The challenge of producing accurate Lagrangian simulations

Jon Burau, USGS

With help from Stacie Gringbergs, Ed Gross, and friends

Delta Science Conference

October 13, 2013

JRB

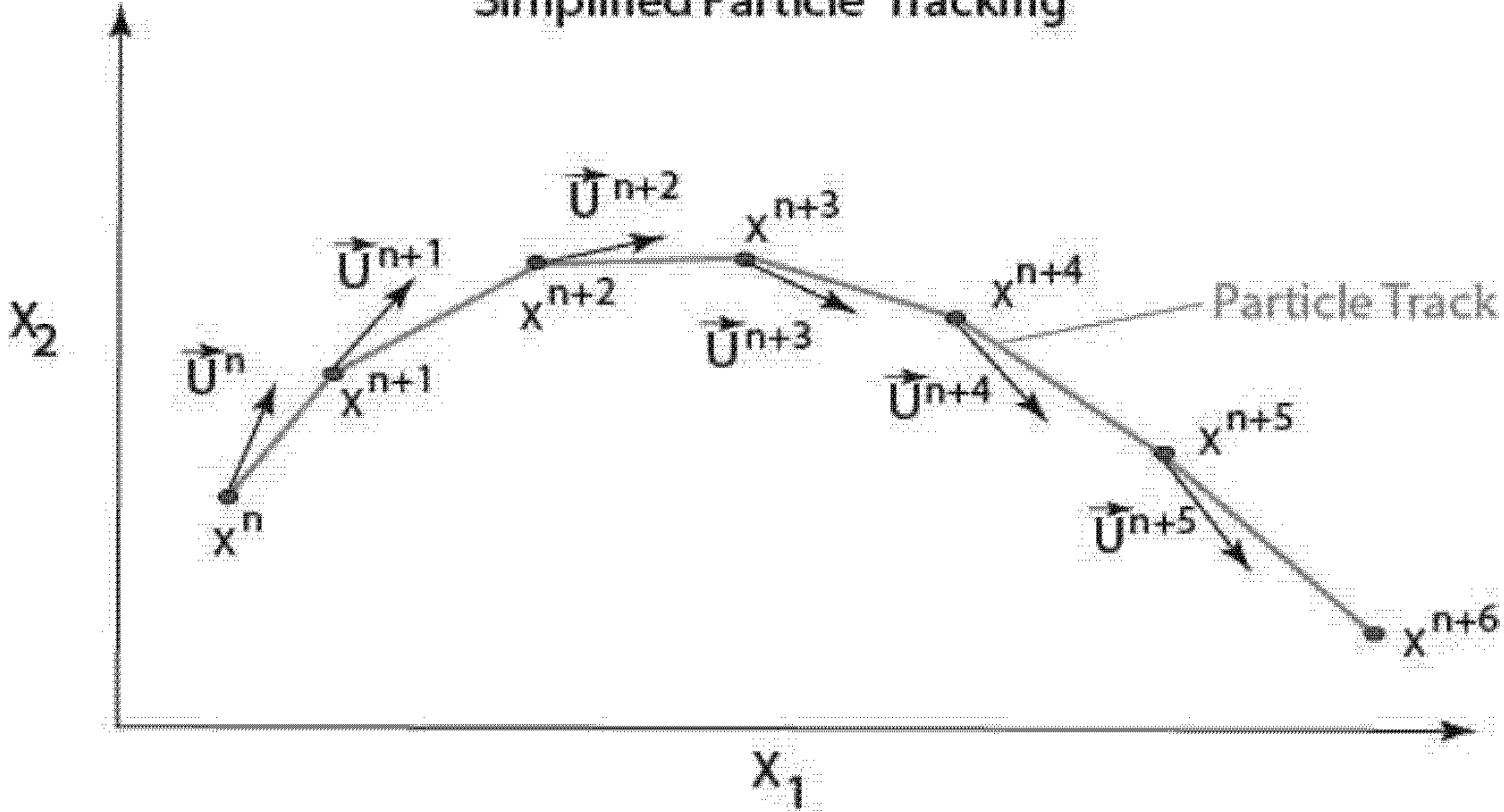
Acknowledgements

DWR: Jacob McQuirk, Ryan Reeves, Bill McLaughlin

USBR: Erwin Van Nieuwenhuse

Errors accumulate in Lagrangian (particle tracking) simulations!

Simplified Particle Tracking



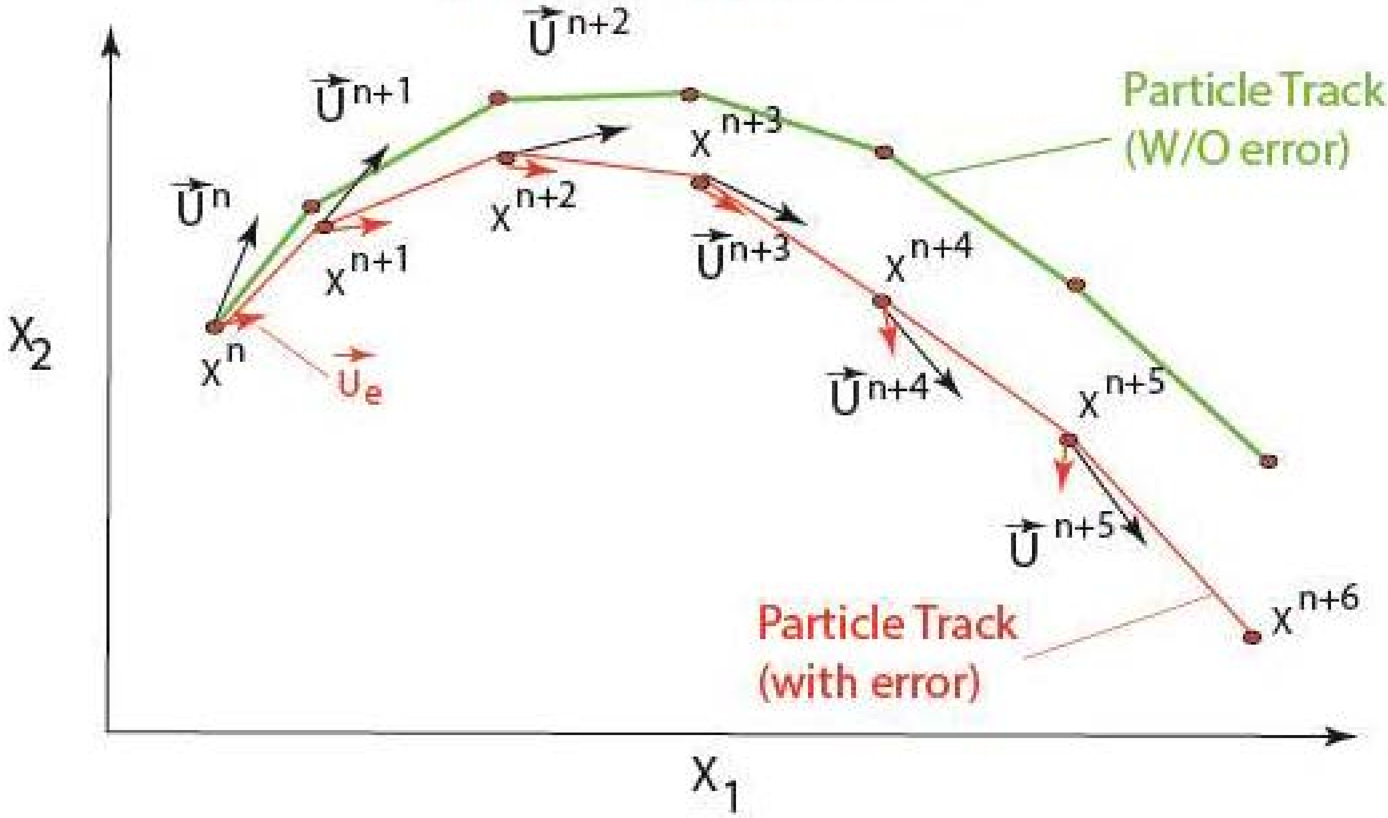
$$x^{n+1} = x^{n} + \vec{U}^{n}(x^{n}) \cdot \Delta t$$

