# Making Sense From Measurements:

## Statistical Advances That Yield More, But Demand More

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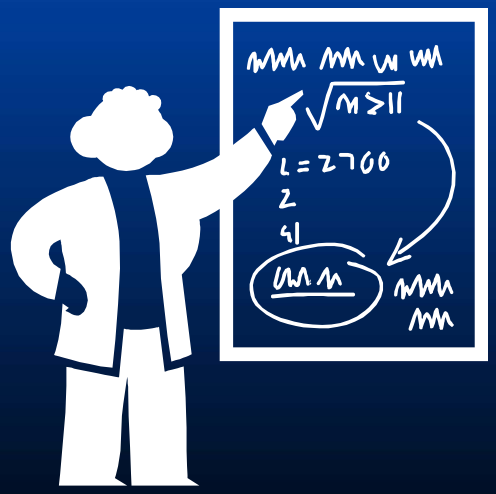
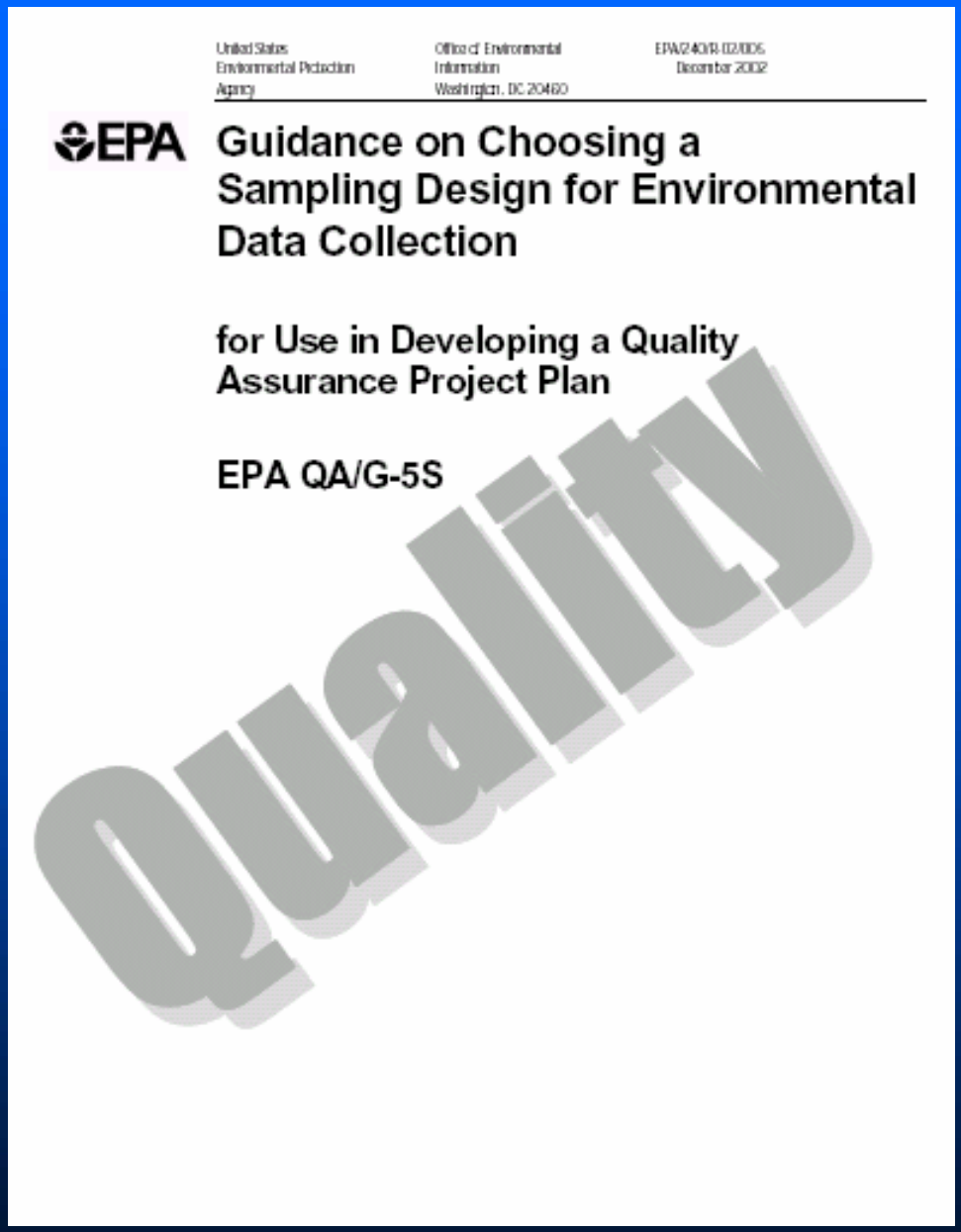
# Overview

