Now-Casting Coastal Water Quality:
A Proposal to the National Council on Water Quality Monitoring

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Outline

- Introduction
- Sources and transport pathways
- Public mis-notification
- Alternative approaches
- Proposed system: CalSWIM

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Ocean Bathing Water Quality Standards for FIB in California

- Total Coliform
  - 10,000 MPN/100 mL (single sample)
  - 1,000 MPN/100 mL (30-day geo mean)
- Fecal Coliform
  - 400 MPN/100 mL (single sample)
  - 200 MPN/100 mL (30-day geo mean)
- Enterococci bacteria
  - 104 MPN/100 mL (single sample)
  - 35 MPN/100 mL (30-day geo mean)

Focus on Fecal Indicator Bacteria

- Adverse human health outcomes linked to exposure to elevated FIB in ocean bathing waters
- 1000s of shoreline sites are impaired for FIB, and hence important to develop approaches for finding and mitigating sources
- Urban runoff has very high concentrations of FIB--hence these organisms may be good tracers for urban runoff in coastal systems

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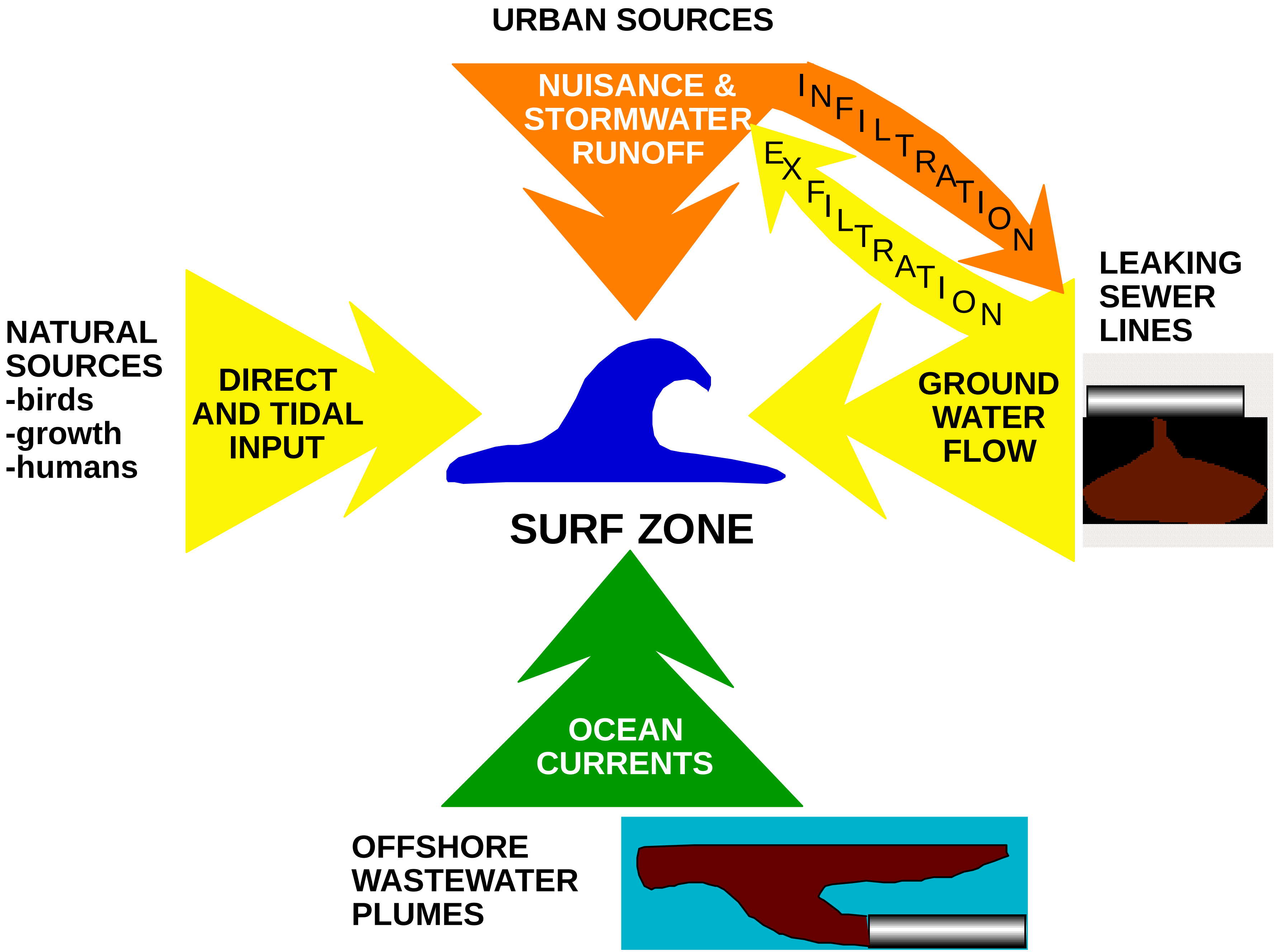
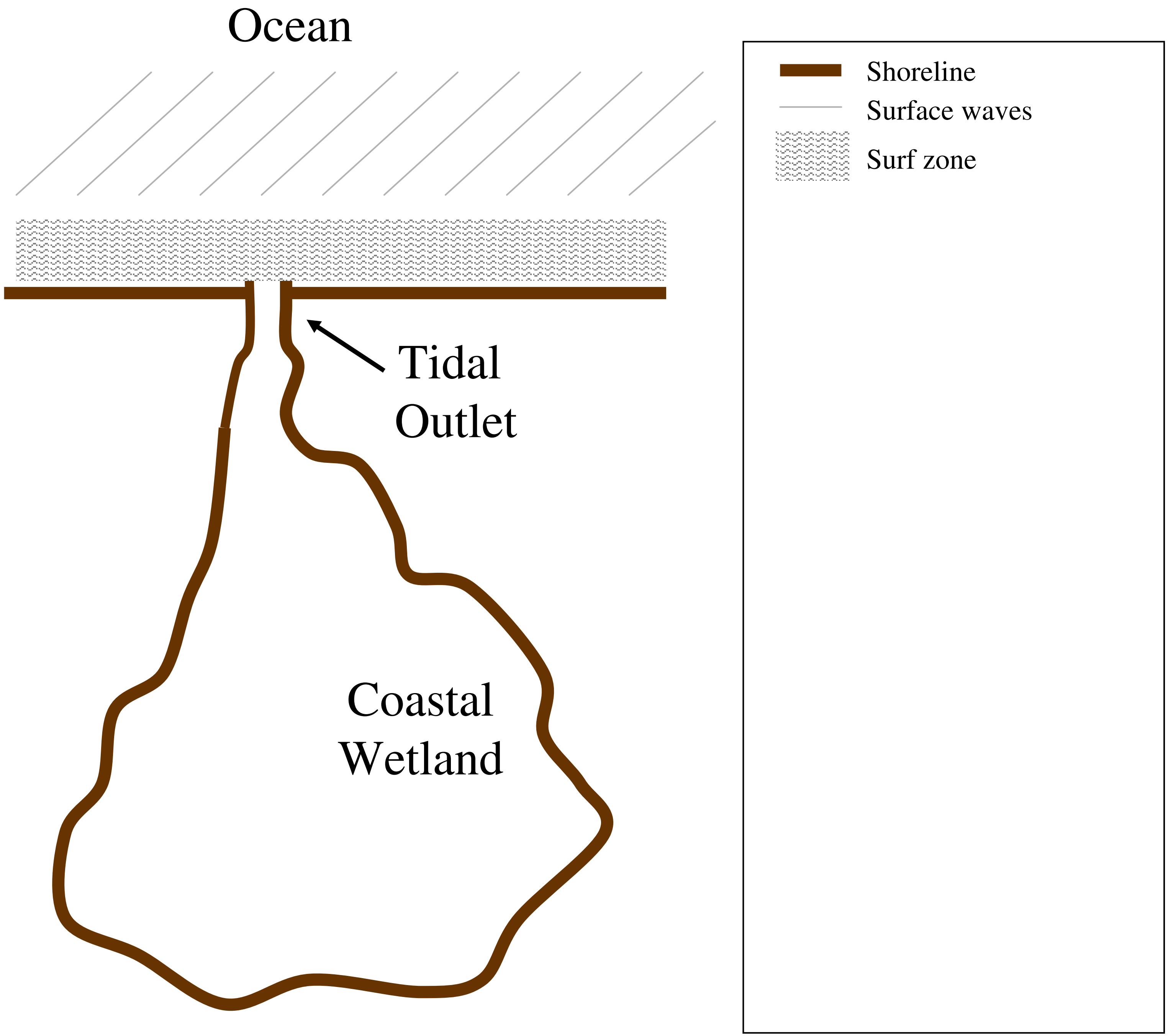
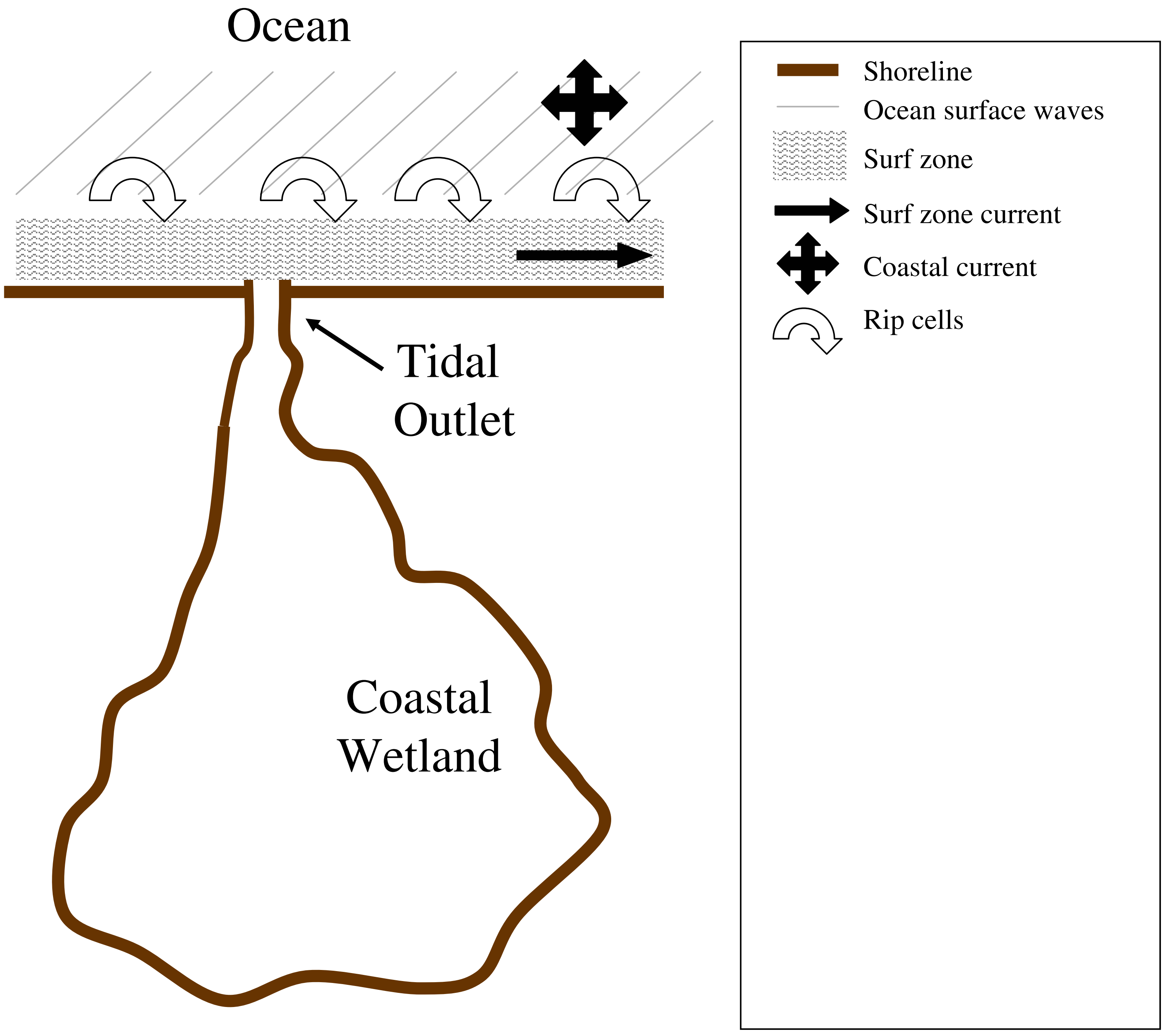
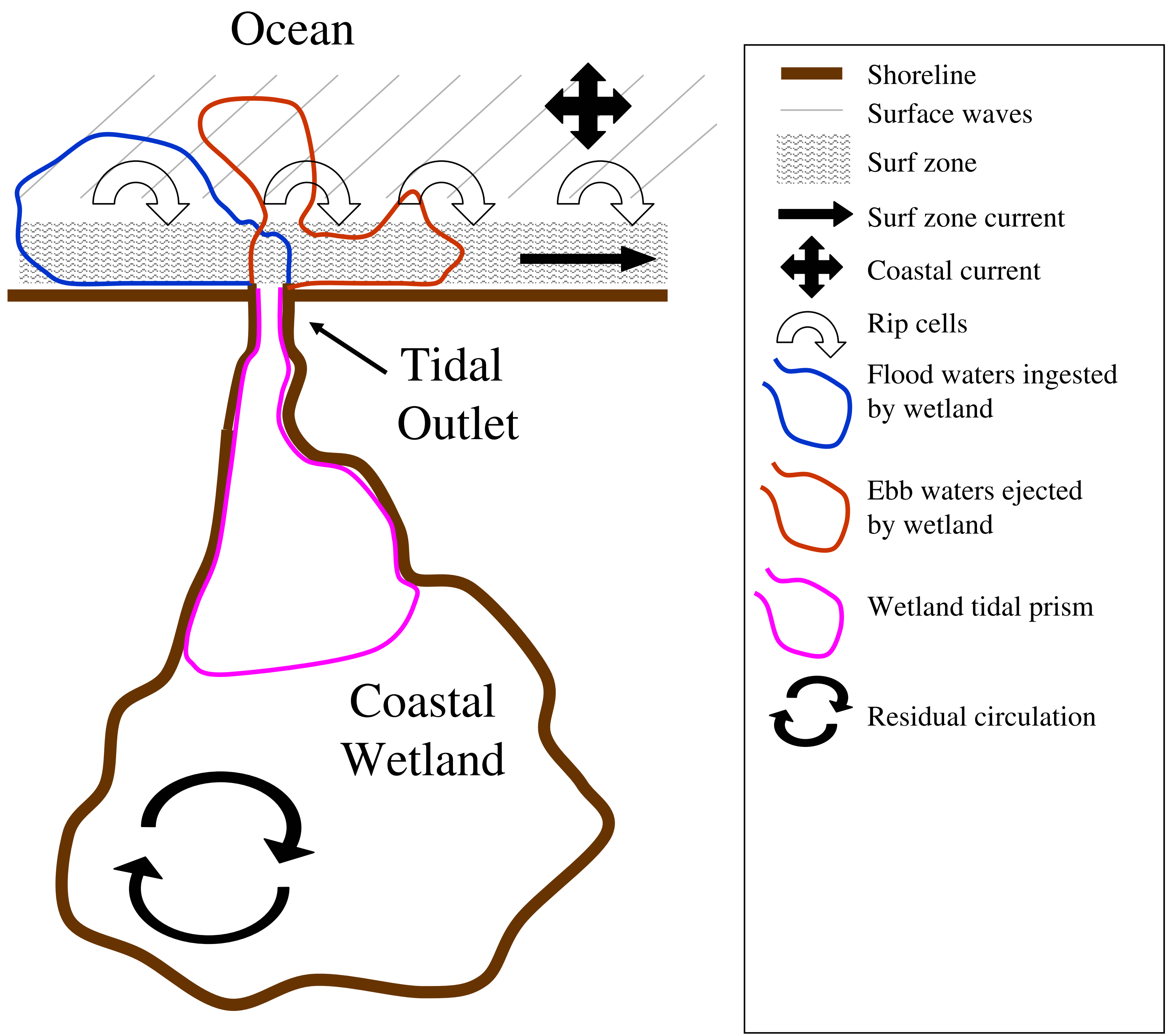
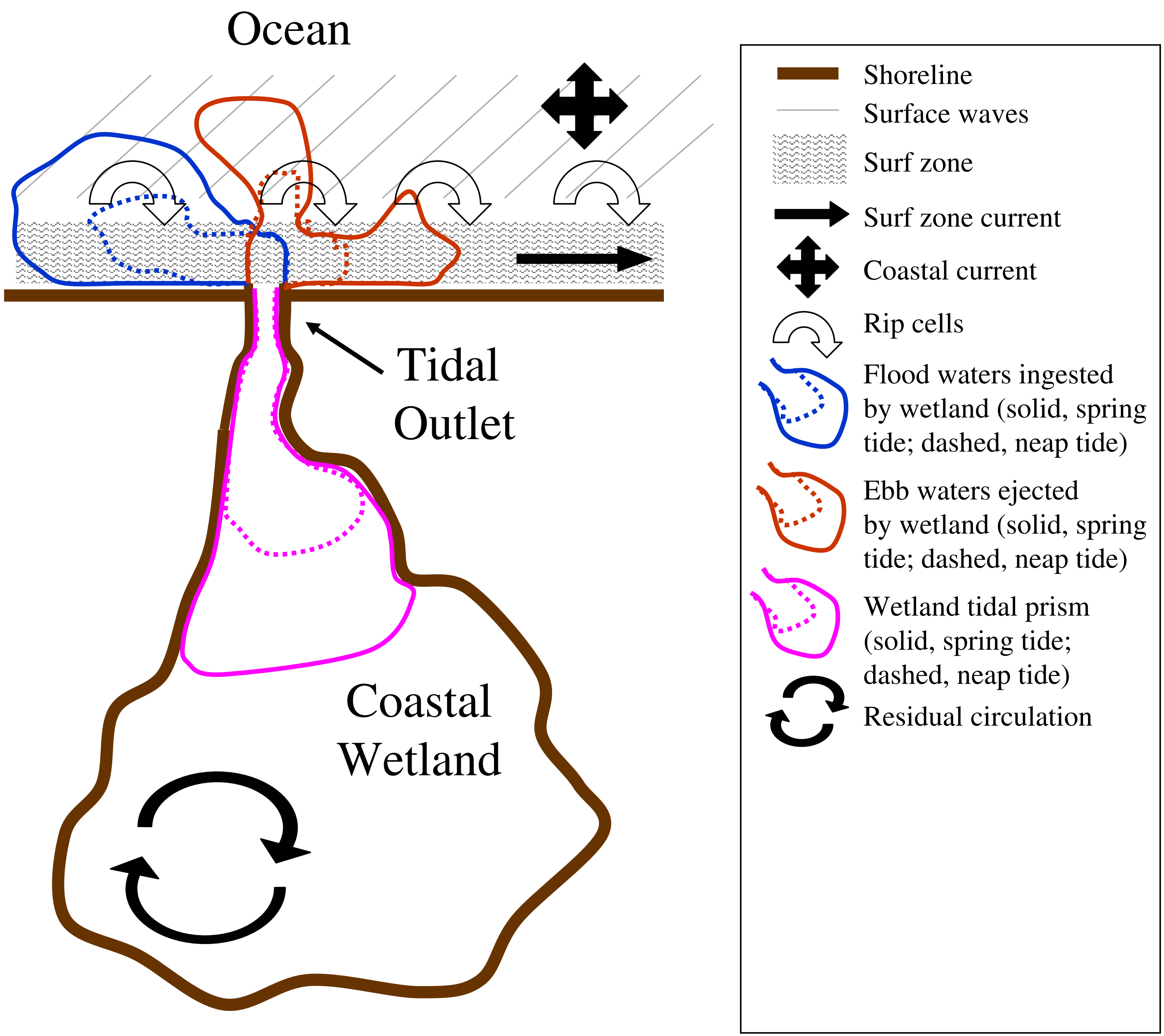

