TMDL Modeling of the Oso Creek – Oso Bay System

Center for Water Supply Studies
Texas A&M University – Corpus Christi

Why Model a Hydrologic System?

- Better understand the interactions between various components of a hydrologic system.
- Predict future consequences of current actions.
- Test management practices.
- Help manage a watershed to meet realistic water quality objective.

What is a Hydrologic Model?

- A mathematical representation of a hydrologic system using the same basic laws of physics that govern water as it flows overland and through channels.

What information does a Hydrologic Model need?

- Gaged stream flow
- Elevation model describing the watershed
- River channel parameters
- Soil characteristics
- Land use – Land cover
- Basin and sub-basin descriptions
- Flow contributions from outside the basin
- Flow contributions from groundwater system
- Precipitation over the basin

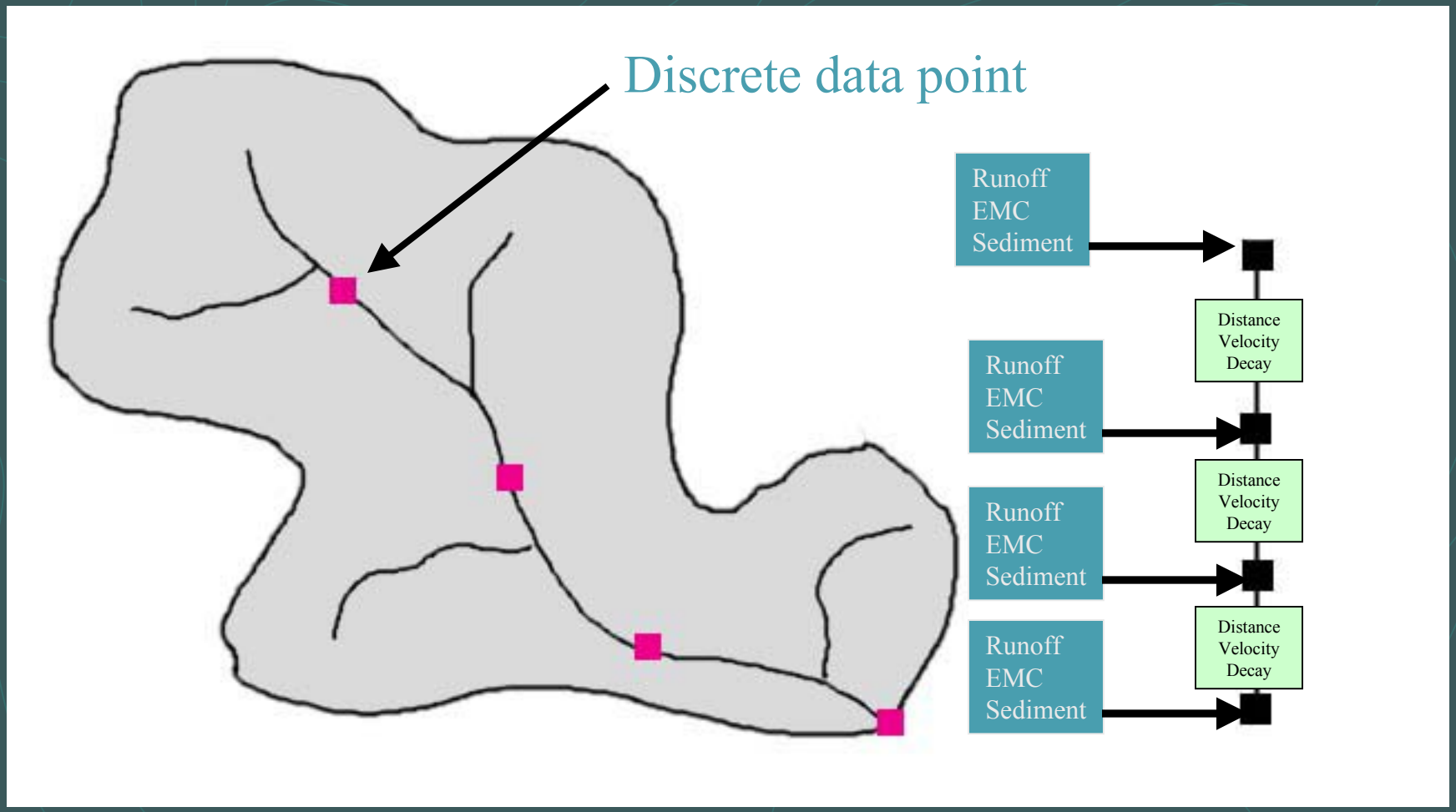
What is a TMDL model?