- Review Traditional Sample Designs
- Discuss Recent Advances
  - Ranked Set Sampling
  - Multiple-Panel Sampling
- “Visual Sample Plan” Software
- Conclusions

# Sampling--Why Do We Care?

- Good estimates
- Reasonable standard error
- Generalization of results
- Reasonable cost






http://www.epa.gov/quality/qs-docs/g5s-final.pdf

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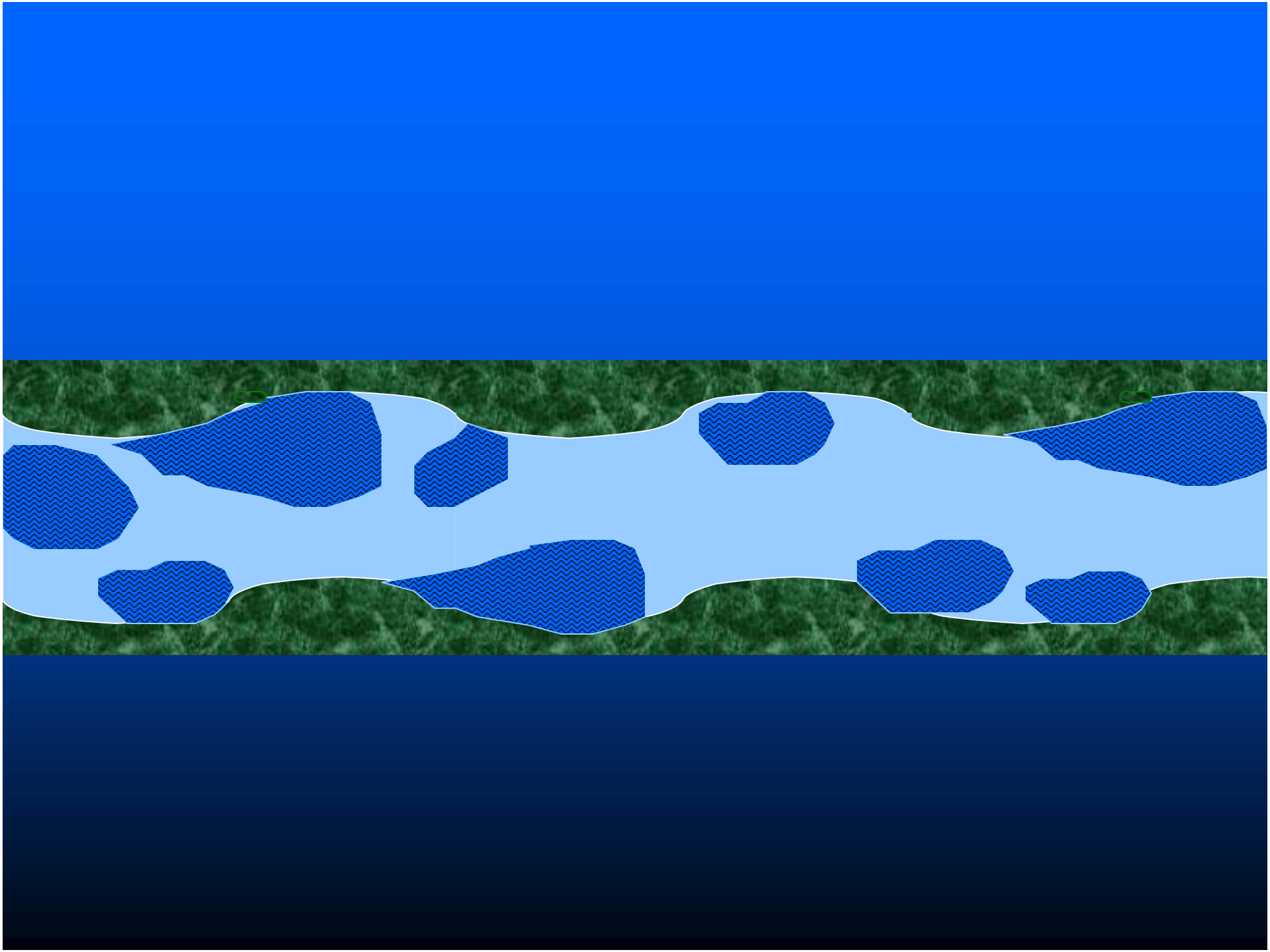