URBAN SOURCES
NUISANCE & STORMWATER RUNOFF
INFILTRATION
EXFILTRATION
LEAKING SEWER LINES
NATURAL SOURCES
-birds
-growth
-humans
DIRECT AND TIDAL INPUT
GROUND WATER FLOW
SURF ZONE
OCEAN CURRENTS
OFFSHORE WASTEWATER PLUMES


Ocean
Tidal
Outlet
Coastal
Wetland
Shoreline
Surface waves
Surf zone


Ocean
Tidal Outlet
Coastal Wetland
Shoreline
Ocean surface waves
Surf zone
Surf zone current
Coastal current
Rip cells



Ocean
Tidal
Outlet
Coastal
Wetland
Shoreline
Surface waves
Surf zone
Surf zone current
Coastal current
Rip cells
Flood waters ingested
by wetland
Ebb waters ejected
by wetland
Wetland tidal prism
Residual circulation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by wetland (solid, spring
tide; dashed, neap tide)
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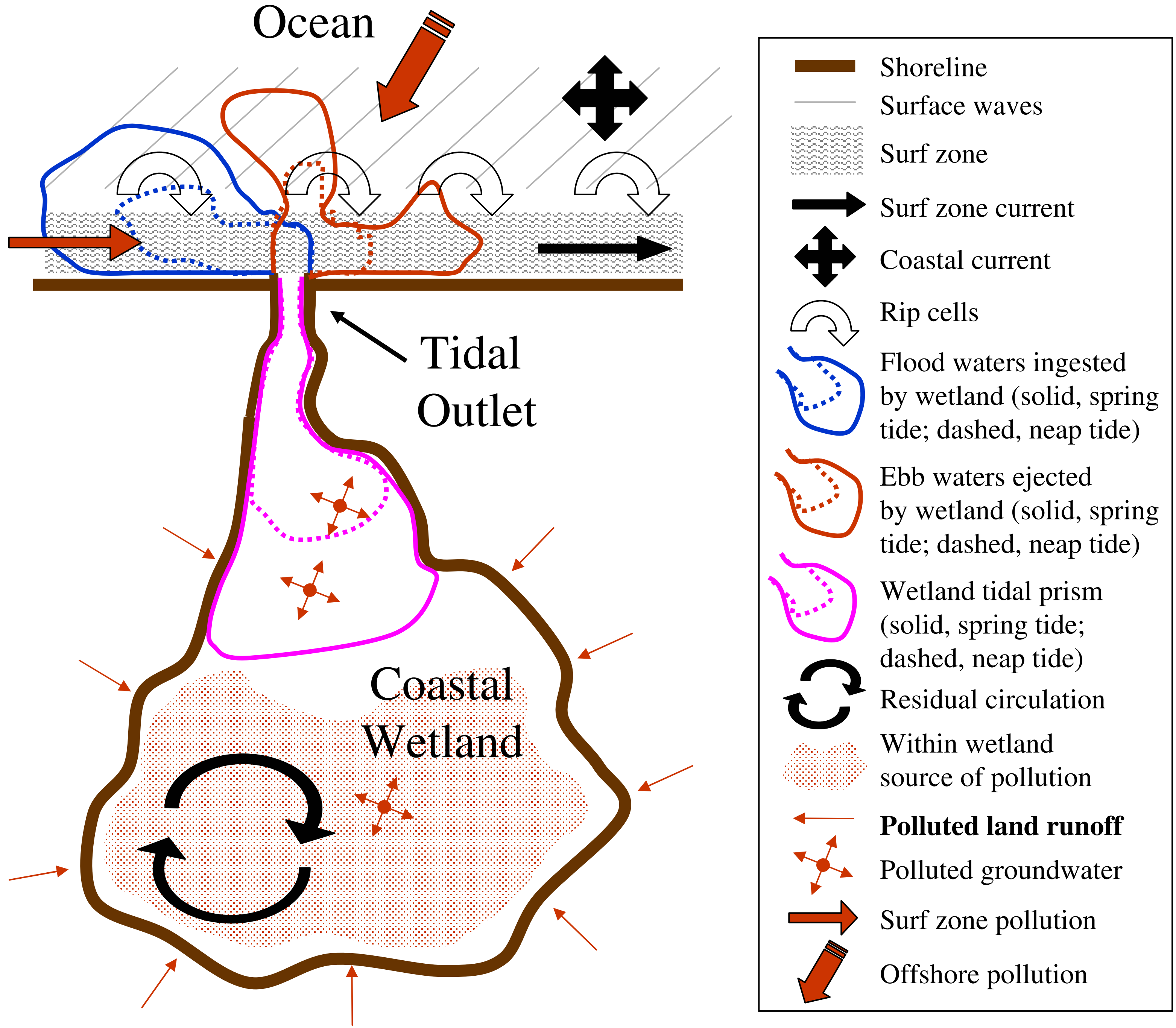
Wetland tidal prism
(solid, spring tide;
dashed, neap tide)
Residual circulation



Ocean
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Flood waters ingested by wetland (solid, spring tide; dashed, neap tide)
Ebb waters ejected by wetland (solid, spring tide; dashed, neap tide)
Wetland tidal prism (solid, spring tide; dashed, neap tide)
Residual circulation
Within wetland source of pollution
Polluted land runoff
Polluted groundwater
Surf zone pollution
Offshore pollution

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Posting/Closure Protocol in California

- If FIB concentrations in the surf exceed any of these standards, the local health officer is required to post a sign on the beach warning the public about potential health risks (*beach posting*)
- If the local health officer believes that the surf may be contaminated with sewage, he/she has the option of closing the beach to the public (*beach closure*)


