?	S
E. Habitat	S	S	P	S	S	S	?	S
II. Public Health	95	70	50	95	80	95	75	95
A. Bacteria	S	NS	NS	S	P	S	S	S
Swimming	S	NS	NS	S	P	S	S	S
Boating	S	S	NS	S	S	S	S	S
B. Aesthetics	S	S	P	S	S	S	S	S
C. Toxics in Fish	S	S	NA	NA	S	S	NS	S

Sampling Strategies

Goal	Segments	Frequency	Indicators
Status	All	Low Flow	Response
Trends	Impaired	Continuous	Exposure
Restoration	PS Impaired	Low Flow	Exposure
	NPS Impaired	Annual Cycle Rainfall	Exposure
Protection	Clean	Continuous	Exposure
Programs	All	Continuous	Exposure

Smart Lesson #4

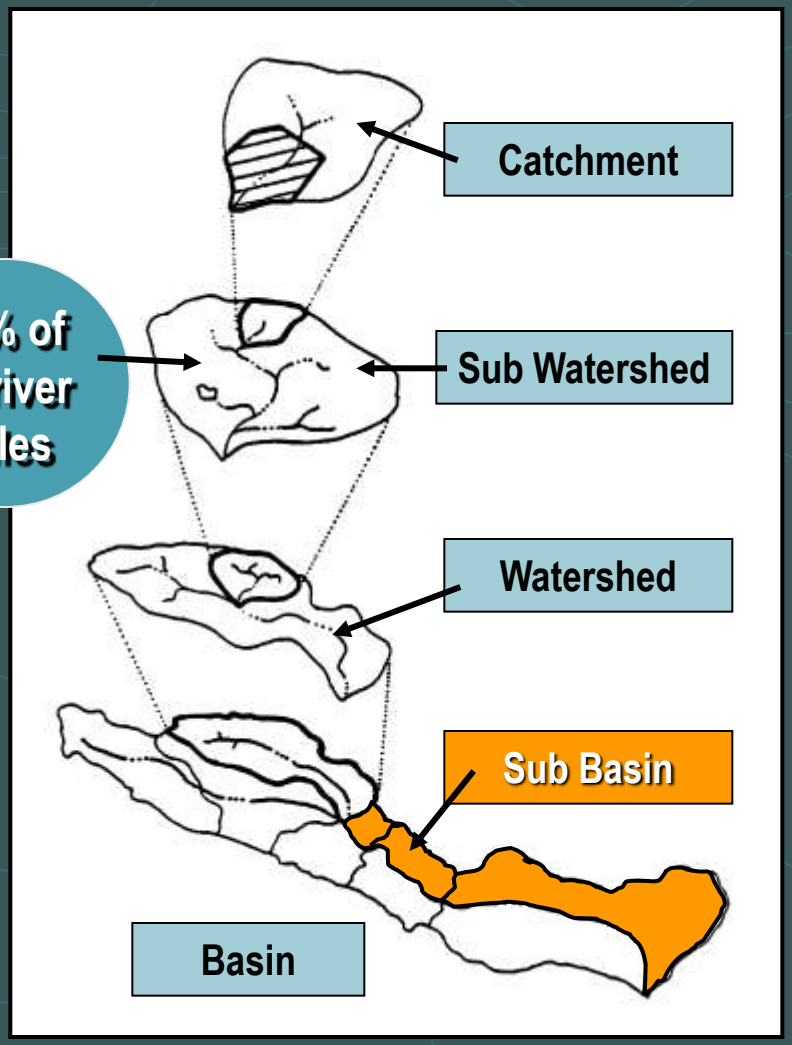
- Different monitoring goals require different monitoring programs.
- Meeting multiple goals requires several (very efficient) programs

Outline

- Goals
- Strategies
  - Sites
  - Frequency
  - Indicators
- Traditional program
  - Successes /failures
- Proposed SMART Program