# Judgmental Sampling

- Allows one to use biological/physical process knowledge to choose a ‘representative’ sample of units
- But, NO standard error/confidence interval estimates result

# Simple Random Sampling

- “Sampling 101”--the first thing we learn!
- All samples of size “n” equally likely
- Standard errors obtainable
- Not so good in heterogeneous environments
- Not so good with small sample sizes

# Stratified Sampling

- Useful in heterogeneous environments
- Randomly sample within each stratum, then combine estimates at the end
- Unequal sample sizes can account for stratum variability and cost
- Strata must be well defined

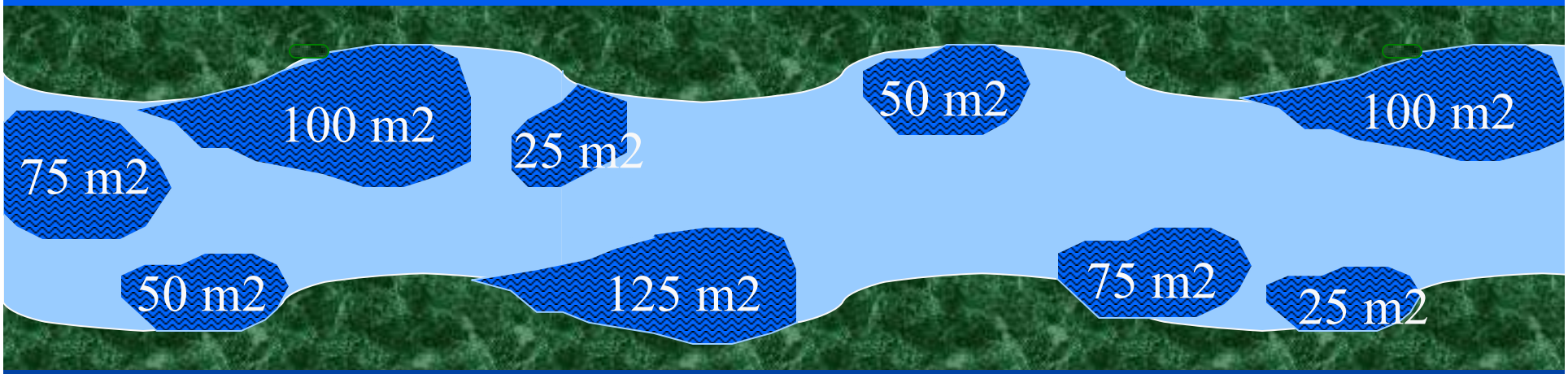
# Sampling Issues

- Small sample sizes in a heterogeneous environment
- Sampling for both status and trend simultaneously
- Accounting for spatial and temporal correlation

# Let's look at an approach that incorporates judgment:

- Want "some small, some medium, some large"--a representative sample!
- Stratify on the ranks of the data
- Useful when measurement is costly (so final sample size is small) but guesses are cheap

