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Chapter 6: Numeric Nutrient Criteria Development for Protection of Downstream Estuaries

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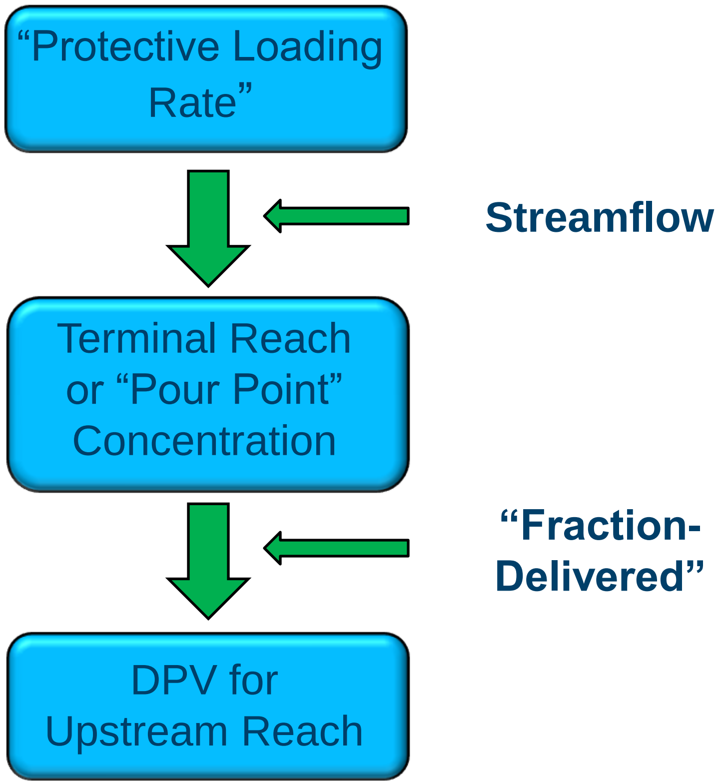
Outline

- Background on Downstream Protection Values (DPVs)
  - Terminal Reach DPVs
  - Upstream DPVs.
- Computing DPVs for Streams to Protect Estuaries
- LSPC Watershed Models
- Computing Fraction-Delivered
- DPVs for Southern Inland Flowing Waters

Background on Downstream Use Protection Values (DPVs)

- EPA regulations 40 CFR 131.10(b) require that criteria provide for the attainment and maintenance of water quality standards of **downstream waters.**
- TN and TP criteria that protect designated uses within streams themselves may not ensure attainment of uses in downstream estuaries.
- EPA is considering approaches for developing criteria for all locations in a watershed, including the “pour point” (i.e., where water enters the estuary), and upstream locations.
- As part of this approach, EPA is considering approaches that would account for retention and/or loss of TN and TP within the stream network.

Computing Downstream Protection Values



Computing Downstream Protection Values

- Estimate protective TN load (Chapter 3)
- (A) Scale loading by average freshwater inflow rate.

$$C_T = \frac{L_m}{\sum Q_f}$$

- (B) Compute upstream DPVs by accounting for N & P loss or retention: “average fraction-delivered," F_i

$$C_i = \frac{C_T}{\overline{F}_i}$$

Protective TN & TP load limit (L_m) for estuary (kg y^{-1})

A

DPV TN/TP concentration at "pour points," C_T (mg L^{-1})

B

DPV TN/TP concentration for individual streams, C_i (mg L^{-1})

Mechanistic Watershed Models

- EPA is considering using mechanistic watershed models to simulate hydrology throughout Florida, except for south Florida.
- Mechanistic models of hydrology can simulate:
  1. Freshwater flow volumes
  2. Average flow velocity
  3. Average water depth
- EPA is considering implementing the Loading Simulation Program in C++ (LSPC) for watershed modeling, which is based on HSPF

