Predictive models for adaptive management of emergent sandbar habitat to support recovery of least terns and piping plovers on the Missouri River

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Adaptive Management

- Management = making decisions, choosing from among alternatives
- Adaptive = has the ability to respond to new circumstances, including information

Structured Decision Making

“A formal application of common sense for situations too complex for the informal use of common sense.”
R. Keeney

Structured Decision Making

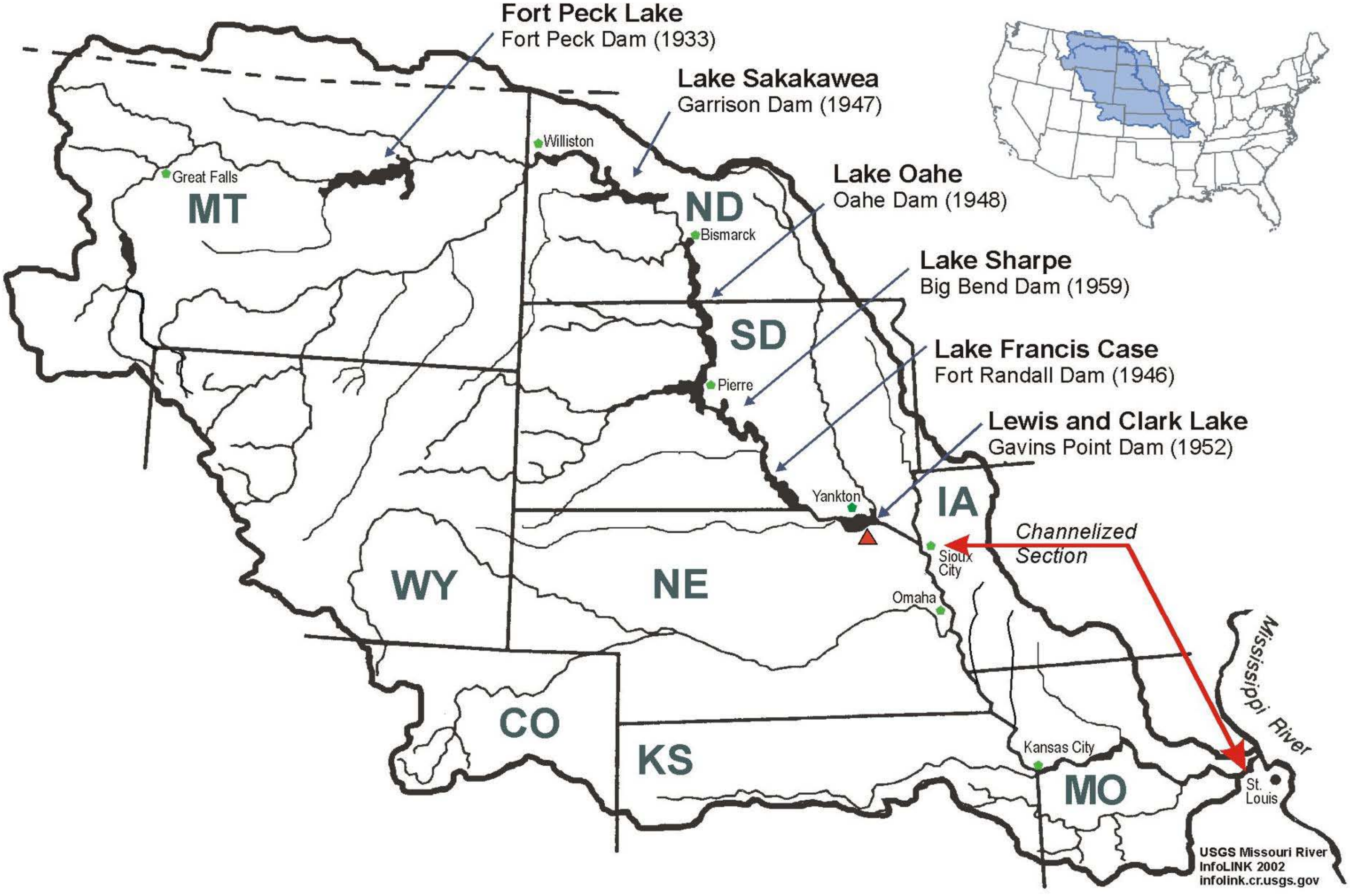
- Break decision into steps
  - **Pr**oblem
  - **O**bjectives
  - **A**lternative Actions
  - **C**onsequences
  - **T**radeoffs

  } **PrOACT**

- AM a special case – sequential linked decisions

Missouri River Emergent Sandbar Habitat

Carol Aron, Jane Ledwin, Mike Olson, US FWS
Kelly Crane, Tim Fleeger, Craig Fleming,
Teresa Reinig, US Army Corps
Wayne Werkmeister, National Park Service


Fort Peck Lake
Fort Peck Dam (1933)
Lake Sakakawea
Garrison Dam (1947)
Lake Oahe
Oahe Dam (1948)
Lake Sharpe
Big Bend Dam (1959)
Lake Francis Case
Fort Randall Dam (1946)
Lewis and Clark Lake
Gavins Point Dam (1952)
Williston
Great Falls
MT
ND
Bismarck
SD
Pierre
Yankton
IA
Channelized Section
Sioux City
Omaha
WY
NE
CO
KS
Kansas City
MO
St. Louis
Mississippi River
USGS Missouri River
InfoLINK 2002
infolink.cr.usgs.gov

1944
FCA

1967
system
Closure

1980's –
Tern and
Plover
listed

1989
Master
Manual
Revision
started

2000
First
Biological
Opi

- Many Court Cases
- Biological Assessment 2003
- Amended BiOp 2003

Revised BiOP on Missouri River Ops

- BO on river operations included emergent sandbar restoration goals (acreages)
- Corps proposes to **mechanically create habitat** to avoid jeopardy to terns and plovers
- BO implementation requires **Adaptive Management Program**
- Ongoing Monitoring and Research Program without clear understanding of use of data/analyses

Spirit Mound
Yankton
Elk Point
Meridian Bridge
Vermillion
Mulberry Bend Bridge
Iona Volcano
Ponca State Park
Ponca
81
19
29
15

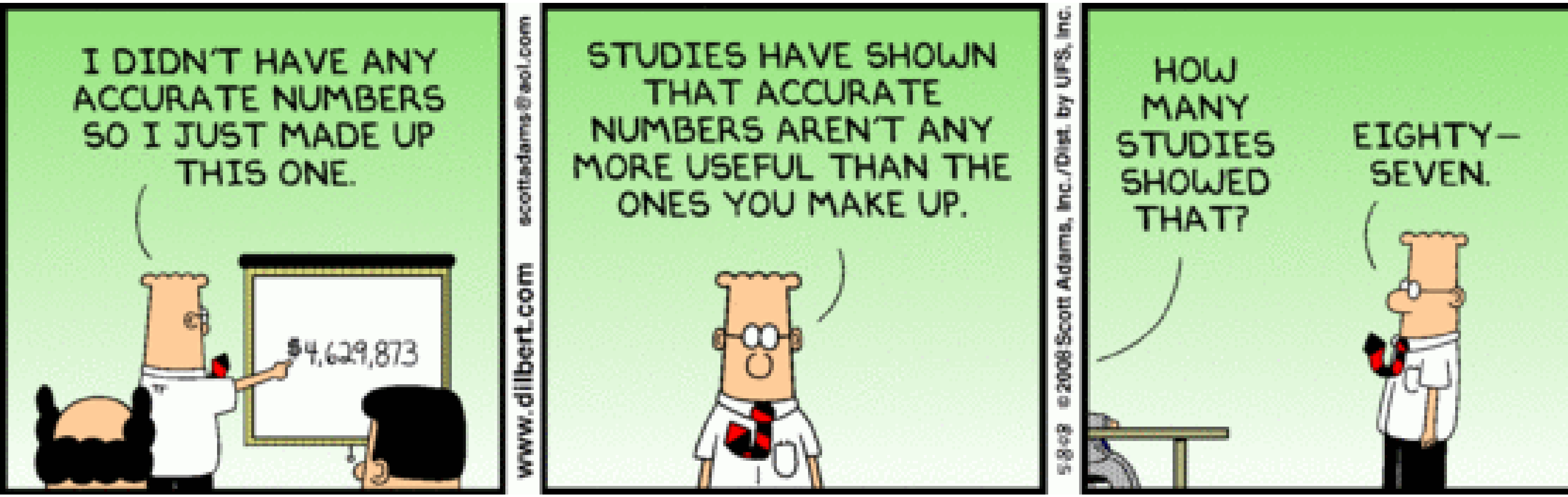
Problem Statement

- How much, where and by which means to create Emergent Sandbar Habitat (ESH) in a focal year (e.g., FY 2015) for **tern** and **plover** nesting and brood rearing in Gavins' Reach?

Objectives

- Minimize cost/acre
- Meet Fledge Ratios
- Meet 2015 Acreage Targets
- Minimize socioeconomic impacts to stakeholders
- Maintain "Outstanding and remarkable values"

"Bob and Ruth! Come on in.... Have you met Russell and Bill, our 1.5 children?"


I DIDN'T HAVE ANY ACCURATE NUMBERS SO I JUST MADE UP THIS ONE.
$4,629,873
www.dilbert.com
scottadams@aol.com
STUDIES HAVE SHOWN THAT ACCURATE NUMBERS AREN'T ANY MORE USEFUL THAN THE ONES YOU MAKE UP.
© 2008 Scott Adams, Inc./Dist. by UFS, Inc.
HOW MANY STUDIES SHOWED THAT?
EIGHTY-SEVEN.

Potential Actions

- How much to create in a year?
- What methods
  - Create
  - Devegetate
  - Devegetate and overtop
  - Flows

Consequences

- What features are necessary in a model
  - that predicts the consequences of each action
  - relevant to the objectives

rapid prototyping

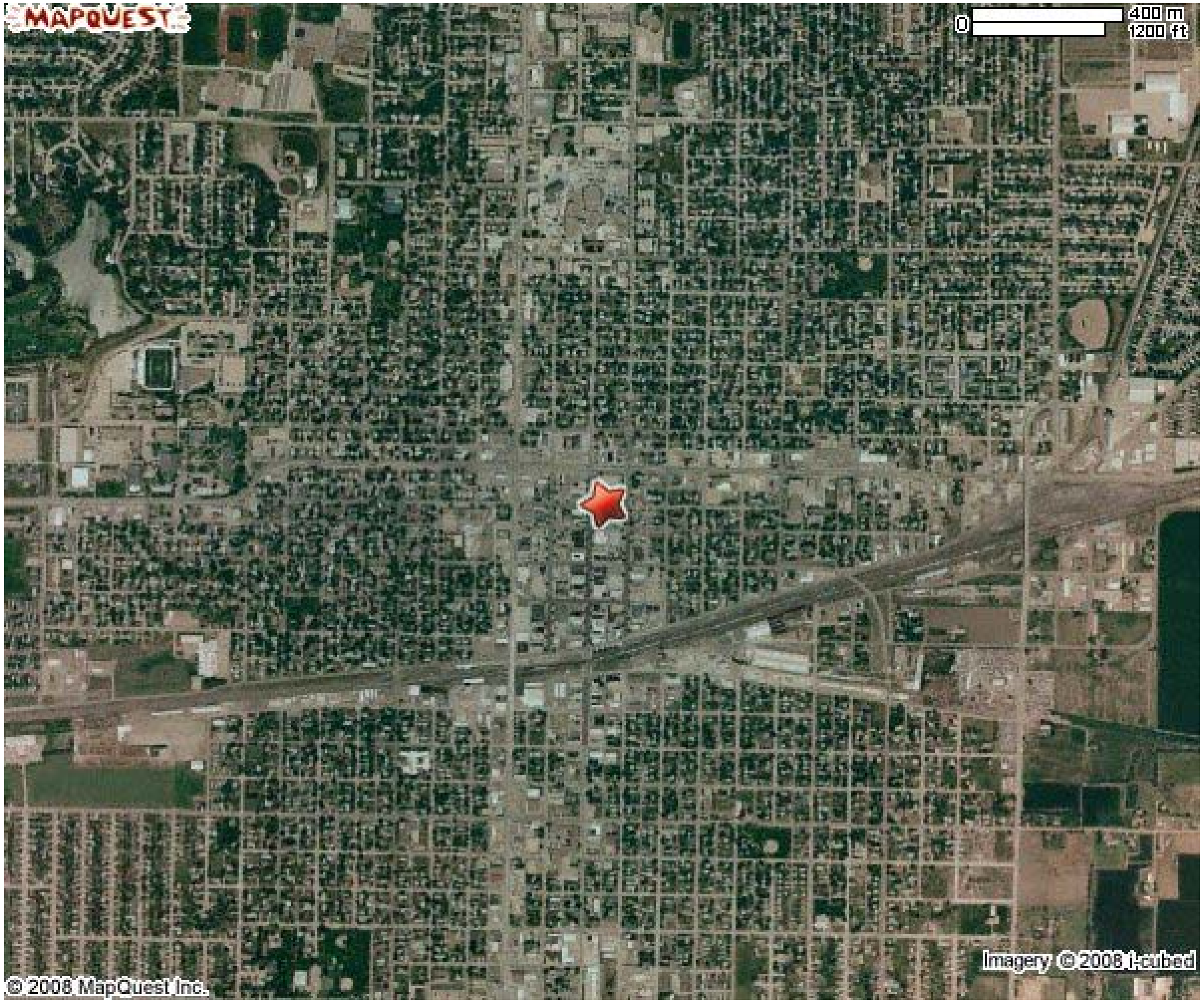
2 types of inference about the future

- Inductive – reason from experience of the past
  - STATISTICS, MONITORING and EXPERIMENTS
- Deductive – if assumptions are true, conclusions follow
  - MATHEMATICAL MODELLING