$$x^{n+2} = x^{n+1} + \vec{U}^{n+1}(x^{n+1}) \cdot \Delta t$$

$$x^{n+3} = x^{n+2} + \vec{U}^{n+2}(x^{n+2}) \cdot \Delta t$$

$$\vdots$$

Simplified Particle Tracking
With errors in velocity field

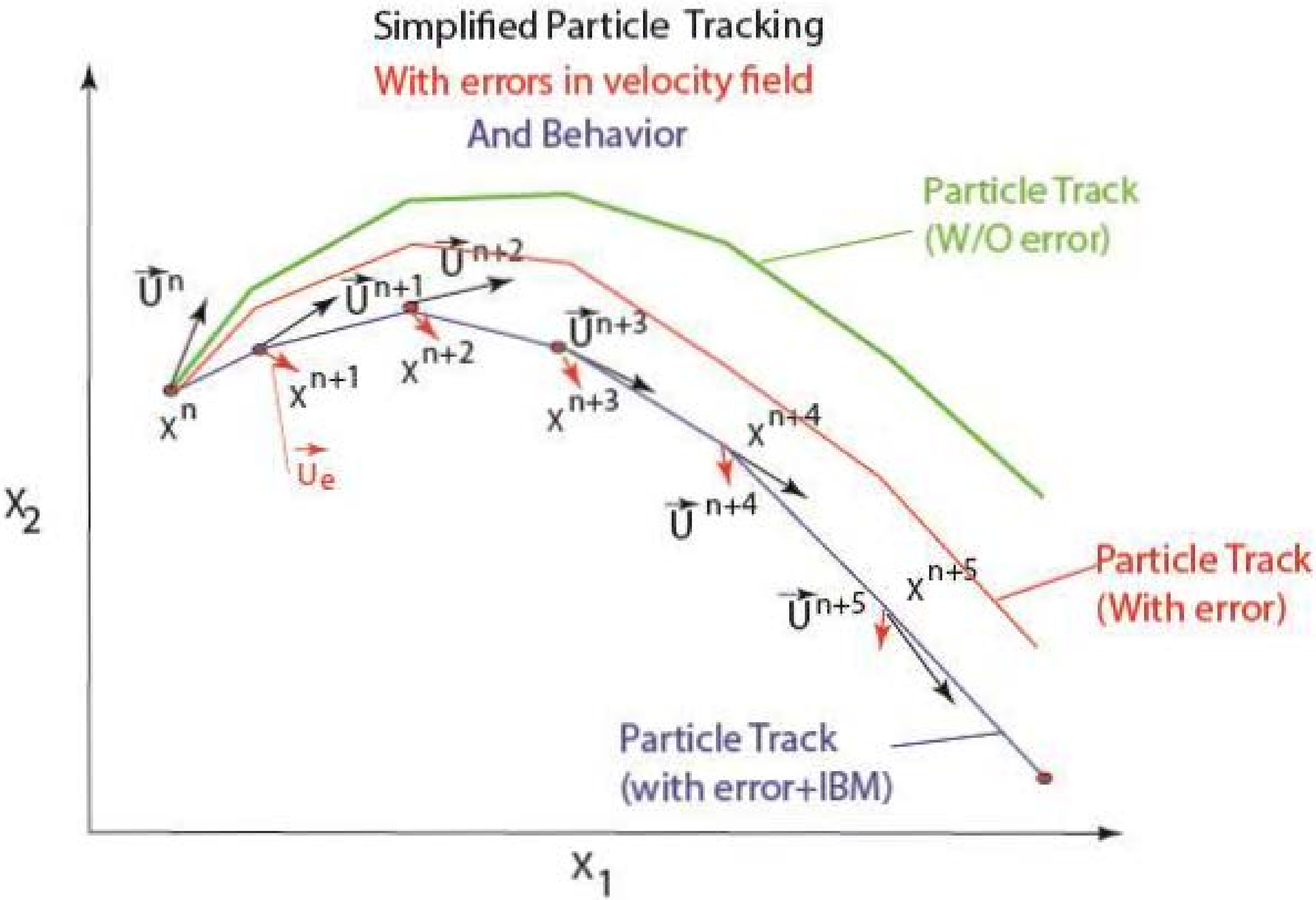


$$x^{n+1} = x^{n} + (\vec{U}^{n}(x^{n}) + \vec{U}_e^{n}(x^{n})) \cdot \Delta t$$

$$x^{n+2} = x^{n+1} + (\vec{U}^{n+1}(x^{n+1}) + \vec{U}_e^{n+1}(x^{n+1})) \cdot \Delta t$$

$$x^{n+3} = x^{n+2} + (\vec{U}^{n+2}(x^{n+2}) + \vec{U}_e^{n+2}(x^{n+2})) \cdot \Delta t$$

$$\vdots$$



$$x^{n+1} = x^n + (\vec{U}^n(x^n) + \vec{U}_e^n(x^n) + B) \bullet \Delta t$$

$$x^{n+2} = x^{n+1} + (\vec{U}^{n+1}(x^{n+1}) + \vec{U}_e^{n+1}(x^{n+1}) + B) \bullet \Delta t$$

$$x^{n+3} = x^{n+2} + (\vec{U}^{n+2}(x^{n+2}) + \vec{U}_e^{n+2}(x^{n+2}) + B) \bullet \Delta t$$

$$\vdots$$

Using particle tracking models to predict/understand salmon outmigration and survival through the delta is going to be challenging.

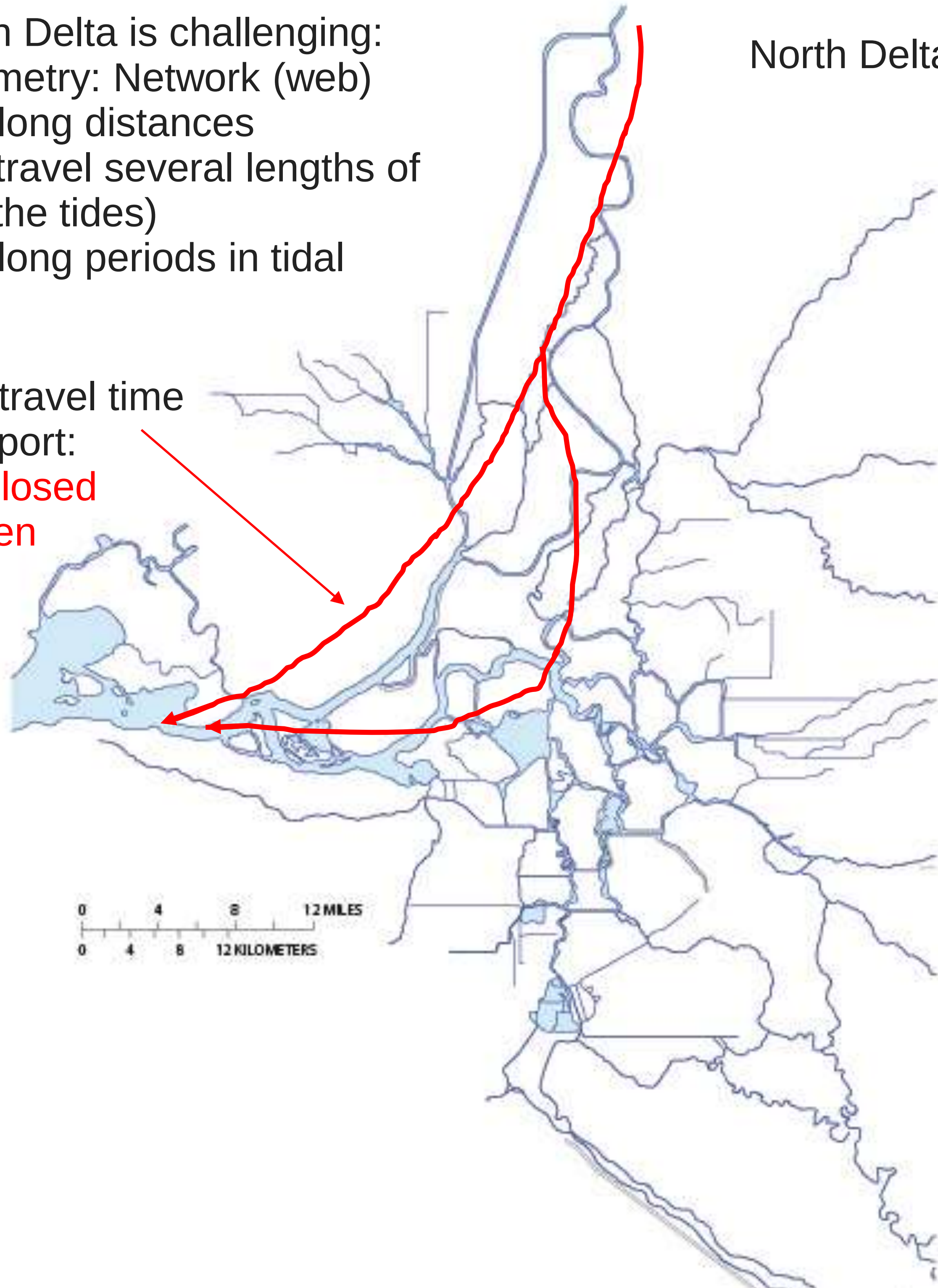
Taking a field data approach in this talk

North Delta Salmon Outmigrants

Particle tracking in Delta is challenging:

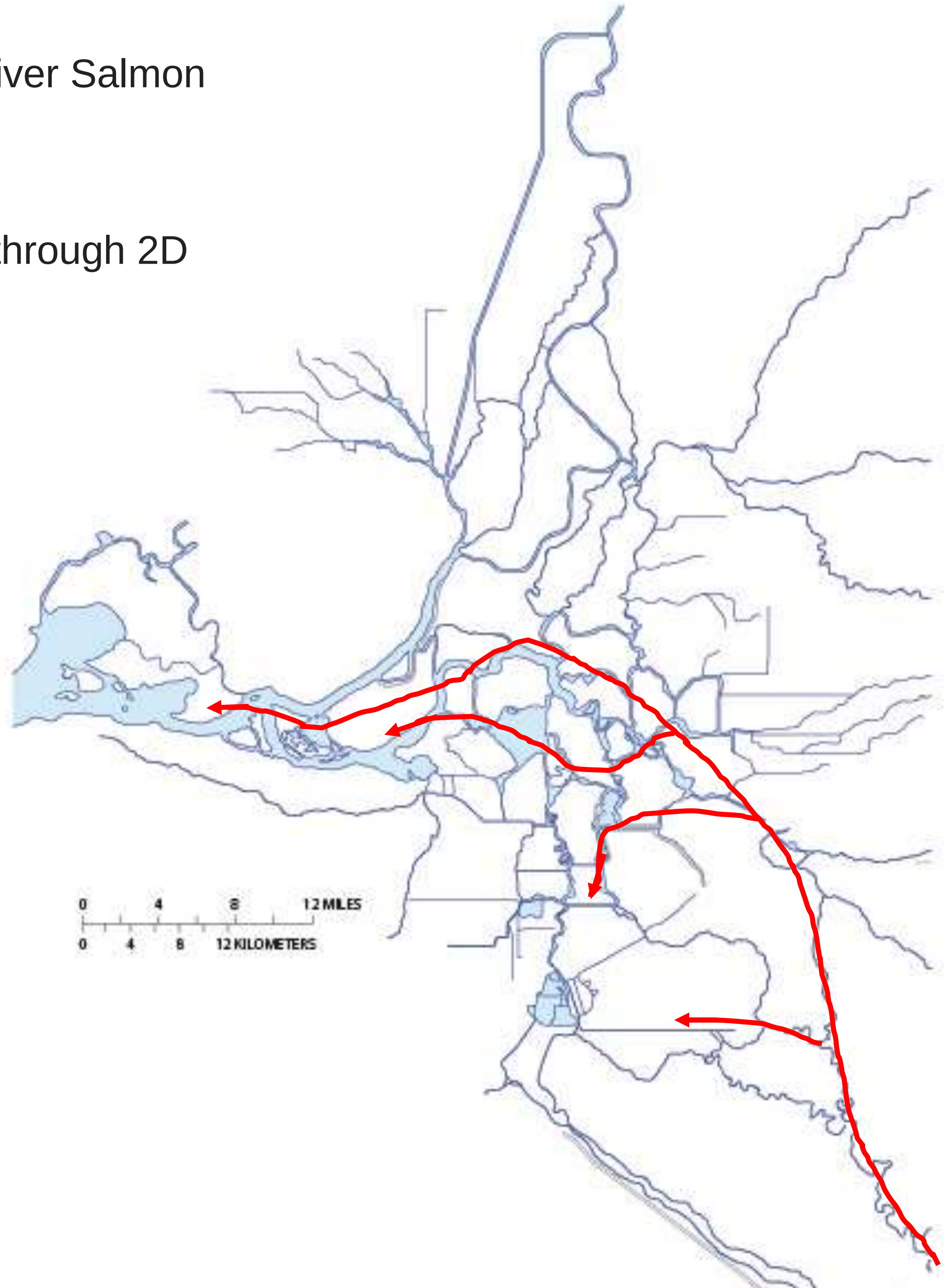
(1) Complex Geometry: Network (web)
(2) Tracking over long distances (particles can travel several lengths of the delta with the tides)
(3) Tracking over long periods in tidal environment