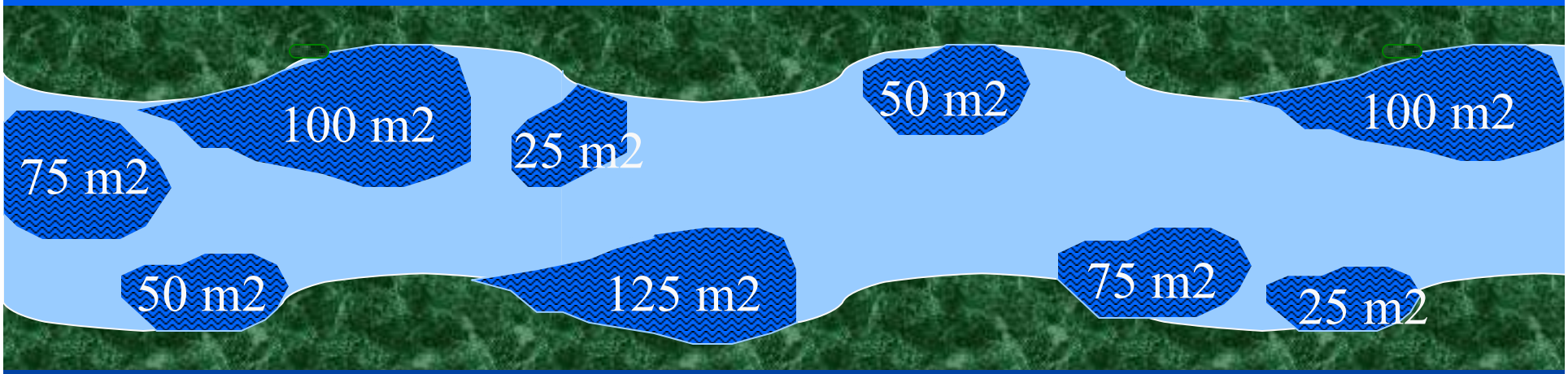
# Ranked Set Sampling




Randomly Select Sets

| | | | |
|---|---|---|---|
| Set 1 | 25 | 50 | 100 |
| Set 2 | 100 | 75 | 75 |
| Set 3 | 50 | 125 | 25 |

# Ranked Set Sampling




Randomly Select Sets

| | | | |
|---|---|---|---|
| Set 1 | 25 | 50 | 100 |
| Set 2 | 100 | 75 | 75 |
| Set 3 | 50 | 125 | 25 |

Rank Sets and Select Pools

| | | | |
|---|---|---|---|
| Set 1 | 25 | 50 | 100 |
| Set 2 | 75 | 75 | 100 |
| Set 3 | 25 | 50 | 125 |

# Ranked Set Sample

- “Set size” = 3; final sample size = 3
- To increase sample size:
  - Increase set size
  - Repeat entire process (cycles)
- Generate estimate and variance (standard error)

# Ranked Set Sampling: Examples

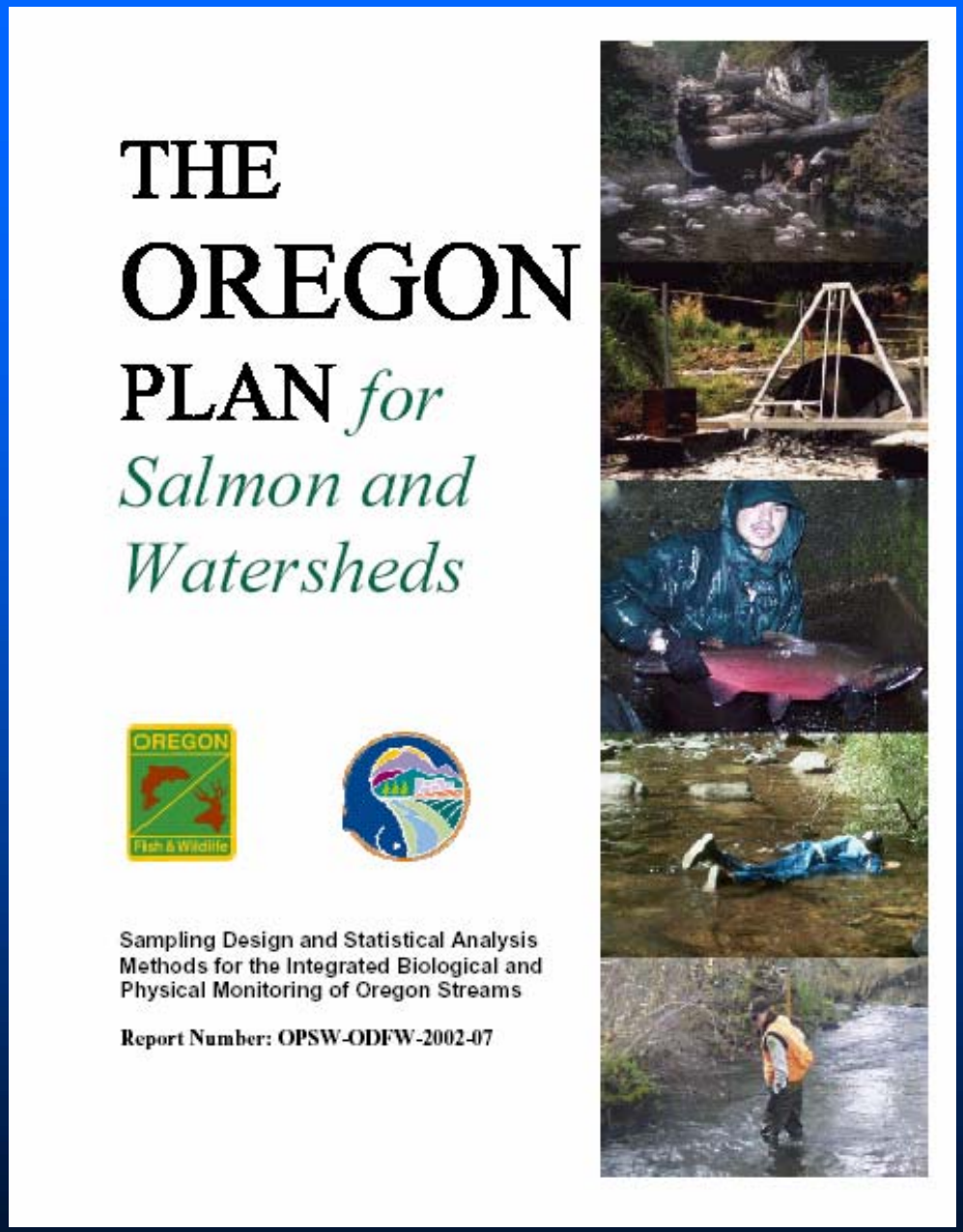
- Mean pool size in Oregon salmon streams (Mode et al. 1999)
- Height and diameter of spruce trees (Patil et al. 1994)
- Shrub phytomass in an oak forest (Martin et al. 1980)