- A TMDL model adds the capability to track a particular water quality component as it moves through the hydrologic system.
- The behavior of the water quality component as it interacts with the hydrologic system is also represented mathematically within the model.

Conceptual Model

- This is the best idea we have as to how the system works.
- Identify components that drive and influence the system.
- Define their relationships.

Conceptual Watershed



Model Architecture

- Selection of modeling code.
- Partitioning of sub-basins.
- Number of segments.
- Grouping of inputs.
- Modeling detail required/possible.

Types of Modeling Code

- Artificial Neural Network (ANN).
- Rules Based Model.
- ArcHydro GIS Based Model.
- Soil and Water Assessment Tool (SWAT).

Artificial Neural Network

- Uses a training set to establish a set of weights and biases that are applied to the input data to obtain results or forecasts.
- Does not directly model the physical processes.
- Requires large amount of data for training set.
- Models systems as they are.

Rules Based

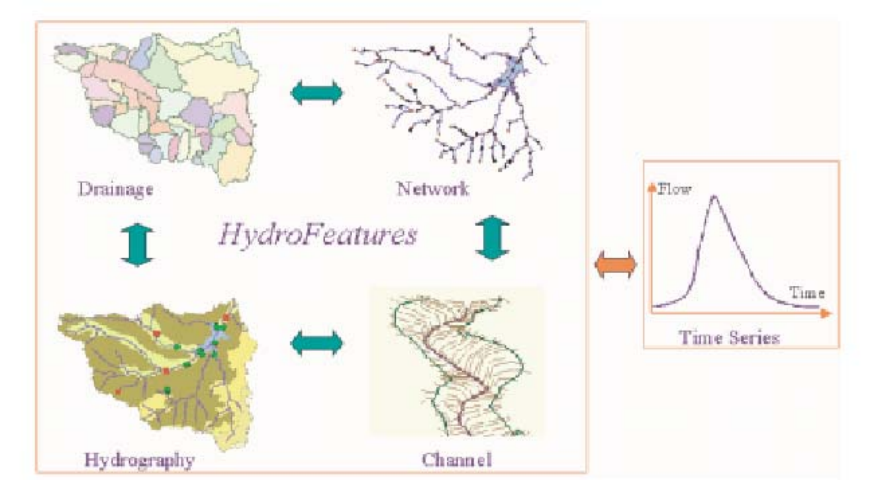
- Develop a set of rules that predict certain results.
- Based on observations.
- Models systems as they are.
  - Example:

    IF RAINFALL TODAY > 1”

    THEN BACTERIA CONCENTRATION GREATER THAN 35 AND LESS THEN 1000

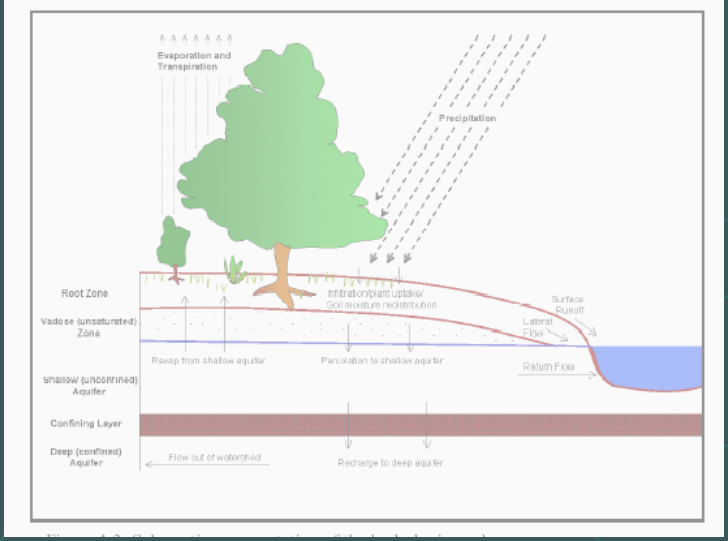
ArcHydro

- Operates within a GIS shell (ArcMap/ArcInfo).
- Divides Model in to 5 systems.
  - Network – Stream connectivity.
  - Drainage – Overland flow (runoff).
  - Channel – Stream channel shape.
  - Hydrography – Measurement points.
  - Time Series – Series of measured values over time (targets).
- Very flexible application.
- Models physical processes.