Average particle travel time from Sac to Freeport:
19.8 days DCC closed
26 days DCC open

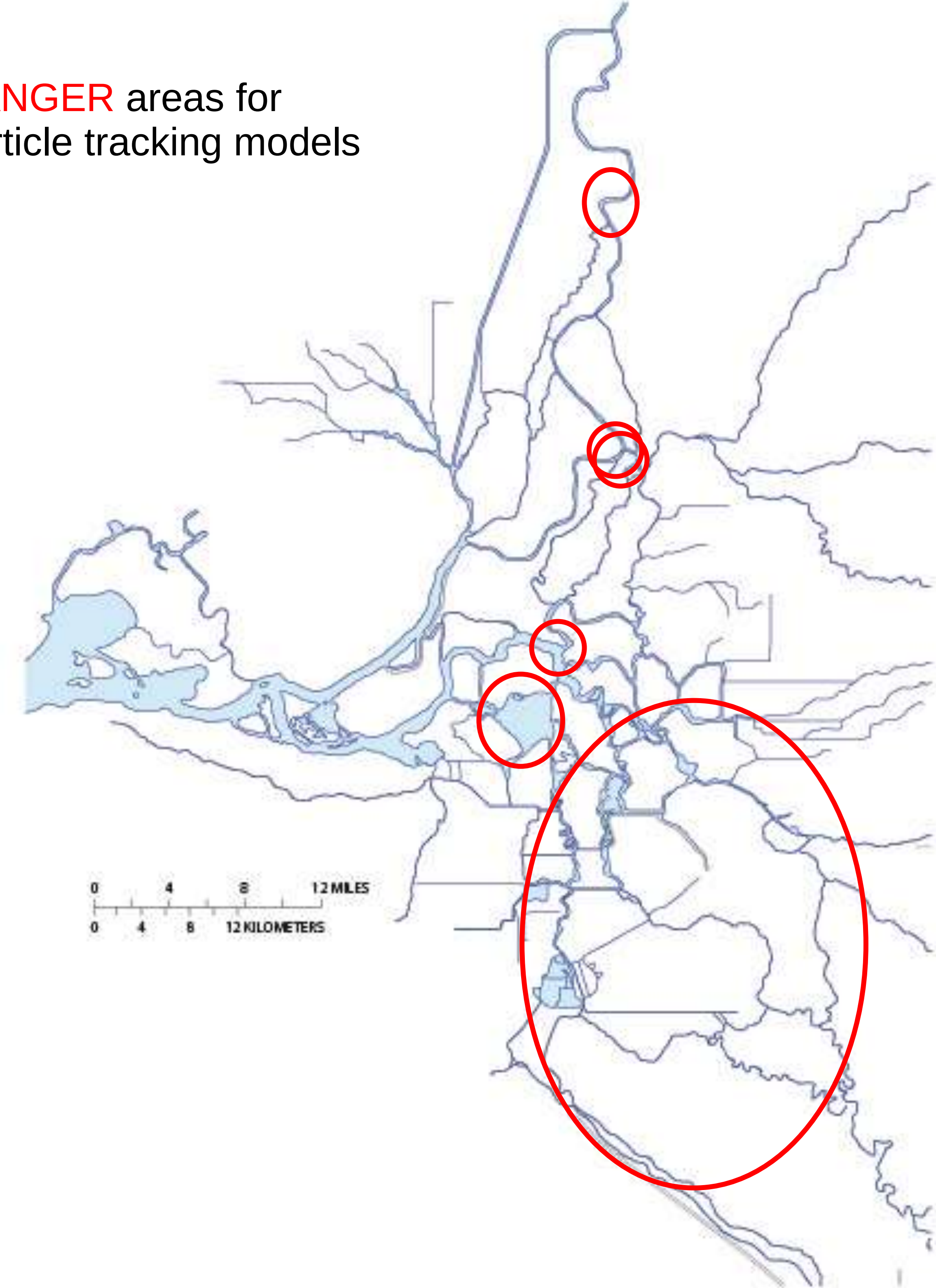


San Joaquin River Salmon Outmigrants

Multiple paths through 2D regions.