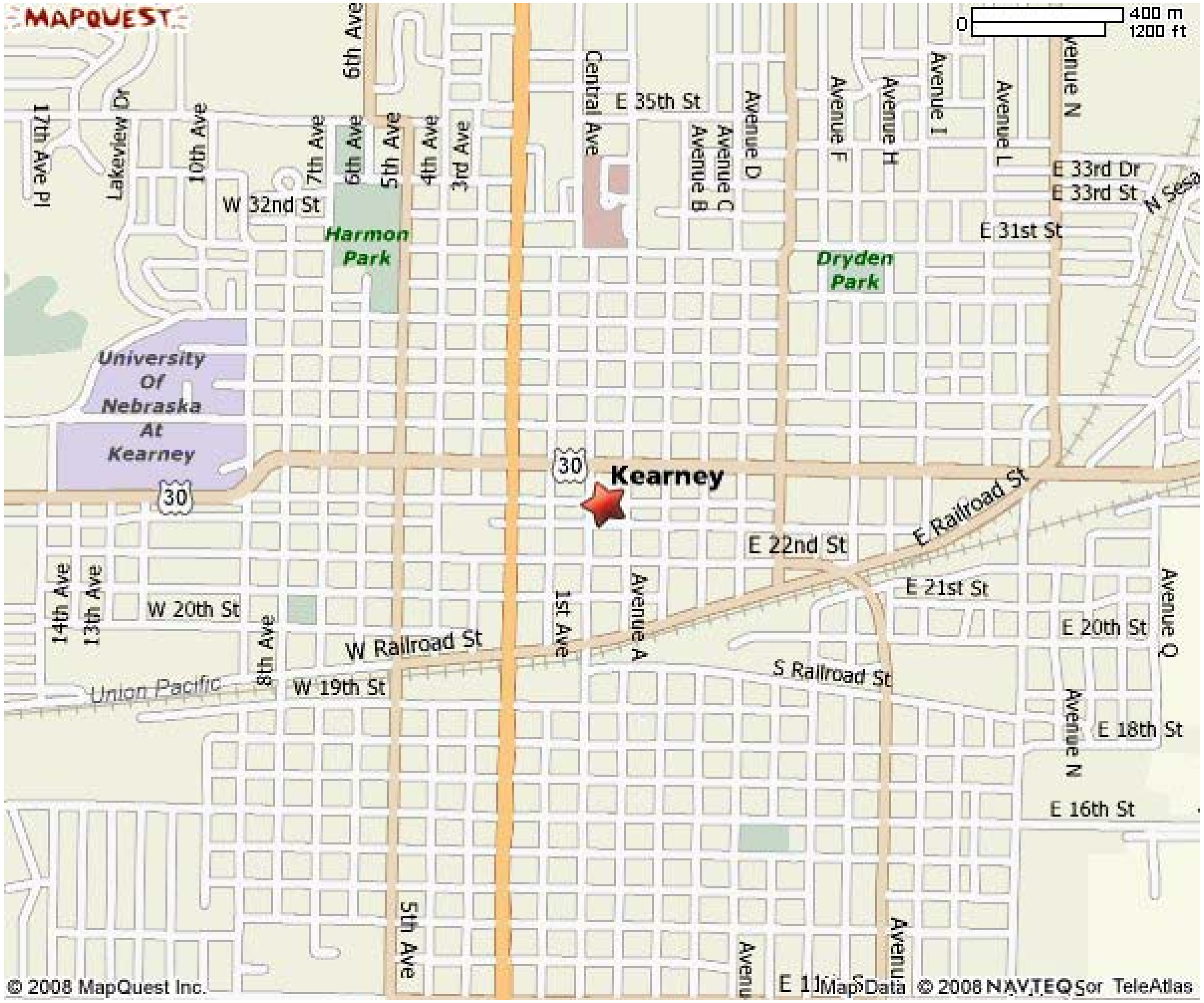
Models

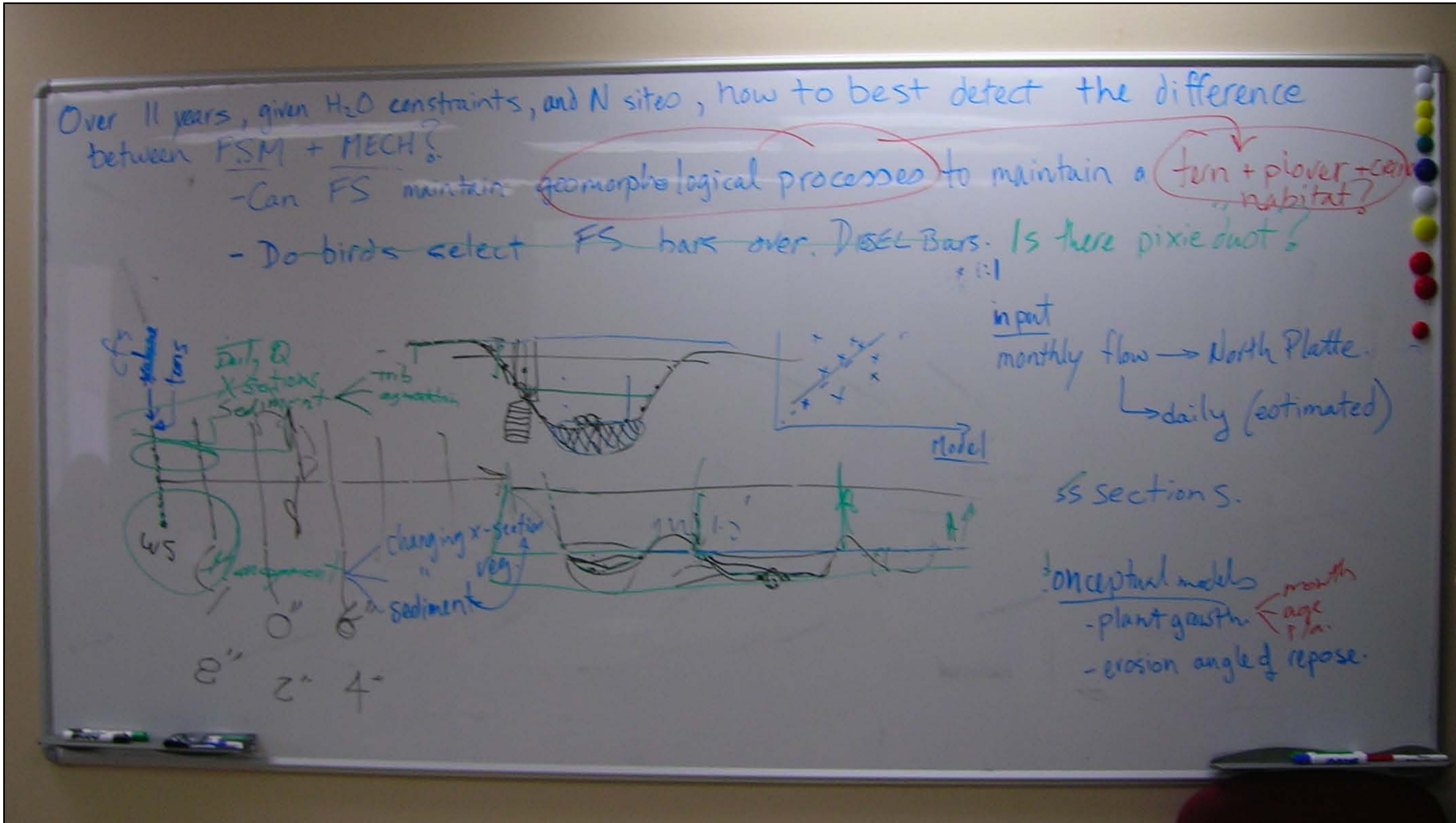
"All models are wrong; some of them are useful."

– George Box

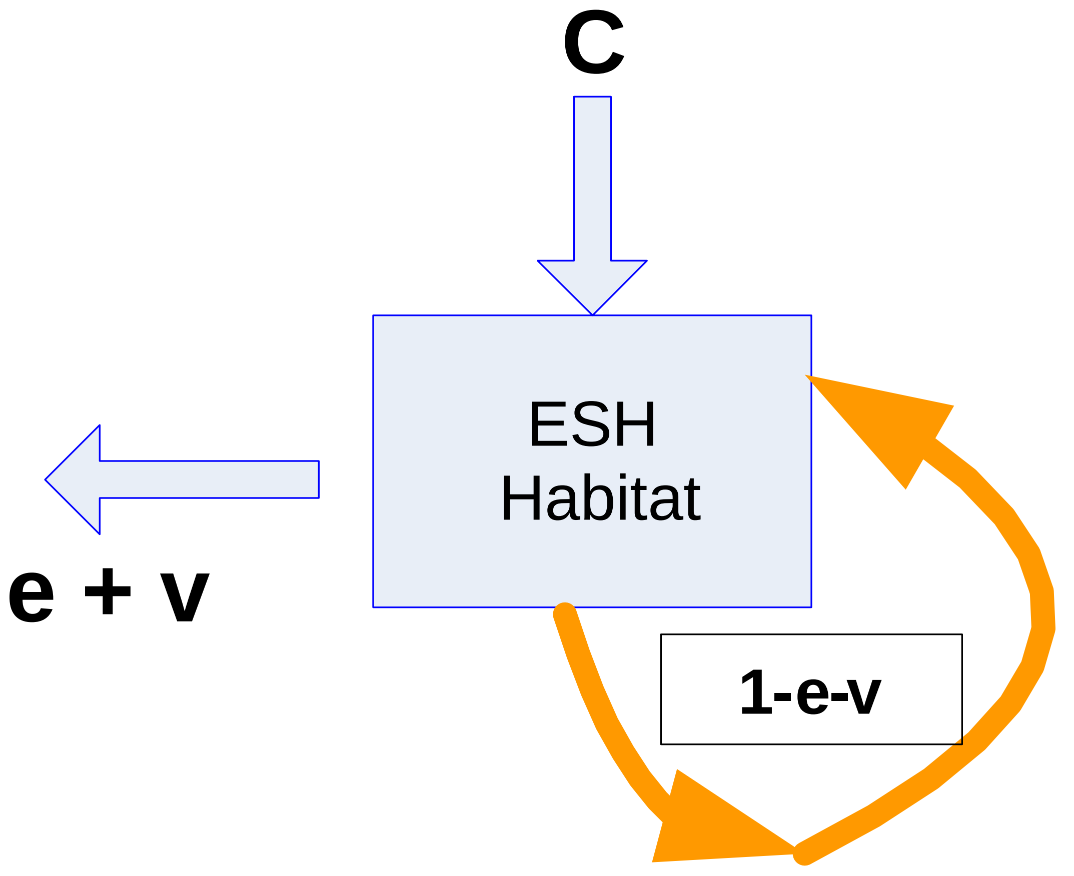

MAPQUEST
0
400 m
1200 ft
Imagery © 2008 i-cubed
© 2008 MapQuest Inc.

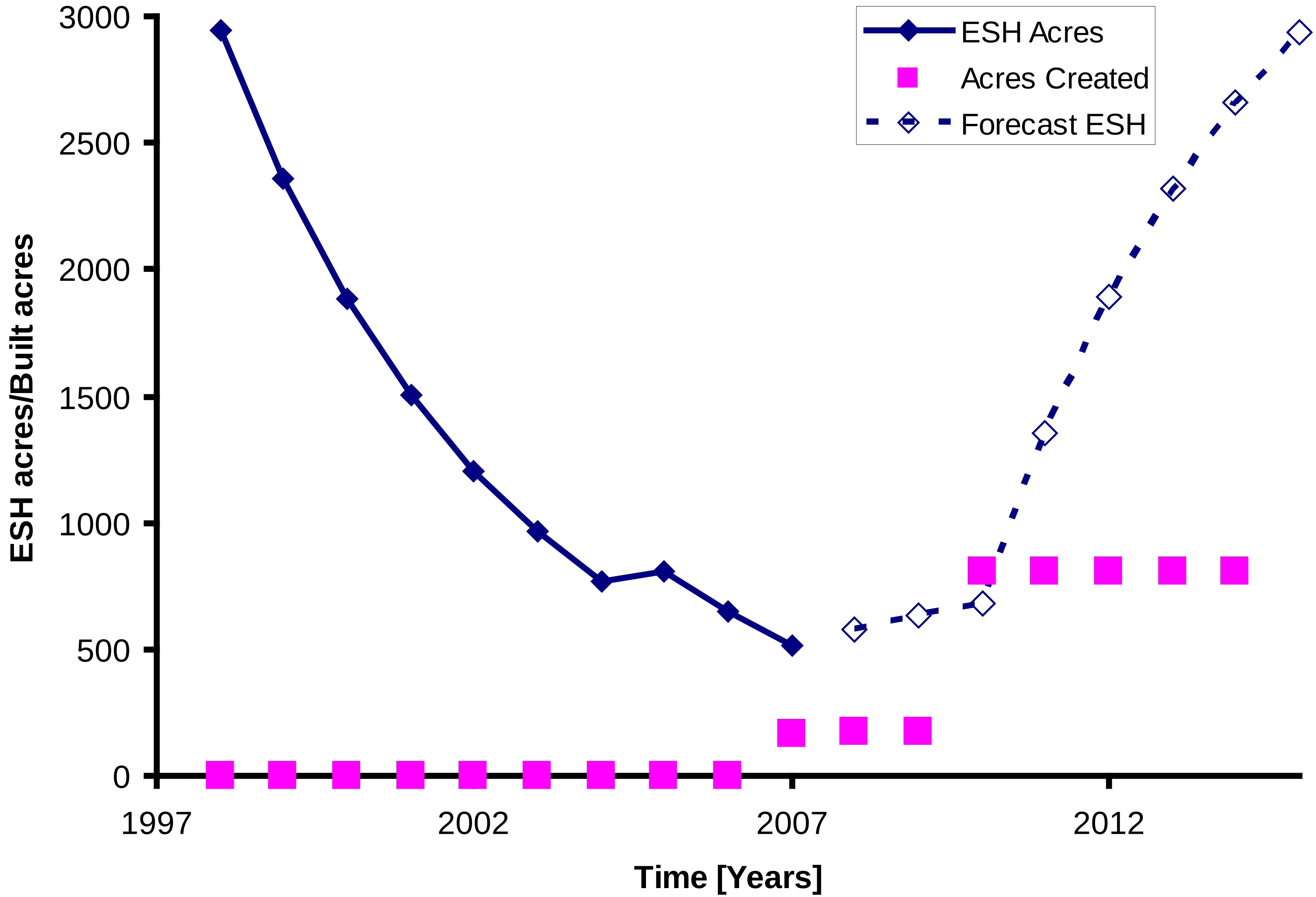
PrOACT


MAPQUEST
400 m
1200 ft
Kearney
Harmon Park
Dryden Park
University Of Nebraska At Kearney
30
W 32nd St
E 35th St
E 33rd Dr
E 33rd St
E 31st St
E 22nd St
E 21st St
E 20th St
E 18th St
E 16th St
W 20th St
W Railroad St
W 19th St
E Railroad St
S Railroad St
Union Pacific
Central Ave
1st Ave
Avenue A
Avenue B
Avenue C
Avenue D
Avenue F
Avenue H
Avenue I
Avenue L
Avenue N
Avenue Q
3rd Ave
4th Ave
5th Ave
6th Ave
7th Ave
8th Ave
10th Ave
13th Ave
14th Ave
17th Ave Pl
Lakeview Dr
© 2008 MapQuest Inc.
Map Data © 2008 NAVTEQ or TeleAtlas


Over 11 years, given H2O constraints, and N sites, how to best detect the difference between FSM + MECH?
-Can FS maintain geomorphological processes to maintain a tern + plover
habitat?
- Do birds select FS bars over DISEL Bars. Is there pixie dust?
Daily Q
X-sections
Sediment
trib augmentation
changing x-section
veg
sediment
WS
8"
2"
4"
Model
input
monthly flow → North Platte
daily (estimated)
ss sections.
onceptual models
-plant growth
month
age
-erosion angle of repose.