Current Monitoring Program

EFFECTS		USE
NONPOINT SOURCE POLLUTION		BMP's, Site Design
	75% of all river miles	NPS Assessment
POINT SOURCE POLLUTION		Land Use Zoning
		Basin Planning
TRENDS		Basin Planning



Traditional Program Strategy

Goal	Segments	Frequency	Indicators
Status	All	Low Flow	Response
Trends	Impaired	Continuous	Exposure
Restoration	PS Impaired	Low Flow	Exposure
	NPS Impaired	Annual Cycle Rainfall	Exposure
Protection	Clean	Continuous	Exposure
Programs	All	Continuous	Exposure

Traditional Program Success

Goals	Attained	Issues
ID Problems	18% river miles	82% unmonitored
Diag. Problems	Point Sources	NPS
Document Improvements	No	$ 4.5 Billion in WWTF's
ID Threats	No	Acid Rain Mercury Climate Change
Improve Programs	No	Nutrients Toxics

5 Year Rotating Basin Approach

Gain Spatial Density

- 5-6 basins/year
- Summer low flow
- Multiple sites
- 15 years for trends
- Avoid clean sites
- Avoid small streams

Lose Temporal Continuity

- Multiple visits/site
- Seasonality
- Hydrograph
- Long term cycles (El Nino)

SMART Lesson # 5

- There is a basic resource conflict between monitoring strategies that require:

multiple sites - Status, Restoration

verses

multiple visits – Trends, Protection, Program Support

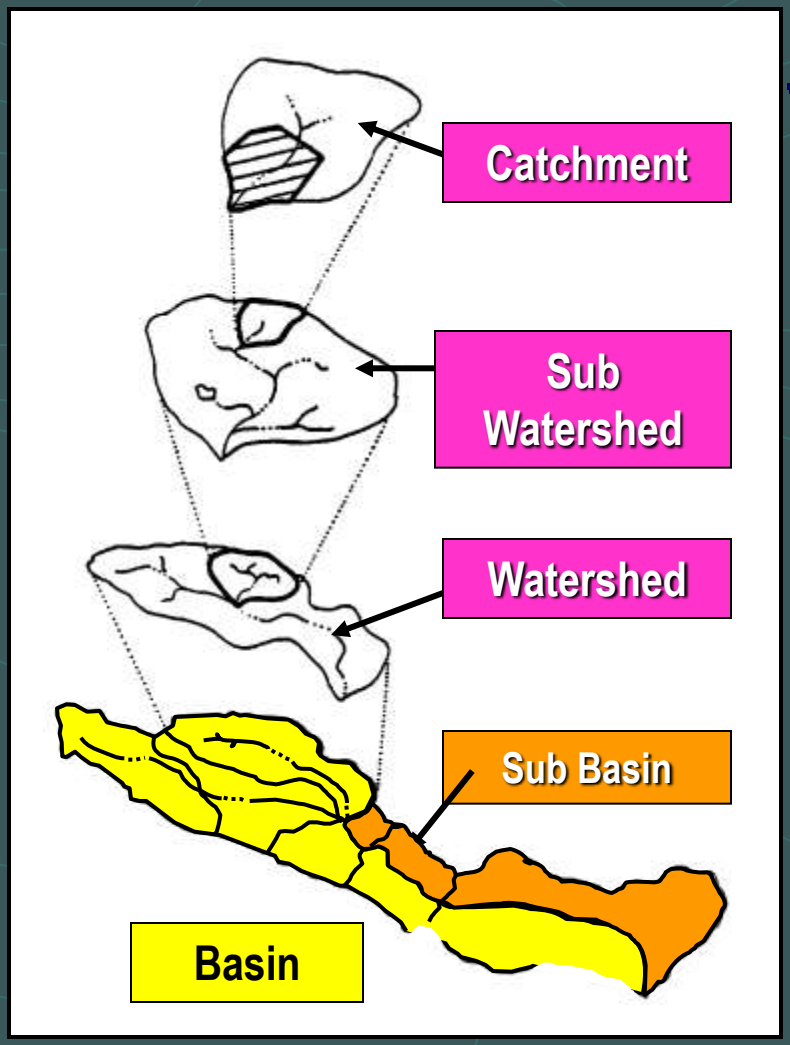
What's Missing?