# Ranked Set Sampling: Summary

- Stratifying on the ranks of the data
- RSS costs less than SRS for given level of precision
- Software, cost models available (Mode et al., 1999, 2002; Buchanan et al., 2004, *Environmetrics*)

How to take care of both status and trend in the same sampling design.

# Multi-panel Sampling Design




http://oregonstate.edu/dept/statistics/epa_program/docs/ntmondesign070302F.pdf

# Multi-panel Sampling Design: Context

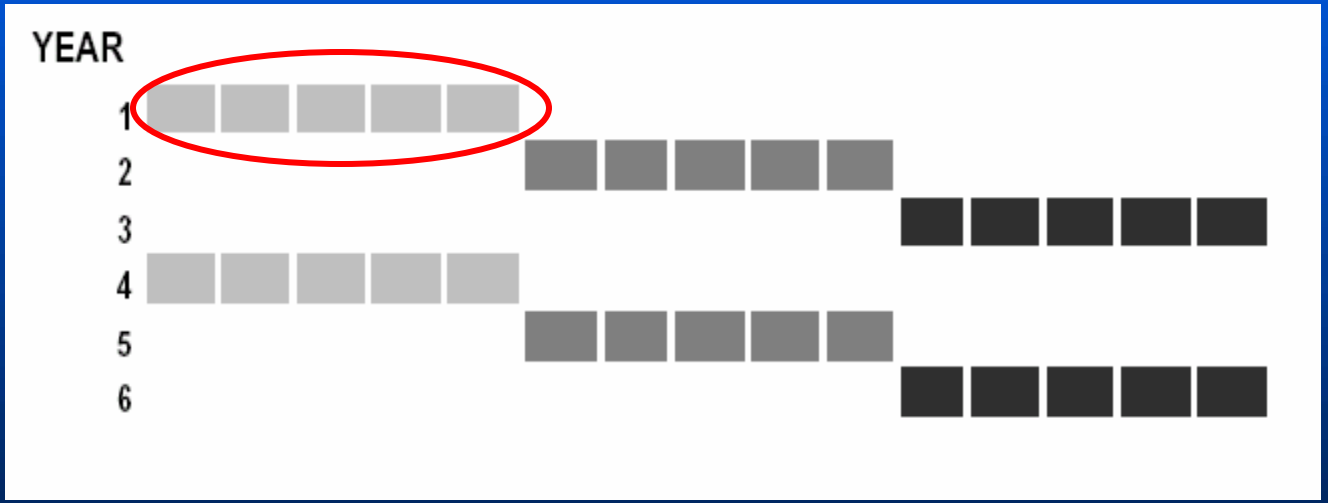
- Monitoring for both status and trend
  - –Status: spatial coverage (sites)
  - –Trend: temporal coverage (times)
- Can accomplish both with this design!

