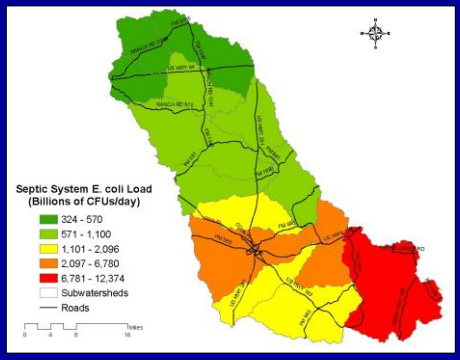
Using Simple Tools or Non-Model Tools

(Alternatives to Mechanistic Models)

Introduction to Watershed Modeling Training



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Key Definition

Mechanistic Model:

- A model that has a structure that explicitly represents an understanding of biological, chemical, and/or physical processes.
- These models attempt to quantify phenomena by their underlying casual mechanisms.

Source: EPA website, glossary of frequently used modeling terms and WPP Handbook

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Why Consider Alternatives to (Mechanistic) Models

- Resource limitations
  - Amount of monitoring data available
  - Time or budget constraints
- Level of "sophistication" requirements
  - bacteria impairments in Texas often addressed with simpler approaches

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Alternative Approaches

- Load duration curves
- GIS land-use based methods
- Export coefficients
- Empirical methods
- Other methods

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Advantages of Alternative Approaches (as compared to mechanistic modeling approaches)

- Less resource intensive
  - Less time, money, and staff commitment
  - Typically requires less monitoring data
  - Less experience required to apply
- Often more easily communicated to stakeholders and interested parties

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Disadvantages of Alternative Approaches (as compared to mechanistic modeling approaches)

- Typically not predictive or not rigorously predictive, thus limited in abilities to evaluate control measures & BMPs
- Typically lacks quantitative link between sources of pollution and receiving water body quality

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Load Duration Curves

- Applicable for determining allowable loading of pollutants and percent reductions needed to restore water quality in streams & rivers
- Uses observed daily streamflow data
- Considers relevant water quality criteria
- Combines observed flow and criteria to establish a curve of loading capacity
- Can be enhanced with observed water quality data
- Frequently used with GIS land-use methods for situations of bacteria impairments

For more information see:

USEPA 2007. An Approach for Using Load Duration Curves (EPA 841-B-07-006)

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Load Duration Curves (continued)

- Combines measured concentrations of a pollutant with flow at the same time to develop a load
- The LDC illustrates the load of a pollutant versus the time that a given load is exceeded
- Time is illustrated as percentage of time
- Able to see if a stream is exceeding the standard in terms of load (flow and measured concentrations)
- Able to calculate a percent reduction based on flow categories

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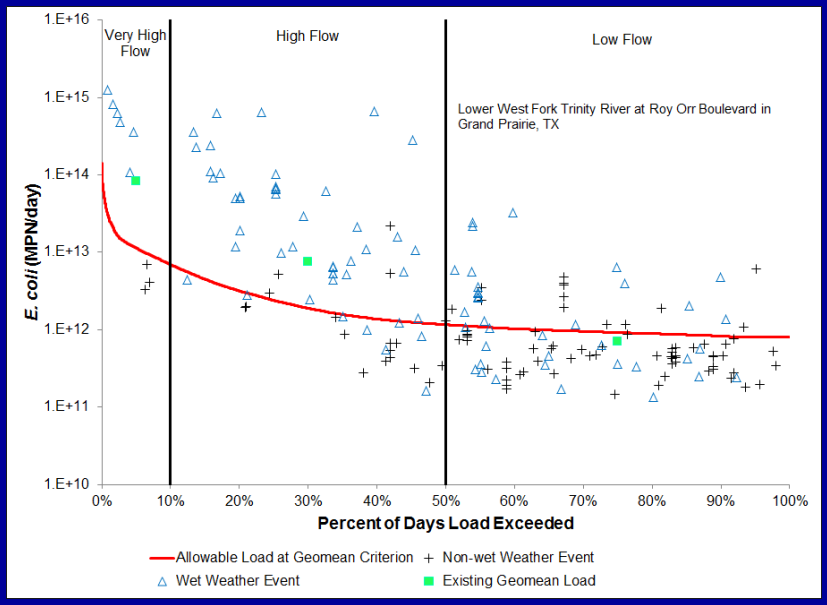
An Example Load Duration Curve