DANGER areas for particle tracking models



Vertical Dimension

Bends

Junctions

Broad Channels

Large flooded islands

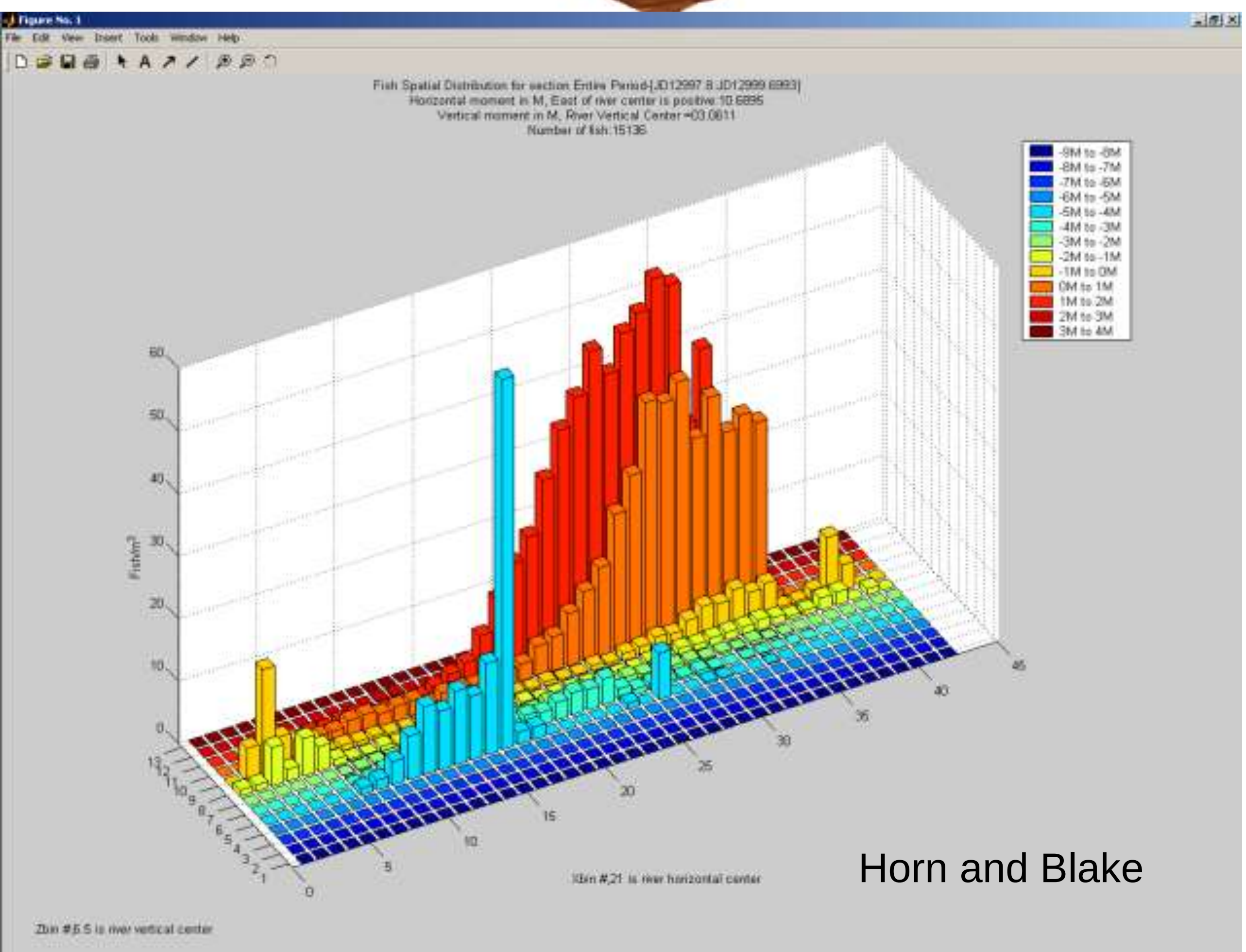
Poor bathymetry

Challenges with Vertical Dimension

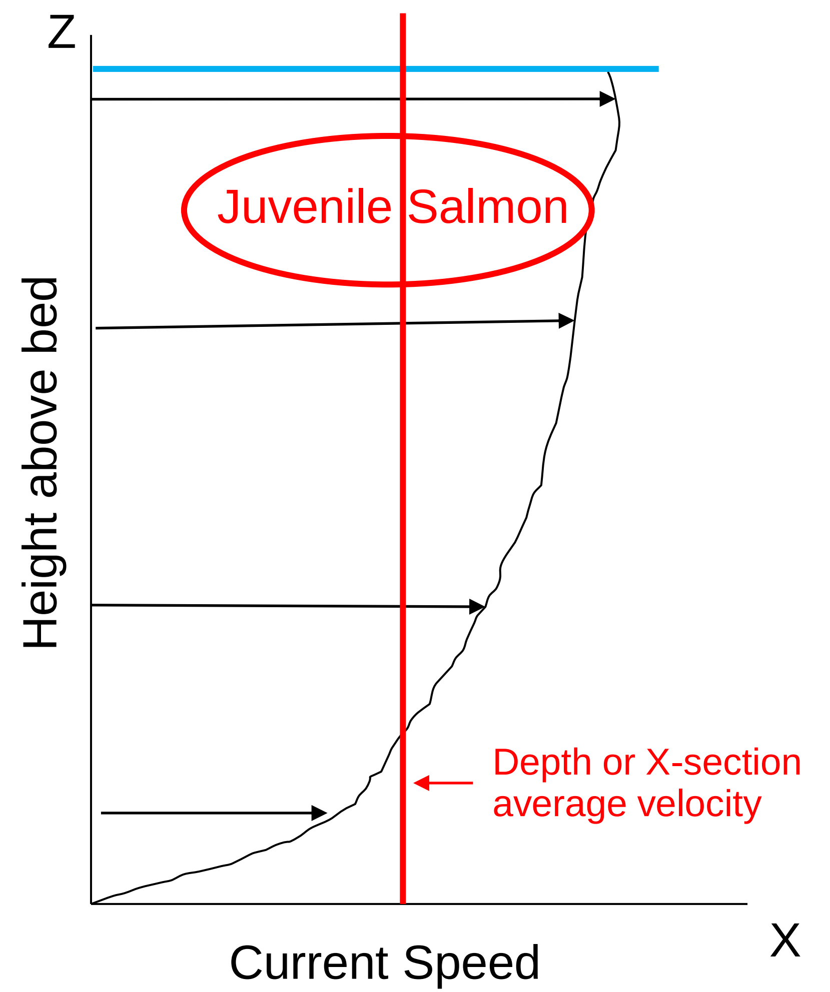
Georgiana Slough

Look at beam cross-section
From down stream

Salmon are in the upper part of Water column

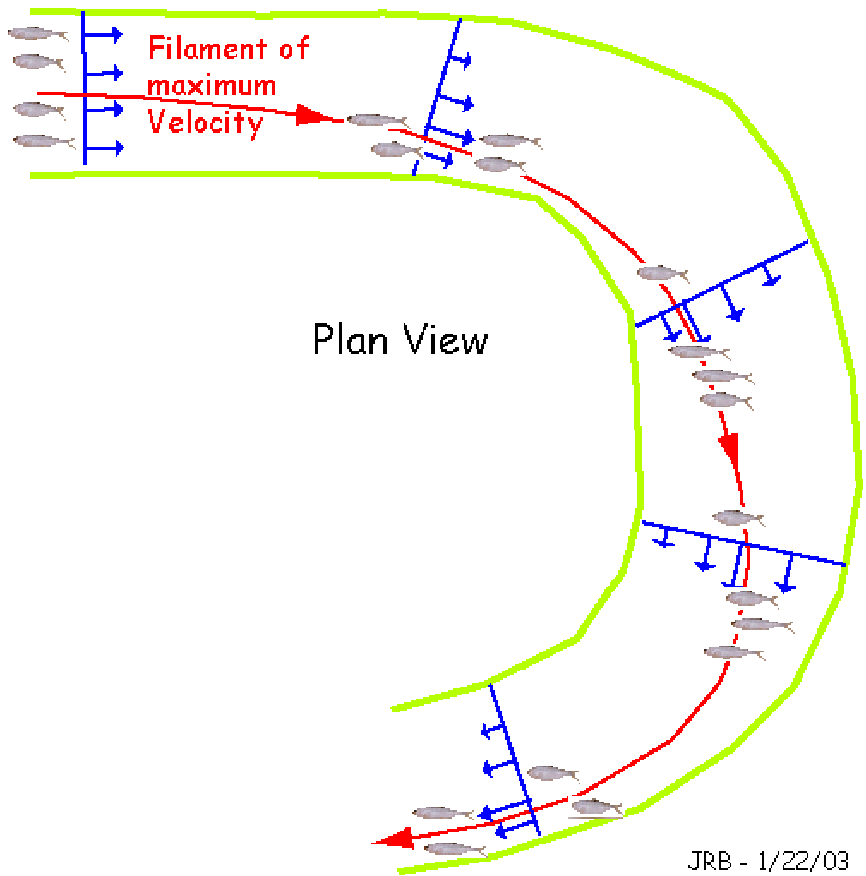


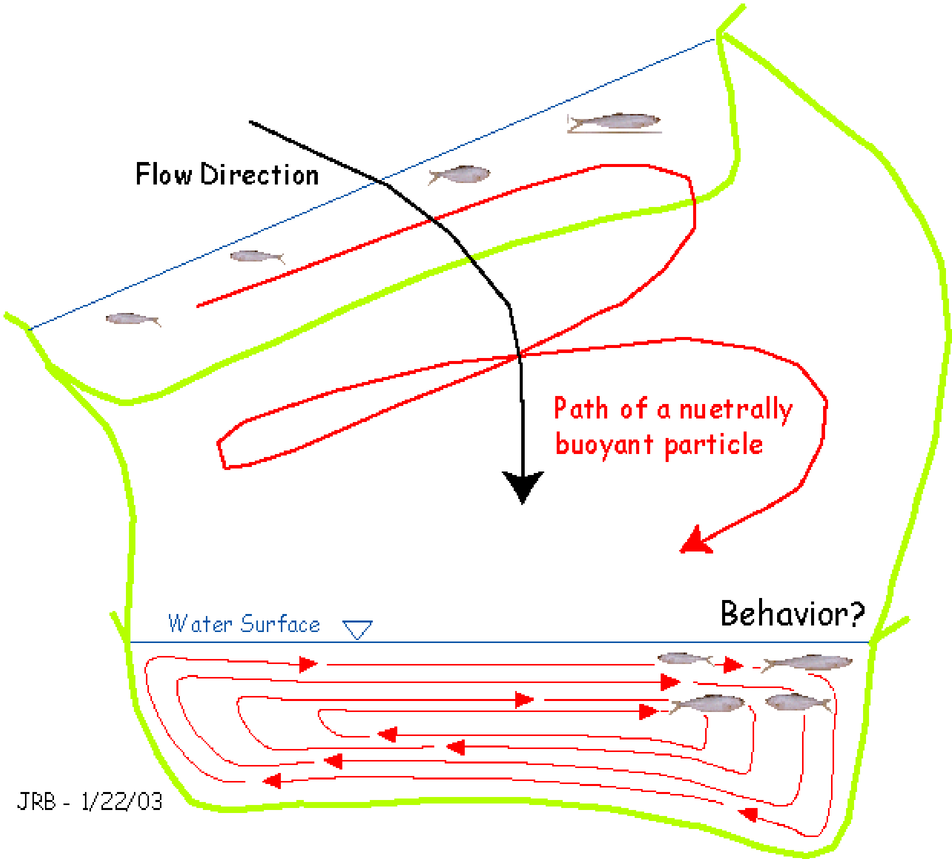
Horn and Blake



Challenges with Bends

Secondary Circulation In Bends:
Biasing route selection towards outside channels?



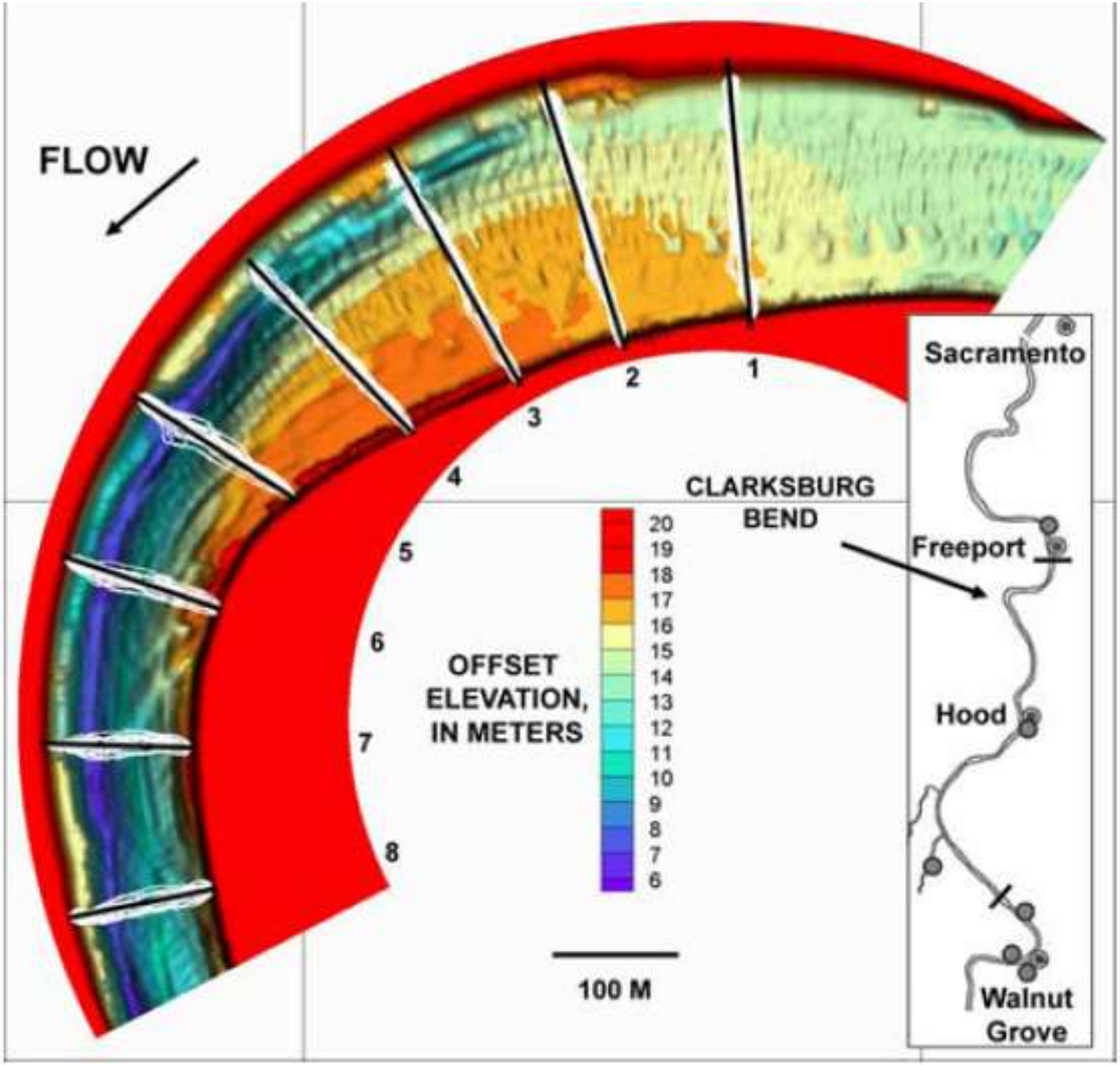


Why Study Salmon movements in Clarksburg Bend?