Soil and Water Assessment Tool

- Uses GIS preprocessing (ArcView) and amalgam of FORTRAN code.
- Primarily an agricultural focus.
- Divides model into 2 main systems.
  - Land Phase
    - Climate (includes ET)
    - Hydrology (includes ground water component)
    - Land cover/Plant growth
    - Erosion
    - Nutrients
  - Routing Phase
    - Flood
    - Sediment
    - Nutrient
- Incorporates physical processes.

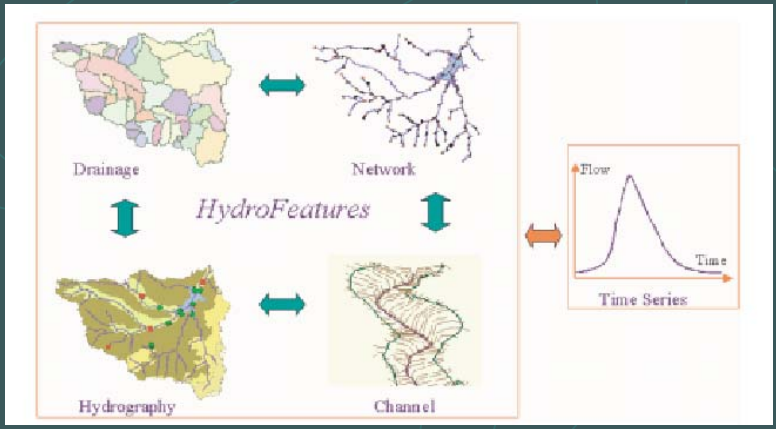


Model Output

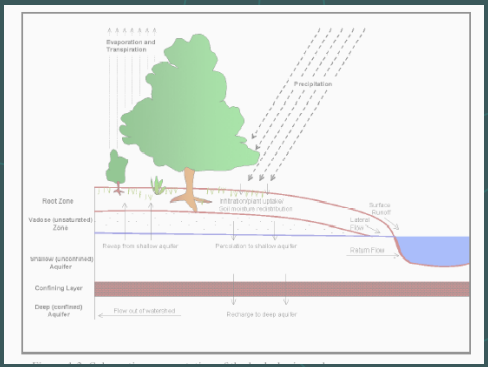
- Calculate bacteria concentrations at various locations.
- Determine bacteria loading to Oso Bay and Oso Creek.
- Test management strategies that alter bacteria source contributions.
- Test management strategies that alter inflow volumes.

Selected Models

- ArcHydro
  - Flexible.
  - Works directly with GIS data.
  - Provides time series output.
  - Models physical processes.
  - Requires some additional coding.



- SWAT
  - Works directly with GIS data.
  - Provides time series output.
  - Models physical processes.
  - Requires data for many input parameters.



Model Calibration

- Shows how well the model can predict bacteria loading compared to known (target) values.
- Iterative process.
  - Run model.
  - Evaluate errors.
  - Review specific parameters.
  - Modify where appropriate.

Available target data

Most active station with most common parameters.