First Prototype

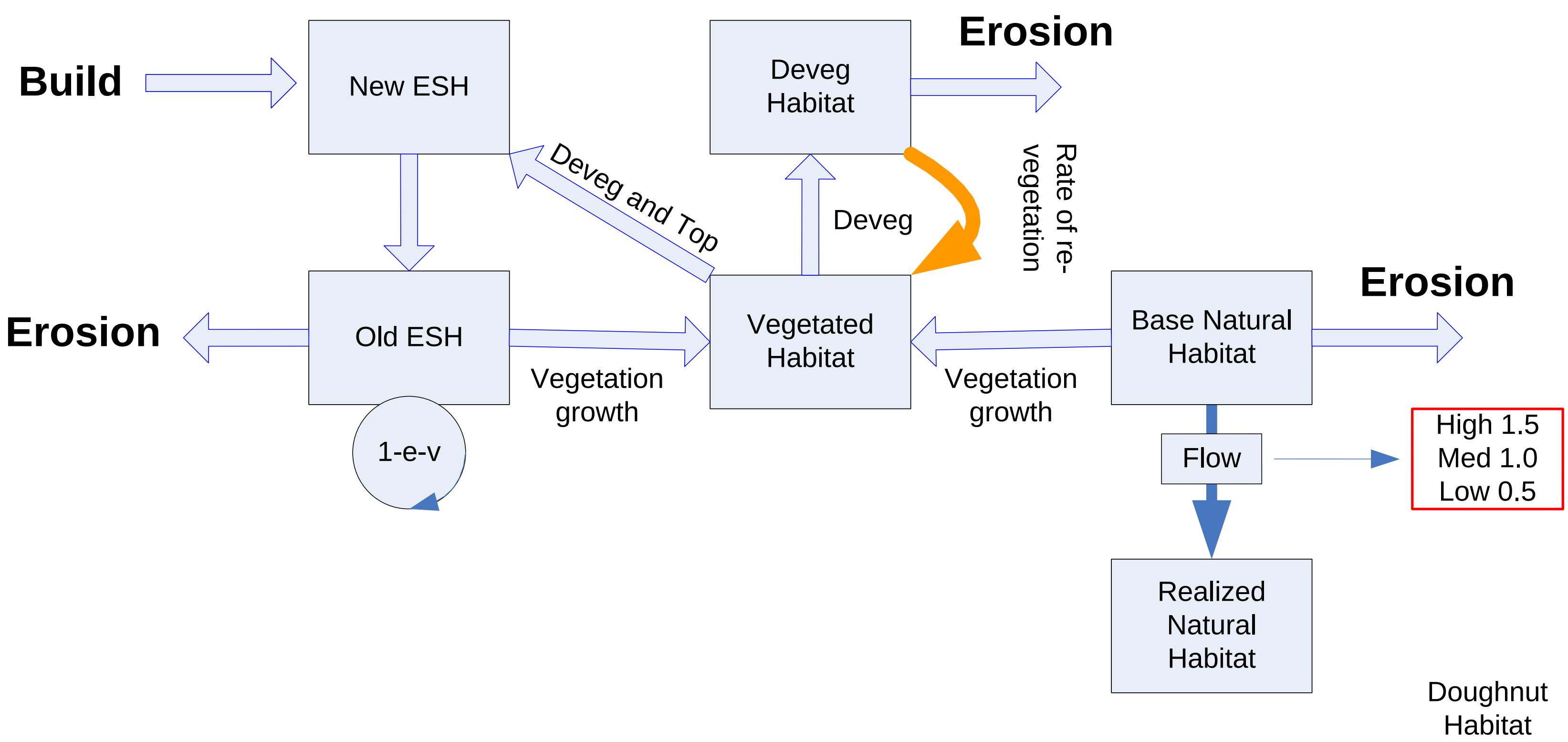




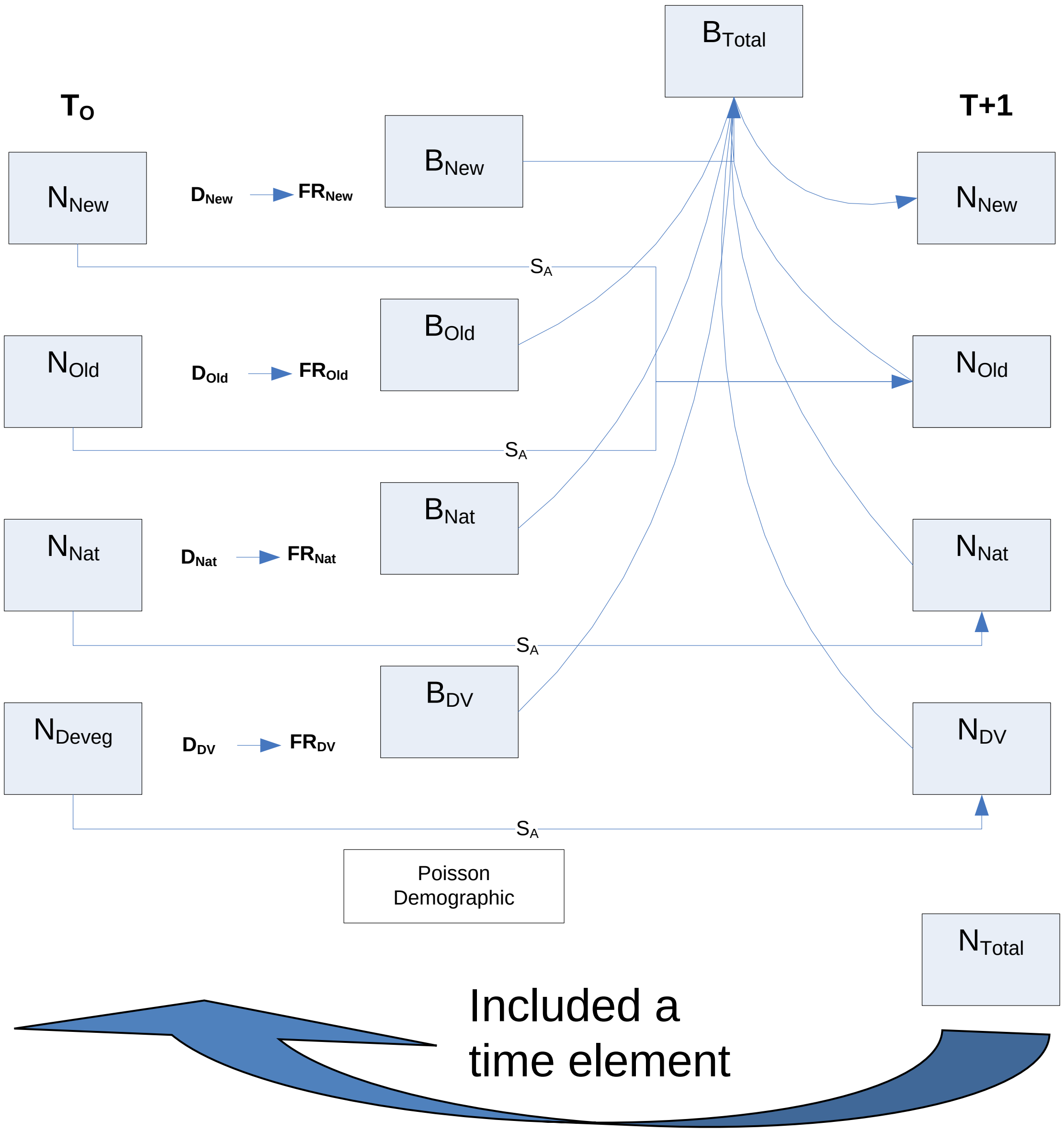
ESH Acres
Acres Created
Forecast ESH
3000
2500
2000
1500
1000
500
0
1997
2002
2007
2012
ESH acres/Built acres
Time [Years]

Second Prototype

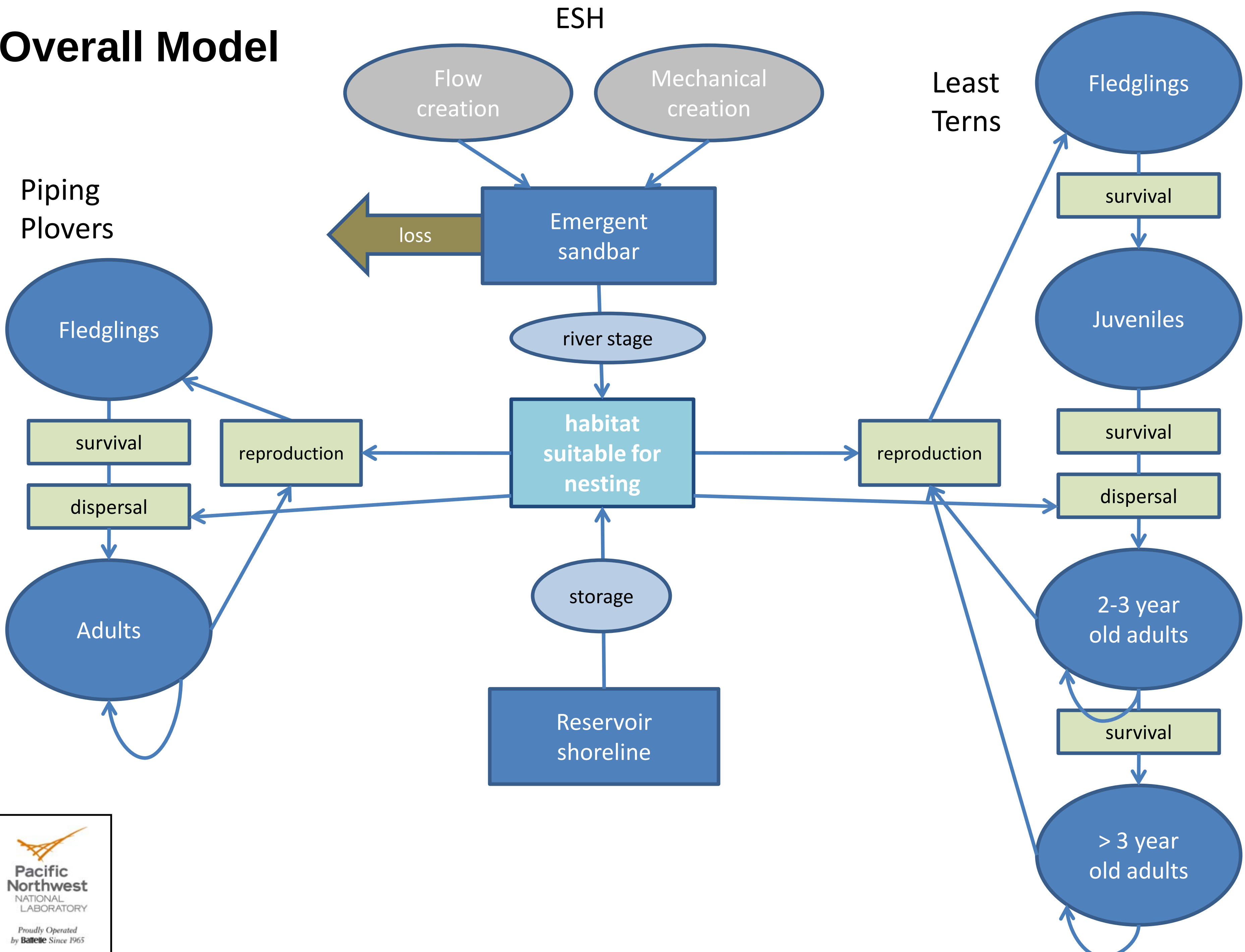
Habitat Model



Population Model for 2nd Prototype



Overall Model

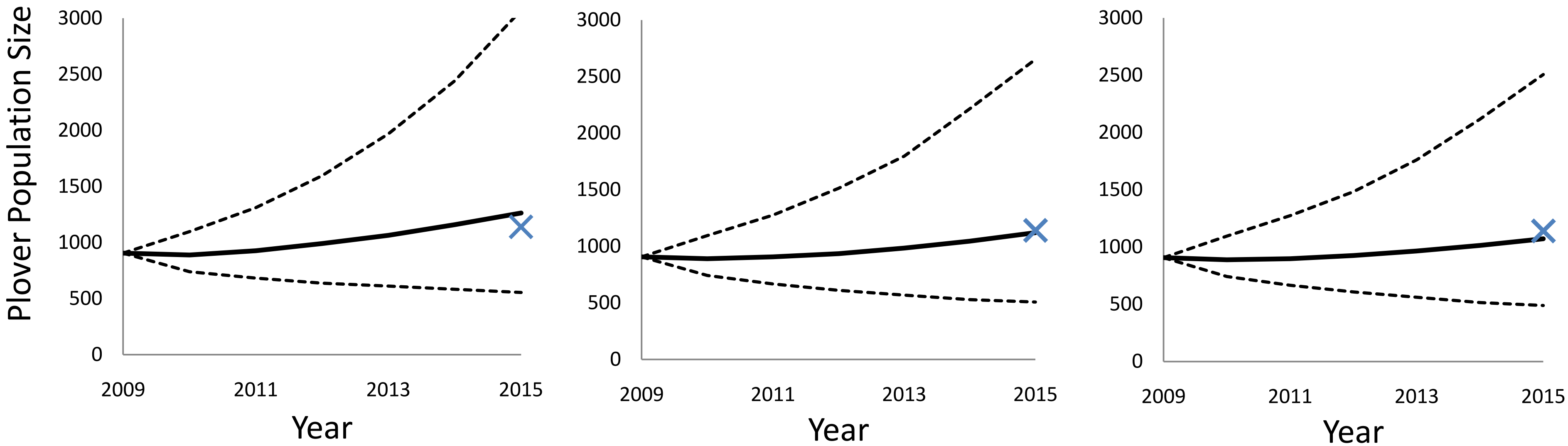


Projected population dynamics

BiOp construction: 11,886 acres by 2015

150 acres/year

No construction



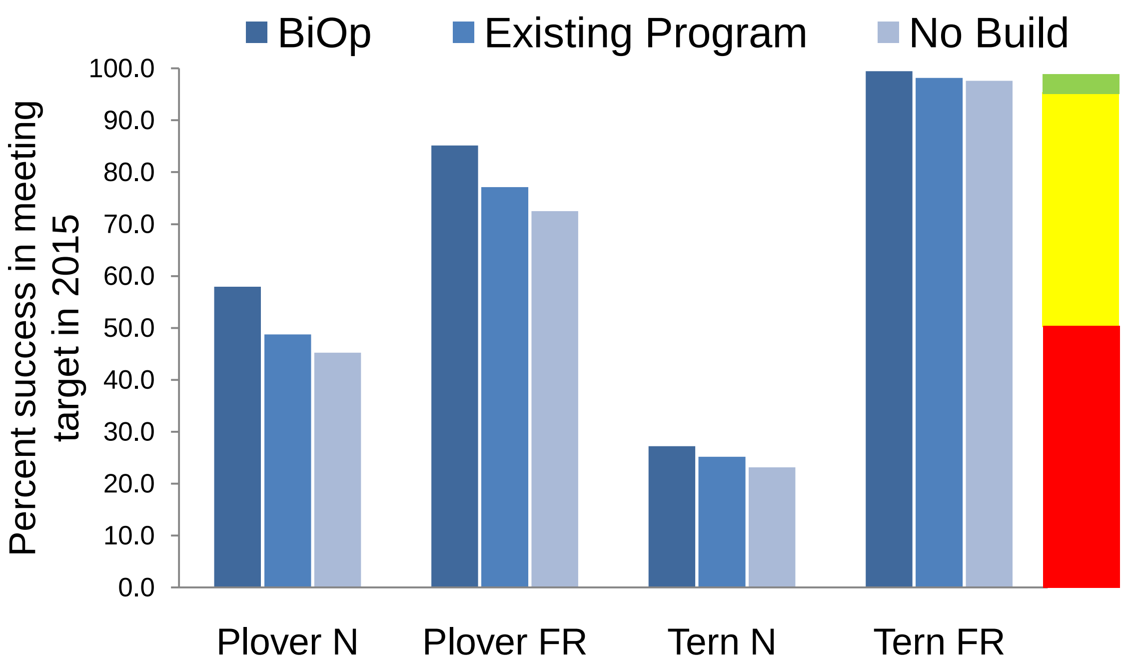
Take home messages

- SDM/Rapid Prototyping works!
  - Built a joint understanding of the problem
  - Connects monitoring data to decision making
- Choose the right problem
  - Nested problems can be solved individually
- A process, not a product
- Not a silver bullet

Questions?

aminpractice.blogspot.com

Predicted outcome of management actions



Target	Metric	BiOp	Existing Program	No Build
Target	ESH	11,886	150/year	N/A
		65.4	78.9	
1140	Plover N	57.9	48.8	45.2
1.22	Plover FR	85.1	77.1	72.5
900	Tern N	27.2	25.2	23.1
0.94	Tern FR	99.5	98.2	97.6

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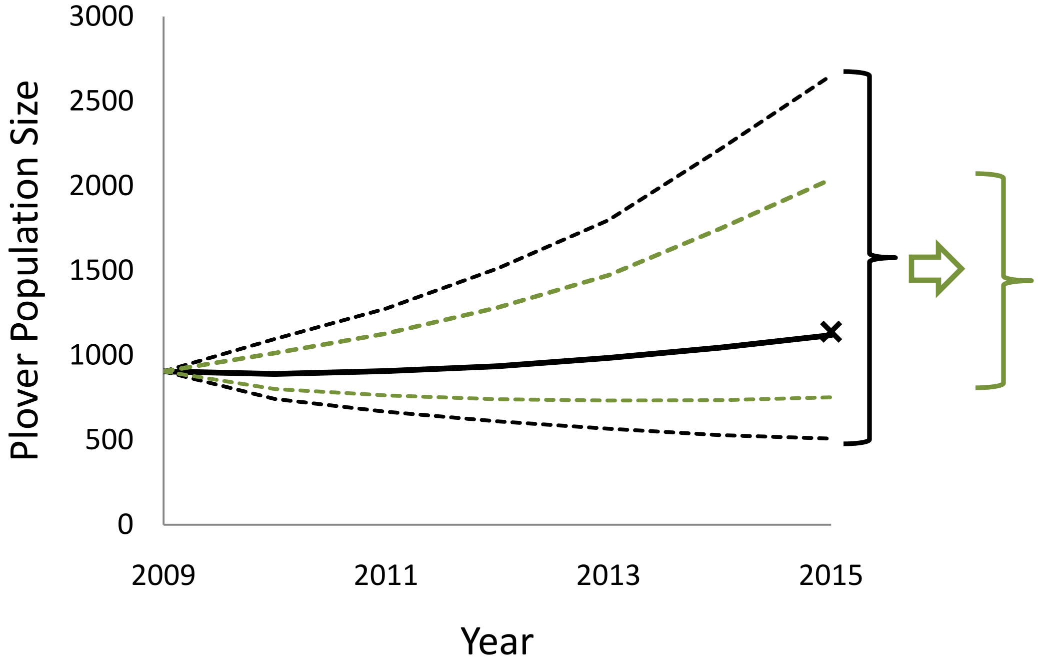
Proudly Operated by Battelle Since 1965

How much does reducing uncertainty improve predictions?