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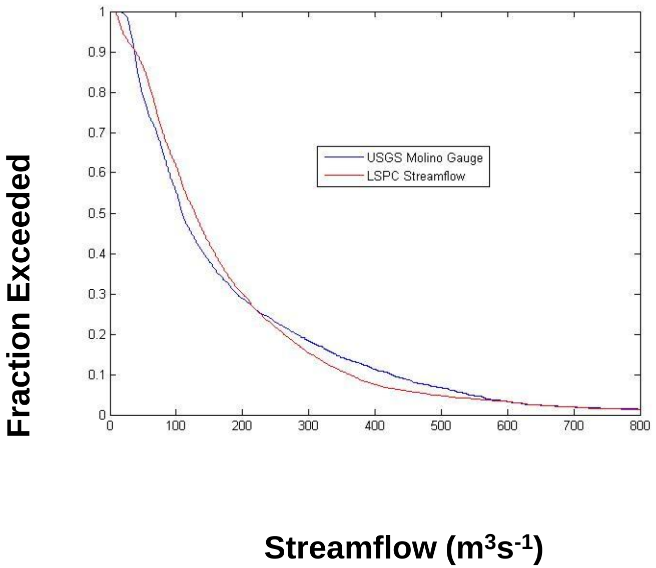
Model Evaluation

- Calibrations attempt to simulate observed stream flow at a variety of temporal scales: long-term, seasonal, high flows, low flows, storm events.
- Several stream gauges used in calibrations.
- Velocity calibrated by adjusting Manning's n (roughness) parameter.



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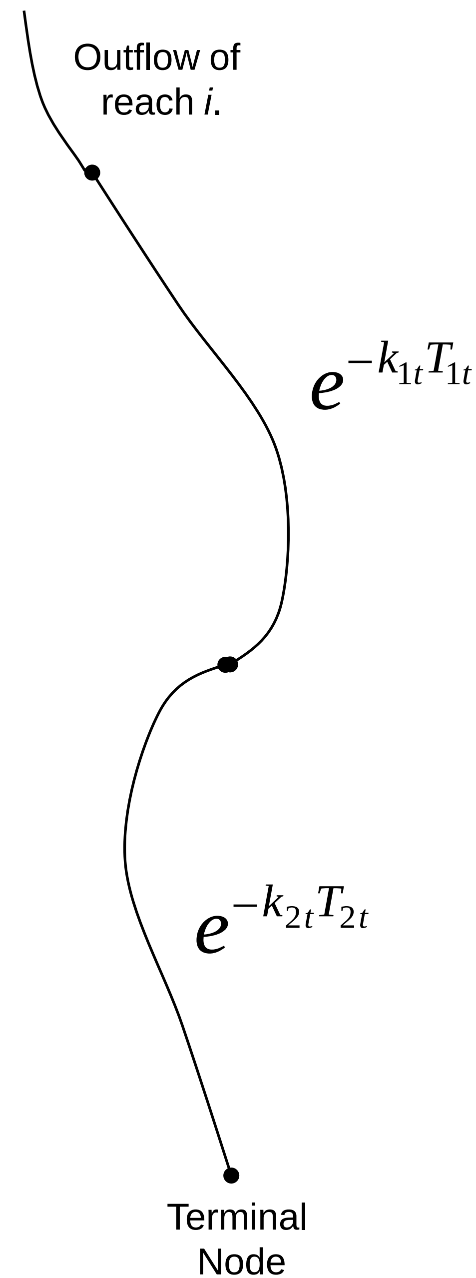
Computing Average Fraction Delivered

Fraction-delivered for reach *i* on day *t*:

$$F_{it} = \prod_{J} e^{-k_{jt} T_{jt}}$$

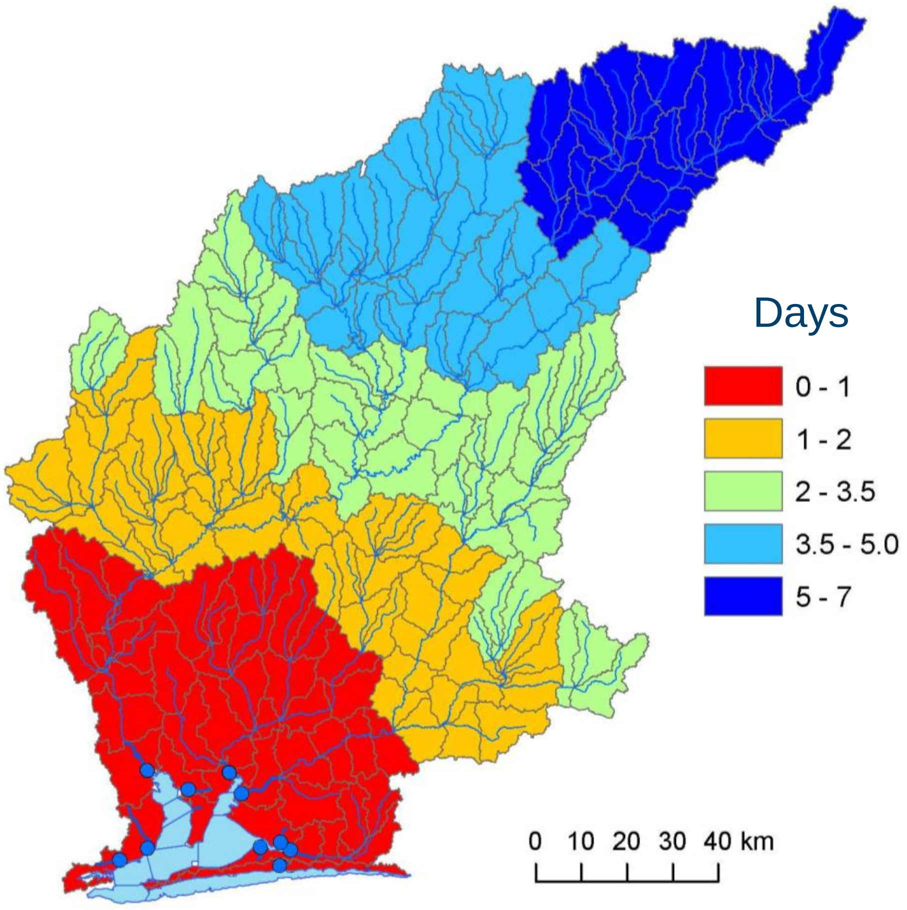
- ***J*** is the sequence of reaches between ***i*** and a terminal reach.
- **k** is the first-order TN loss rate (day^{-1}) in reach ***j*** on day ***t*** and depends on flow (Q).
- **T** is the time-of-travel (days) in reach ***j*** on day ***t***.

➢ Average fraction-delivered is computed by averaging across all days.



Computing Reach Time of Travel

- Time of travel computed from simulated daily average stream velocity for each reach on each model day.
- Pensacola Bay watershed model has 224 sub-watersheds and representative reaches, 12 of which are terminal reaches.
- Model simulates 14 years.



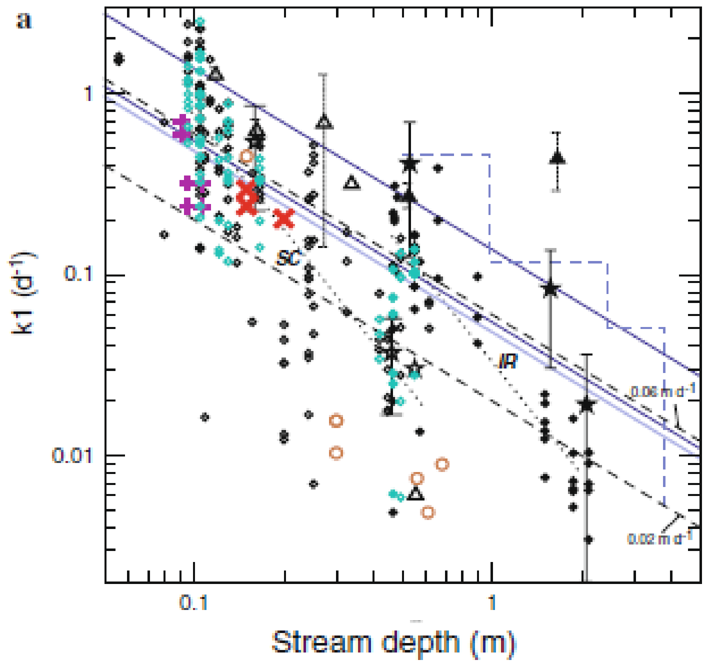
Average Time of Travel
to Estuary

First-Order Loss Rate for Total Nitrogen

- TN loss rate generally decreases with stream depth, but with considerable variability.
- Also decreases with stream discharge (deeper streams usually have higher discharge).
- Empirical estimates from South Atlantic/Gulf/Tennessee SPARROW model (Hoos and McMahon 2009).