Station 13440 - Oso Bay at South Padre Island Drive (SH 358)								
Parameter Code	Description	Max Date	Min Date	N	Max Value	Min Value	Average	STD Dev
00010 '	Water Temperature (Celcius)	19-Aug-03	27-Apr-93	75	33.78	9.07	23.04	5.38
00094'	Specific Conductance (UMHOS/cm)	19-Aug-03	27-Apr-93	75	83400.00	18286.00	52789.47	12613.49
00300'	Dissolved Oxygen (mg/L)	19-Aug-03	27-Apr-93	73	10.60	1.18	6.44	2.19
00301'	Dissolved Oxygen (Percent Saturation)	19-Sep-00	13-Oct-99	18	119.00	38.30	84.34	21.75
00400'	pH (Standard Units)	19-Aug-03	27-Apr-93	75	9.14	7.50	8.17	0.28
00480'	Salinity (ppt)	19-Aug-03	27-Apr-93	75	58.10	6.55	34.95	9.33
00625'	Total Kjeldahl Nitrogen (mg/L)	20-Jun-01	27-Apr-93	41	4.68	0.26	1.57	0.85
00665'	Total Phosphorus (mg/L)	19-Aug-03	27-Apr-93	51	0.66	0.01	0.14	0.11
00680'	Total Organic Carbon (mg/L)	19-Aug-03	27-Apr-93	55	32.00	1.00	4.20	5.23
00940'	Total Chloride (mg/L)	19-Aug-03	27-Apr-93	49	36800.00	20.00	21239.80	6794.78
00945'	Total Sulfate (mg/L)	19-Aug-03	27-Apr-93	56	6390.00	19.90	2634.71	1322.41
31616'	Fecal Coliform, Membrane Filter Method	19-Aug-03	27-Apr-93	68	3000.00	2.00	185.15	548.74
31648'	E. Coli	19-Sep-00	27-Oct-99	19	4700.00	2.00	325.32	1066.52
31649'	Enterococci	19-Aug-03	13-Oct-99	34	3100.00	1.00	214.06	535.49
70507'	Phosphorus in Total Orthophosphate (mg/L)	19-Aug-03	16-Feb-98	33	0.54	0.01	0.15	0.13

Bacteria all stations

- *Enterococci*
  - 10/99 to 8/03
  - 18 data points in common
- *E. Coli*
  - 10/99 to 10/00
  - 15 data points in common
- Fecal Coliform
  - 4/93 to 8/03
  - 18 data points in common

Parameter Code 31649 - Enterococci							
Station_ID	Max Date	Min Date	N	Max Value	Min Value	Average	STD Dev
13026	19-Sep-00	13-Oct-99	18	26500.00	1.00	1695.28	6227.32
13027	18-Sep-00	12-Oct-99	18	47500.00	5.00	4351.44	11292.20
13028	19-Aug-03	12-Oct-99	33	10636.00	17.00	889.30	2006.62
13029	18-Sep-00	12-Oct-99	18	24000.00	235.00	2846.06	5816.77
13440	19-Aug-03	13-Oct-99	34	3100.00	1.00	214.06	535.49
13442	19-Sep-00	13-Oct-99	18	955.00	1.00	165.83	266.55
16712	18-Sep-00	12-Oct-99	18	43500.00	45.00	4139.56	11536.07

Parameter Code 31648 - E. Coli							
Station_ID	Max Date	Min Date	N	Max Value	Min Value	Average	STD Dev
13026	19-Sep-00	14-Dec-99	15	659.00	2.00	125.33	224.56
13027	18-Sep-00	14-Dec-99	15	8650.00	8.00	1981.73	3238.76
13028	11-Oct-00	27-Oct-99	20	8000.00	70.00	1261.30	2258.02
13029	18-Sep-00	13-Dec-99	15	4250.00	98.00	676.40	1016.33
13440	19-Sep-00	27-Oct-99	19	4700.00	2.00	325.32	1066.52
13442	19-Sep-00	13-Dec-99	15	505.00	1.00	58.40	126.58
16712	18-Sep-00	14-Dec-99	15	20500.00	48.00	2493.40	5238.92

Parameter Code 31616 - Fecal Coliform, Membrane Filter Method							
Station_ID	Max Date	Min Date	N	Max Value	Min Value	Average	STD Dev
13026	19-Sep-00	12-Oct-95	19	8591.00	2.00	530.05	1962.38
13027	18-Sep-00	12-Oct-95	19	8773.00	6.00	1783.74	2917.58
13028	19-Aug-03	27-Apr-93	49	9000.00	7.00	746.16	1600.88
13029	18-Sep-00	27-Apr-93	24	8318.00	7.00	993.78	2015.49
13440	19-Aug-03	27-Apr-93	68	3000.00	2.00	185.15	548.74
13442	19-Sep-00	12-Oct-95	19	3050.00	2.00	258.42	713.03
16712	18-Sep-00	12-Oct-99	18	24000.00	20.00	2651.22	5803.41

Nutrients and Organic Carbon all stations

- Total Nitrogen
  - 4/93 to 10/03
  - 15 data points in common
- Total Phosphorus
  - 4/93 to 10/03
  - 15 data points in common
- Total Organic Carbon
  - 4/93 to 10/03
  - 15 data points in common