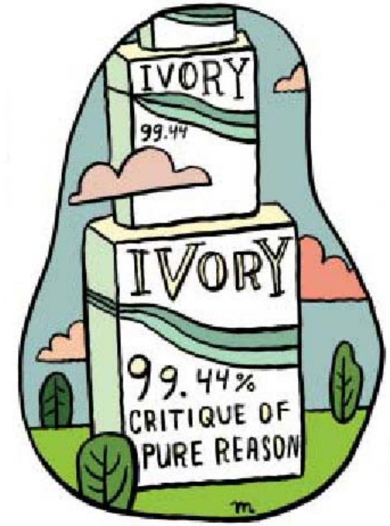
Reducing uncertainty about a parameter reduces the variability of predictions

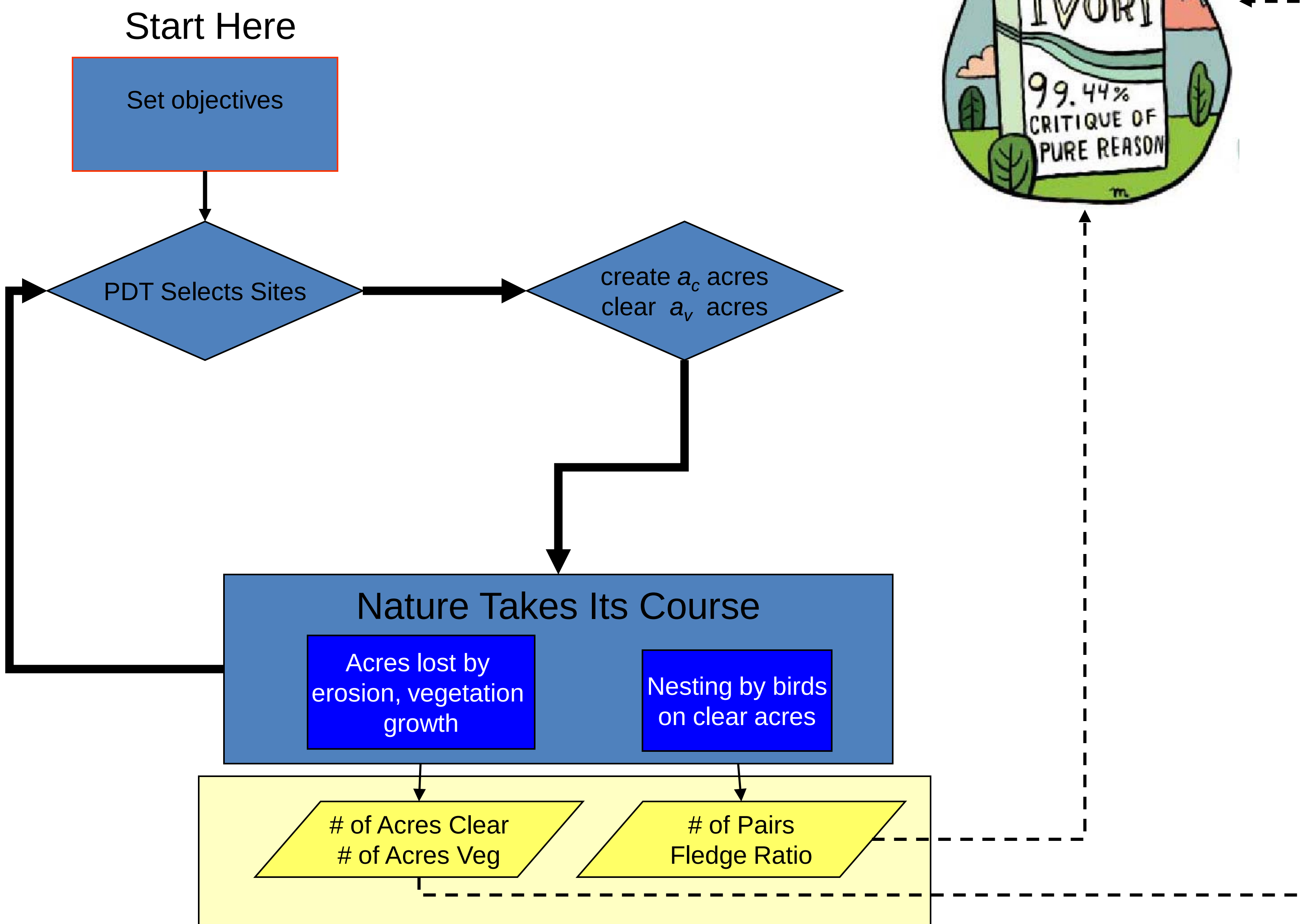
Improve ability to decide between management actions

Modeling Myths

- They have to be “right” to be useful
- Ergo – they must be complicated

Just right sized prototype decision model v0



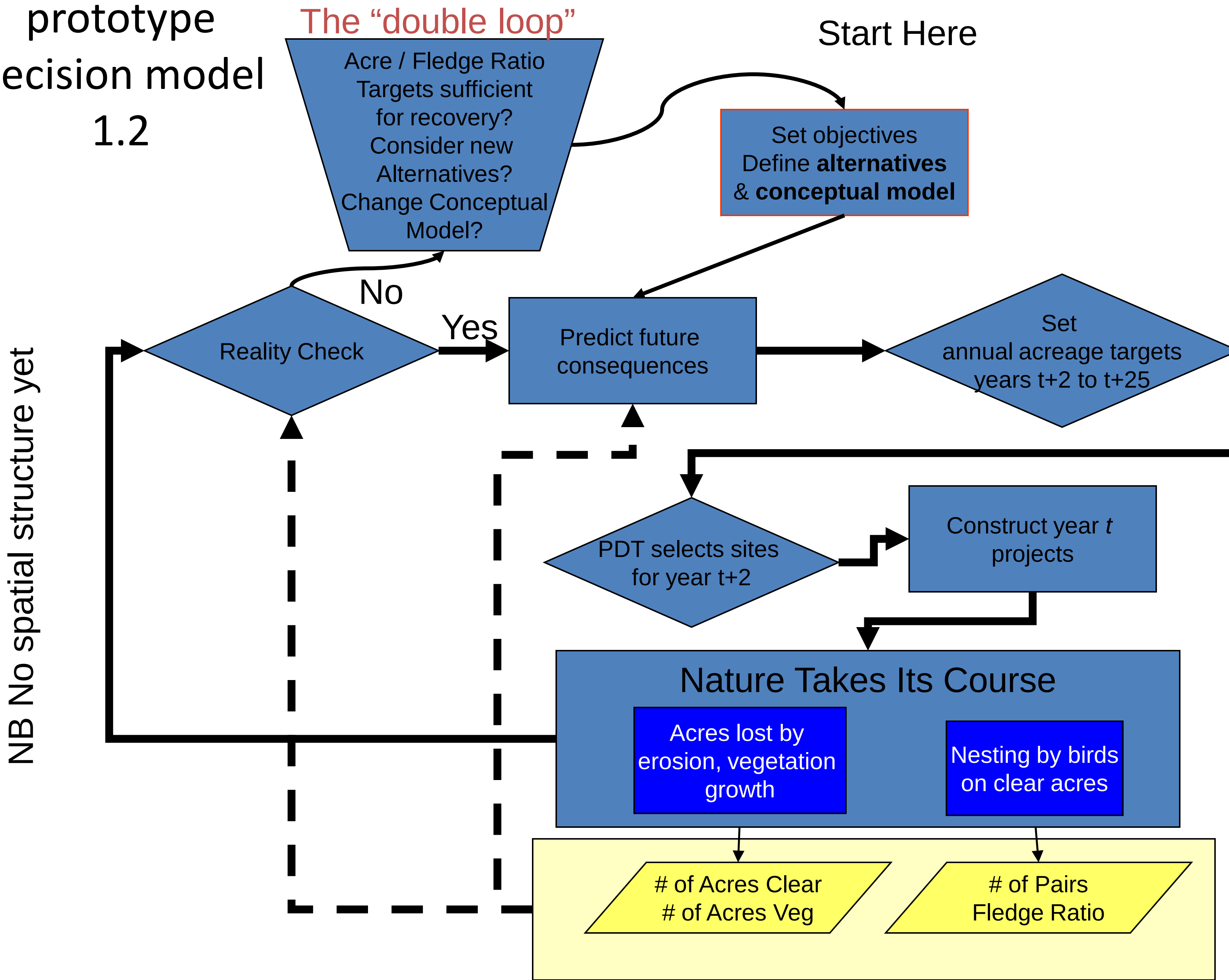


Making Decisions

- Complex Processes
- High Uncertainty
- Incompletely known actions
- Conflicting Objectives
- The answer:

Adaptive Management

Just right sized prototype decision model 1.2

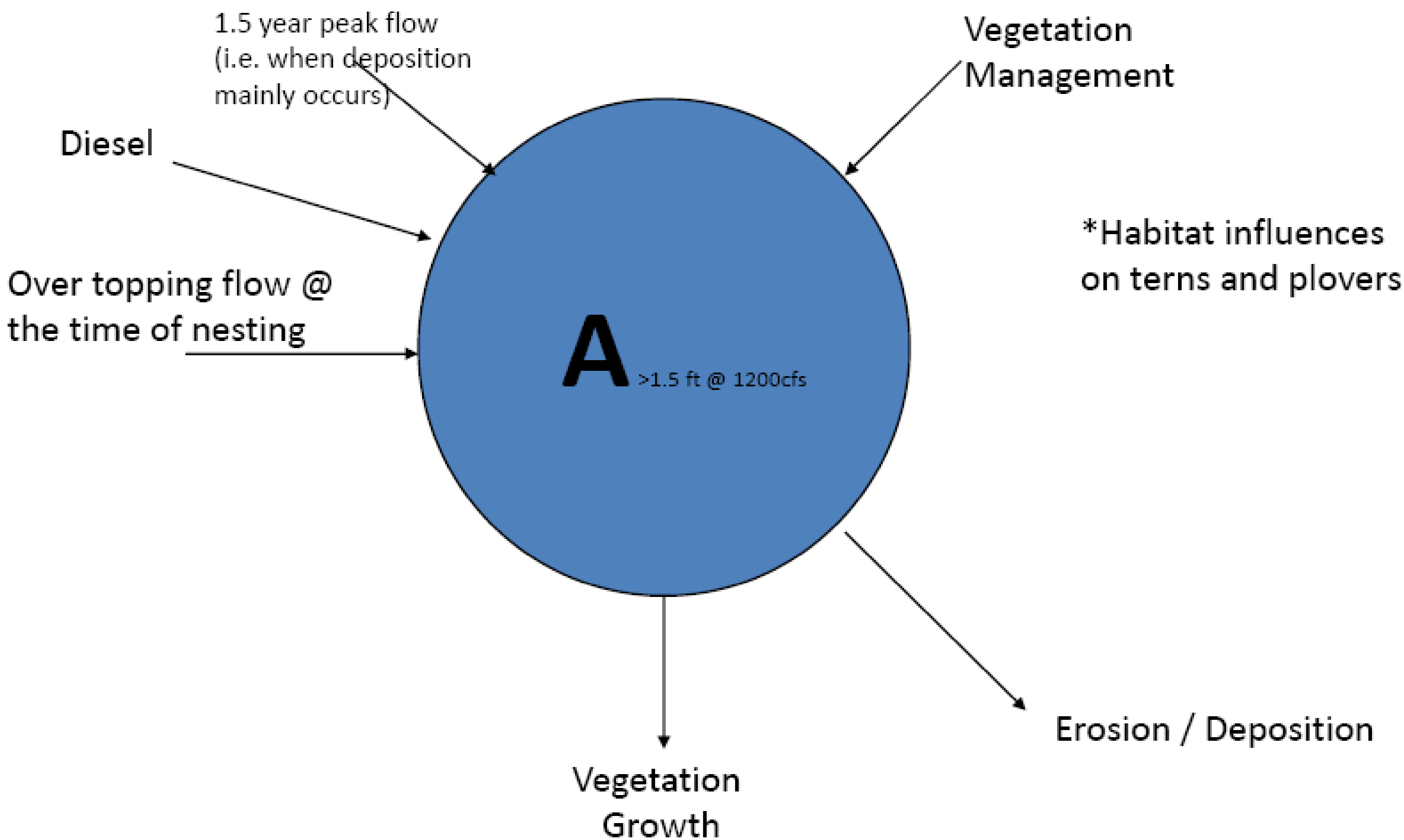


Making Decisions

- Structured Decision Making (SDM)
- Adaptive Management (AM)
- Rapid Prototyping of models (RP)

Donald Rumsfeld

“Plan backwards as well as forward. Set objectives and trace back to see how to achieve them. You may find that no path can get you there. Plan forward to see
e your steps will take you,
n may not be clear or
ive.”


1.5 year peak flow
(i.e. when deposition
mainly occurs)
Vegetation
Management
Diesel
*Habitat influences
on terns and plovers
Over topping flow @
the time of nesting
A
>1.5 ft @ 1200cfs
Erosion / Deposition
Vegetation
Growth