# Multi-panel Sampling Design-- What is a panel?

- Panel = set of sites with a revisit period
- Panels chosen to reflect spatial patterns

# Multi-panel Sampling Design

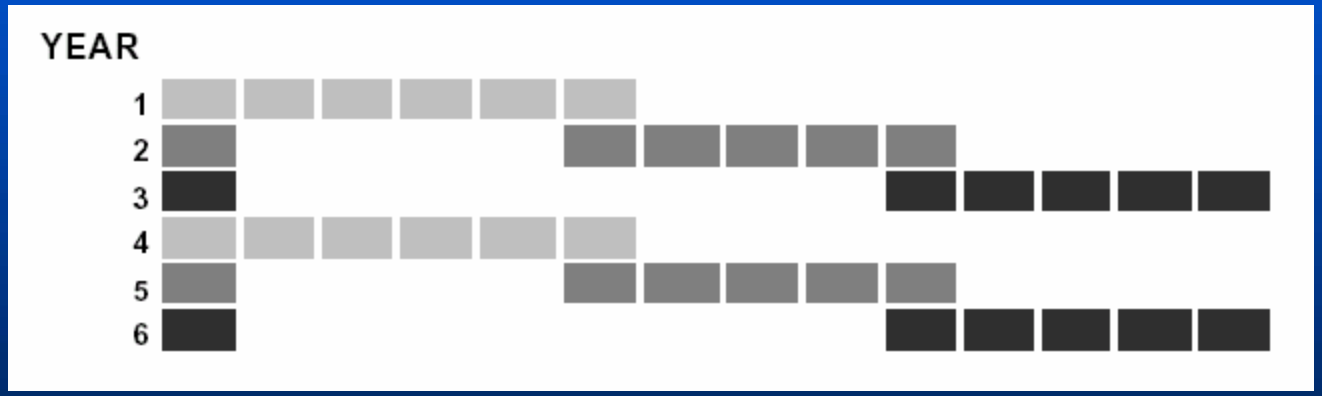
## Simplified Rotating Panel Design:




Reproduced from: Firman, J.C. and Jacobs, S.E. 2003. A Survey Design for Integrated Monitoring of Salmonids. Oregon Department of Fish and Wildlife