Parameter Code 00625 - Total Kjeldahl Nitrogen (mg/L)							
Station_ID	Max Date	Min Date	N	Max Value	Min Value	Average	STD Dev
13026	19-Sep-00	12-Oct-95	16	2.97	0.82	1.72	0.67
13027	18-Sep-00	12-Oct-95	16	5.40	1.03	2.54	1.01
13028	20-Jun-01	27-Apr-93	38	6.00	1.00	1.89	0.87
13029	18-Sep-00	27-Apr-93	22	7.03	0.14	1.54	1.30
13440	20-Jun-01	27-Apr-93	41	4.68	0.26	1.57	0.85
13442	13-Oct-03	12-Oct-95	19	1.99	0.47	1.31	0.47
16712	18-Sep-00	12-Oct-99	15	2.30	0.78	1.53	0.41

Parameter Code 00665 - Total Phosphorus (mg/L)							
Station_ID	Max Date	Min Date	N	Max Value	Min Value	Average	STD Dev
13026	19-Sep-00	12-Oct-95	16	0.46	0.03	0.15	0.11
13027	18-Sep-00	12-Oct-95	16	1.49	0.20	0.57	0.34
13028	19-Aug-03	27-Apr-93	51	3.23	0.12	1.29	0.74
13029	18-Sep-00	27-Apr-93	22	3.14	0.59	1.63	0.67
13440	19-Aug-03	27-Apr-93	51	0.66	0.01	0.14	0.11
13442	13-Oct-03	12-Oct-95	19	0.55	0.01	0.13	0.12
16712	18-Sep-00	12-Oct-99	15	2.50	0.27	1.15	0.65

Parameter Code 00680 - Total Organic Carbon (mg/L)							
Station_ID	Max Date	Min Date	N	Max Value	Min Value	Average	STD Dev
13026	19-Sep-00	12-Oct-95	16	11.00	1.00	5.34	3.50
13027	18-Sep-00	12-Oct-95	16	20.00	1.00	13.13	5.06
13028	19-Aug-03	27-Apr-93	52	20.00	1.00	8.84	4.70
13029	18-Sep-00	27-Apr-93	22	14.00	1.00	9.55	3.45
13440	19-Aug-03	27-Apr-93	55	32.00	1.00	4.20	5.23
13442	13-Oct-03	12-Oct-95	19	6.00	1.00	3.47	2.01
16712	18-Sep-00	12-Oct-99	15	19.00	5.00	10.07	3.56