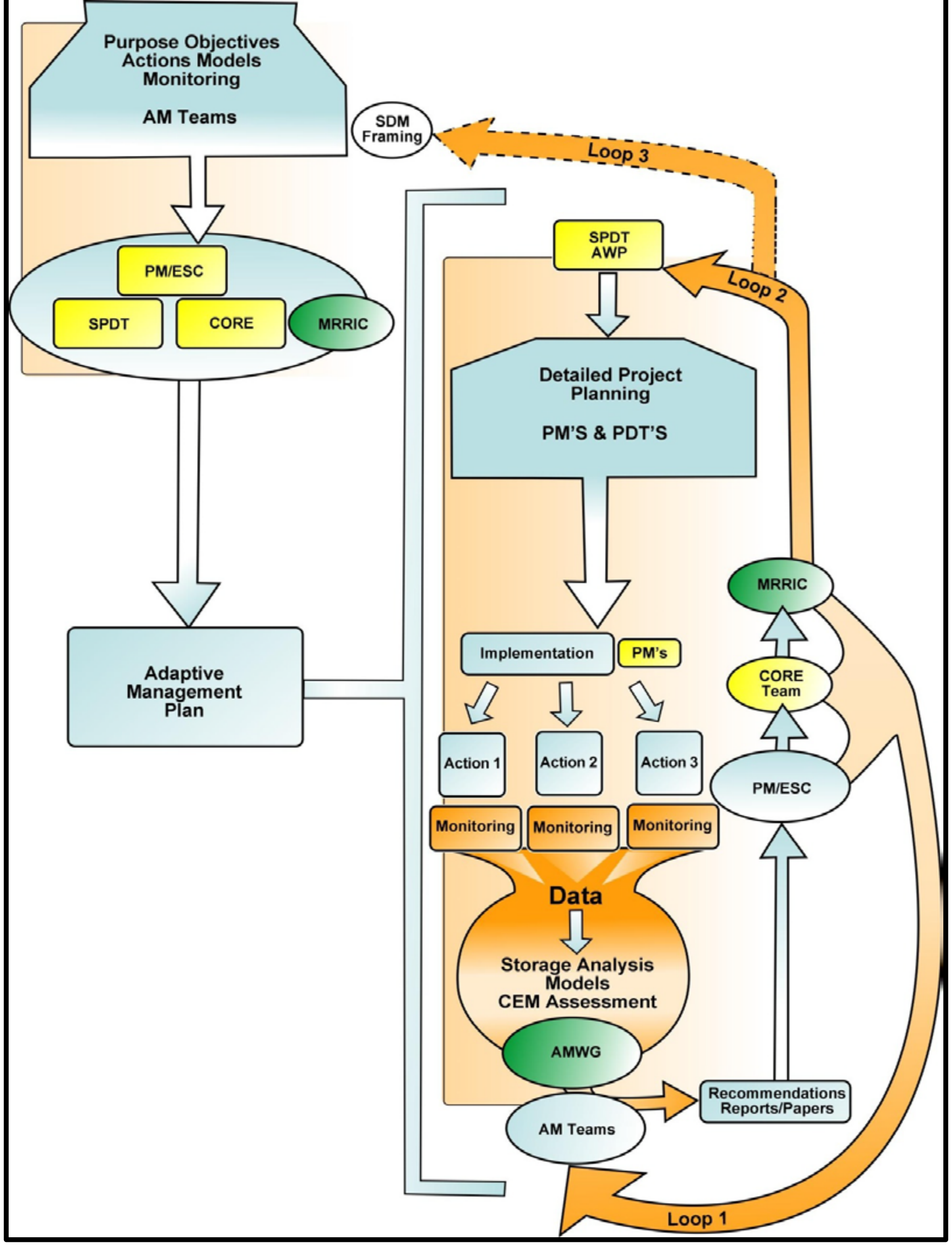
Charadrius melodus

total range area = 1,552,665 km²

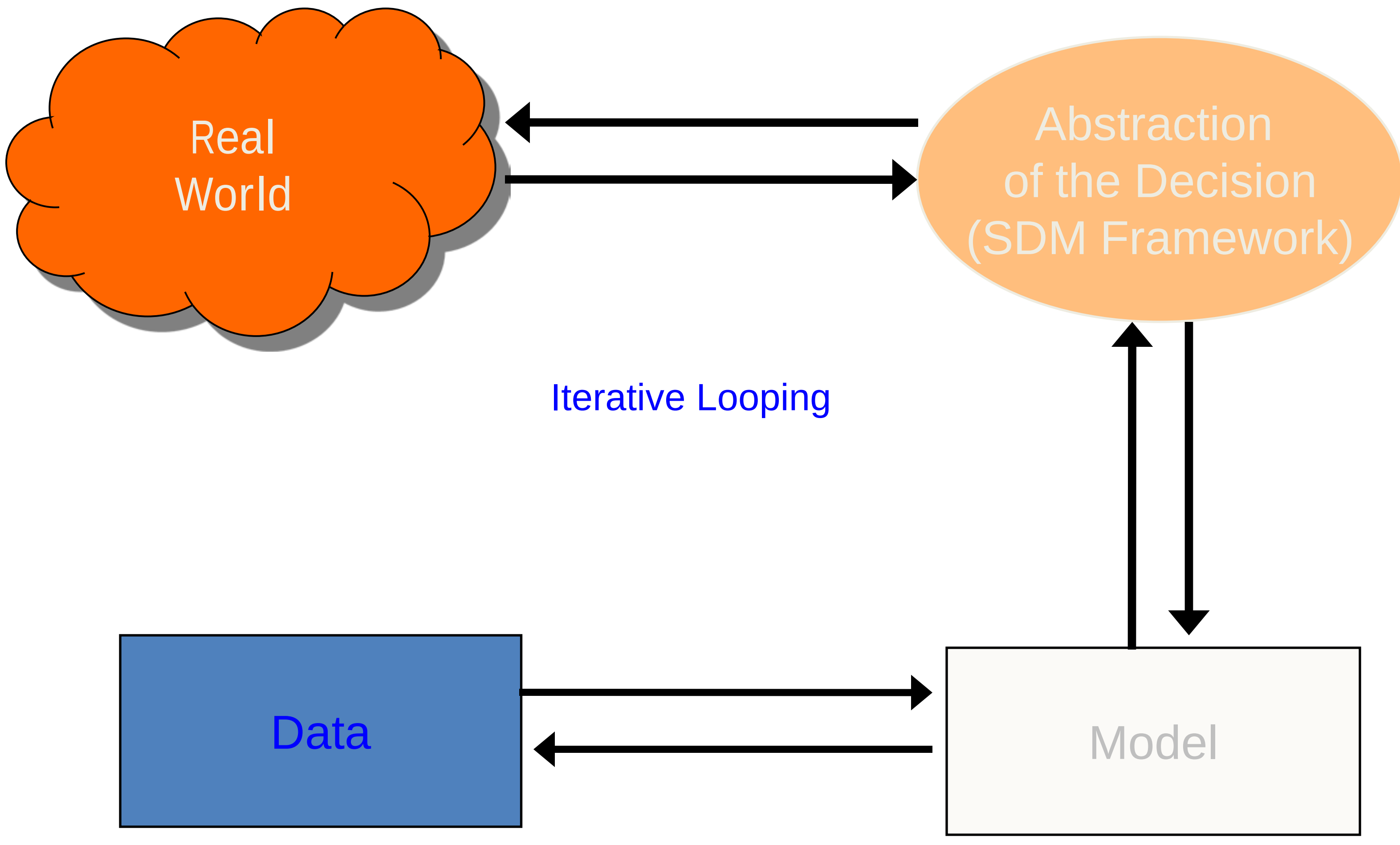
Interior Least Tern

Unknown Unknowns

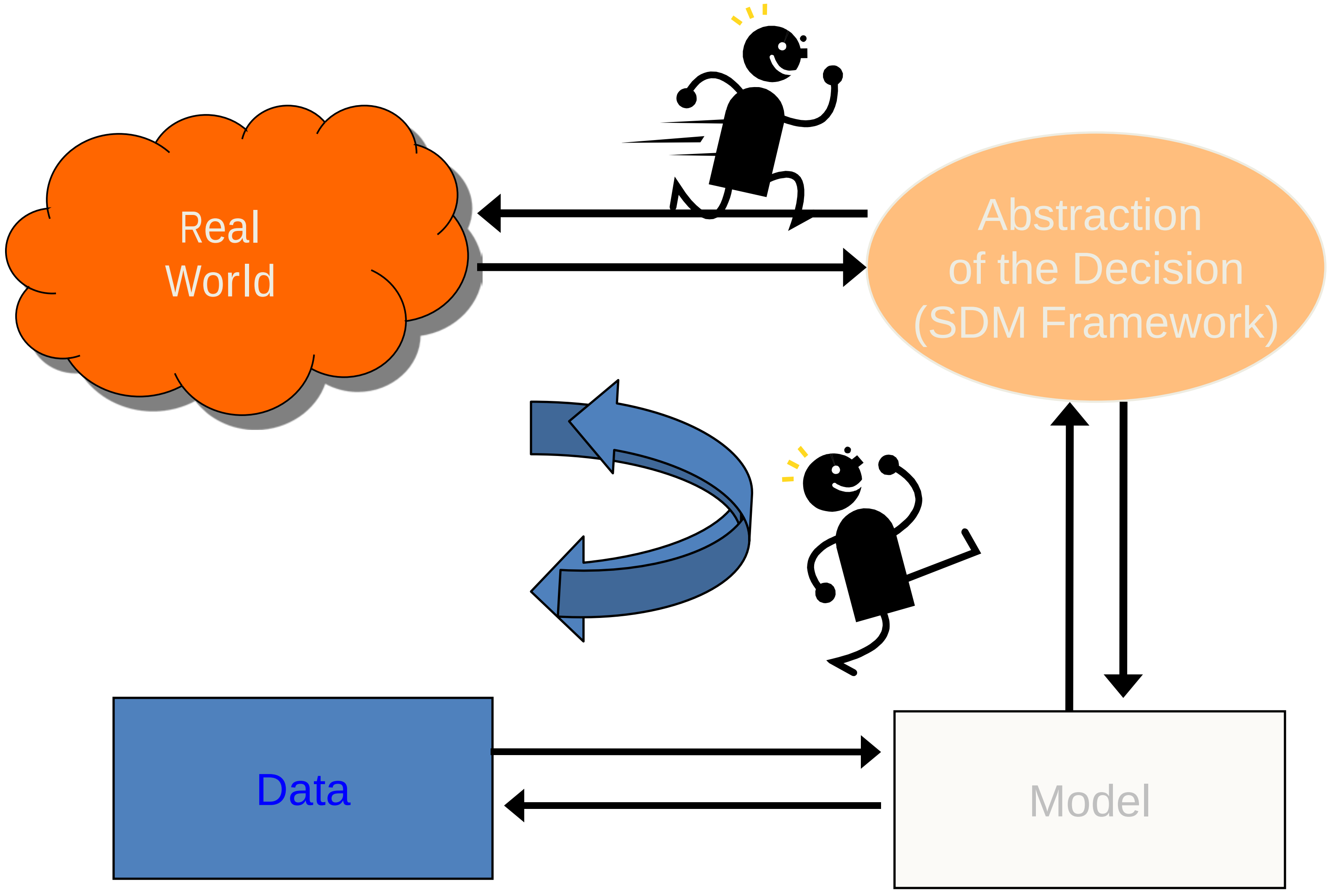
"There are known knowns. These are things we know that we know. There are known unknowns. That is to say, there are things that we now know we don't know. But there are also unknown unknowns. These are things we do not know we don't know." – Donald Rumsfeld


Purpose Objectives
Actions Models
Monitoring
AM Teams
SDM
Framing
Loop 3
PM/ESC
SPDT
CORE
MRRIC
SPDT
AWP
Loop 2
Detailed Project
Planning
PM'S & PDT'S
Adaptive
Management
Plan
Implementation
PM's
MRRIC
CORE
Team
Action 1
Action 2
Action 3
PM/ESC
Monitoring
Monitoring
Monitoring
Data
Storage Analysis
Models
CEM Assessment
AMWG
AM Teams
Recommendations
Reports/Papers
Loop 1

Rapid Prototyping



RAPID PROTOTYPING



Rapid Prototyping

- Get around the track as fast as you can the first time
  - Include all the elements of a structured decision, but keep them very simple (find the skeleton)
  - Use placeholders and guesses to keep going
- See how it works
  - Check back to Real World – is this abstraction working?
  - Discover what needs to be improved
- Low risk – high return approach
  - It doesn’t matter if you’re wrong the first time, you can start over with little loss
  - Don’t invest more than you need to – build iteratively

Actions	Option 1	Option 2	Option 3	Option 4
Build (acres)	200	100	50	0
Deveg (acres)	0	333	500	667
Objectives				
Cost	4M	4M	4M	4M
Incremental Area	200	433	550	667
Total Area	835	1068	1185	1302
Fledge Ratio	1.1	1.0	0.9	0.8
Disturbance	H	M	M	L

Epiphanys from First Model

- Exact data not necessary
- Practice leads to comfort
- Improved understanding of the system
- This is too simple for the real world

2^{nd} Go-Around

- Added
  - multiple year influence
  - stochastic flow
  - tern & plover breakdown
  - Different habitat types

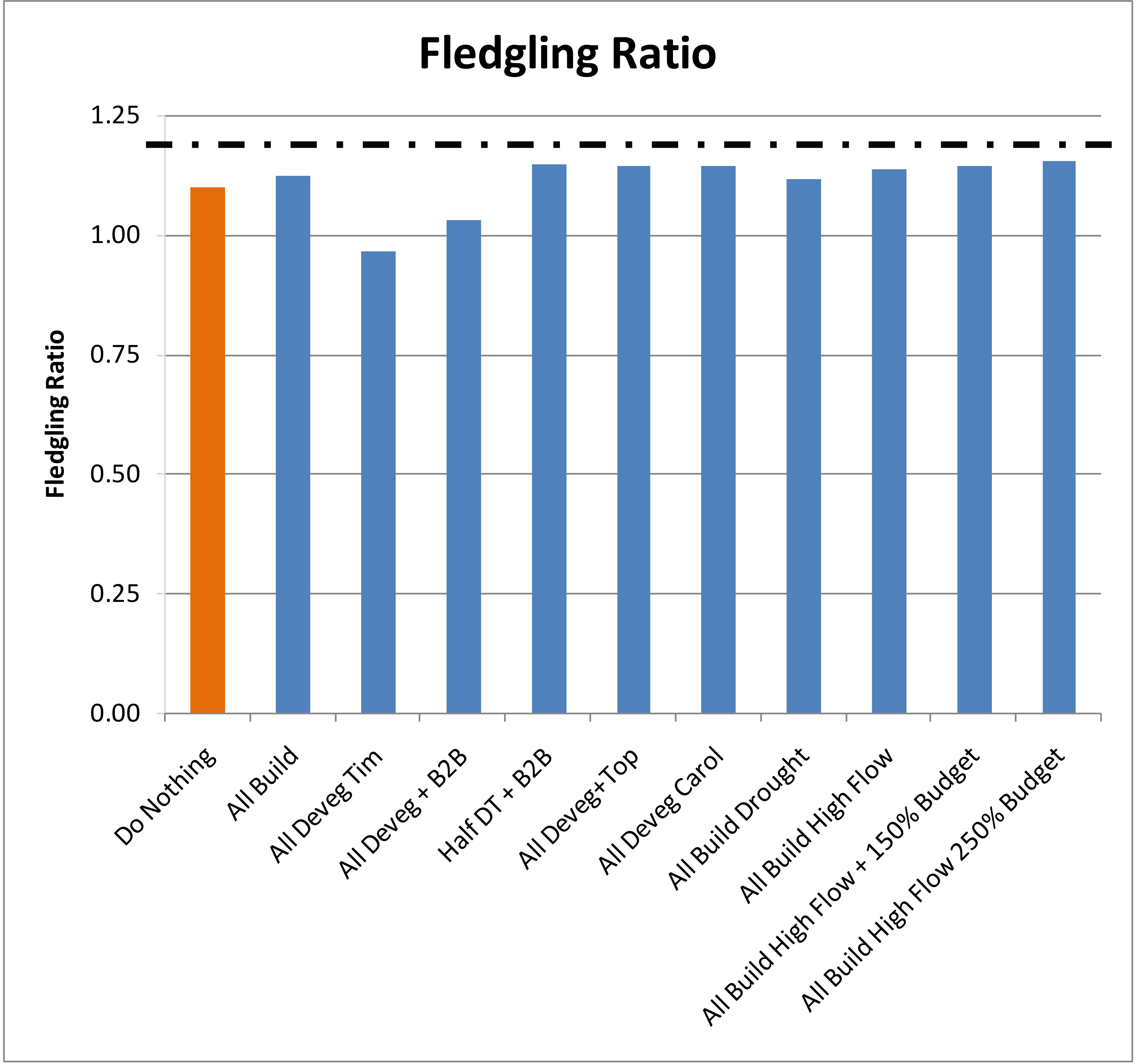
Objectives

- Minimize cost/acre
- Meet fledge ratios
- Minimize construction-related disturbance
- Meet acreage target 2015
- Minimize socio-economic impacts
- Maximize Expected Minimum Population Size (MEMPS) to 20XX
- Minimize cumulative impacts to outstandingly remarkable values* and freeflowing characteristics and water quality

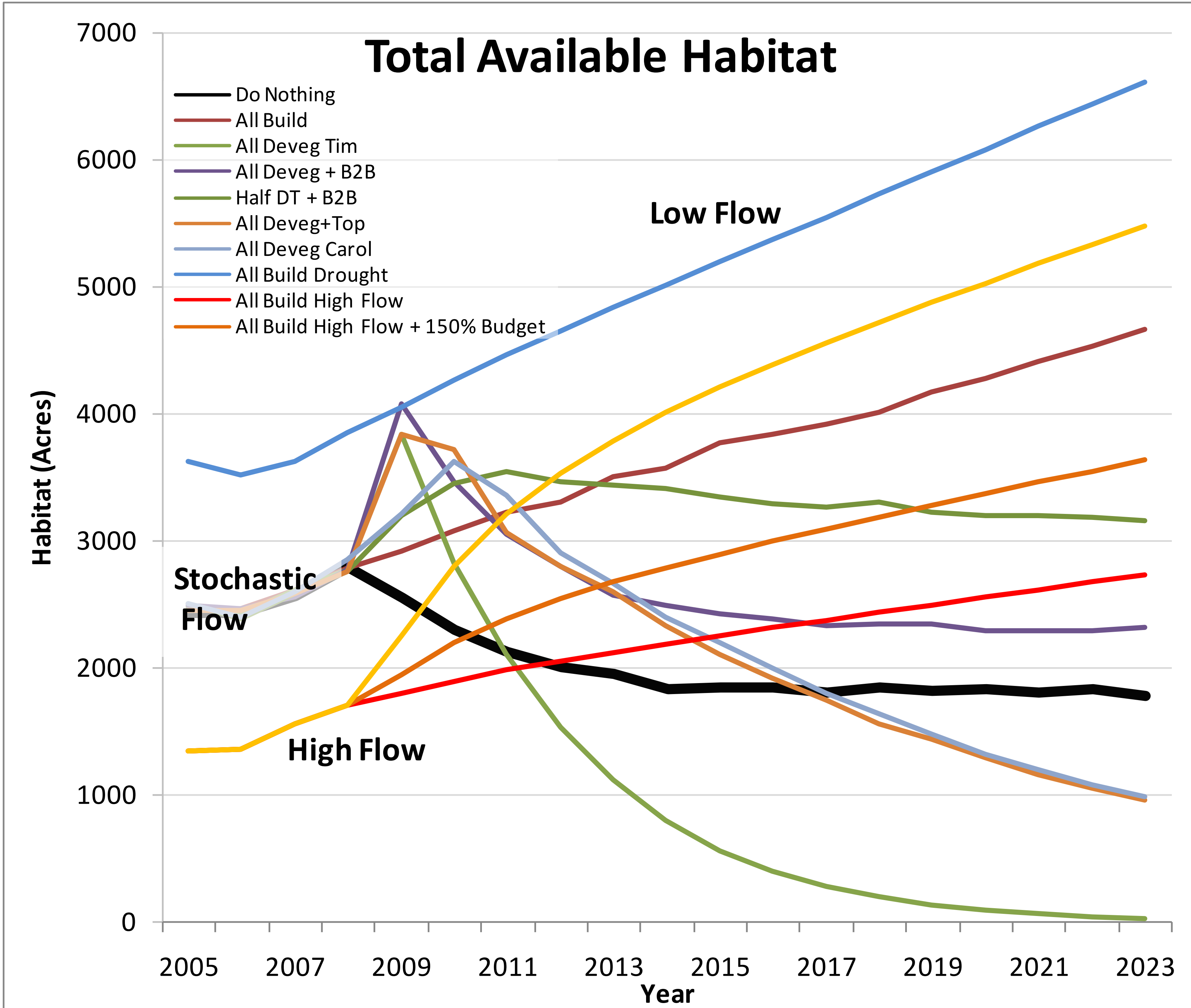
* As defined in the Wild and Scenic Rivers Act