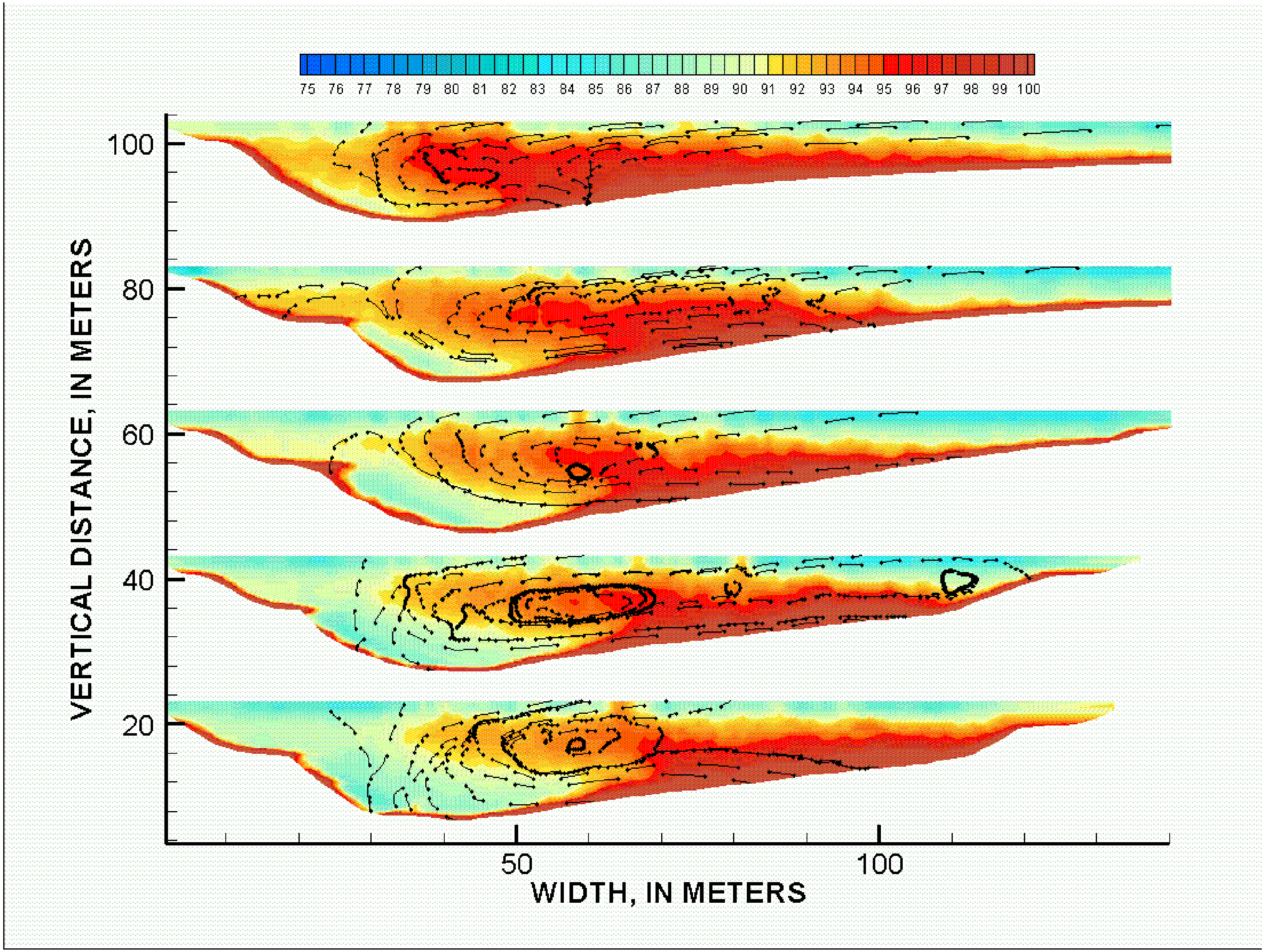
(1) Very tight radius (secondary currents scale with the radius)