WARNING
OCEAN WATER CONTACT MAY
CAUSE ILLNESS
ACTERIA LEVELS EXCEED
HEALTH STANDARDS
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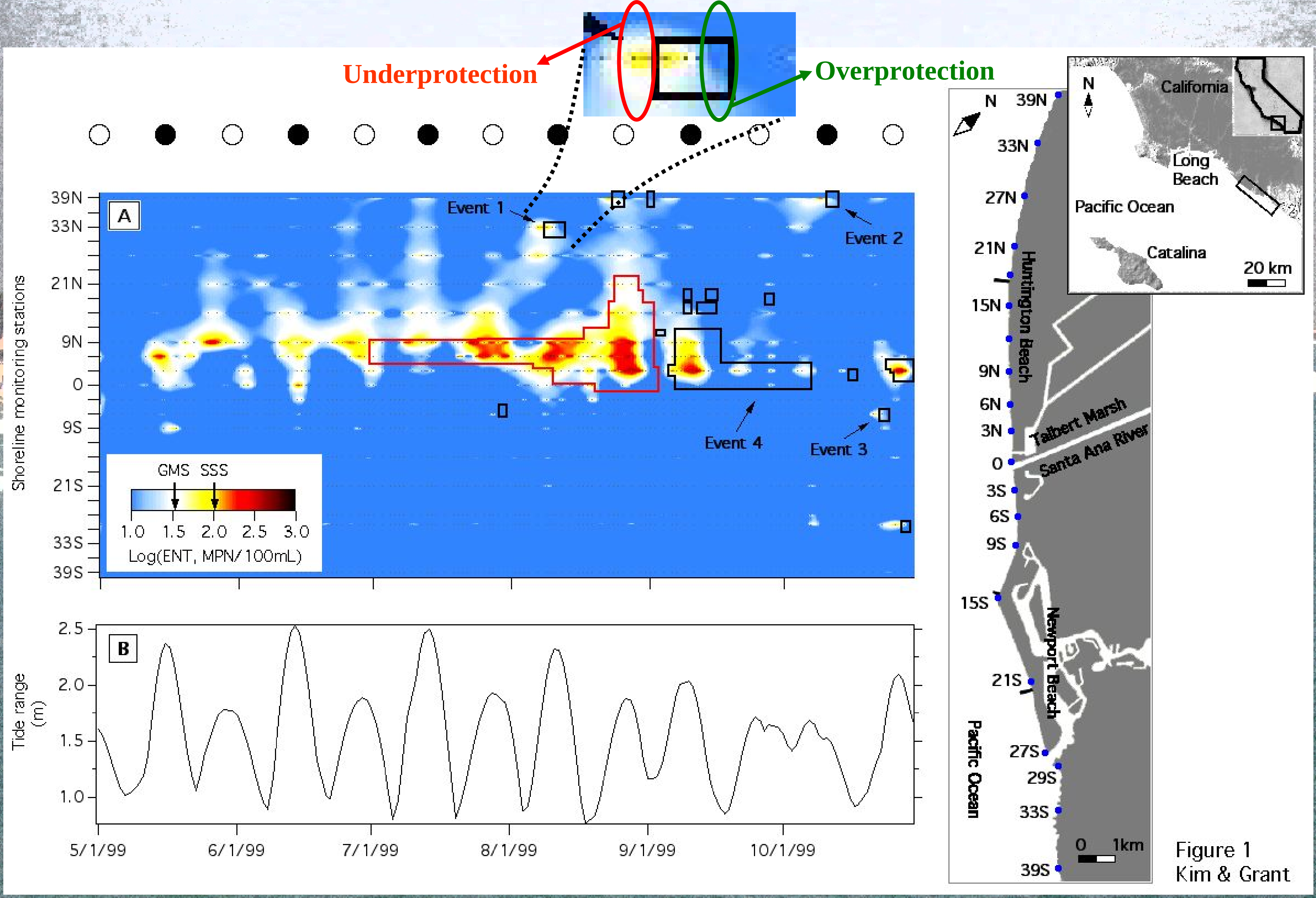
ELES DE BACTERIAS EXCEDEN
S ESTANDARES DE SALUD

Observations of Posting Errors at Huntington Beach



Summary: Observations of Posting Errors

- **Comparison of posting records and water quality test results indicates that the public is often mis-notified about current water quality conditions (i.e., underprotection/overprotection errors occur frequently).**

- **Posting errors caused by the single sample standards originate from the variable nature of water quality in the surf zone and the inherent time delay (*ca*. 2 to 3 days) between when a sample is collected and a sign is posted or taken down.**

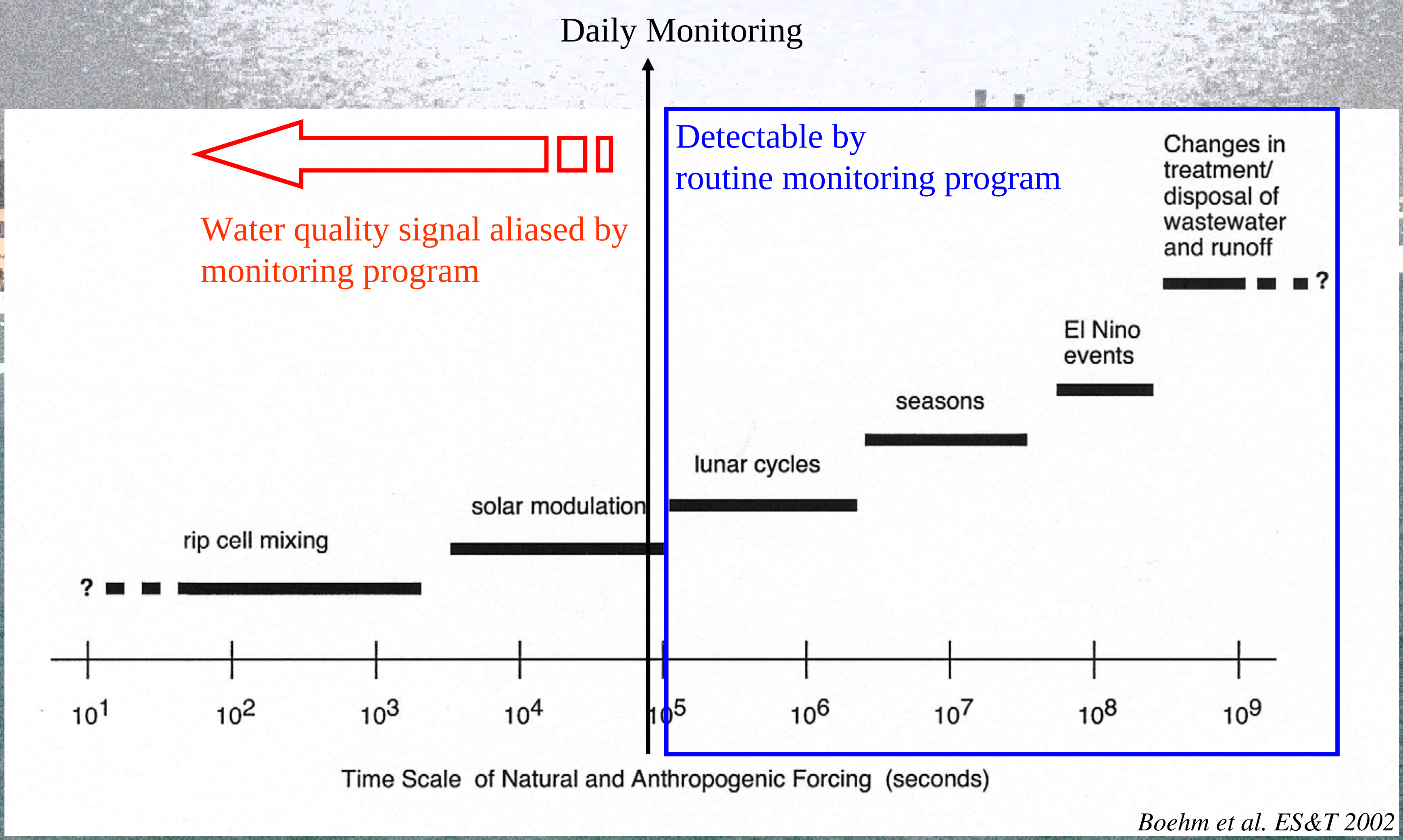
- **Posting error rates might be reduced if posting protocols were design to take into account factors known to influence local water quality (e.g., tide range).**

What factors influence water quality test results?

- Sources of indicator organisms (human fecal, non-human fecal, and re-growth)
- A cascade of periodic cycling driven by physical processes (next slide)
- Errors associated with the test results themselves (ca., 20-30%)

Periodic Patterns and Aliasing

To detect a periodic pattern, sampling rate should be shorter by a factor of two than characteristic period of the particular pattern of interest (*Nyquist Sampling Rate*).



Boehm et al. ES&T 2002

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Alternate approaches

- Probability models (predict probability of water quality exceedence based on prior and current information)
- Physical models (predict water quality based on source measurements, physics, biology)
- Artificial intelligence models (ANN, information theory)

Probabilistic example: Huntington Beach (published in *EST*)

FIB concentration c conditioned on daily tide range, l

↓ $f_{C|L}(c|\ell)$

↓ Normal pdfs for C and L

Probability of exceedence: $P_{ex|l}(\mu_C, \mu_L, \sigma_C, \sigma_L, \rho_{CL}, l)$

Expected value: $\mu_{C|l}(\mu_C, \mu_L, \sigma_C, \sigma_L, \rho_{CL}, l)$

↓ Dose/Response Model (Cabelli)