Actions

- Build X acres in year *t*
- Deveg Y acres in year *t*
- Deveg and top Z acres in year *t*
- Flow
  - Island building
  - Conditioning
  - Low summer



Fledgling Ratio
1.25
1.00
0.75
0.50
0.25
0.00
Fledgling Ratio
Do Nothing
All Build
All Deveg Tim
All Deveg + B2B
Half DT + B2B
All Deveg+Top
All Deveg Carol
All Build Drought
All Build High Flow
All Build High Flow + 150% Budget
All Build High Flow 250% Budget


Total Available Habitat
Do Nothing
All Build
All Deveg Tim
All Deveg + B2B
Half DT + B2B
All Deveg+Top
All Deveg Carol
All Build Drought
All Build High Flow
All Build High Flow + 150% Budget
Low Flow
Stochastic
Flow
High Flow
Habitat (Acres)
Year
7000
6000
5000
4000
3000
2000
1000
0
2005
2007
2009
2011
2013
2015
2017
2019
2021
2023

Realizations from 2nd Prototype

- More realistic, but large data uncertainties
  - Fledge ratios probably not right
  - Density dependence unknown
  - Flow effects on habitat

Conceptual Model: erosion/veg

- First cut – forget vegetated state
- *A* is the # acres ESH in year *t*, *c* is the amount created in acres / year, *d* is the amount lost to erosion/veg growth in acres/acre/year
- *d* is assumed constant, but probably changes with area/shape
- *c* is our decision variable – how much to create – all means combined

Conceptual Model of Erosion/Veg

- As a difference equation:

$$A_{t+1} = c + A_t\left(1 - d\right)$$

$$A^* = c / d$$

A^* is the equilibrium amount of ESH, if c and d are constant

Conceptual model: nesting

- Fledging ratio =
  nest success * eggs laid/pair * chick survival
- Nest success and eggs / pair DO NOT change with area or shape
- Chick survival increases with foraging area

$$Forage\ area \propto \begin{cases} \sqrt{ESH\ area},\ plovers \\ SWH\ area,\ terns \end{cases}$$

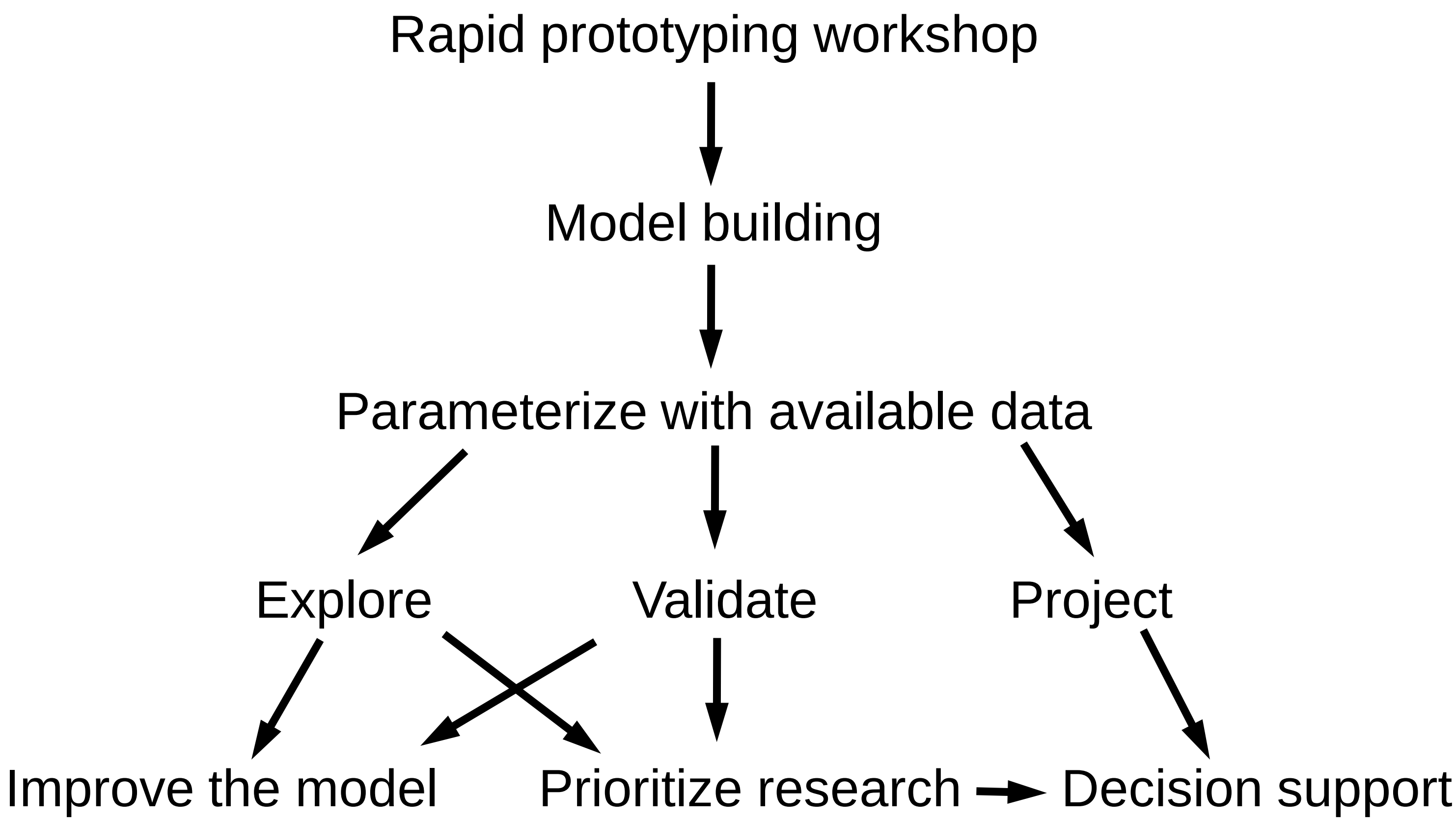
Outstandingly Remarkable Values

- Fish and Wildlife
- Recreation
- Cultural Resources
- Historical Resources

The role of models in adaptive management

- State assumptions explicitly
- Predict outcome of management actions
- Examine impact of uncertainty

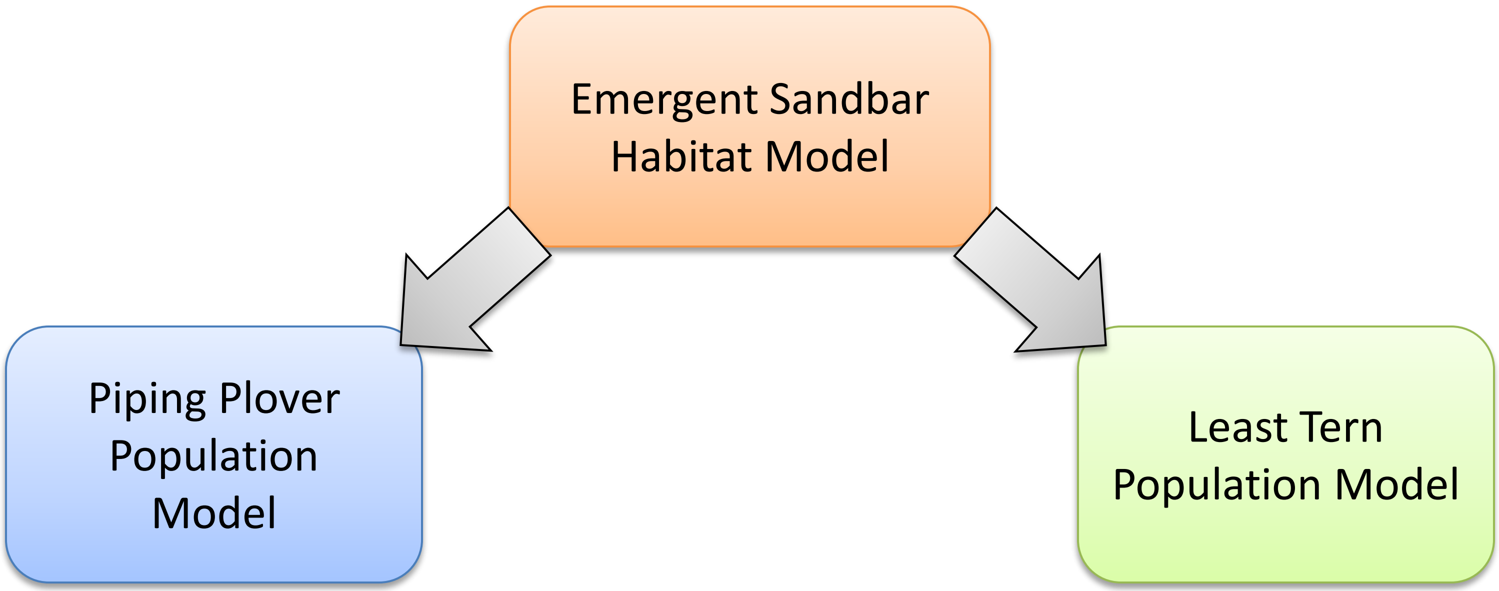
Model development

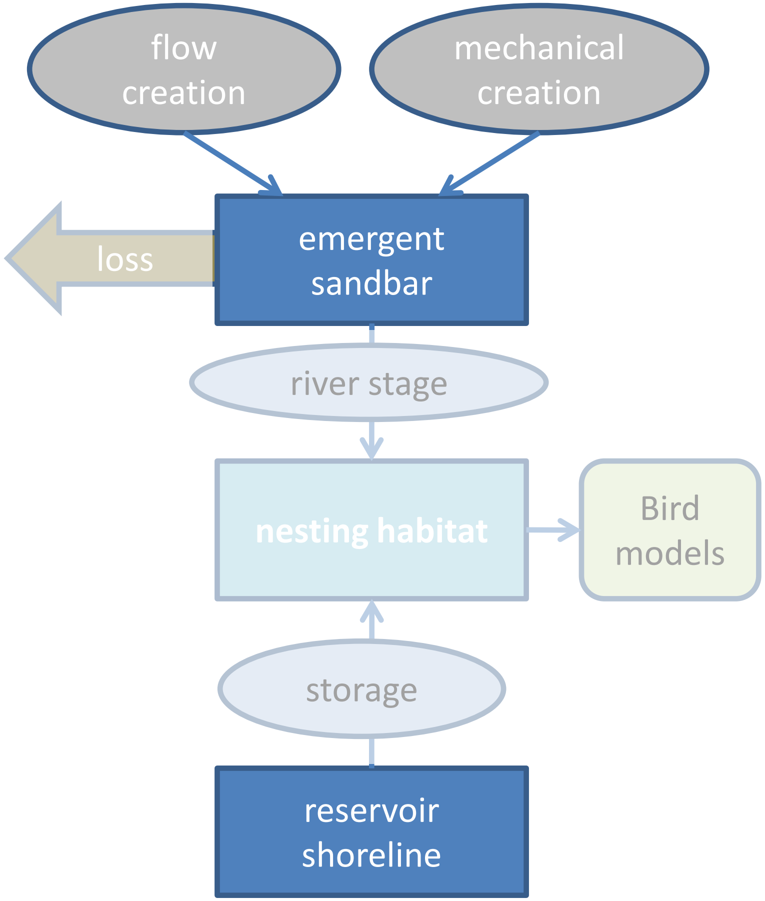


Types of assumptions and estimations

- What relationships are important?
- What form do those relationships take?
- What are the parameter values?
- How uncertain are parameter estimations?
- How do processes vary with time?

Basic model structure



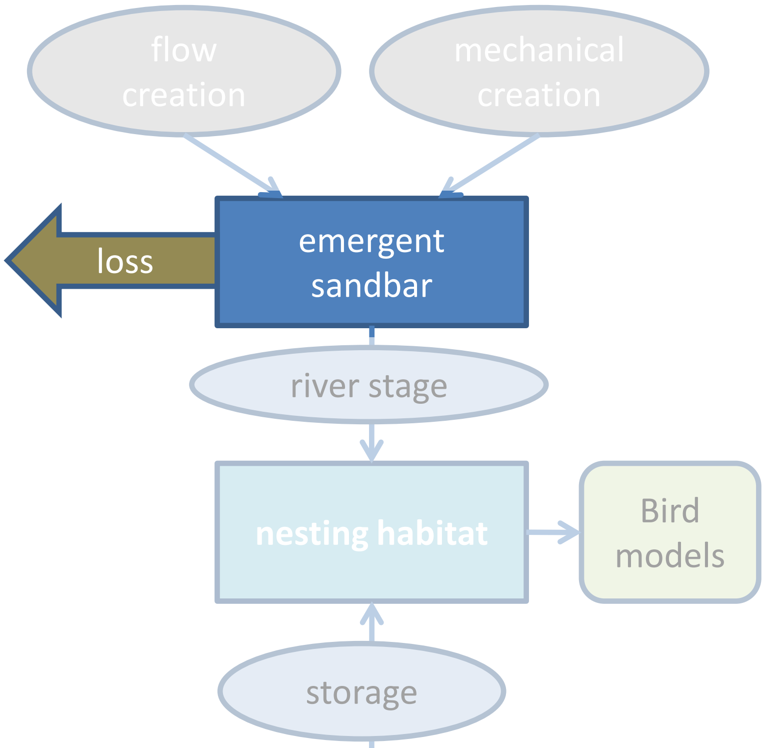


Emergent Sandbar Habitat Model

Two modeled categories of habitat:

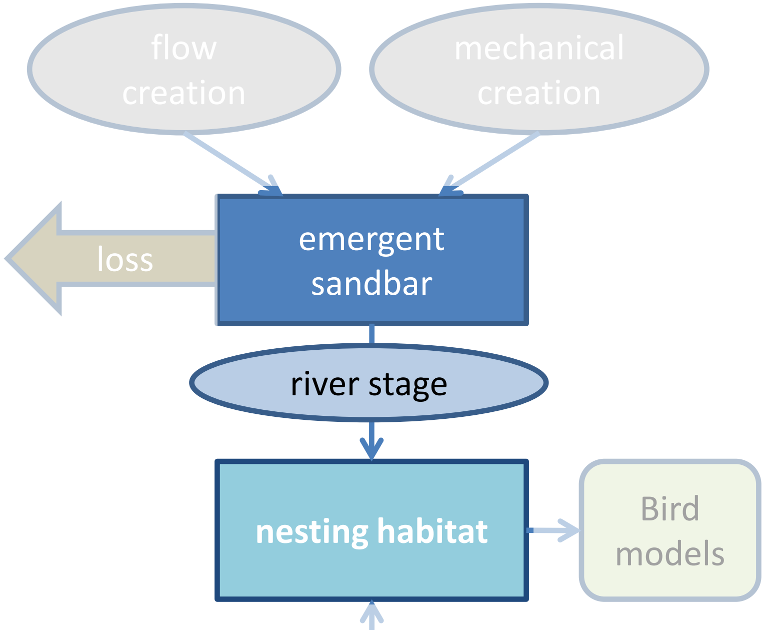
- Emergent sandbars in rivers
  - natural, through flooding
  - mechanically created
- Reservoir shorelines

How much habitat is available for nesting each year?