Avg. Q ($m^3\ s^{-1}$)	k (day^{-1})
< 28 $m^3\ s^{-1}$	0.14±0.05
> 28 $m^3\ s^{-1}$	0.014±0.02

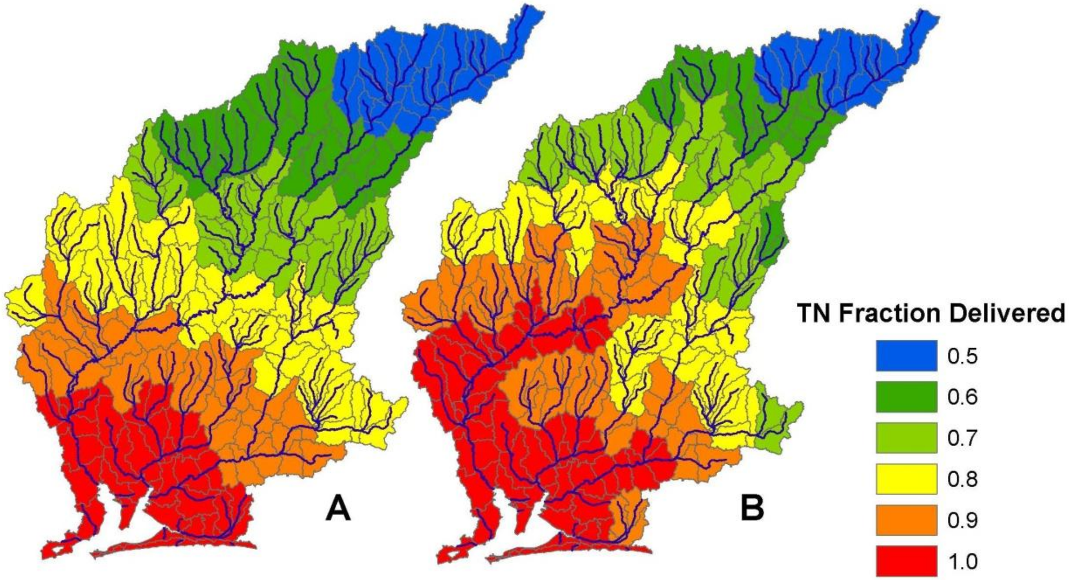
First-Order Decay of NO_3^-



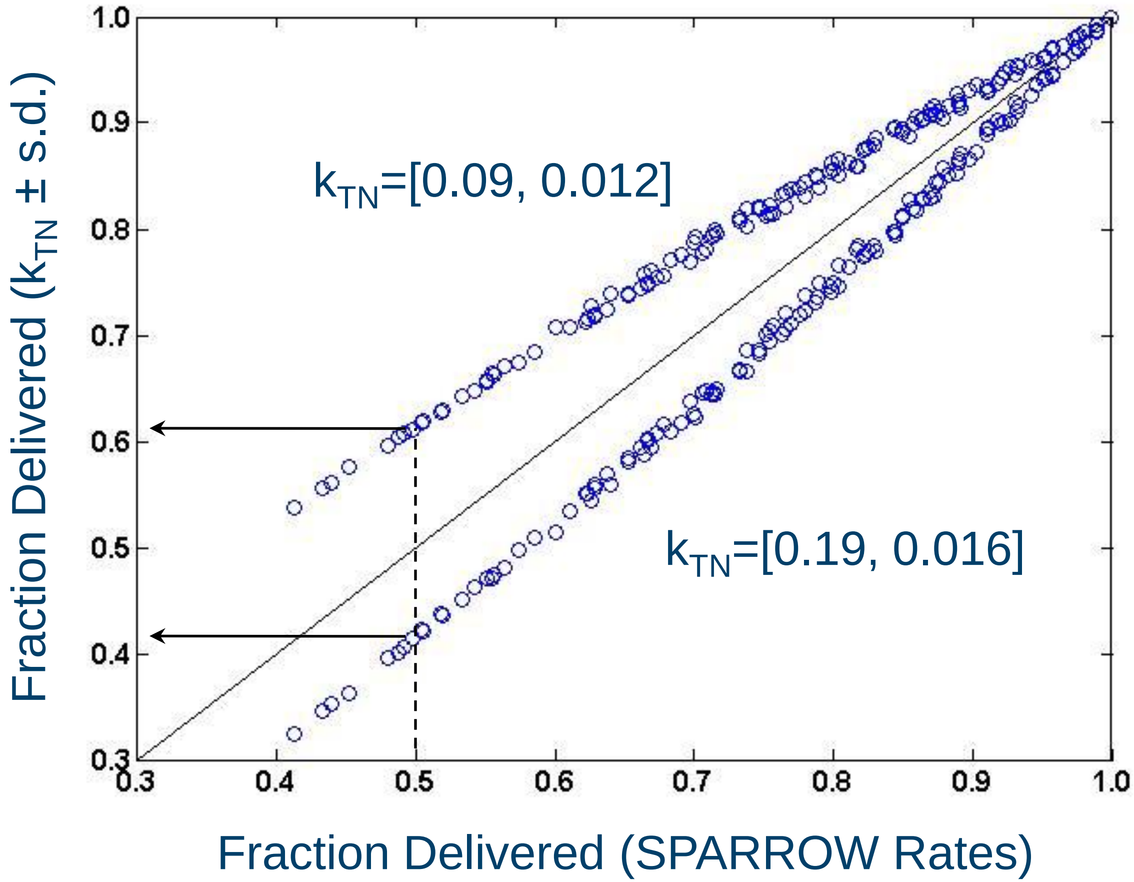
Bohlke et al. 2009

Computed TN Fraction-Delivered

- Fraction-delivered depends on approach for specifying k_{TN}.