(2) Contraction of cross sectional area

(3) No junction to confuse the results

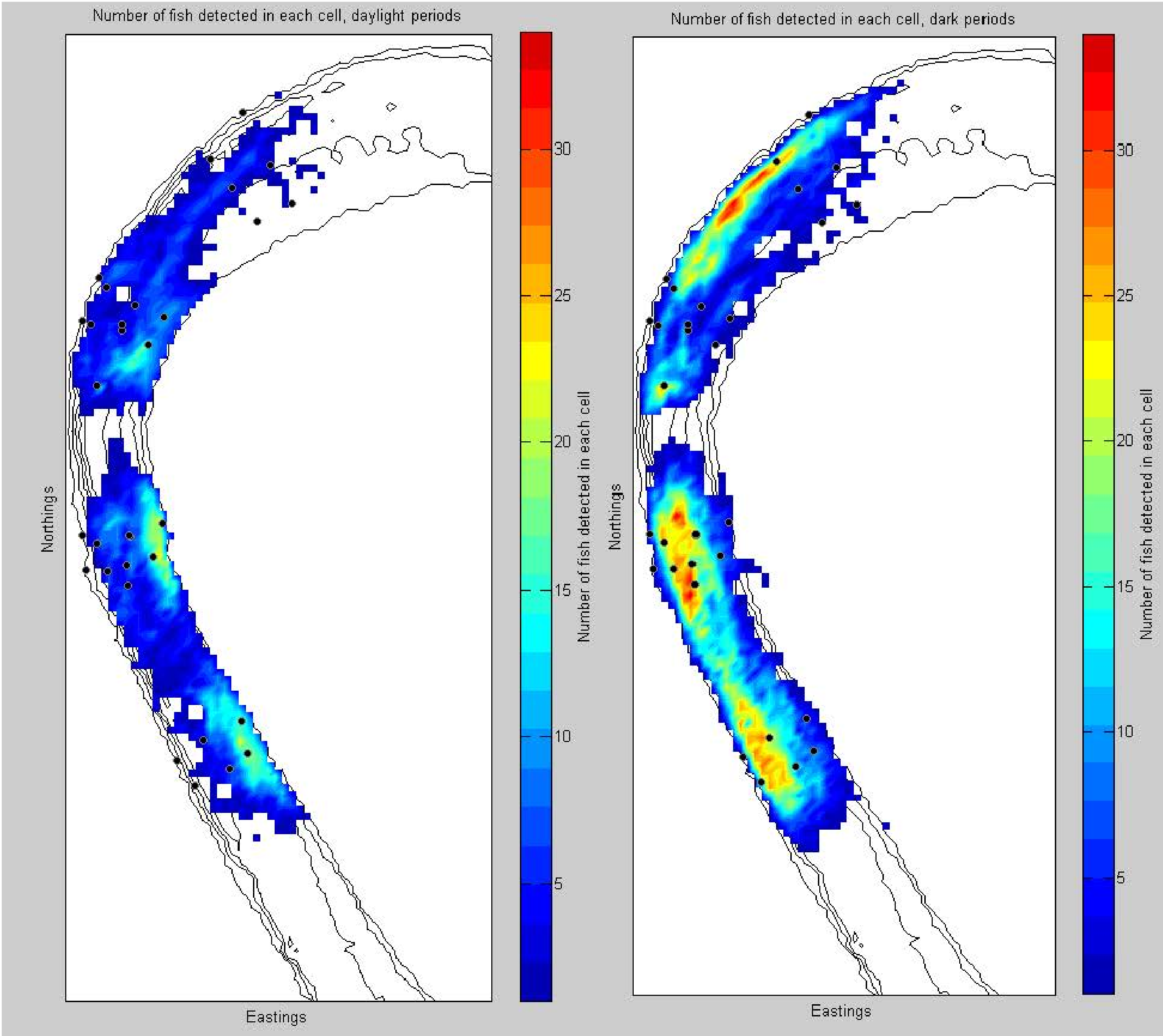


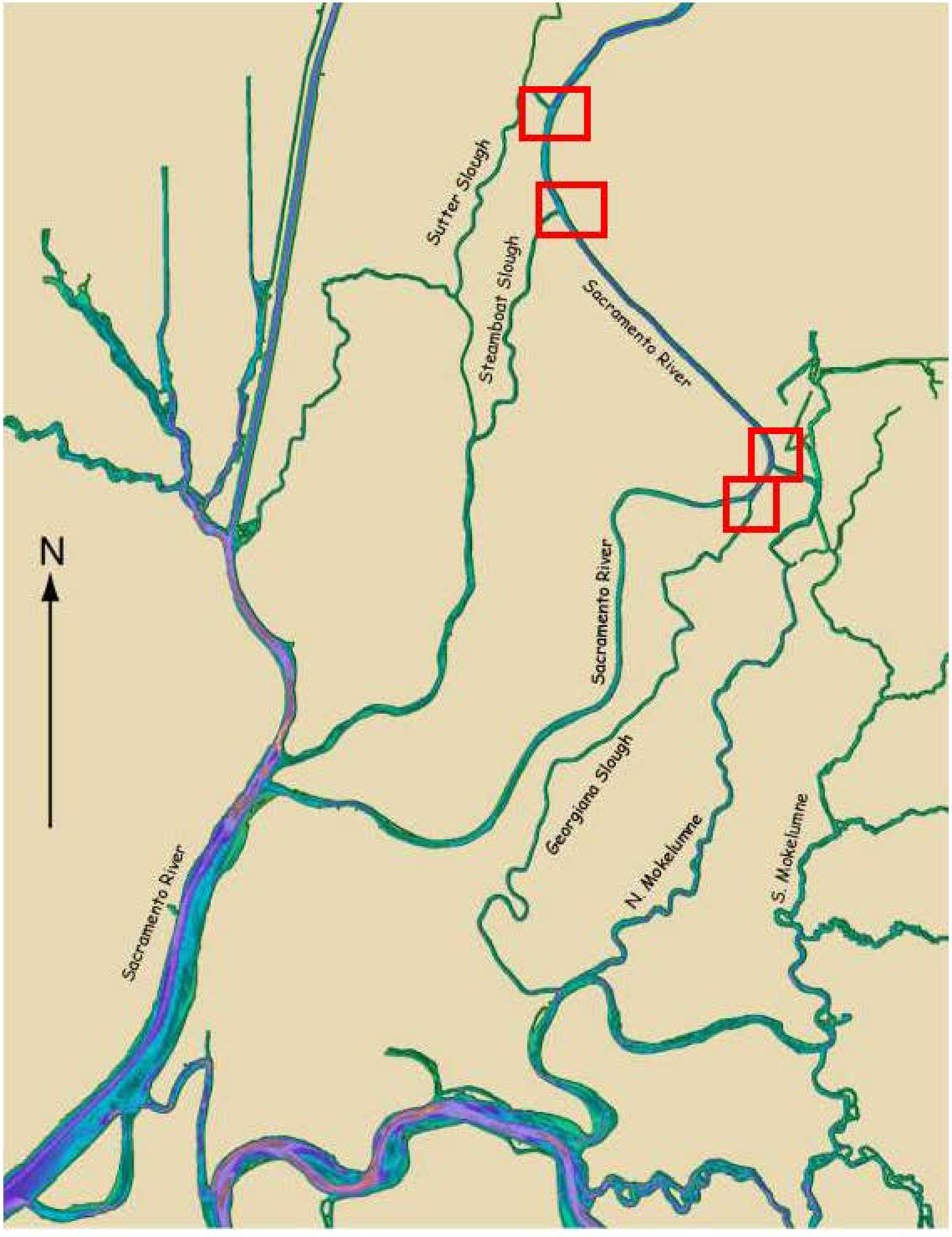
Measurements of Secondary currents in Clarksburg Bend



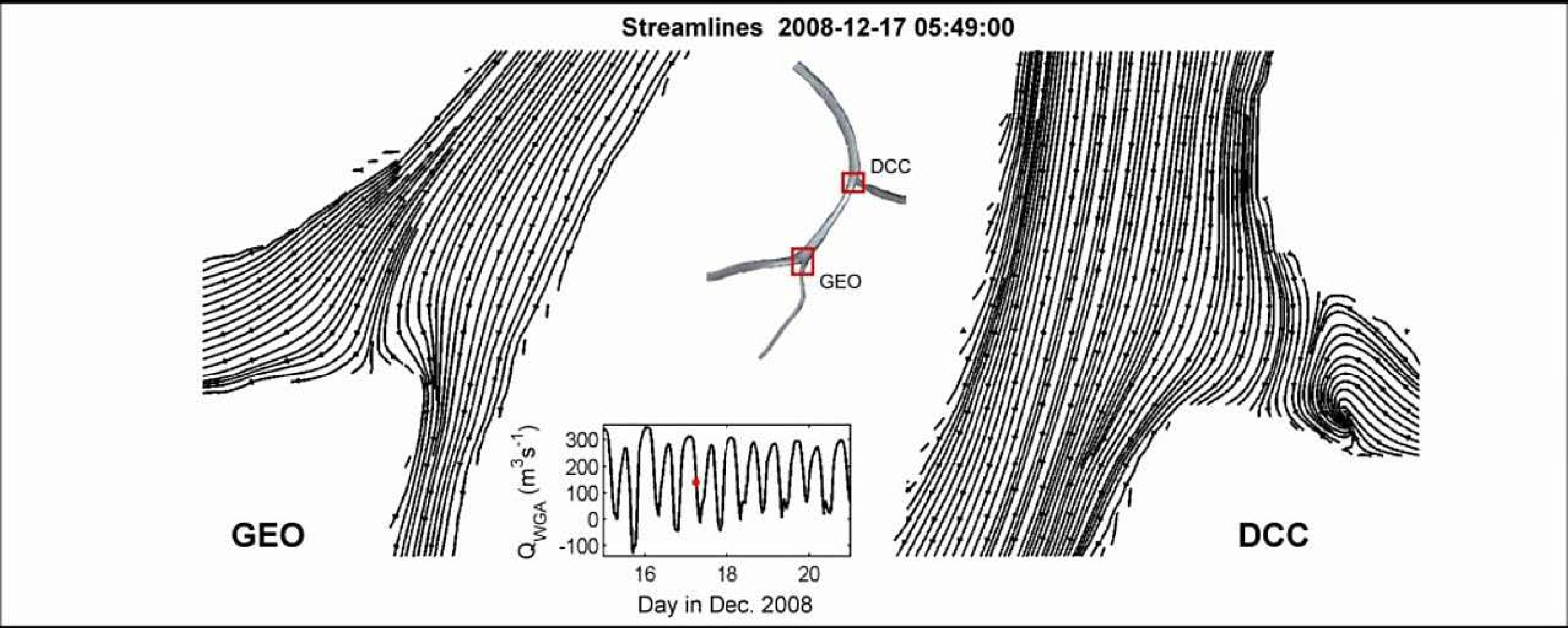
Dinehart, R. and J. Burau, 2005, Averaged indicators of secondary flow in repeated acoustic Doppler current profiler crossings, Water Resources Research

Day and Night Fish Distributions in January




N
Sutter Slough
Steamboat Slough
Sacramento River
Sacramento River
Georgiana Slough
N. Mokelumne
S. Mokelumne
Sacramento River

Challenges with Junctions



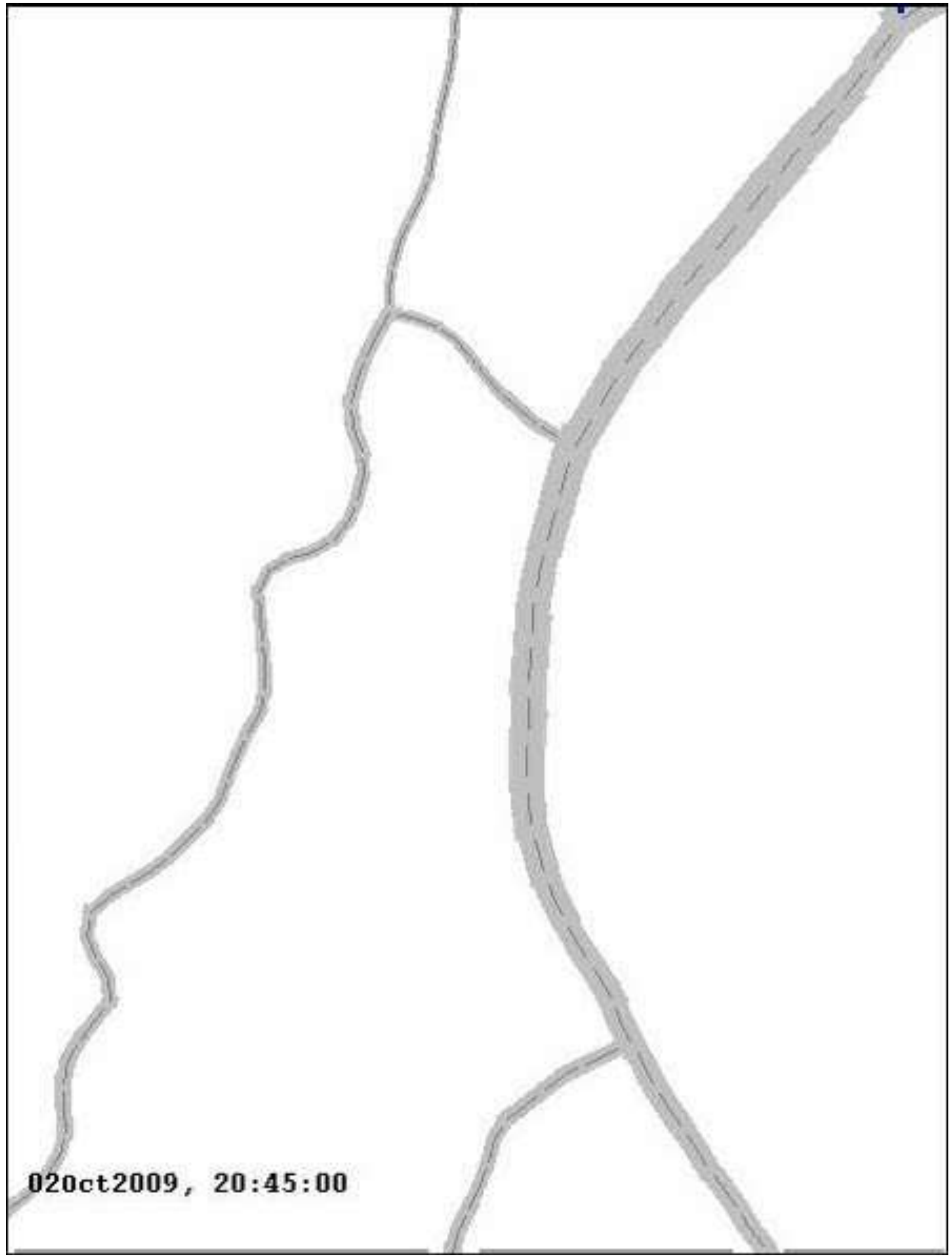
Courtesy of Cintia Casanas, Pete Smith (SI3D)