Determine how much sandbar acreage is lost to erosion and vegetation

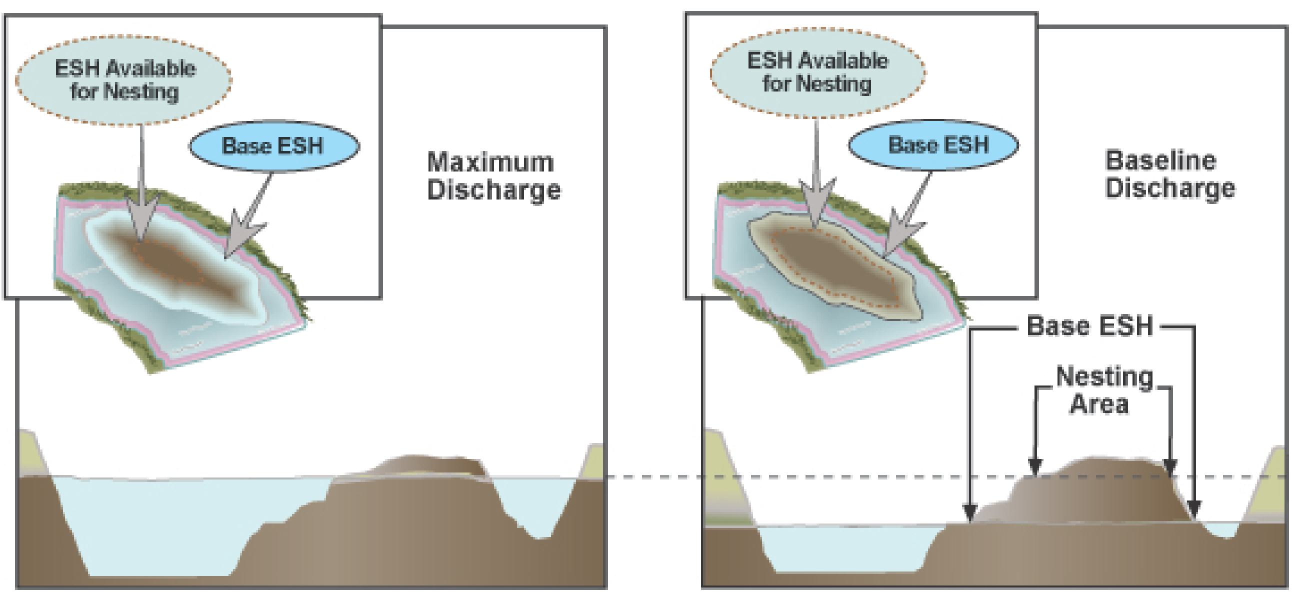
Loss rates depend on [redacted]

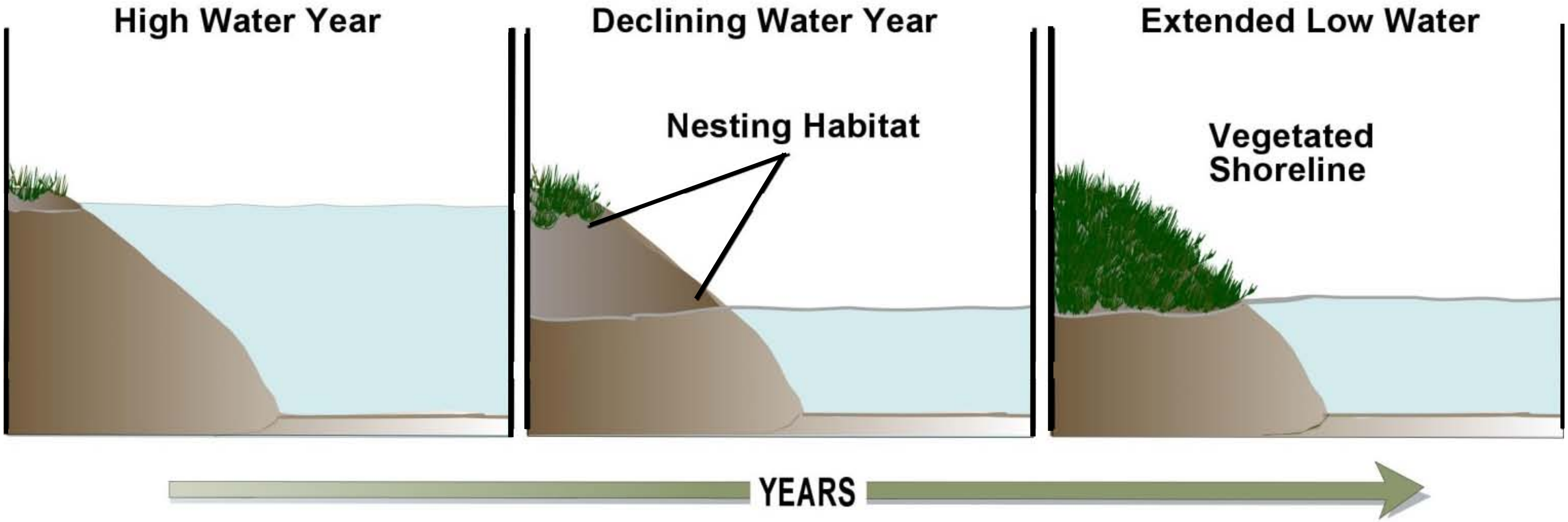


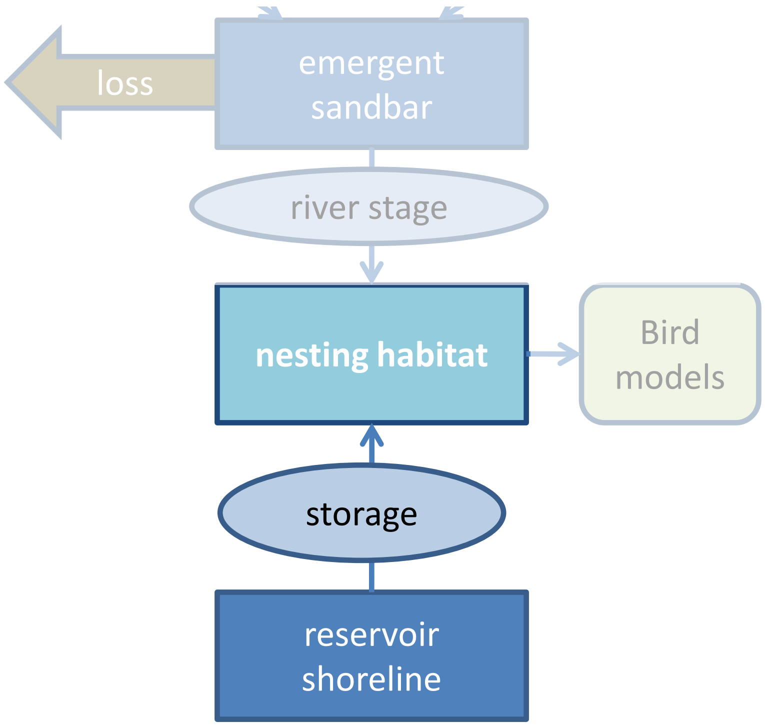
Determine how much habitat is safe from inundation during a season

Use historical data on river stage and estimates of stage-area relationships for each reach

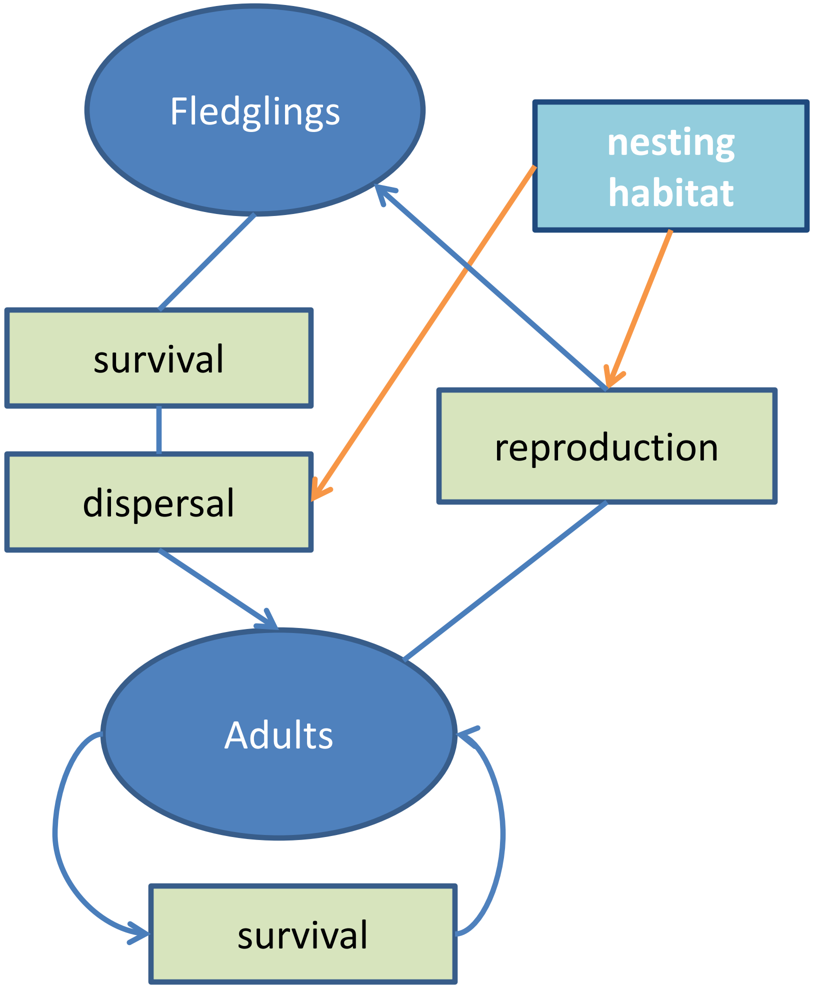
Variation in ESH During Nesting Season







Reservoir shoreline habitat is available for one year after water levels go down



Bird population models

Nesting habitat influences bird population in two ways

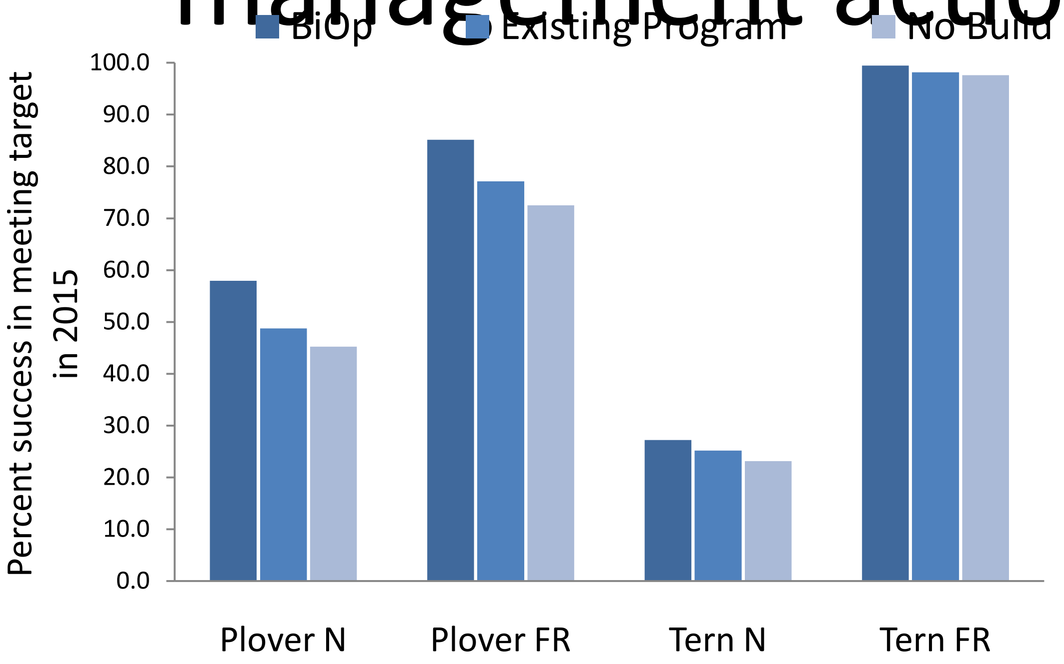
i. Fledglings/pair decreases with density of birds in a reach or reservoir

ii. First-time breeders select a river segment based upon habitat availability

Key simplifying assumptions (tentative…too much text)

- Historical flows and reservoir shoreline habitat (1967-2007) are a reasonable estimate of future conditions
- Once habitat is considered “available,” it is all equally attractive and equally suitable for both bird species
- Birds only disperse before first breeding, and then return to the same site each year
- No movement in or out of the Missouri River Mainstem System

Predicted outcome of management actions



Shallow Water non-example

- Loss of shallow water habitat through channelization jeopardizes Pallid Sturgeon
- USACE building habitat
  - $US 25 Million / year
- USFWS – is it working?

Questions?

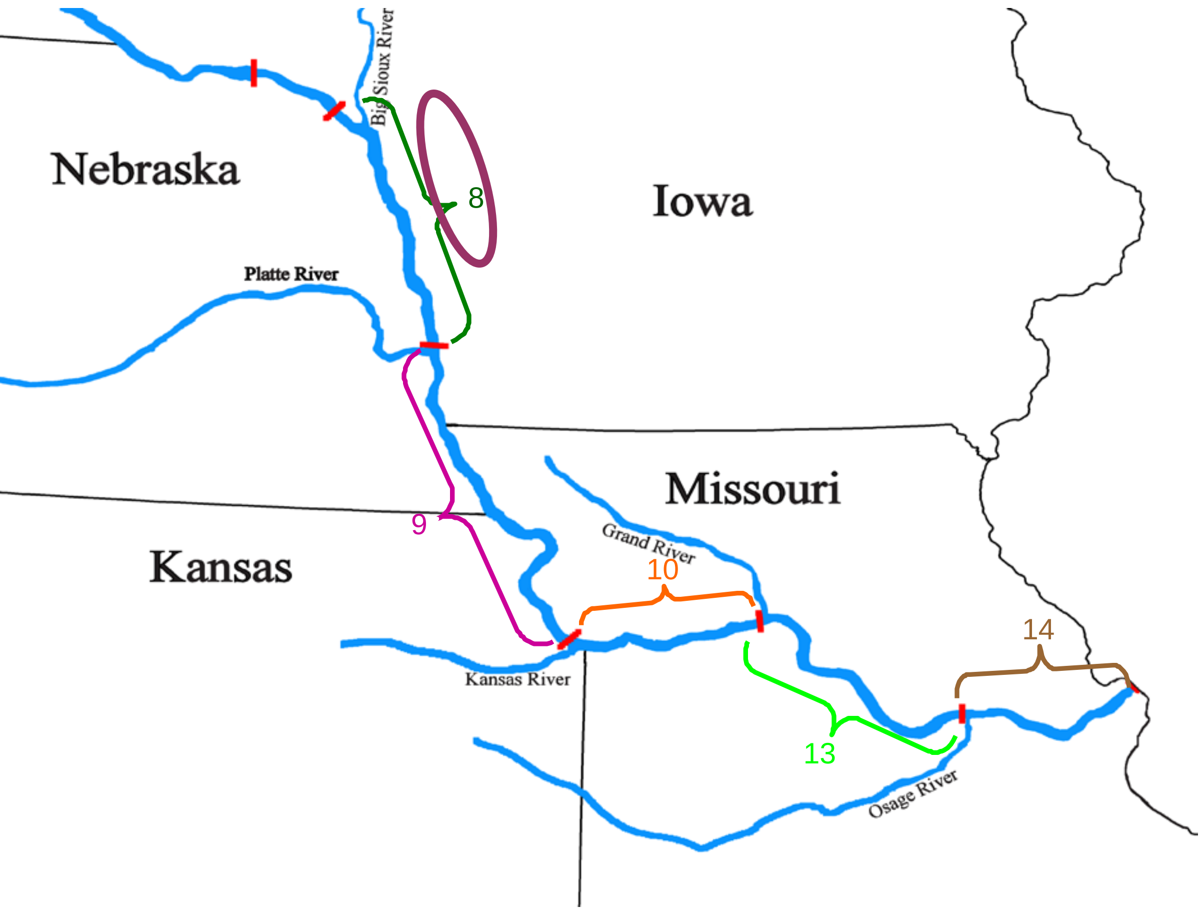
Cumulative Actions within a Bend (Bend Scale)

Experience with Habitat Creation Projects: Shallow Water Habitat

- 2004 created 1200 acres
- 2005 established BACI design to test effectiveness
  - Physically
  - Biologically
- 2006 creations and monitoring
- 2007 same
- 2008 same

Decision Problem?