- Values generally between 0.5 and 1.0.
- Using constant k_{TN}=0.14 d^{-1}, fraction-delivered corresponds directly to time-of travel (A)
- Fraction-delivered higher along larger streams and rivers using flow-dependent k_{TN} (B)



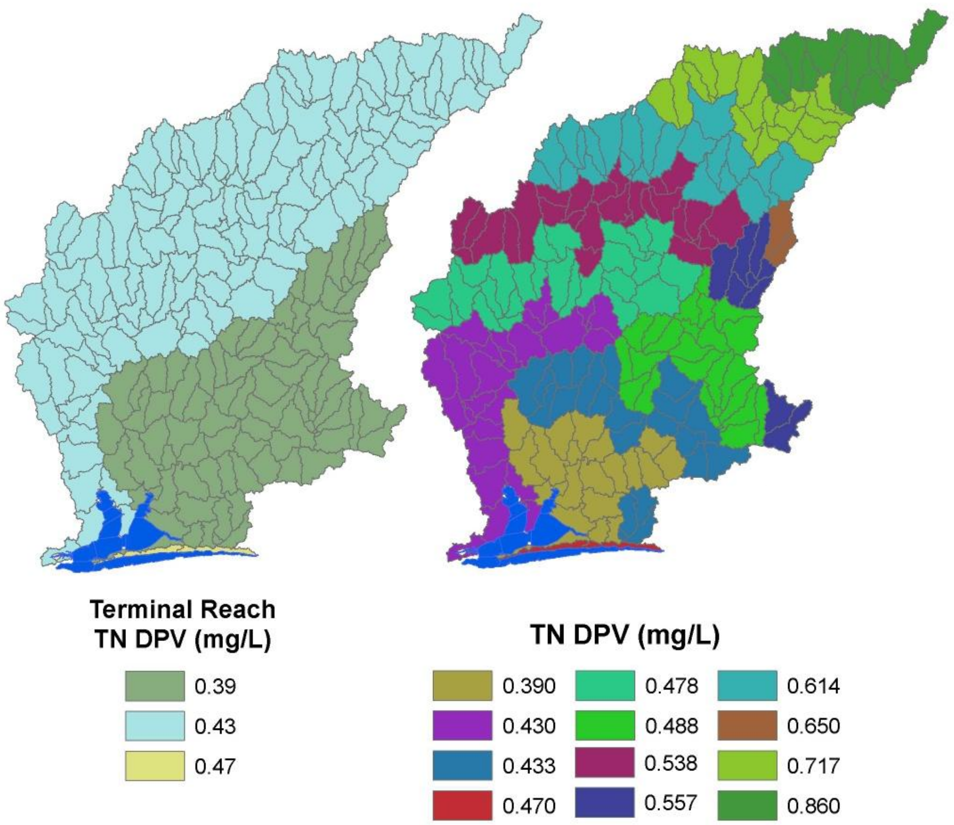
Dependence of Fraction Delivered on TN Loss Rate (k_{TN})