Illness Rate: $Y = a + b\mu_{c|l}$

Now-casting Results

of 6N station at Huntington Beach

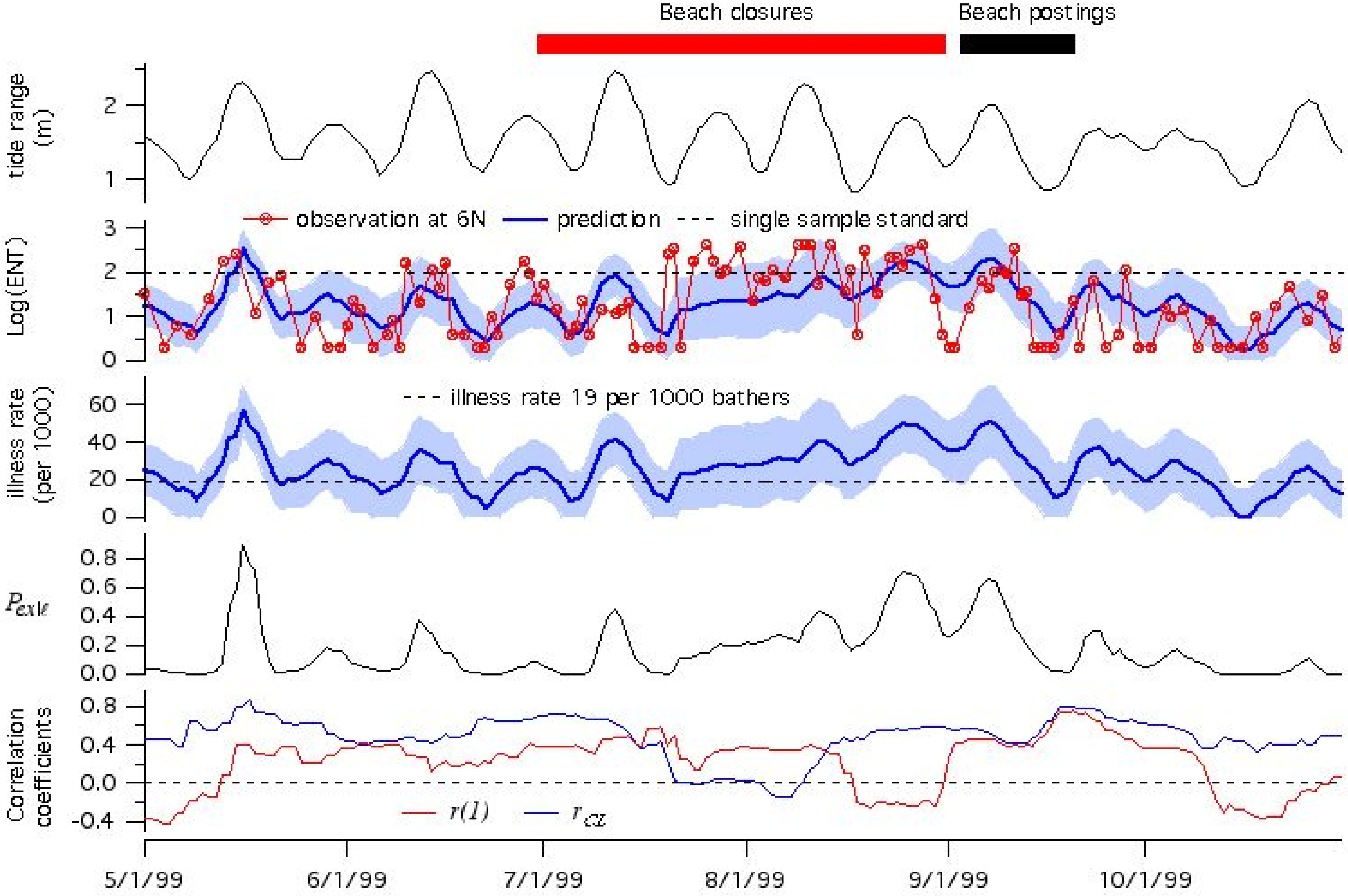


Figure 5
Kim & Grant

Deterministic example: Newport Bay

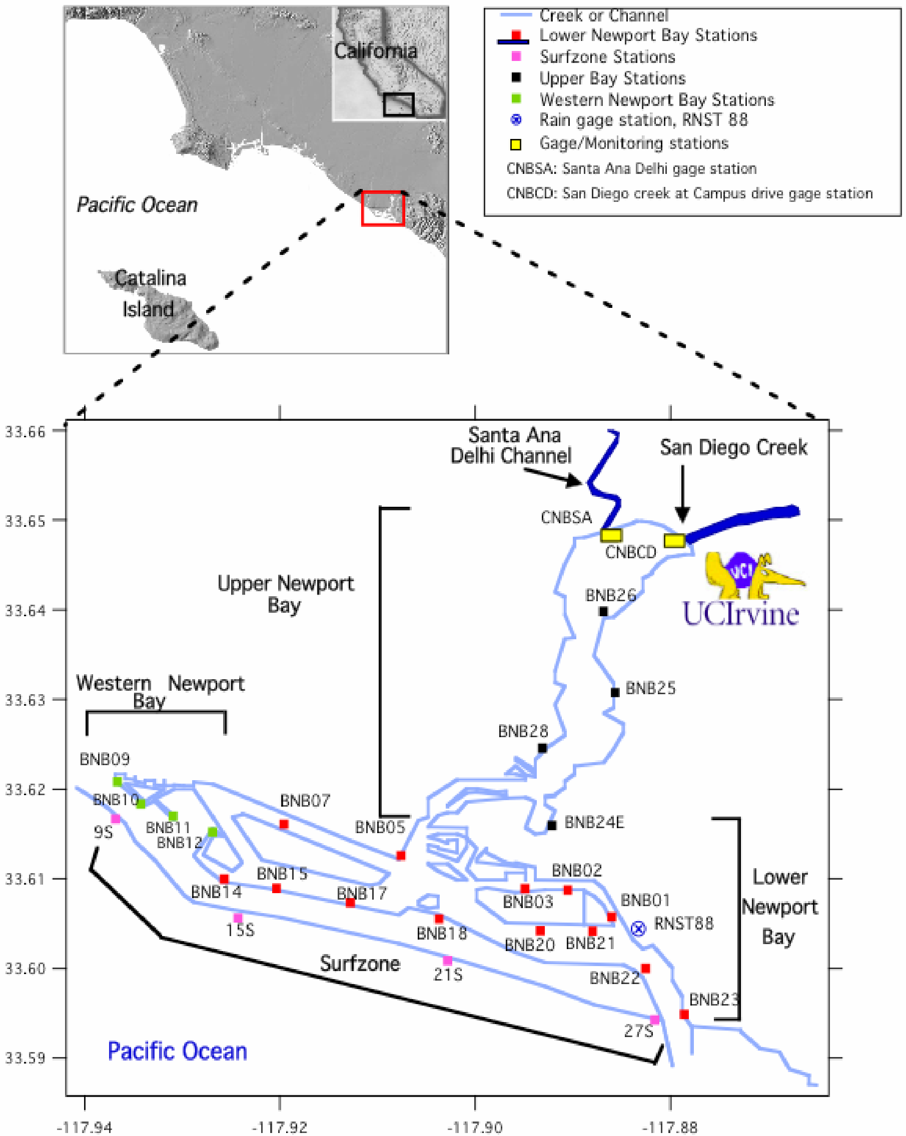


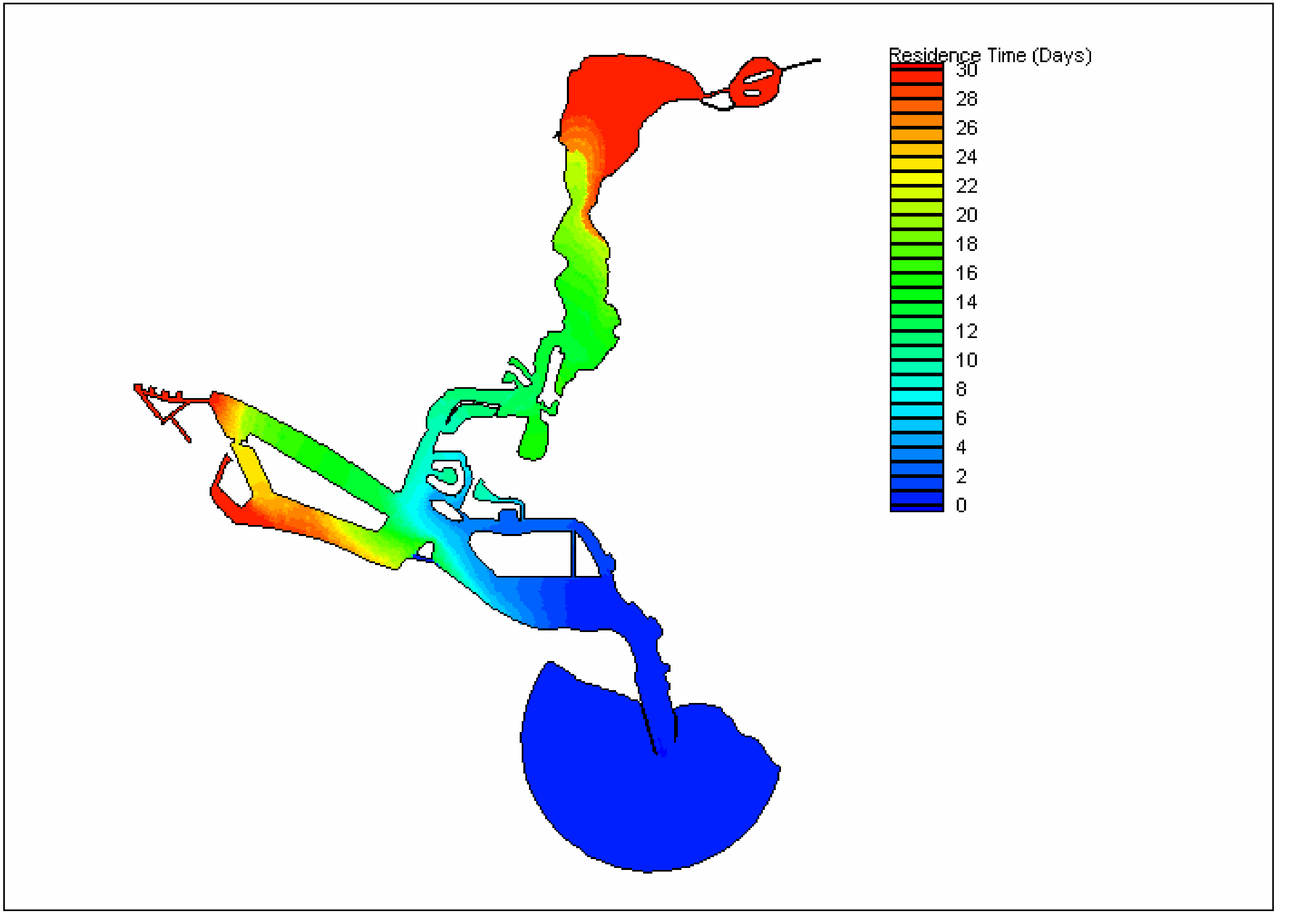
Fig. 1: Field site map indicating monitoring and gage stations and major creeks draining into Newport Bay