Dissolved Solids

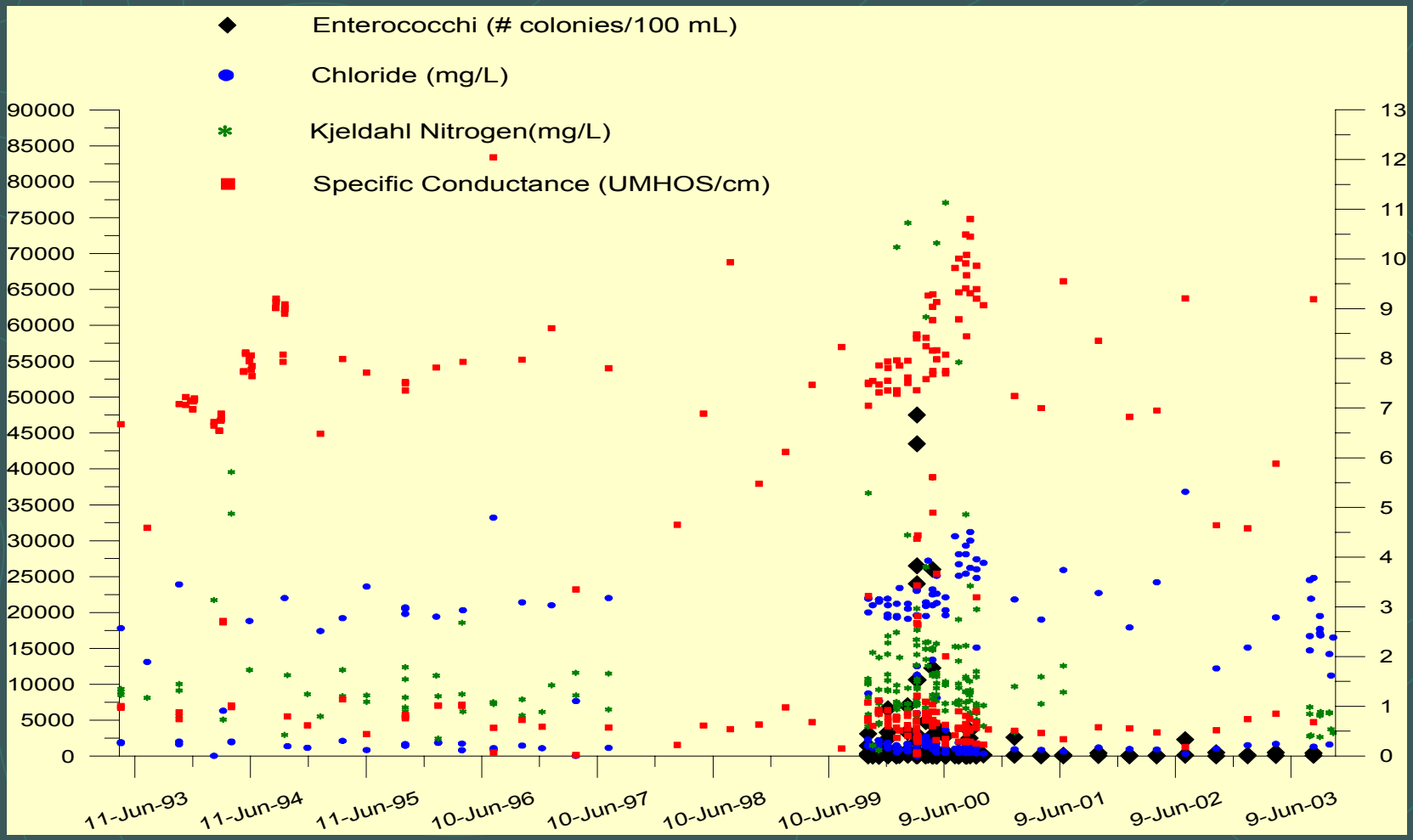
- Specific Conductance
  - 4/93 to 8/03
  - 18 data points in common
- Salinity
  - 4/93 to 8/03
  - 18 data points in common
- Total Chloride
  - 4/93 to 8/03
  - 18 data points in common

Parameter Code 00094 - Specific Conductance (UMHOS/cm)							
Station_ID	Max Date	Min Date	N	Max Value	Min Value	Average	STD Dev
13026	19-Sep-00	12-Oct-95	19	72347.00	8400.00	53609.63	15521.37
13027	18-Sep-00	12-Oct-95	19	7736.00	488.70	5007.62	1821.75
13028	19-Aug-03	27-Apr-93	57	7910.00	147.00	4210.02	1686.13
13029	18-Sep-00	27-Apr-93	25	7450.00	280.20	4737.21	2086.82
13440	19-Aug-03	27-Apr-93	75	83400.00	18286.00	52789.47	12613.49
13442	19-Sep-00	12-Oct-95	19	65137.00	30251.00	52711.42	9286.15
16712	18-Sep-00	12-Oct-99	18	6436.00	278.10	3914.01	1567.66

Parameter Code 00480 - Salinity (ppt)							
Station_ID	Max Date	Min Date	N	Max Value	Min Value	Average	STD Dev
13026	19-Sep-00	12-Oct-95	19	49.54	4.71	35.76	10.96
13027	18-Sep-00	12-Oct-95	19	4.33	0.26	2.76	1.02
13028	19-Aug-03	27-Apr-93	55	4.40	0.16	2.35	0.86
13029	18-Sep-00	27-Apr-93	25	4.10	0.14	2.65	1.01
13440	19-Aug-03	27-Apr-93	75	58.10	6.55	34.95	9.33
13442	19-Sep-00	12-Oct-95	19	44.10	19.05	34.94	6.58
16712	18-Sep-00	12-Oct-99	18	3.48	0.13	2.15	0.87

Parameter Code 00940 - Total Chloride (mg/L)							
Station_ID	Max Date	Min Date	N	Max Value	Min Value	Average	STD Dev
13026	19-Sep-00	12-Oct-95	16	30000.00	3060.00	21778.75	5866.29
13027	18-Sep-00	12-Oct-95	16	2220.00	106.00	1458.81	561.26
13028	19-Aug-03	27-Apr-93	46	2100.00	11.00	1171.98	475.69
13029	18-Sep-00	27-Apr-93	22	2300.00	30.00	1359.32	598.17
13440	19-Aug-03	27-Apr-93	49	36800.00	20.00	21239.80	6794.78
13442	13-Oct-03	12-Oct-95	19	26200.00	11200.00	19815.79	4169.37
16712	18-Sep-00	12-Oct-99	15	1760.00	30.00	972.13	422.74

Significant parameters over time



Model Verification

- Testing the calibrated model with new data.
- Verifies that model is not designed to work only within the calibration set.