- Uncertainty due to TN loss rate estimates from SPARROW is ±10% on longest, slowest flow paths.
- Uncertainty decreases as time-of-travel decreases.

Computation of TN DPVs

- Differing "terminal reach" criteria … create "zones."
- Reduce number of DPVs by "binning" FD values.
- Hypothetical application with 3 "zones" creates 12 DPVs.
- Recently promulgated stream criteria for TN limits P'cola streams to 0.67 mg N L^{-1}.
- If DPVs become very high due to low fraction-delivered, IPVs will apply.

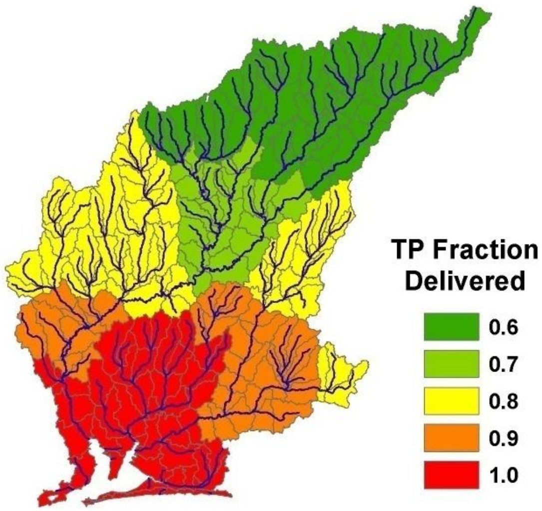


Total Phosphorus Retention

- TP is "retained" in watersheds rather than "lost."
- Different perspectives on P retention in stream networks:
  - Permanent P retention in streams is minimal; P accumulates only in lakes and reservoirs along the flow-path.
  - P is retained in shallower channels and is transported in deeper channels. Leads to dynamic similar to nitrogen.
- TP SPARROW model for southeast region estimates first-order loss (i.e., retention) parameter (d^{-1}) as:

$$k_{TP} = \frac{0.049}{\bar{z}}$$

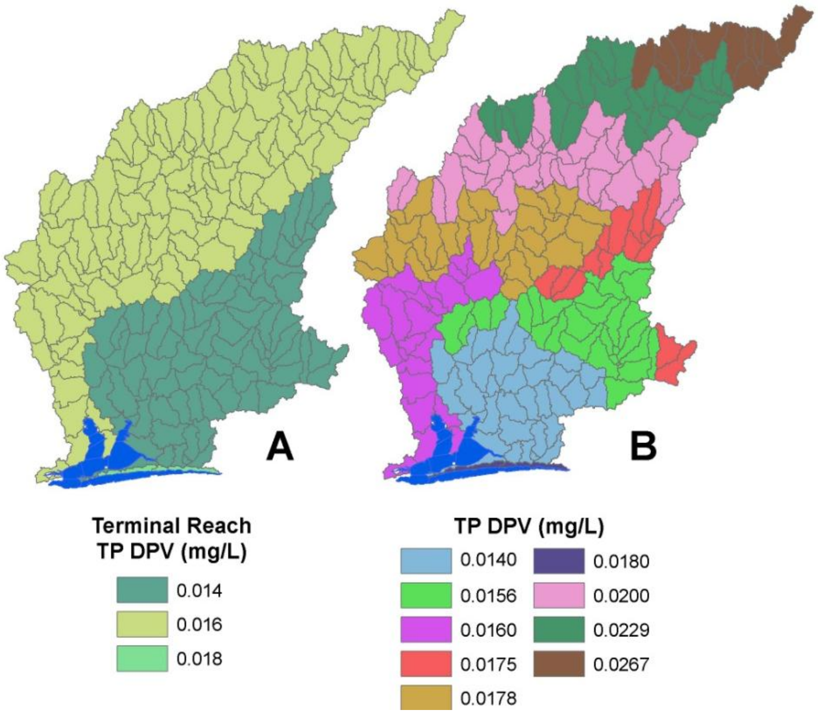
where z (meters), supporting second approach.