# Multi-panel Sampling Design

## Slightly More Complicated Panel Design:

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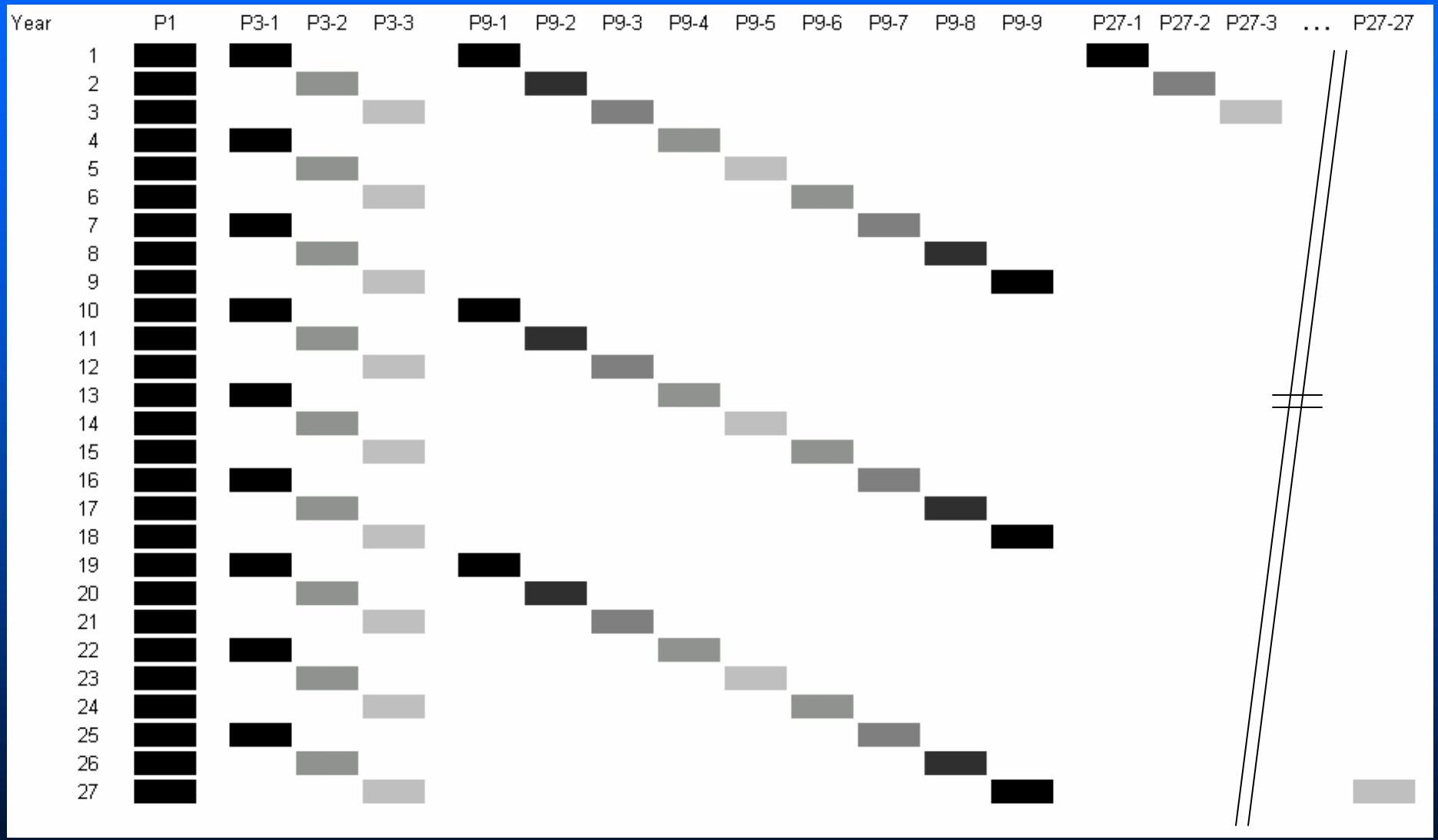
# ODFW Integrated Monitoring Design:




Modified from: Firman, J.C. and Jacobs, S.E. 2003. A Survey Design for Integrated Monitoring of Salmonids. Oregon Department of Fish and Wildlife

# Multi-panel Sampling Design

Panel designs are usually based on a 3-5 year rotation.

ODFW's design adopted a three-year rotation to coincide with the three-year life cycle for coho salmon.

# Multi-panel Sampling Design

In ODFW study a panel consisted of:

- ~ 79 Habitat Sites
- ~ 41 Spawning Sites
- ~ 13 Juvenile Sites

# Multi-panel Sampling Design: Summary

- Useful when both spatial and temporal coverage  required
- Accounts for temporal correlation at a site and spatial correlation among sites
- Requires all sites be known to define the panels