Pednekar et al., 2004

FIB concentration in the Bay depends on:

- Bacterial mass inputs from creeks and drains
- Sunlight intensity
- Tidal mixing

Residence Time Calculations for Newport Bay (from Dr. Ying Poon)



Simple reactor model of Upper Newport Bay

<u>Inputs:</u>

V: Mean volume of Bay

M: Bacterial mass input (daily)

T: Tidal prism (daily)

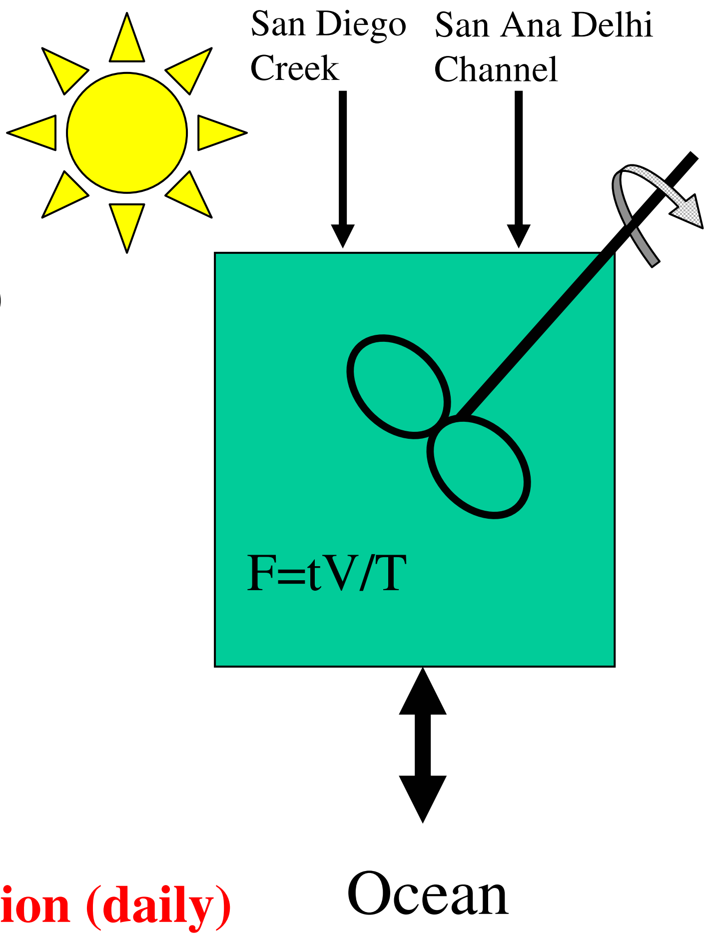
F=tV/T: Flushing time (daily)

D: UV modulated die-off

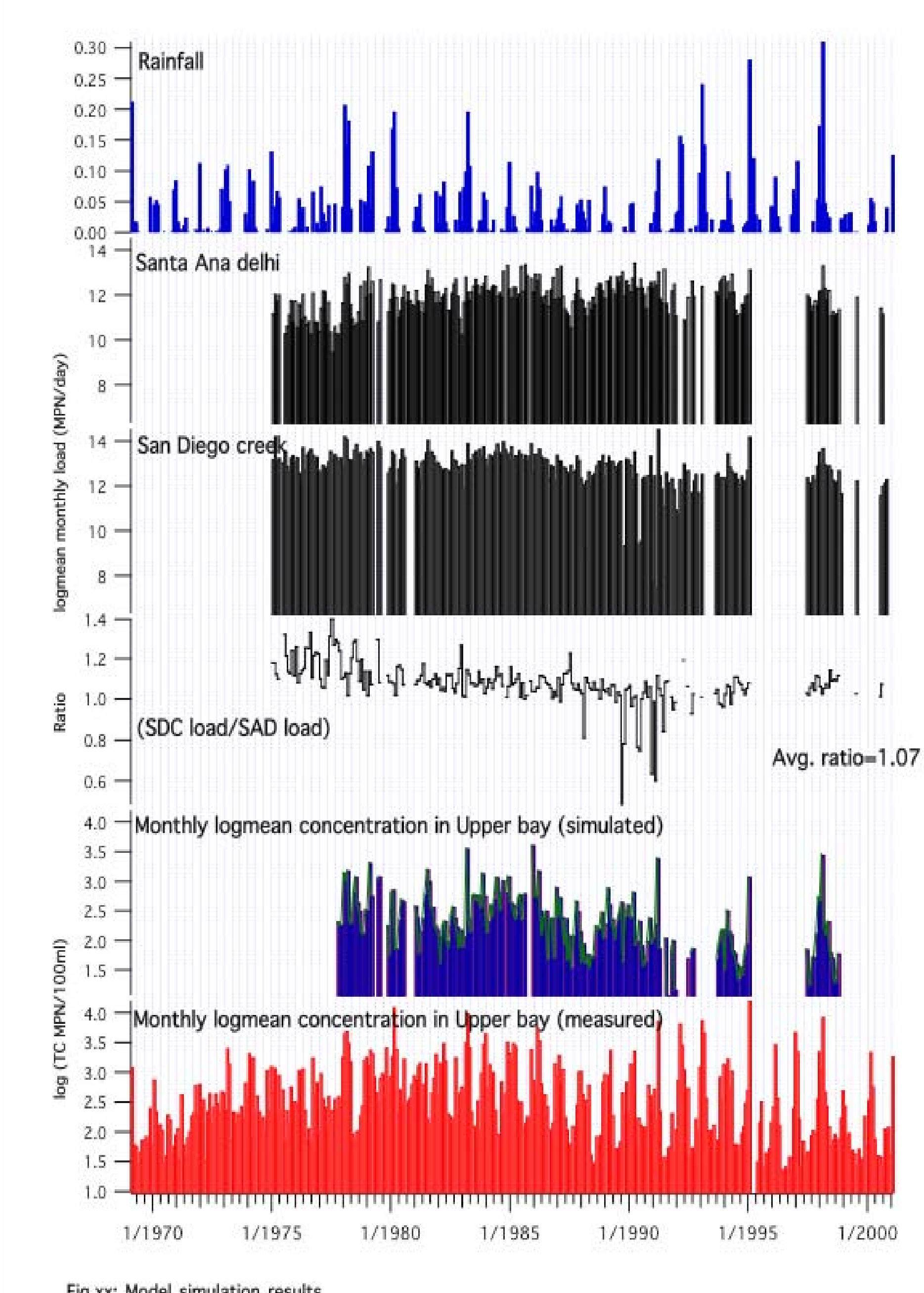
S: Solar insolation (daily)

<u>Output:</u>

C: Predicted FIB Concentration (daily)



Predicted vs Observed: 32 years of historical data



← Rainfall

← Mass in, SAD

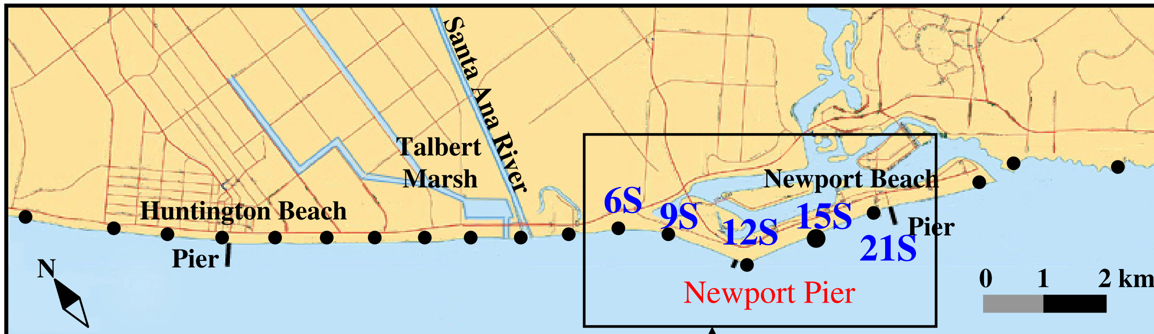
← Mass in, SDC

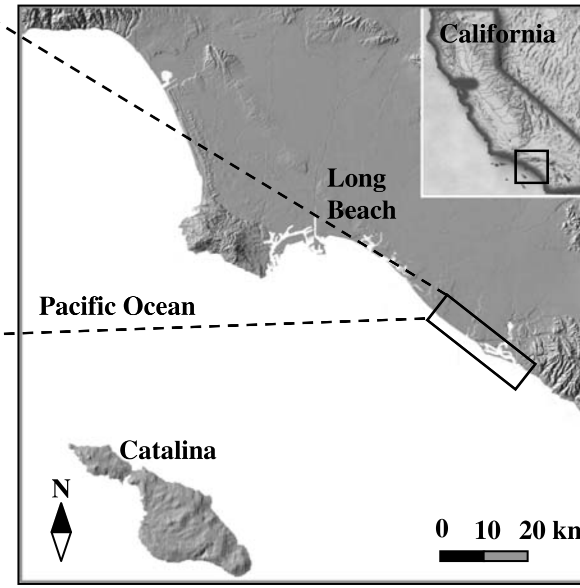
← Mass ratio, SDC/SAD

← Model simulations

← Historical Obs

AI example: Newport Beach





Sampling Stations;