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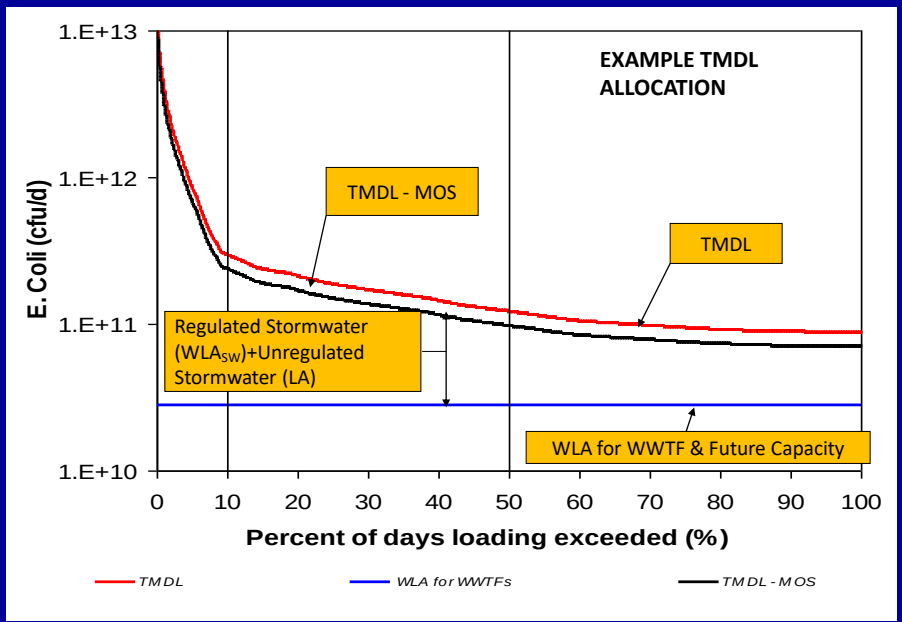
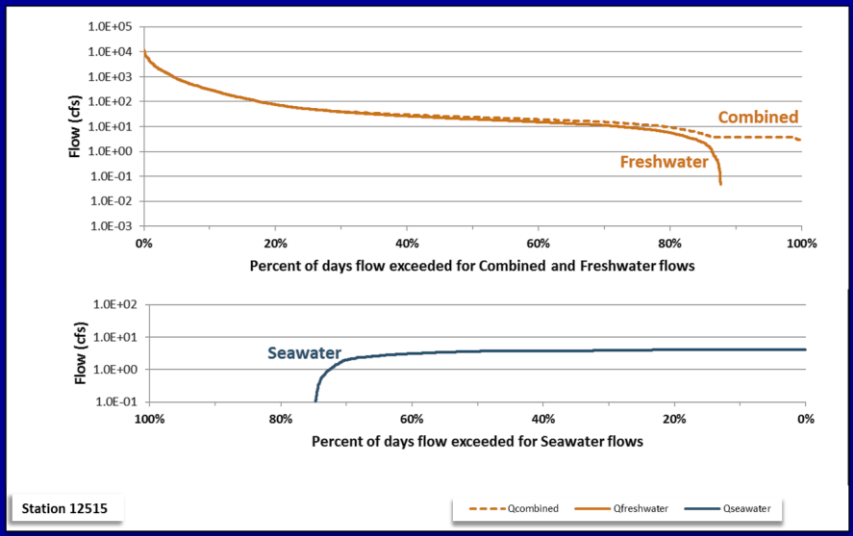
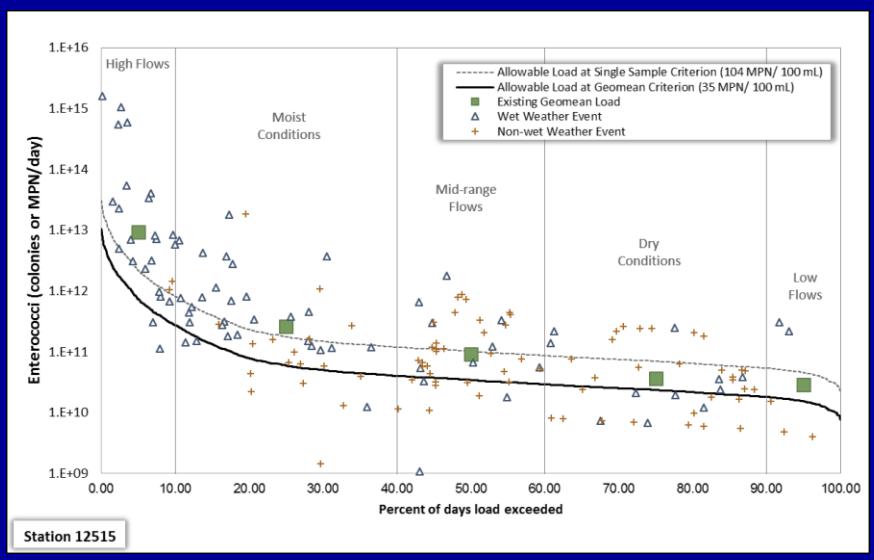
TMDL = WLA_{WWTF} + WLA_{SW} + LA + Future Growth + Margin of Safety