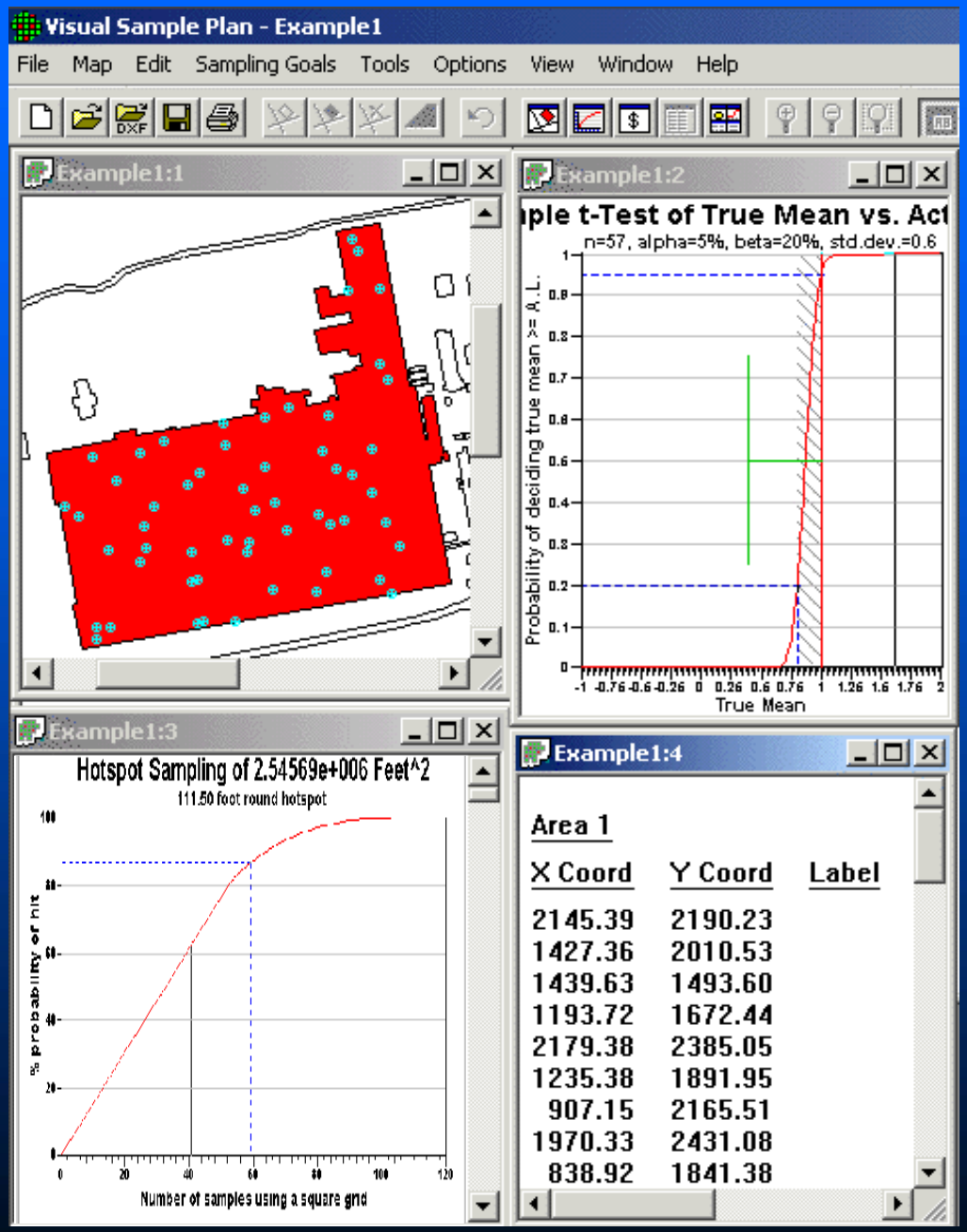
# “Visual Sample Plan” Software

- Uses site maps and interactive questions to determine # samples, cost, sampling locations
- User imports a site map
- Spatial sampling, but not set up for stream networks
- http://dqo.pnl.gov/vsp

# Visual Sample Plan (VSP)


http://dqo.pnl.gov/vsp

# Visual Sample Plan (VSP)




Modified from:

http://dqo.pnl.gov/vsp

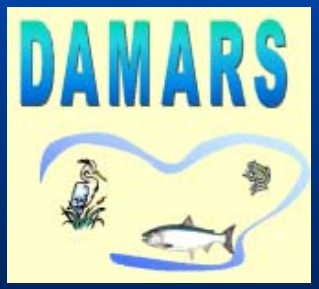
# Conclusions

- Sampling approaches take into account complex and connective nature of stream networks
- Computationally complex estimates, but better attention to spatial and temporal correlation
- Requires more up front collaboration between biologists and quantitative folks

# Acknowledgements



EPA Cooperative Agreement
CR82-9096-01 (STAR)




Program on Designs and Models for Aquatic Resource Surveys,
Don Stevens, Director
Oregon State University

# Web Sites

- www.epa.gov/quality/qa_docs.html
- dqo.pnl.gov/vsp
- oregonstate.edu/dept/statistics/epa_program/docs/

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