TP Fraction-Delivered based on k_{TP} from SPARROW model.

Computation of TP DPVs

- Similar approach as for TN…
- “terminal reach zones.”
- Reduce number of DPVs by “binning” FD values.
- Hypothetical application with 3 “zones” creates 9 DPVs.
- Applicable IPV for TP is 0.06 mg/L.



Downstream Protection Values for Southern Inland Flowing Waters

- Concerned with ensuring protection of marine receiving waters in South Florida by establishing DPVs for Southern Inland Flowing Waters, such as canals.

Downstream Protection Values for Southern Inland Flowing Waters

- EPA is considering a different approach for south Florida. Specifically,
  - DPV could be expressed as a load limit rather than a concentration.
  - EPA could apply DPVs only at terminal reaches, rather than throughout the canal system.
- Why:
  - South Florida hydrology highly altered to meet human needs.
  - Water flows in canal system artificially-controlled via water control structures (pumps, gates).
  - Cannot use hydrological models developed for (mostly) natural hydrological processes.

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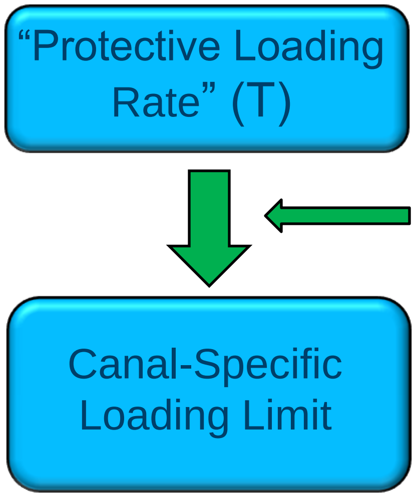
Downstream Protection Values for Southern Inland Flowing Waters



Total Canal Outflow (q_t)

$$L_i = T\left(\frac{q_i}{q_t}\right)$$

(eq. 6-5)

Alternative (eq. 6-6)

$$T = L_1 + L_2 \ldots + L_n$$

- Protective total loading rate (T) for marine receiving waters estimated using approaches in Chapter 5.
- L_i would apply at the terminal pump-station or gate for each canal.
- Alternative simply limits total load, without flow-based apportionment.

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Expression of Downstream Protection Criteria

- Objective of DPVs is to limit pollutant loading to the receiving water.
- Most accurate if concentrations are evaluated within in the context of flow (i.e., flow-weighted) and/or season.
- EPA is considering whether to apply DPV criteria
  - as flow-weighted averages,
  - as values empirically adjusted to account for differences resulting from season and flow levels
  - as independent observations without regard for these factors.

Charge Questions

a) Are the methods EPA is considering for deriving downstream protection values (DPVs) for estuaries (excluding marine water in South Florida) appropriate to ensure attainment and maintenance of downstream water quality standards, given available data? Please describe additional approaches that EPA should consider when developing numeric criteria to protect these downstream waters, given available data.

b) Are the methods that EPA is considering for deriving DPVs for marine waters in South Florida appropriate to ensure attainment and maintenance of downstream water quality standards, given available data? Please describe additional approaches that EPA should consider when developing numeric criteria to protect downstream marine waters in South Florida, given available data.