6S: 52nd/53rd street

9S: 38th street

12S: Newport pier (NEOCO Site)

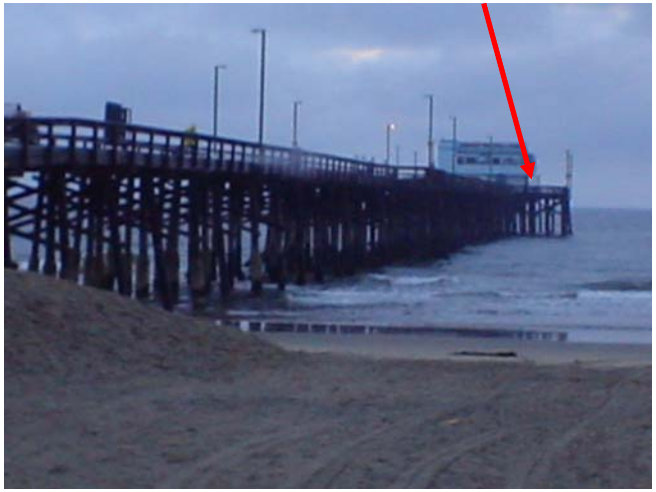
15S:15/16th street

21S: Balboa pier

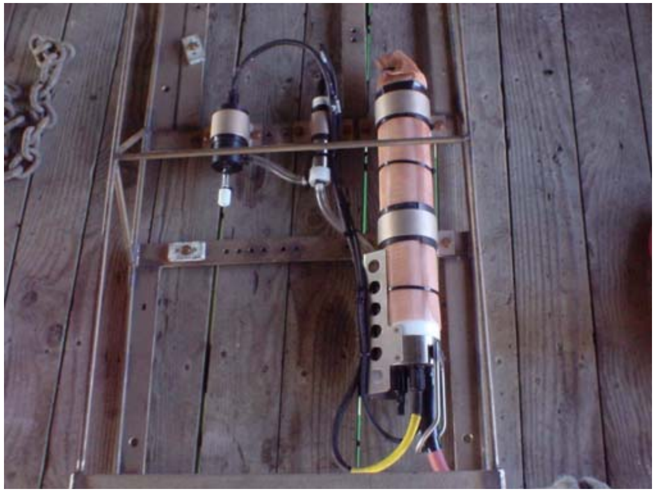
Newport pier NEOCO site and measurement sensor pictures (Measurement started on Jan. 28, 2004)

Newport pier sampling site (12S)

NEOCO site

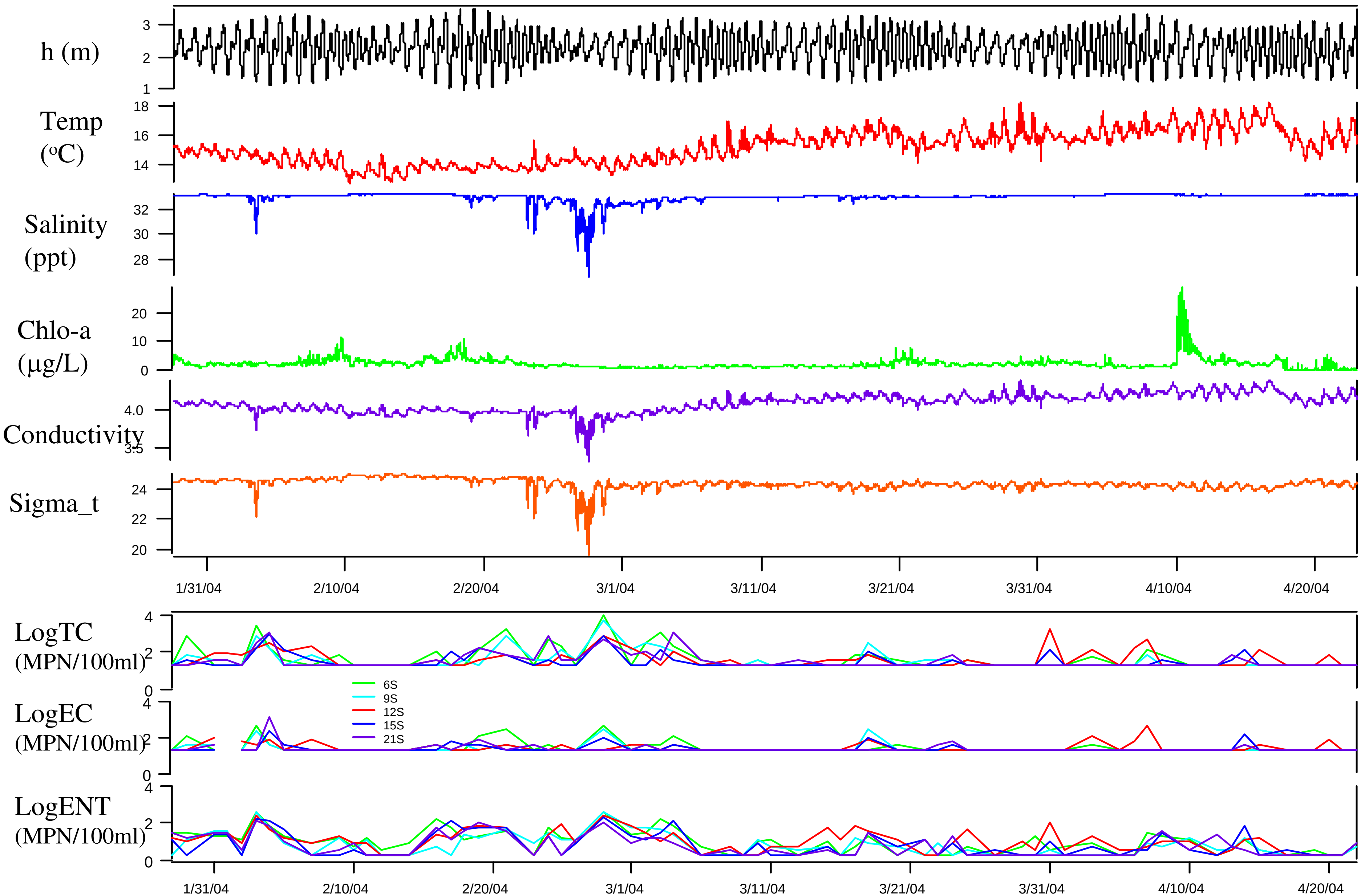


NEOCO sensor



NEOCO sensor deployed location (1m below minimum low-low tide)

NEOCO measurements and FIB records (01/28 - 04/22/2004)