Modified Flow & Load Duration Curves Applied to Tidal Streams



Results for Station 12515, Tres Palacios Creek Tidal



Results for Station 12515, Tres Palacios Creek Tidal

Advantages of Load Duration Curves

- Widely accepted and used in Texas
- Only moderate data requirements
- Ease of application
- Identifies allowable loading for all flow conditions
- When combined with monitoring data, identifies existing loading for all flow conditions and can provide percent reduction required
- Readily communicated to stakeholders

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Disadvantages of Load Duration Curves

- Only identifies broad categories of sources (i.e., nonpoint source and point source) – not a problem if sources already well understood
- Does not quantitatively link sources to receiving water body quality
- Generally applicable only to non-tidal streams (selectively applicable in transition zones of reservoirs & in weakly tidal streams)
- Not readily applied in predictive mode (e.g., to evaluate control measures & BMPs)

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GIS Land-Use Based Methods

- Applicable for determining likely sources of loadings of pollutants and areas of highest loadings and facilitating stakeholder interactions
- Can use readily available GIS data layers
  - Digital elevation models (DEMs)
  - Land use/land cover (e.g., NLCD 2006)
  - Soil layers (NRCS STATSGO & SSURGO)
  - Stream networks (USGS NHD), etc.
- Can use other readily available data sources
  - For example, USDA Agricultural Census Data

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One Land-Use Based Method SELECT

- Spatially Explicit Load Enrichment Calculation Tool (SELECT)
- GIS based tool
- Originally used Visual Basic frontend for easier interface
- Recently updated to Python frontend compatible with later versions of ArcGIS (pySELECT)
- Developed at Texas A&M University

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Examples of Input Included in SELECT

- Census Blocks (U.S. Census Bureau)
- Soils (USDA-NRCS)
- Digital Elevation Map (BASINS)
- Urban Areas (TCEQ)
- Sub-watersheds & stream network
- Livestock
  - Stakeholder input
  - Agricultural Statistics (USDA)
  - Poultry Operations within the watershed (TSSWCB)
- Wildlife
  - Stakeholder input
  - Wildlife experts input, Resource Management Unit data for Deer (TPWD)

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Examples of Sources Considered in SELECT

- Range and pastured cattle
- Animal feeding operations
- On-site sewage facilities (septic)
- Domestic wastewater treatment facilities
- Urban runoff
- Dogs
- Wildlife (e.g., deer)
- Feral hogs