Sensitivity Analysis

- Determines which parameters have the most influence over the model outcome.
- Iterative Process.
  - Major input parameters are varied individually (e.g. 1%, 2%, or 5%) of the model value and the change in results is compared to that of the calibrated results.
- Assists in assessing confidence level in model.

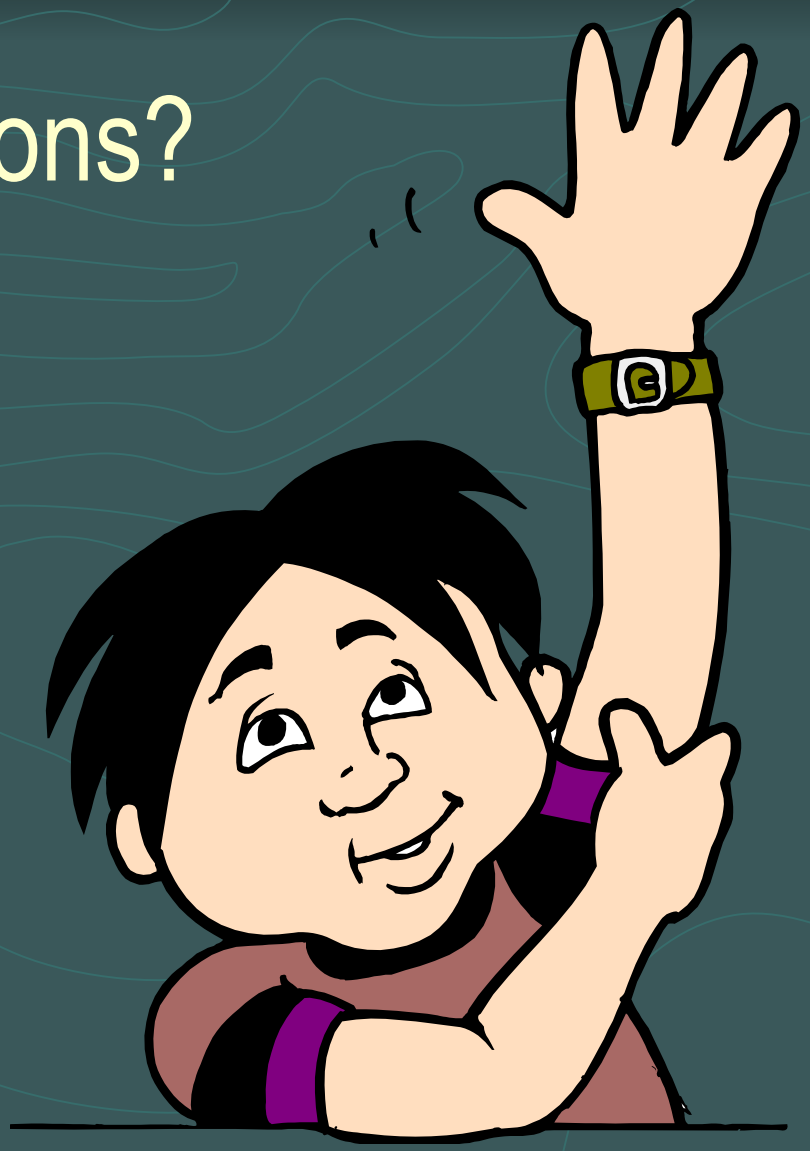
Model Post-Audit

- Review model when new data has been collected.
- Re-evaluate model based on results of new runs.
- Make changes to improve model.

Model Limitations

- Quality of input data.
- Quantity and detail of input data.
- Confidence in results is highest at calibration points and lowest at points furthest from calibration data.
- Simplified representation of a complex system.

Questions?



Next Stakeholder meeting near end of April!

Contact:
Richard Hay 361-825-3347
rhay@falcon.tamucc.edu