Goal	Segments	Frequency	Indicators
Status	All	Low Flow	Response
Trends	Impaired	Continuous	Exposure
Restoration	PS Impaired	Low Flow	Exposure
	NPS Impaired	Annual Cycle Rain/events	Exposure
Protection	Clean	Continuous	Exposure
Programs	All	Continuous	Exposure

Outline

- Goals
- Strategies
  - Sites
  - Frequency
  - Indicators
- Traditional program
  - Successes /failures
- Proposed SMART Program

Three Tiered Program



Day - Week

Rainfall

Diurnal Effects

Day - Week

Month - Season

Hydrograph

Climatic Effects

Year - Year

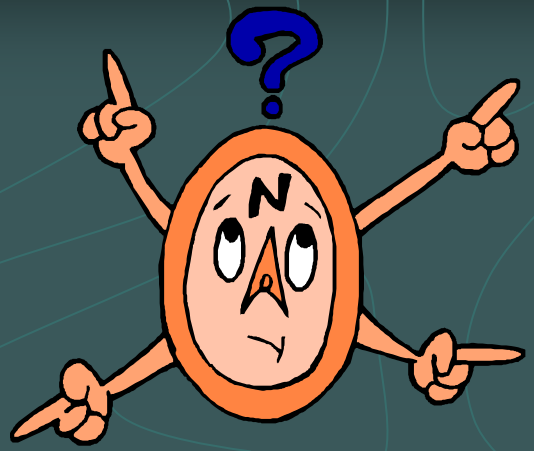
3 Coordinated Programs

- Mainstems
  - periodic variables -hydrograph, climatic effects
- Mainstems /Tributaries
  - periodic variables- diurnal effects
- Tributaries/ Headwaters
  - Random events- rainfall/runoff

Statewide Network

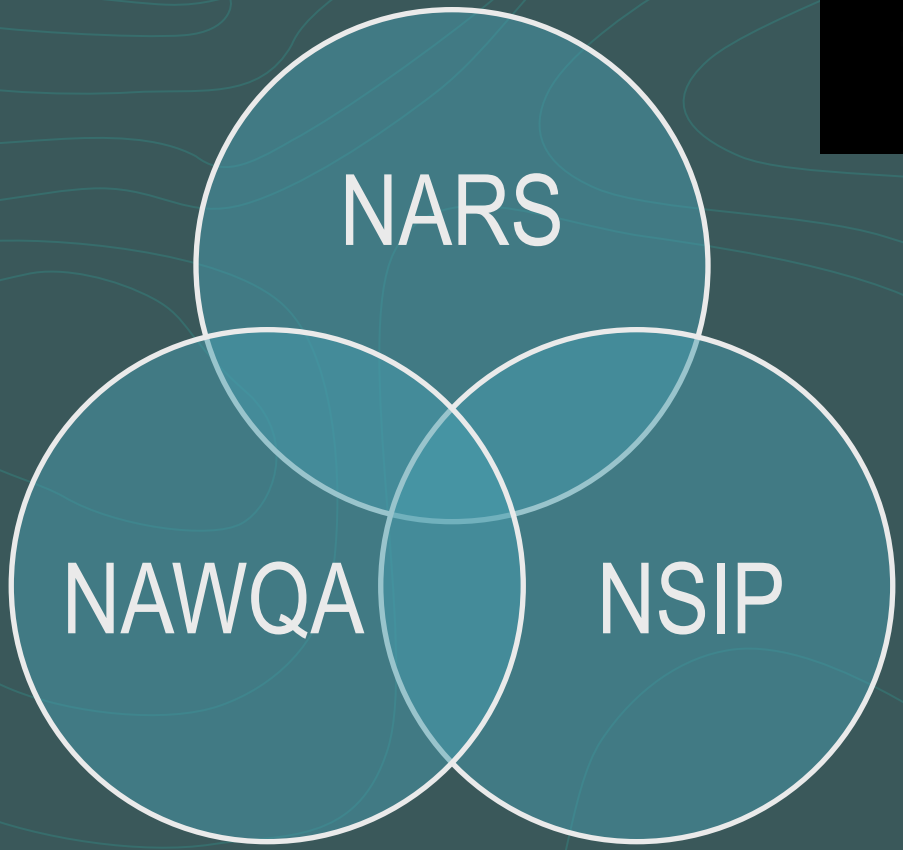
Goal	Segments	Frequency	Indicators
Status	All	Low Flow	Response
Trends	Impaired	Continuous	Exposure
Restoration	PS Impaired	Low Flow	Exposure
	NPS Impaired	Annual Cycle Rainfall	Exposure
Protection	Clean	Continuous	Exposure
Programs	All	Continuous	Exposure