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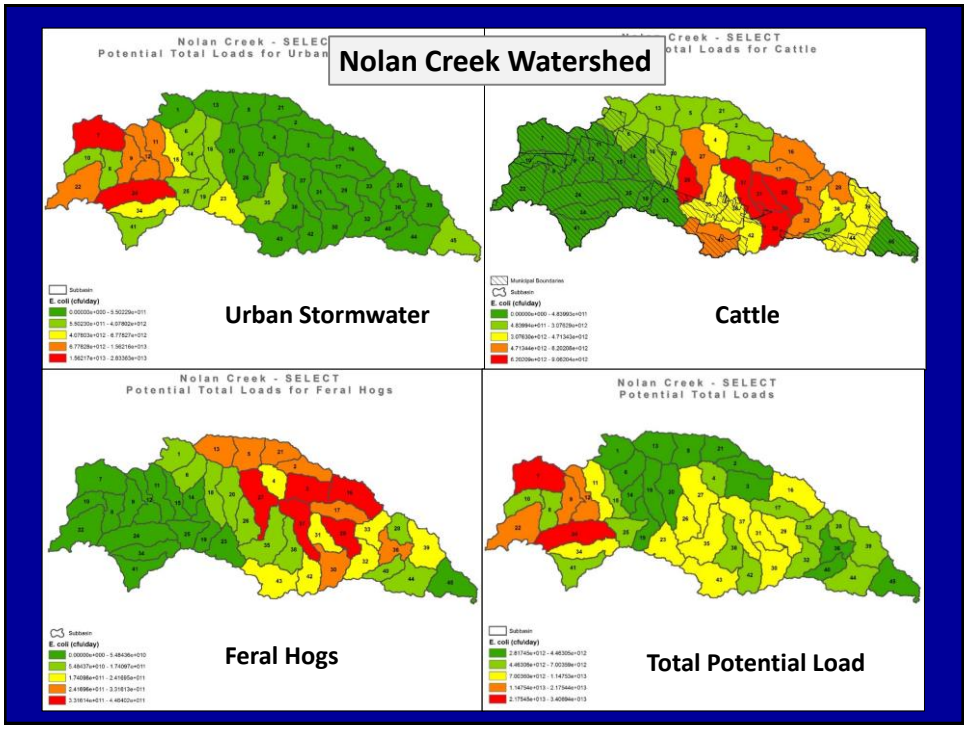
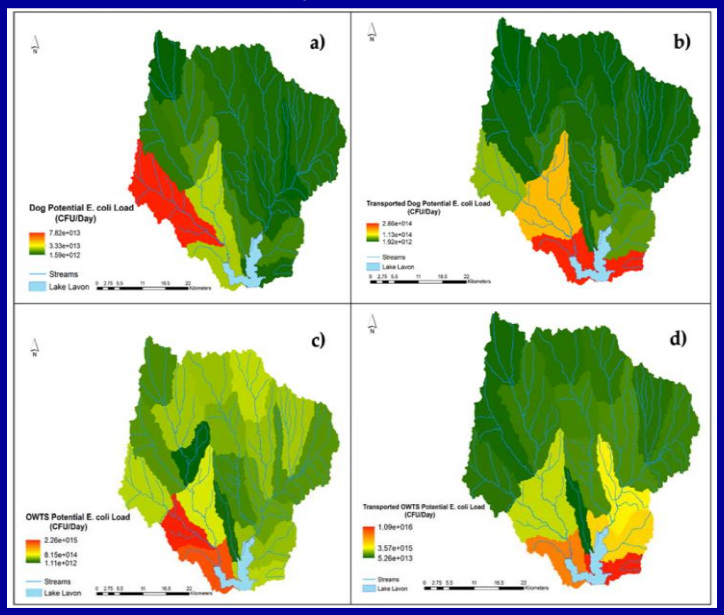


Example Results from pySELECT, Lake Lavon watershed



Source: Borel et al., Modeling the Dispersion of E. coli in Waterbodies Due to Urban Sources: A Spatial Approach. Water 2017. (9)