Particle Tracking in Junctions

Particle fate is determined
At junctions
Numerics at junctions
must be good

Discrete particle
Release strategy

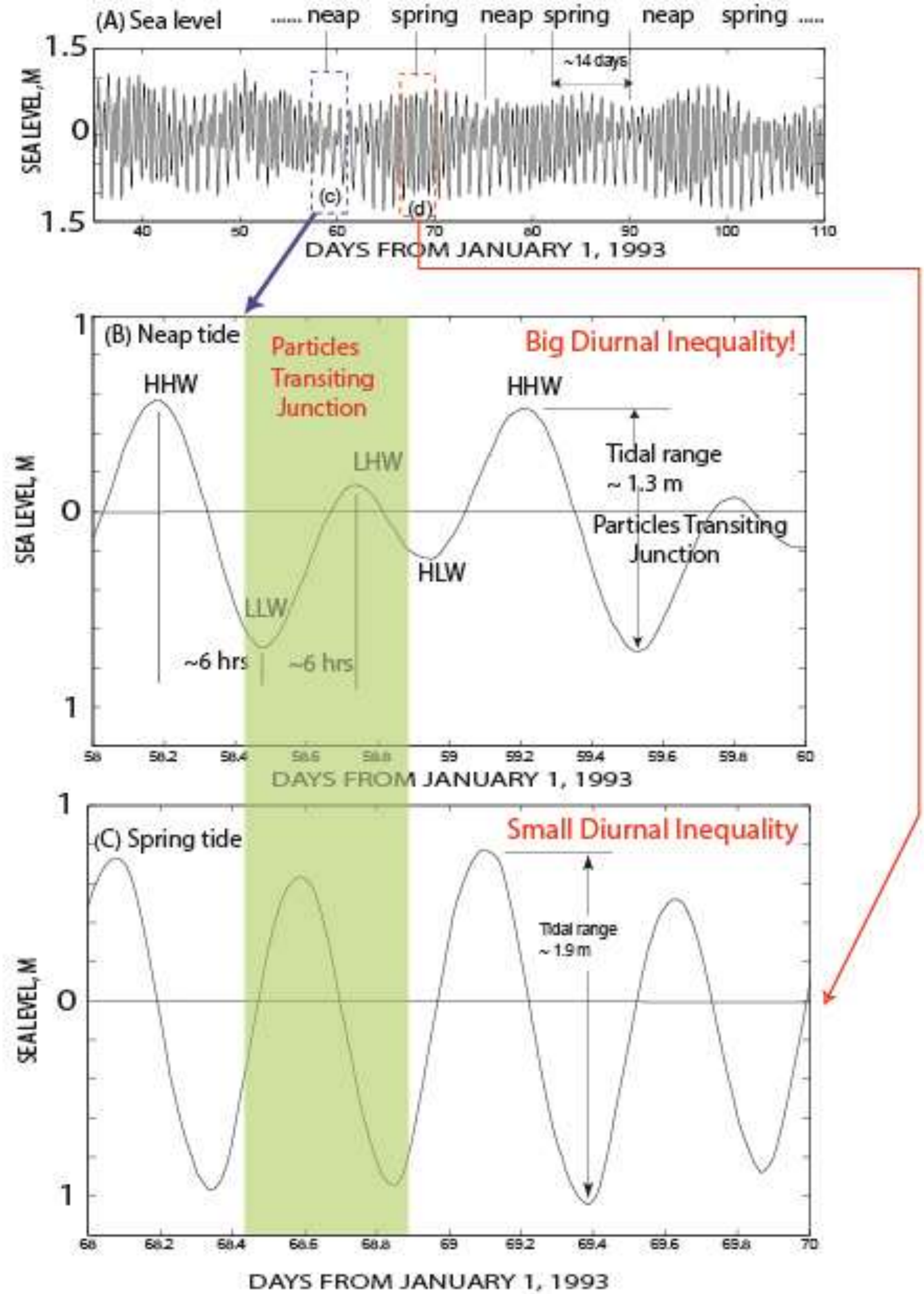
12 hour release in Sac



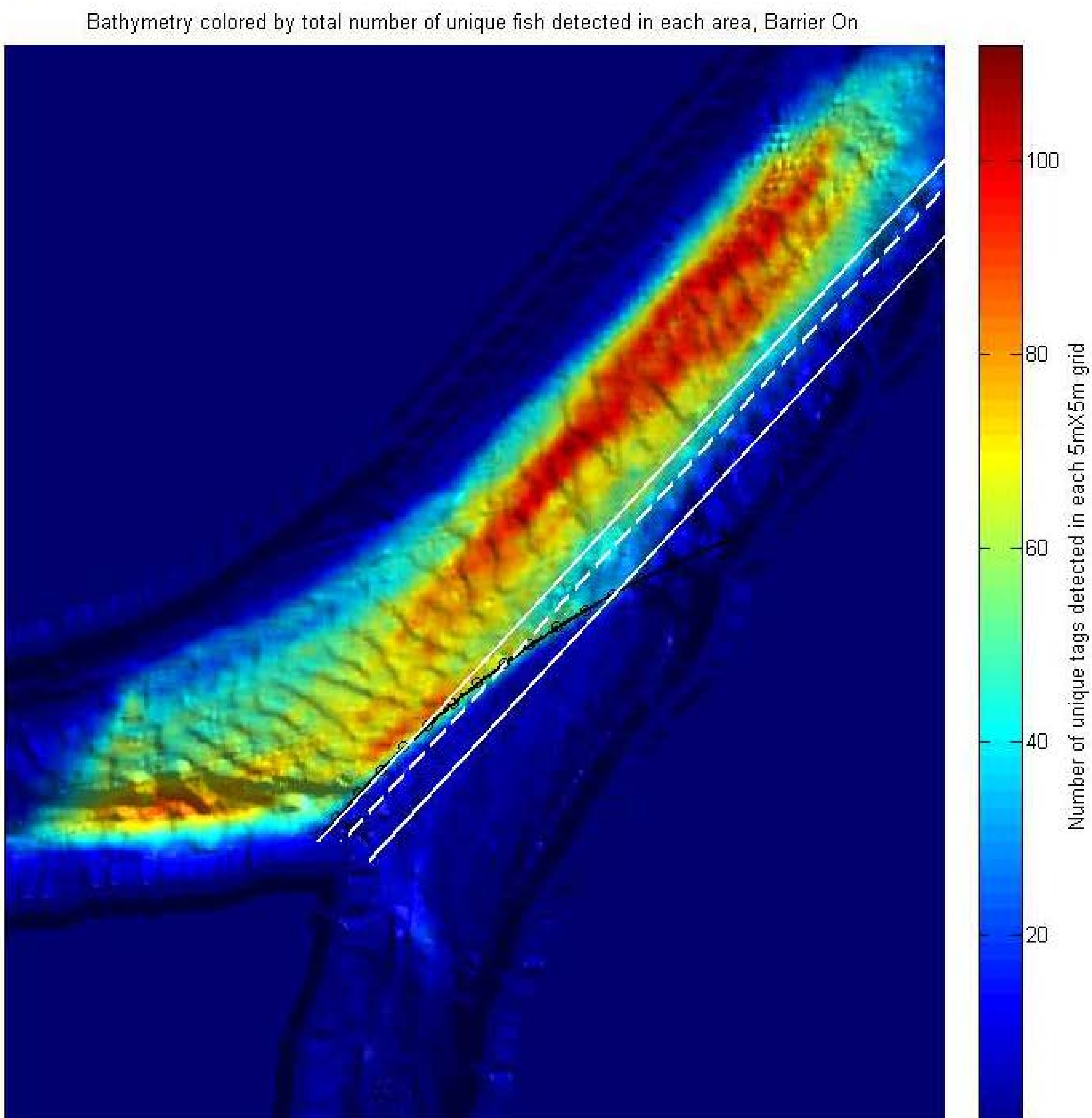
The problem of a discrete release strategy

Particles interact with
The junction over
a limited period of
time

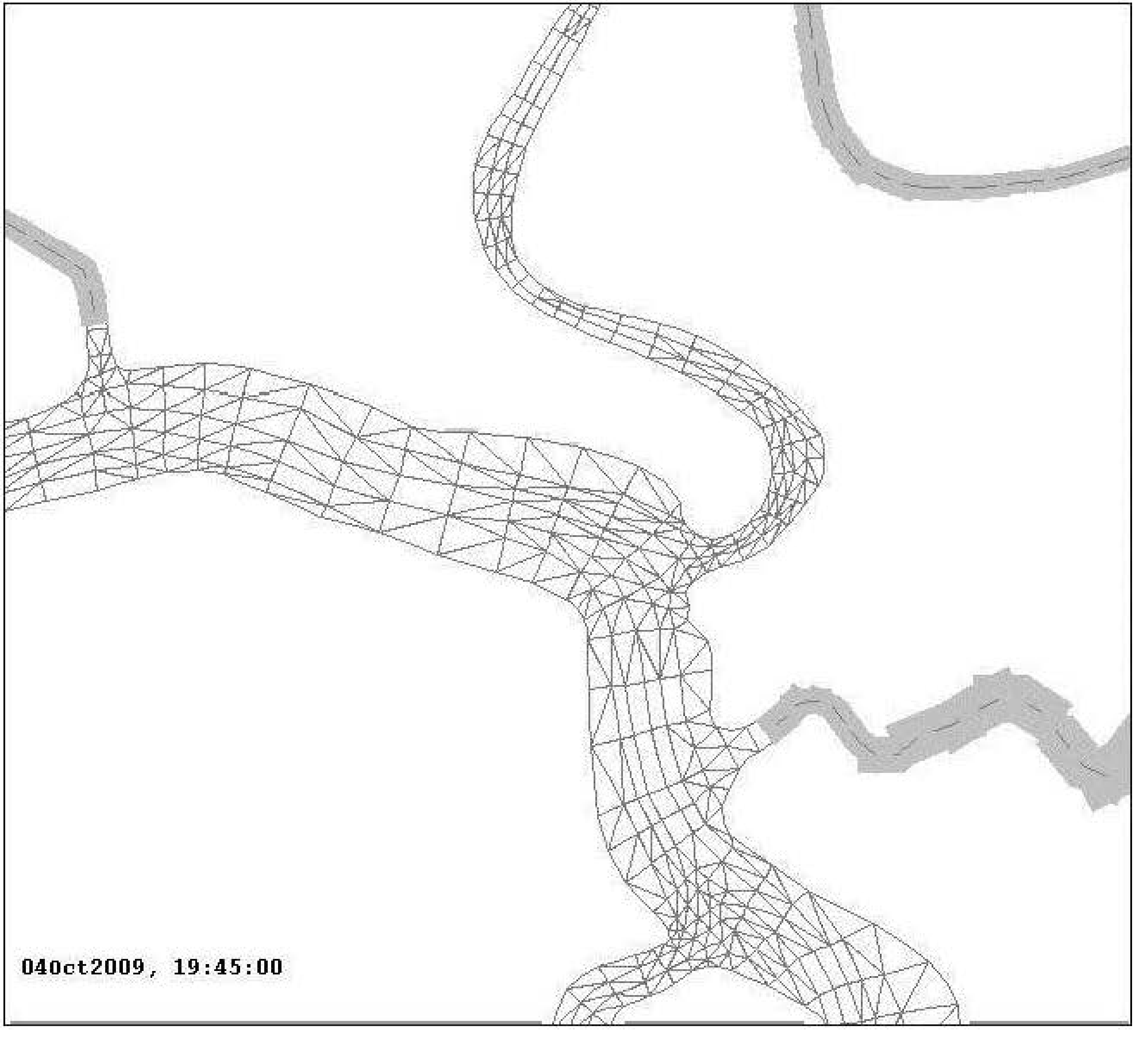
The Diurnal Inequality
(Spring/Neap cycle)