Large Scale Programs



- NAWQA
- NASQUAN
- NARS
- NEON
- NSIP
- FEMA
- Nat. Weather Service
- Climate Change
- FERC
- TMDL
- STREON
- HBN
- COE Flood Control
- MWRA Reservoirs
- LTM
- 305b

Multipurpose Monitoring



Stream Gages are the Sweet Spot

- Frequency
  - Continuous-Long term
- Continuous Flow Monitoring
  - Hydrologic context
  - Real time reporting
  - Surrogate sampling

Strategic Site Selection

- Modeling Concepts-3 Mass Balance Points

- Inputs –Upstream reference station
- Sources and sinks- Most impacted site (largest source or sink)
- Outputs- Loadings exported from the basin

Strategic Site Selection

- Clean water – 13 ecoregions
- Impacts sites – 18 major abatement projects
- Loading sites – 19 locations, 67 % of land area

- All historical stations
- Modeling calibration points

Strategic Stations

- Reference distributions for ecoregions
  - Developing criteria-nutrients, toxics
- Trends at major abatement projects
  - Point source program success
- Loadings exported from the state
  - NPS Program success
- Sentinel stations for threats
  - Acid rain, mercury, climate change

SMART Lesson #6

- A small number of multipurpose (workhorse) stations can be selected using
  - Modeling concepts
  - Historical data
  - Continuous Stream Gages

Basins Network

Goal	Sites	Frequency	Indicators
Status	All	Low Flow	Response
Trends	Impaired	Continuous	Exposure
Restoration	PS Impaired	Low Flow	Exposure
	NPS Impaired	Annual Cycle Rainfall	Exposure
Protection	Clean	Continuous	Exposure
Programs	All	Continuous	Exposure

Basin Network Sites

- Point Sources (NPDES Program)
  - Summer low flow
- 5 basins/year
  - Basin approach-sampling economy
  - Entire state every 5 years
- Bracket major point sources
- Work in concert with Statewide stations
  - Recalibrate model every 5 years

Basin Network Sites

- 134 major point sources
  - 5 point sources/ basin
  - Sites / basin = 2(# PS) +1 = 11
  - 11sites/basin x 27 basins = 300 sites
  - 300 sites statewide – 50 Statewide sites = 250 sites
- 50 sites /year

Local Network

Goal	Sites	Frequency	Indicators
Status	All	Low Flow	Response
Trends	Impaired	Continuous	Exposure
Restoration	PS Impaired	Low Flow	Exposure
	NPS Impaired	Annual Cycle Rain Events	Exposure
Protection	Clean	Continuous	Exposure
Programs	All	Continuous	Exposure

Local Network Sites

- 350 tributary segments
- 50 sampled by Basins Network
  - Point sources
- 300 sites or 11 / basin

- Direct volunteer effort to these sites

Volunteer SMART Lessons

- Prescheduled sampling can (randomly) catch random events
- Time/ space scale analysis for indicators
  - Bacteria
  - Aesthetics
  - Habitat
- Stream walks/ Colilert™ System

The Problem with Headwaters

- NPS diagnosis
- 75% river miles
- 4,000 segments
  - Any realistic state monitoring program for response or exposure indicators will leave the vast majority of streams unsampled.