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Advantages of GIS Land-Use Based Methods

- One such tool has been developed in Texas (SELECT) and has been successfully applied in Texas watersheds
- Uses readily available data sources
- Relative ease of application
- Readily communicated to stakeholders
- When properly used can facilitate stakeholder input & interest (project buy-in)
- Can locate areas for control measure and BMP implementation

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Disadvantages of GIS Land-Use Based Methods

- Can evaluate only potential loadings and not actual loadings of pollutants
- Does not quantitatively link sources to receiving water body quality
- Not readily applied in predictive mode (e.g., to evaluate control measures & BMPs), but could be based on best professional judgment
- SELECT – present applications limited to bacteria, but should be adaptable to other pollutants

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Export Coefficients

- An export coefficient is the loading of a specific pollutant per unit area for a specific land use and time period
- Examples:
  - Kilograms/hectare/year of lead from industrial land use
  - Pounds/acre/month of phosphorus from cultivated agricultural fields

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Export Coefficients

- Applicable for determining pollutant loadings, likely sources of loadings of pollutants & areas of highest loadings
- Values can be obtained in literature from regional and national studies
- Requires GIS land use/land cover data layer (typically readily available from various sources)
- Approach amenable to including point sources or permitted discharges

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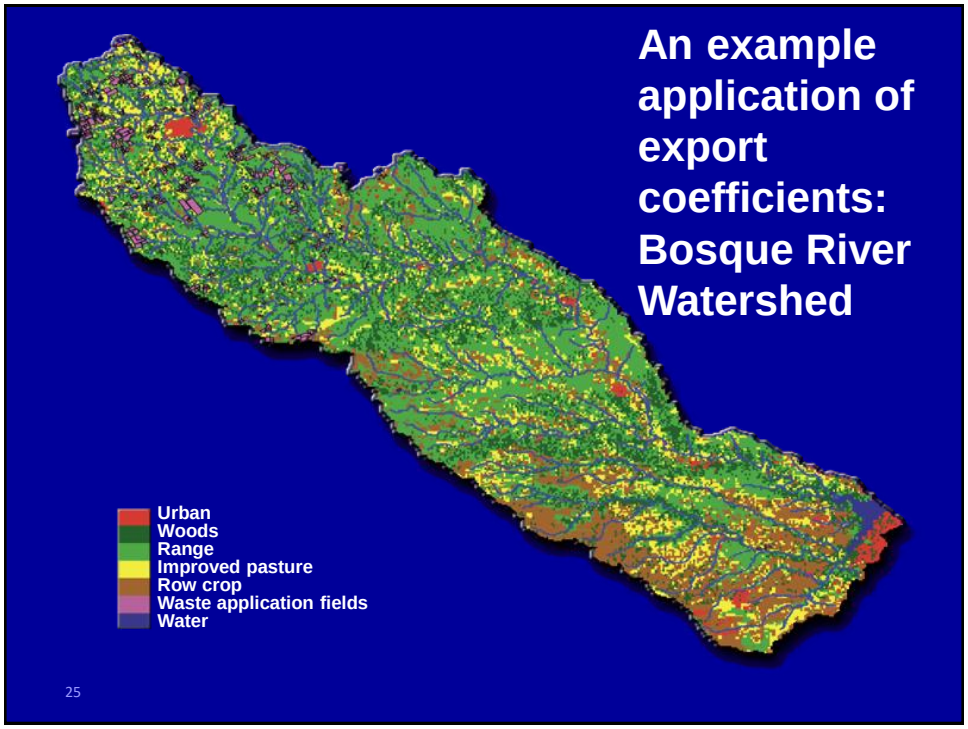

Soluble Reactive Phosphorus (PO_4-P) Export Coefficients Estimated Using Multiple Regression Models