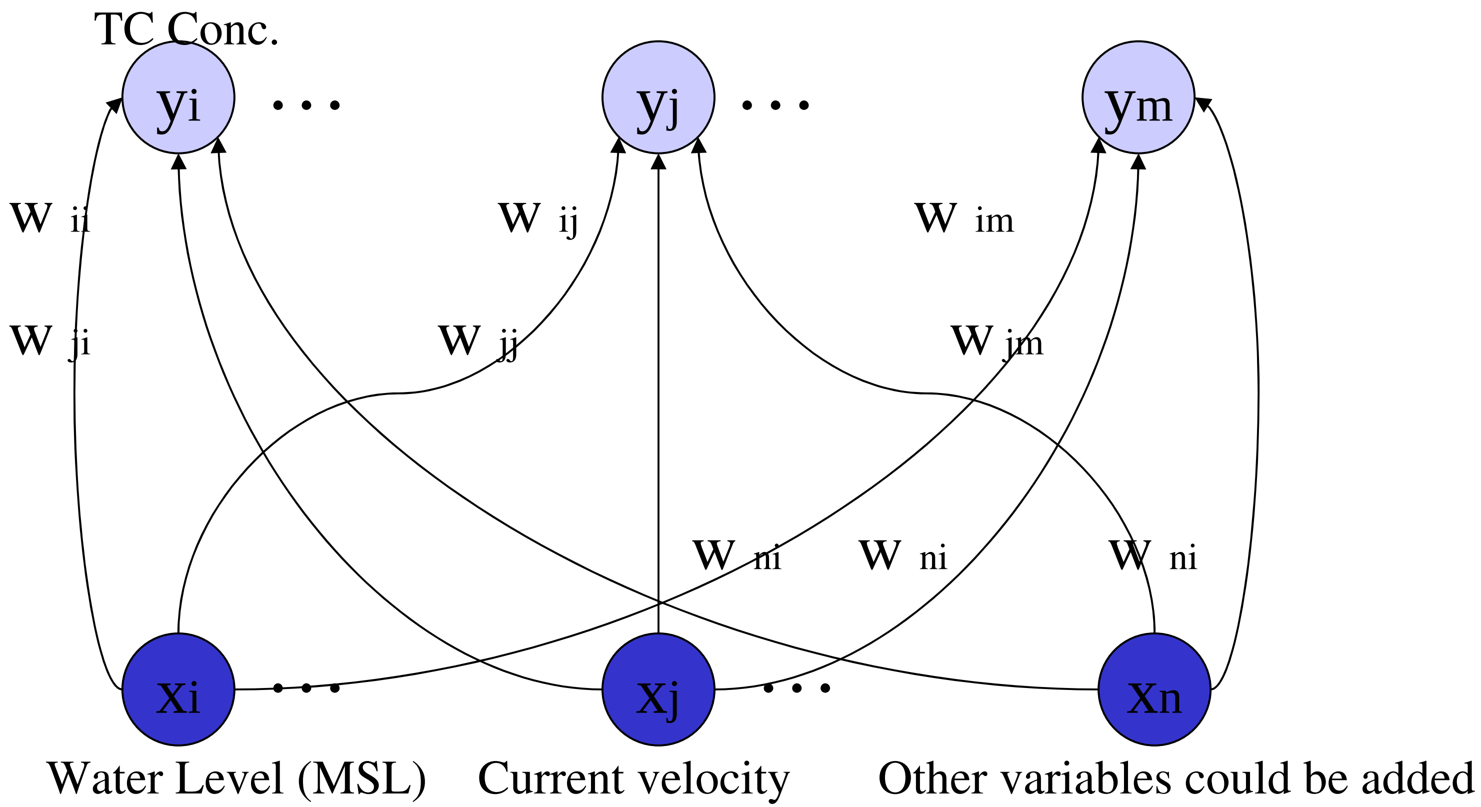
Architecture of Learning Vector Quantization (LVQ)

-How it works?

Classification based on the Euclidean distance between input and output value

Classify input value of TC concentration based on the level of pollution

(Clean (1): 0-1,000, Medium (2): 1000-10,000, Poor (3): >10,0000 (MPN/100ml)

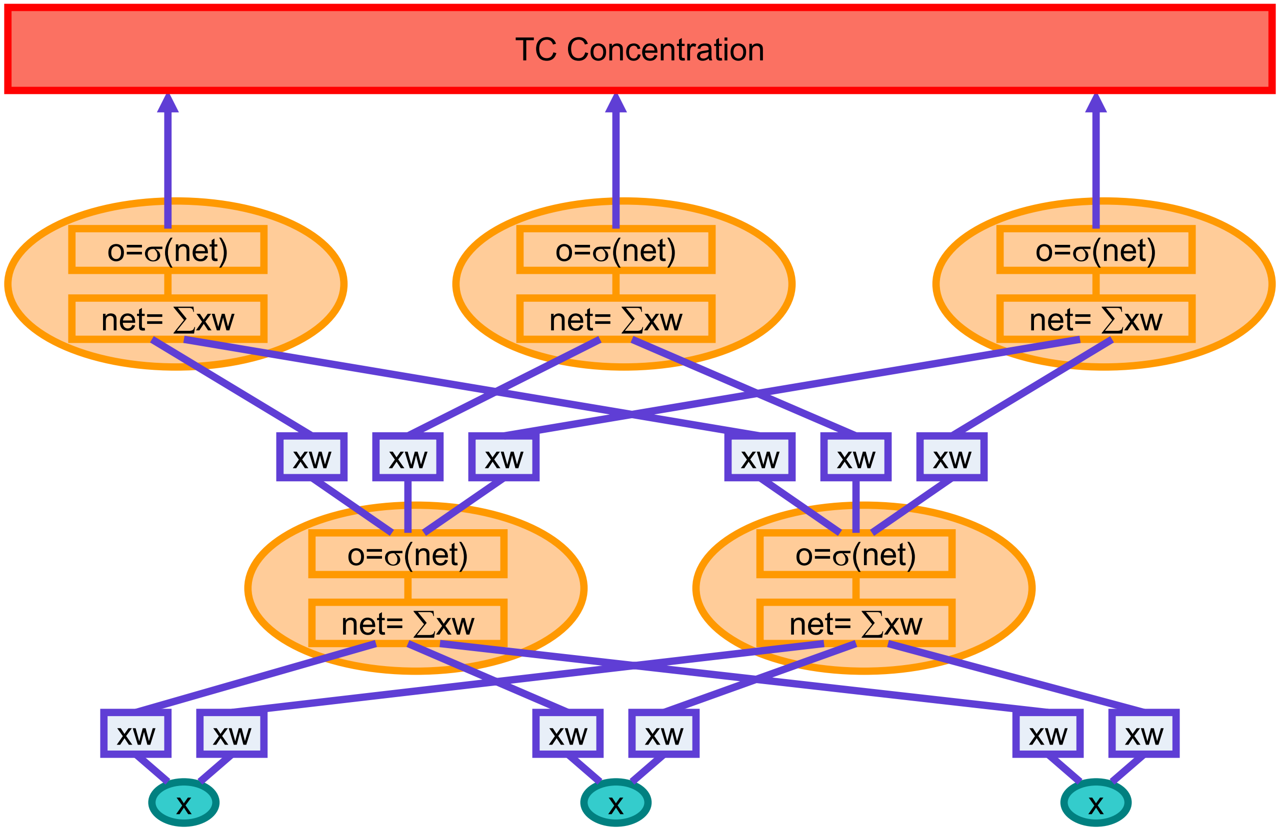


Architecture of Multilayer Perceptron (MLP)

-How it works?

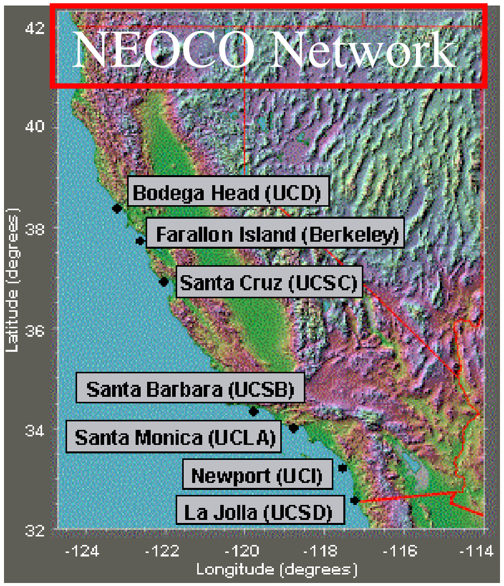
Predict output based on the minimization of root-mean-square error

Forecast the (real) values of TC concentration



Water Level (MSL) Current velocity Other variables could be added!

NEOCO (Network for Environmental Observations of the Coastal Ocean) Project



NEOCO
NETWORK FOR ENVIRONMENTAL OBSERVATIONS OF THE COASTAL OCEAN

Purpose: Establish centralized, long-term repository of high-resolution data obtained from the participating UC campus sites along the coast of California.

1) Concurrent measurement of physical, chemical, and biological parameters (Temperature, salinity, chlorophyll fluorescence, turbidity (light transmission), sea level (pressure) with every 4 minutes sampling frequency)
2) Link coastal time-series data with oceanic, atmospheric, and terrestrial time-series data
3) Ongoing records at UC marine stations, network of sites, and real time access through internet (http://www.es.ucsc.edu/~neoco/)

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CalSWIM: California Surfzone and Watershed Information Manager

- Web-based data repository and interactive water quality simulations (water quality version of SimCity)
- Focus on simple interactive models whose inputs can be easily modified by the user (e.g., to simulate how water quality would change in Newport Bay given certain management decisions in the watershed)

CalSWIM: Potential Applications

- A tool for forecasting or now-casting coastal water quality based on historical FIB data and physical variables (e.g., tide range) that can be accurately predicted.
- A tool for coastal managers to locate and utilize relevant historical and real-time data, and develop scientifically sound TMDL management plans
- A tool for K-12 educators to demonstrate human impacts on coastal resources

CalSWIM: Prototype

- Orange County has provided seed funding ($80K over 6 months) for:
  - Development of web platform (web site already up: www.calswim.org)
  - Uploading of GIS and some historical data for Newport Bay
  - Implementation of interactive water quality simulations for Upper Newport Bay (TMDL)

CalSWIM: Proposal

- Funding to:
  - Develop and implement interactive now-casting and forecasting at one or more beach sites
  - Locate, digitize, and upload California and/or national water quality data into the web site
- Guidance on:
  - Data issues (e.g., meta-data requirements, QA/QC standards)
  - Website “look, feel, and content”
  - How to increase the value of the end-product

Contact Information

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