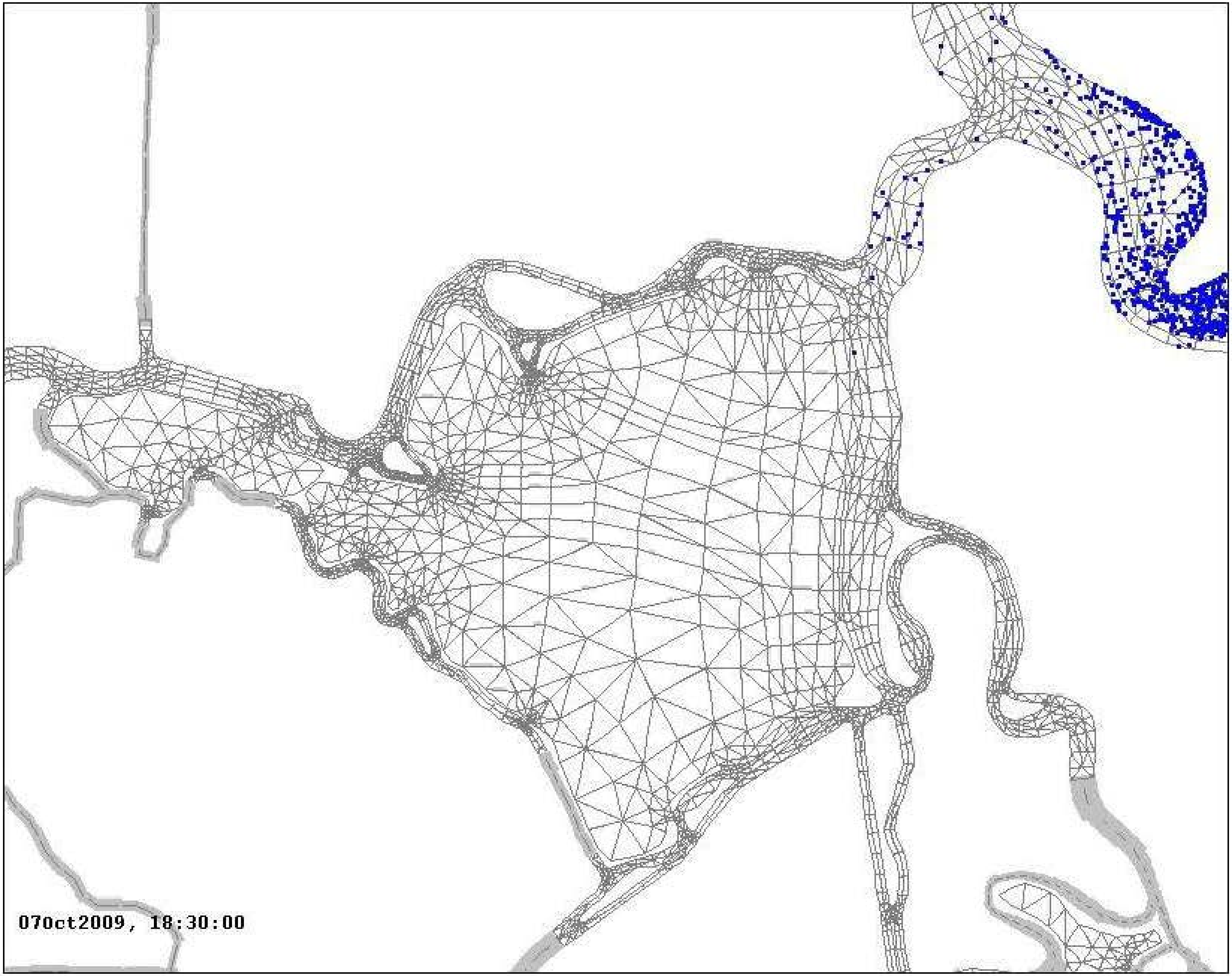
Non-uniform fish spatial distribution



Challenges with Broad Channels



Challenges with large flooded Islands



The challenge of particle tracking in the delta is an example of the butterfly effect (chaos theory) in which there is sensitive dependence on initial conditions:

A small change in one state of a deterministic nonlinear system can result in large differences in a later state.

The name is derived from the observation that minor perturbations (or errors), such as the flapping of the wings of a distant butterfly can alter the strength and movement of a Hurricane.

But, there is hope….

Hurricane predictions have dramatically improved since the butterfly effect was coined because of large investments in:

(1) Better models (numerics)
(2) Higher resolution grids
(3) Large investments in (super) computer time
(4) Data assimilation

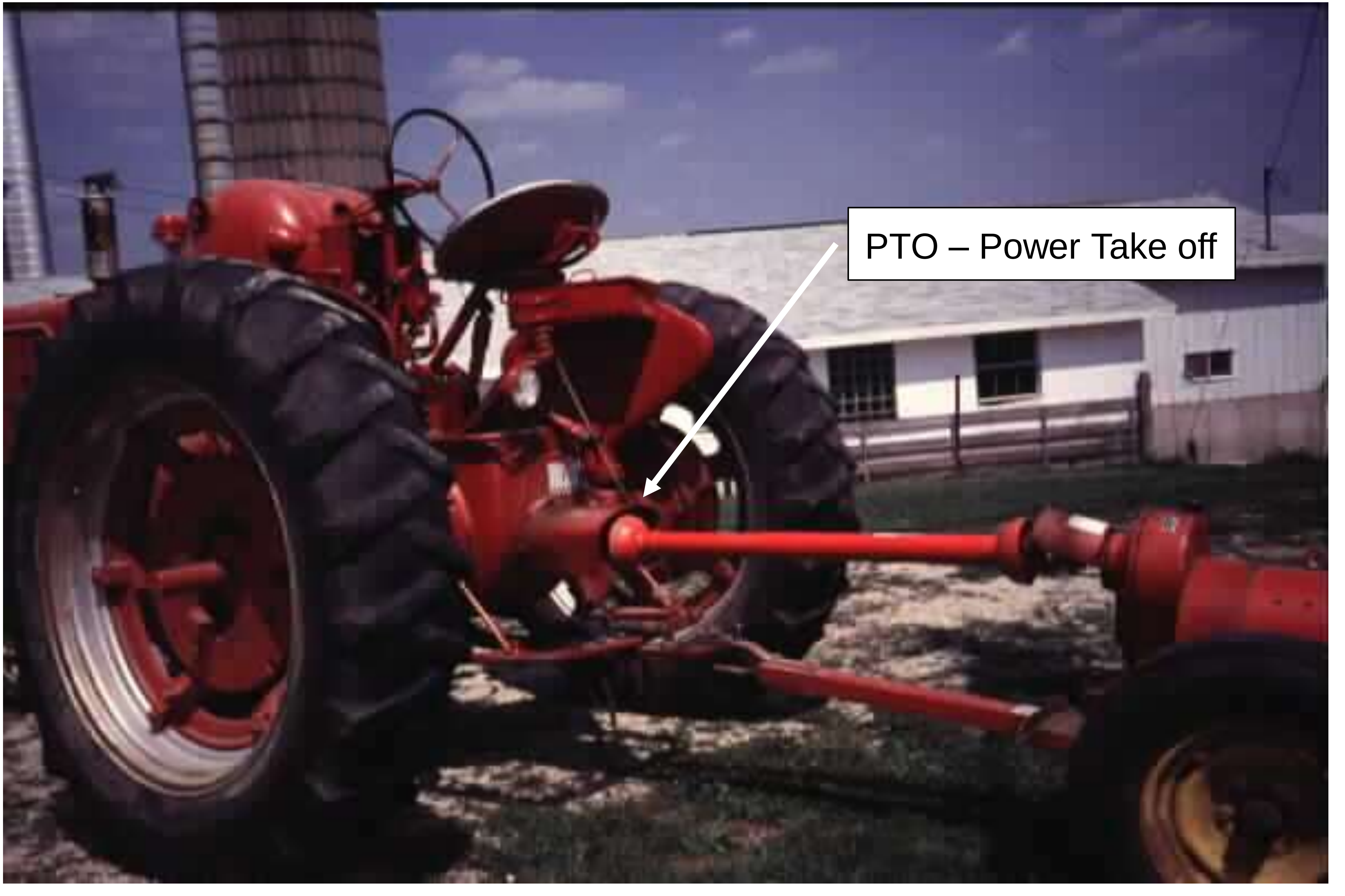
Is the Delta worthy of these investments?

Conclusions

Tools can be dangerous

Read the operating instructions before use

On the use of using dangerous tools!



Modern tools (2D and 3D models) are safer