DATA: 1 November 1995 – 30 March 1998

Land Use	Export Coefficient
Wood/Range	0.07 lb PO_4-P / ac /yr
Pasture/Cropland	0.14 lb PO_4-P / ac /yr
Urban	0.98 lb PO_4-P / ac /yr
Dairy manure application fields	3.08 lb PO_4-P / ac /yr

Source: McFarland and Hauck (1998), McFarland and Hauck (2000)

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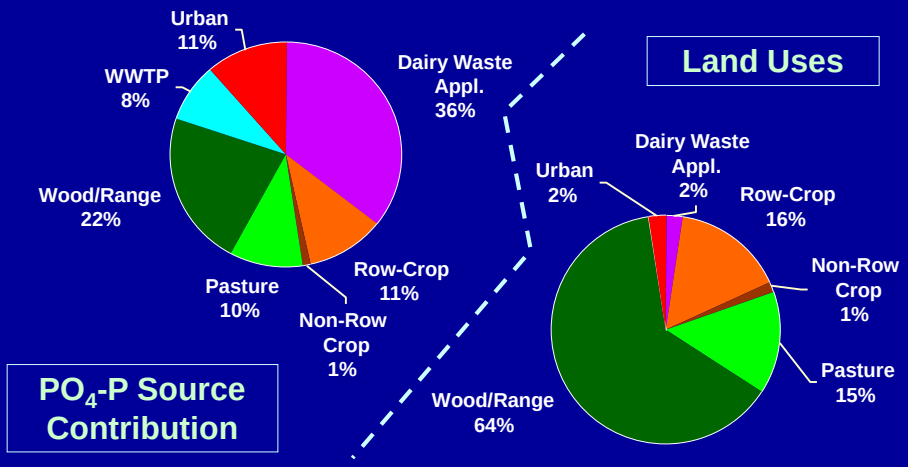
Bosque-Lake Waco Watershed

01 Nov 95 - 30 Mar 98



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Advantages of Export Coefficients

- Limited watershed specific water quality data requirements, unless developing project specific export coefficients
- Uses readily available data sources
- Ease of application
- Readily communicated to stakeholders
- Can locate land-use types for control measure and BMP implementation

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Disadvantages of Export Coefficients

- May not quantitatively link sources and loadings to receiving water body quality
- Not readily applied in predictive mode (e.g., to evaluate control measures & BMPs), but could be based on best professional judgment

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Empirical Methods

- Applicable for determining loadings of pollutants; sometimes even allowable loadings
- Various methods available
  - Simple Method – for small urban catchments
  - Vollenweider approach – allowable phosphorus loadings to meet desired trophic level based on lake characteristics

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Empirical Model or Method:

- A model where the structure is determined by the observed relationship among experimental data.
- These models can be used to develop relationships for forecasting and describing trends.
- These relationships and trends are not necessarily mechanistically relevant.

Source: EPA website, glossary of frequently used modeling terms.

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An Example of an Empirical Model:

- Investigating the relationship of inflowing nutrients in a lake to algal biomass production (eutrophication).
- Most early (circa 1970) lake eutrophication models based on statistical relationships between mass loading of nutrients and average algal biomass (e.g., Vollenweider models with numerous adaptations by others)
- Applied to PL-566 reservoirs in North Bosque River Watershed

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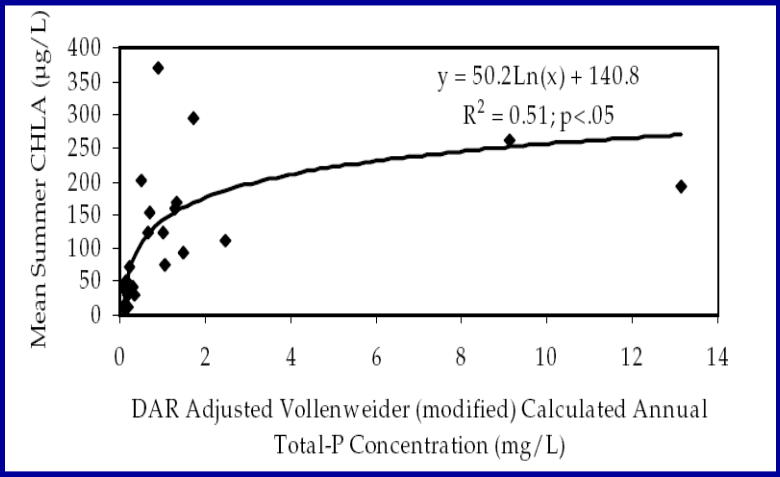
Example of an Empirical Approach Used in Data Analysis