Headwater Monitoring Options

- Probabilistic (generic)
  - ID problems
  - ID Threats
- Targeted (site specific)
  - Geo-target solutions
  - Diagnose and fix
  - Track Improvements

Indicator Levels

Response	Biota Bacteria
Exposure	Water Chemistry Sediment Chemistry Flow Regime Physical Habitat Fish Tissue
Stressor	Land Use Loadings
Administrative	Permits WWTF Construction

Impervious Cover Method

- Surrogate for Impacts
  - Physical
  - Chemical
  - Biological
  - Hydrological

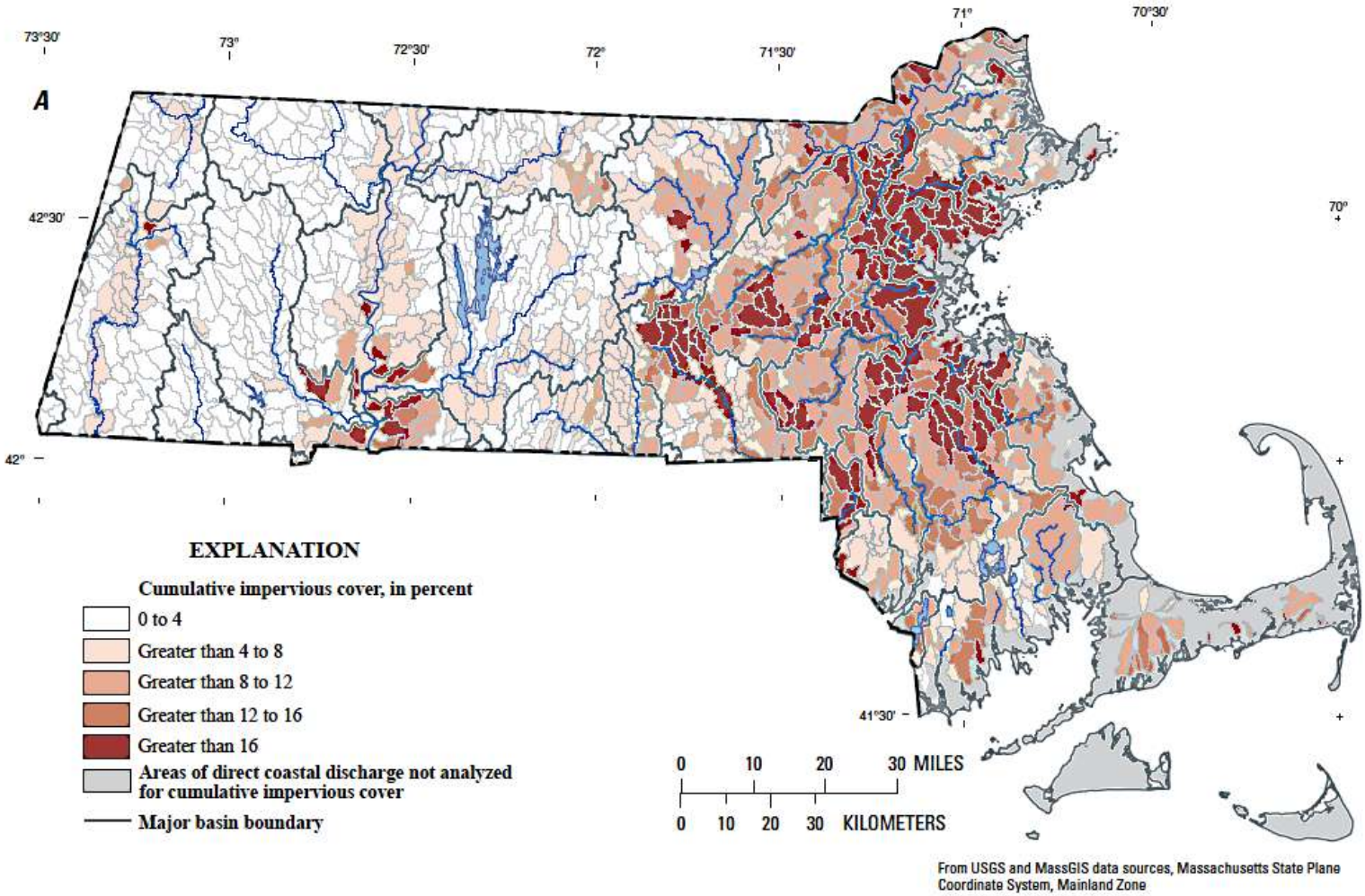


Figure 24. *(A)* Cumulative percent impervious cover in Massachusetts subbasins. *(B)* Cumulative percent impervious cover in Massachusetts 12-digit Hydrologic Unit Code (HUC-12) basins.

Headwaters Strategy

ID problems ID threats	Impervious Cover Model
Diagnose and fix Improve programs	National Studies
Document improvements	Geo-targeted monitoring ? Volunteers/Watershed Associations?

SMART Networks

Goal	Segments	Frequency	Indicators
Status	Mainstems Tributaries	Low Flow	Response
Trends	Strategic	Continuous	Exposure
Restoration	PS Impaired	Low Flow	Exposure
	NPS Impaired	Annual Cycle Rain/events	Exposure
Protection	Strategic	Continuous	Exposure
Programs	Strategic	Continuous	Exposure

SMART Networks Summary

Tier	Schedule	Purpose
Statewide 50 sites	Continuous	Trends Protection Program Support
Basins 50 sites/year	5 year Cycle Summer Low Flow	Point Source Restoration