Sampling Design



38 bends:

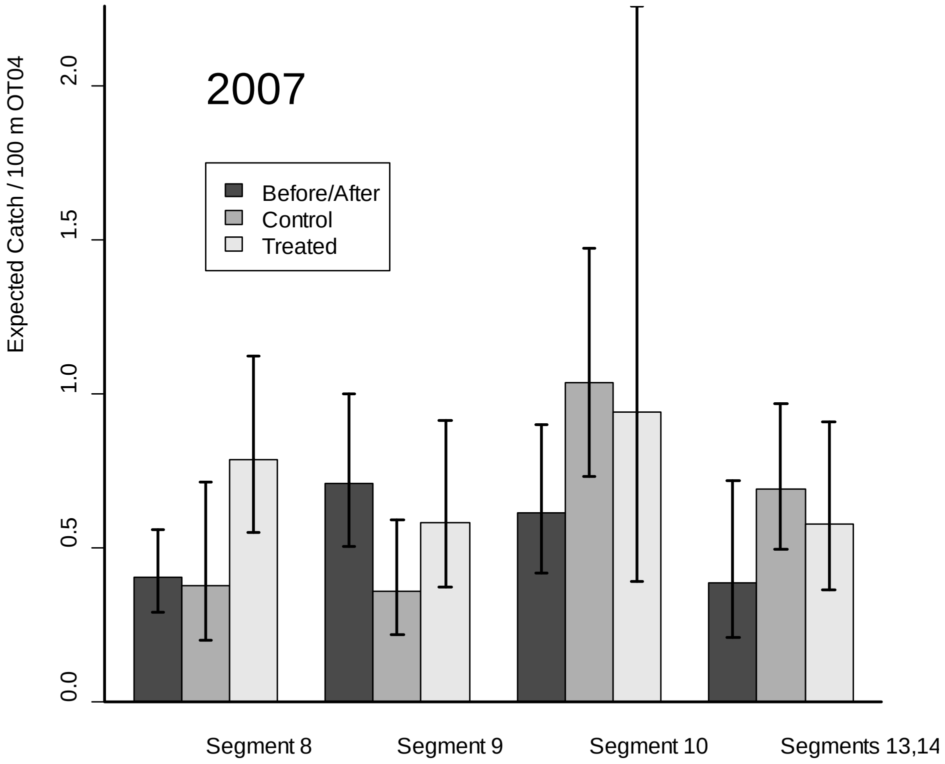
- 10 Seg 8
- 10 Seg 9

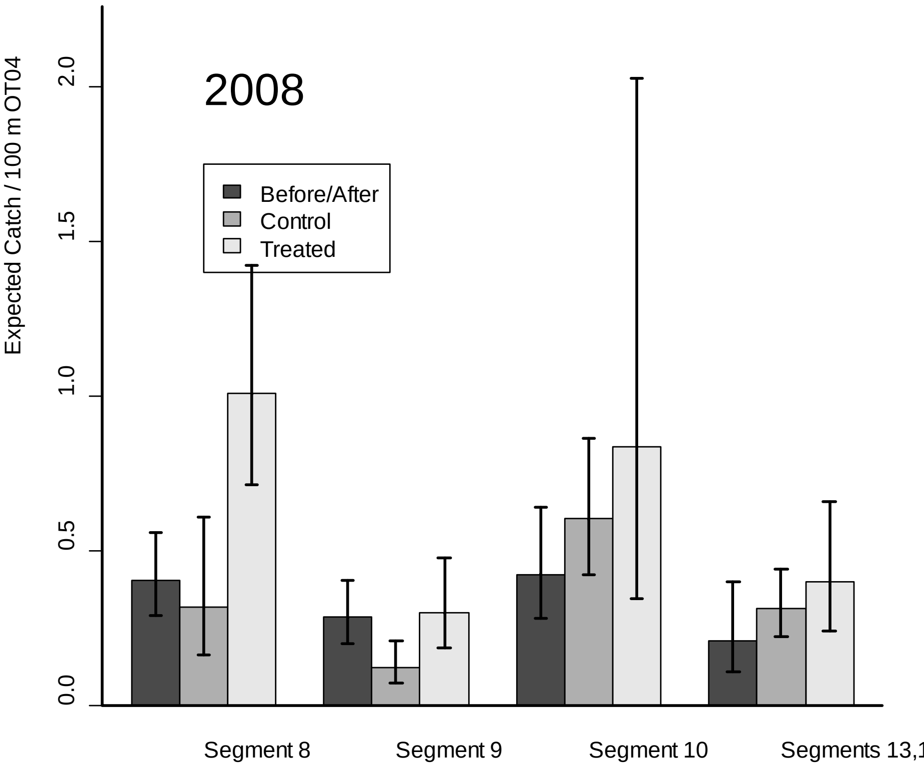
1 @ control-75
1 @ control-25
2 @ before-75
2 @ before-25
2 @ mod-75
2 @ mod-25

- 6 Seg 10
- 6 Seg 13
- 6 Seg 14

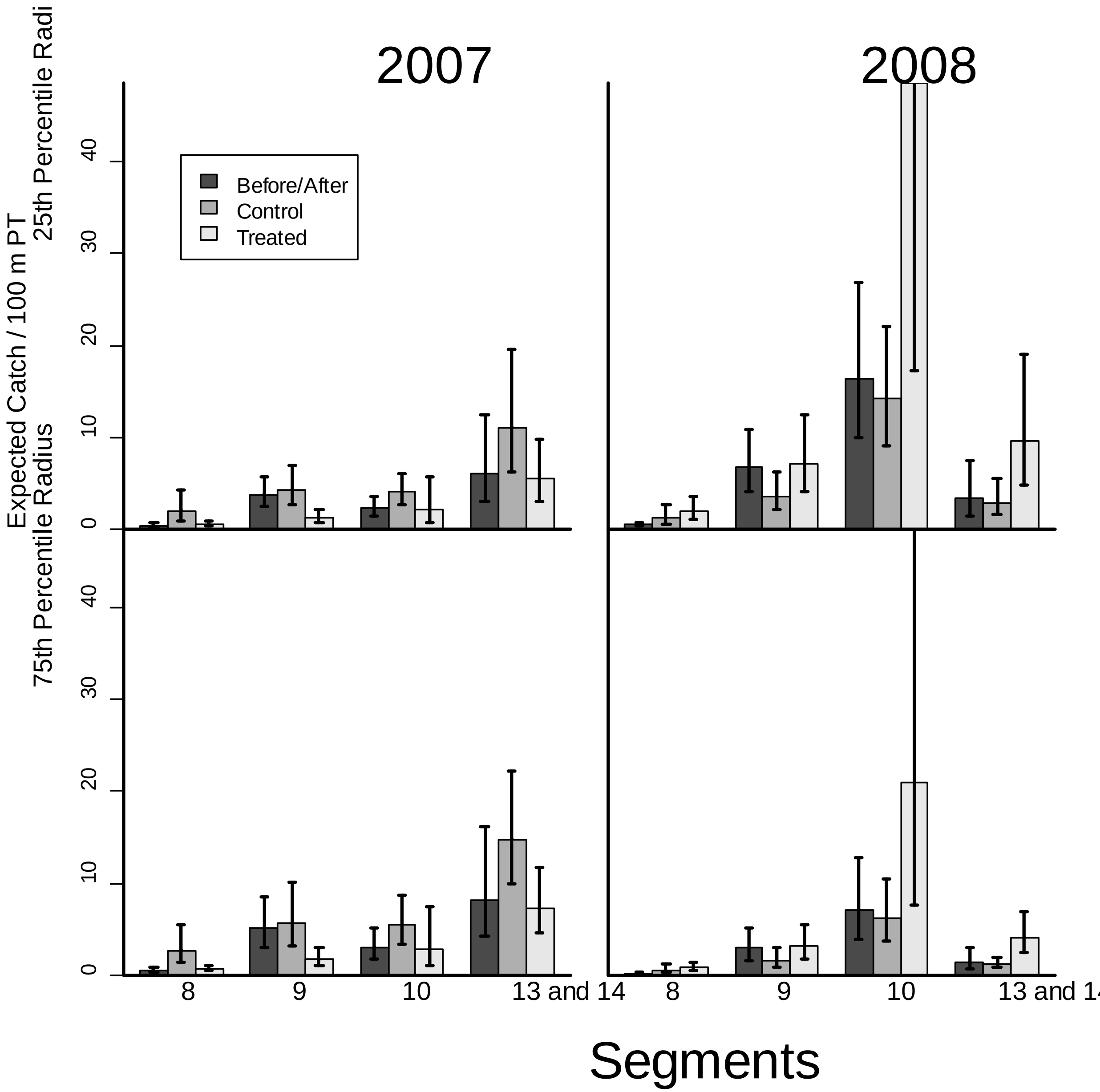
1 @ control-75
1 @ control-25
1 @ before-75
1 @ before-25
1 @ mod-75
1 @ mod-25

Sturgeon CPUE





Target Chubs



Sampling Design

38 bends:

- 10 Seg 8
- 10 Seg 9

1 @ control-75
1 @ control-25
2 @ before-75
2 @ before-25
2 @ mod-75
2 @ mod-25

- 6 Seg 10
- 6 Seg 13
- 6 Seg 14

1 @ control-75
1 @ control-25
1 @ before-75
1 @ before-25
1 @ mod-75
1 @ mod-25

Progress and next steps

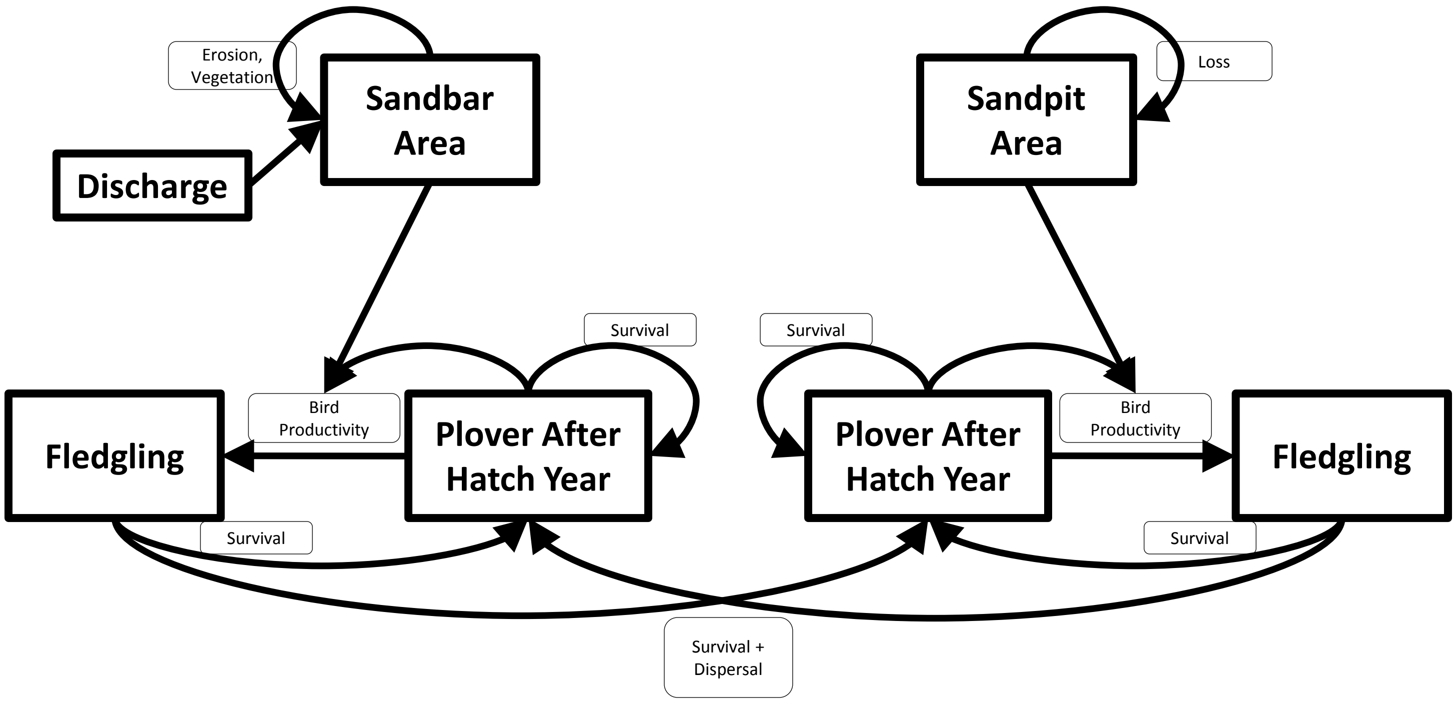
- **State assumptions explicitly**
  - Model guide available
  - Model validation (next presentation)
  - Continue exploring the consequences of key assumptions
- **Predict outcome of management actions**
  - Model predictions and "report card" in Annual Adaptive Management Report

Progress and next steps

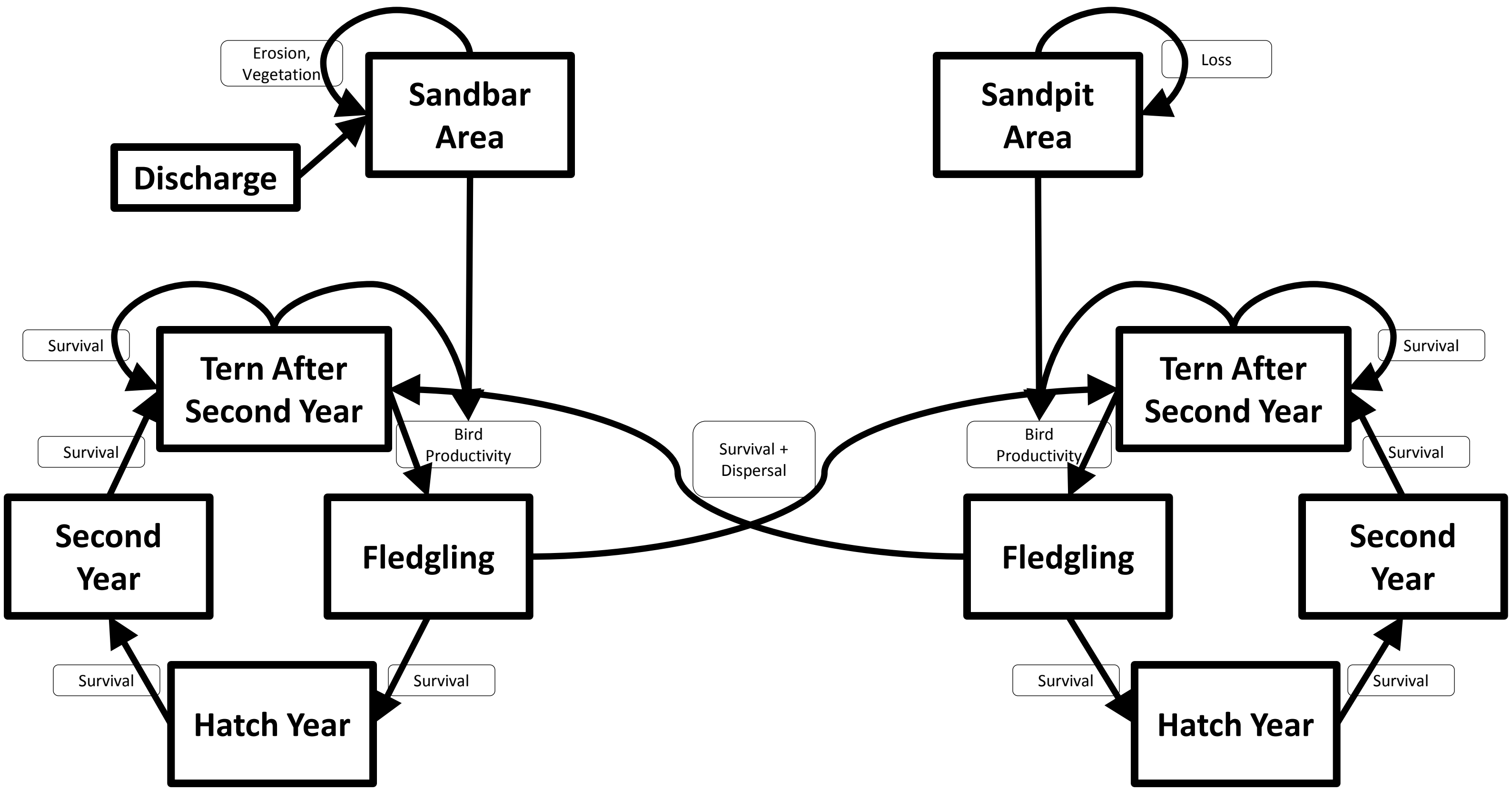
- **Examine impact of uncertainty**
  - Basic sensitivity analysis
  - Quantify the value of reducing uncertainty about parameters and processes
  - Prioritize research for improving model predictions

Acknowledgments

Plover Conceptual Model



Tern Conceptual Model



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Choosing a Mortgage

- Your bank offers you two possible 30-yr fixed rate mortgages: $5\frac{1}{4}$ %, or $4\frac{1}{4}$ % with 2 points. Which do you choose?

Financial Example

- Problem: Choose a mortgage
- Objectives: Maximize proceeds less costs
- Actions: Choice between two 30-yr fixed rate mortgages
- Consequences: Use financial formulas (model) to calculate costs and proceeds at time of sale
- Trade-offs: Directly compare consequences (only 1 objective here)

Spreadsheet

OK, that was easy

- Why?
  - Simple set of actions
  - Single, clear objective
  - System dynamics known with certainty
  - Choice of best action transparent
- But what if
  - One of the choices is a 1-yr ARM? Or, in fact, there is a bewildering array of choices from many lenders?
  - You don't know how long you'll be in the house?
  - You have other objectives or constraints (e.g., monthly payments need to be less than $1000)?