Annual mean summer chlorophyll-a concentration as a function of predicted total-P for years 1993-1998 from PL-566 reservoirs. N=25

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Advantages of Empirical Methods

- Limited watershed specific water quality data requirements, unless developing project specific empirical relationships
- Uses readily available data sources
- Ease of application
- If applicable to your situation, significant savings in commitment of resources

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Disadvantages of Empirical Methods

- Do not quantitatively link sources and loadings to receiving water body quality
- Depending upon data used in developing the empirical method, may not be applicable to your watershed or water body

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Other Methods – An Overview

- Steady-State or Mass-Balance Analysis
  - Typically applied to critical flow condition to determine allowable loading
  - Assumes conservation of mass
  - Can accommodate multiple sources
- Percent Reduction
  - Existing pollutant concentrations compared to applicable criteria to get percent load reduction
  - Assumes 1:1 relationship between water body concentrations and pollutant loadings to determine an allowable loading

Source: USEPA. 2008. Draft Handbook for Developing Watershed TMDLs

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Other Methods – An Overview (cont'd)

- Tidal Prism Method
  - Used to determine allowable loading under environmental conditions of concern
  - Applicable to tidal water bodies (tidal streams and bay & estuaries)
  - Simplified approach compared to a mechanistic model for tidal water bodies
  - Has been applied on Texas coast to situation of bacteria impairment
  - Savings in resources compared to mechanistic modeling approaches

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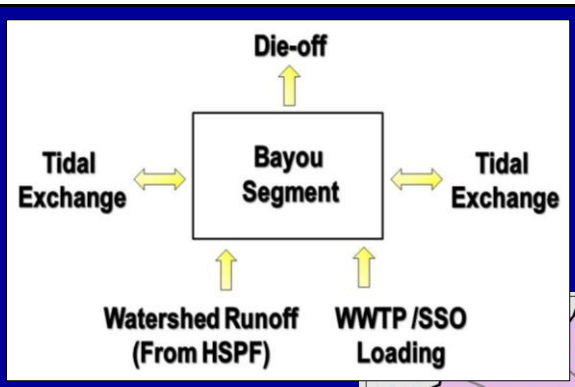
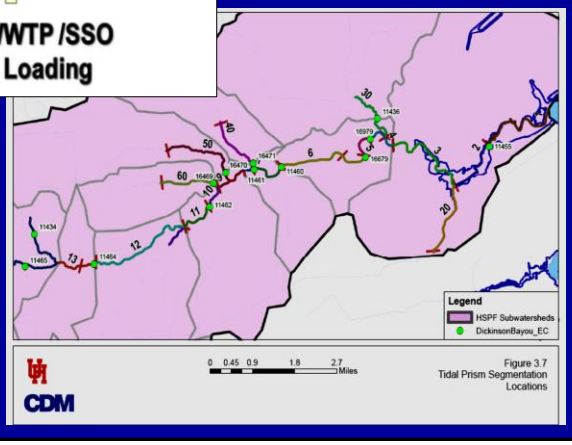


Dickinson Bayou TMDL – Tidal Prism Model



Concluding Comments

- Simple alternative approaches often used together
  - LDCs for allowable loadings and SELECT for pollutant loadings, probable sources & generally locating BMPs
  - Mass-Balance Analysis for allowable loading and Export Coefficients for pollutant loadings, probable sources & generally locating BMPs Simple alternative approaches
- Viable alternative to mechanistic modeling in certain situations
  - When data is limiting or other resources are limiting
  - Often used in Texas for bacteria impairments

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Thank You

Questions?

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