Local 11 sites /basin	Flexible Rain Events	Nonpoint Source Restoration

Natural Partnerships

Program	Partners	Indicators
Statewide	Federal/State (USGS)	Flow Sediment Nutrient loading
Basins	State/Municipal (POTW's)	Biology Chemistry
Local	State/Local (Volunteers)	Habitat Bacteria Aesthetics

Features

- Stratified Sites (River Continuum Concept)
  - Mainstem-periodic variables , point sources
  - Tributaries- random variables , nonpoint sources
  - Headwaters- land use ,ICM
- Mass Balance Modeling (calibration points)
  - 50 workhorse stations
  - 50 NPDES sites /year
  - River model recalibration every 5 years

Features Continued

- Partnerships
  - Federal- Stream gaging stations
  - Municipal-POTW's
  - Local- volunteer monitoring
- Doing more with less
  - SMART

Program Summary

	STATE-WIDE	BASINS	LOCAL
1. Who	**Federal/State**	**State/Regional**	**Regional/Local**
2. What			
Biology	High Level	Rapid Assessment	Low level
Water Quality	X	X	(X)
Sediment Quality	X	X	
Flow	X	X	(X)
Fish Tissue	X	X	
Habitat		(X)	X
Bacteria		(X)	X
Aesthetics			X
3. Where			
Mainstem (5+)	X	X	
Tributaries (3+4)	(X)	X	X
Headwaters (1+2)			X
4. When	**Continuous**	**Every 5 Yrs**	**As Needed**
Year	X		
Season	X		
Month		X	
Week		X	X
Day			X
5. Why			
Status	X	X	X
Trends	X		
Program Support	X		
Remediation		X (PS)	X (NPS)
6. How			
Fixed Station	X	X	(X)
Synoptic		(X)	X