Lake Granbury
Phase I Report Summary

David Harkins, Ph.D., P.E.
Tim Osting, P.E.
Espey Consultants, Inc.
May 22, 2007

Phase I Study Goals

- Collect and Evaluate Water Quality Data,
- Recommend Additional Water Quality Data Collection, if Needed,
- Evaluate Water Quality Models,
- Recommend Water Quality Model for Canal Evaluations.

Summary of Study

- Data Collection
  - Data was collected and compiled from the BRA, TCEQ, Texas Natural Resources Information System (TNRIS), Texas Water Development Board (TWDB), National Climatic Data Center (NCDC), University of Texas Bureau of Economic Geology (UTBEG) and US Geological Survey (USGS).
  - BRA study in 1982.
    - Evaluated treatment of septic systems,
    - Evaluated nutrient loads.
  - BRA study 1995.
    - Identified canal systems with high bacteria concentrations.
  - Clean Rivers Program and special studies 2001-current.
    - 50 monitoring locations.

Summary of Study (Cont.)

- Data Evaluation (Main Body)
  - Increasing nutrient and chlorophyll-a levels.
  - Decreasing dissolved oxygen (DO) concentrations and secchi depth readings.
  - Elevated bacteria levels did not appear regularly. Background bacteria levels less than 10 MPN per 100 mL.
- Data Evaluation (Cove/Canals)
  - High levels of bacteria (spikes of greater than 2,400 MPN per 100mL).
  - Nutrient levels were consistent with main body measurements.
  - Additional data collection needed.

Summary of Study (Cont.)

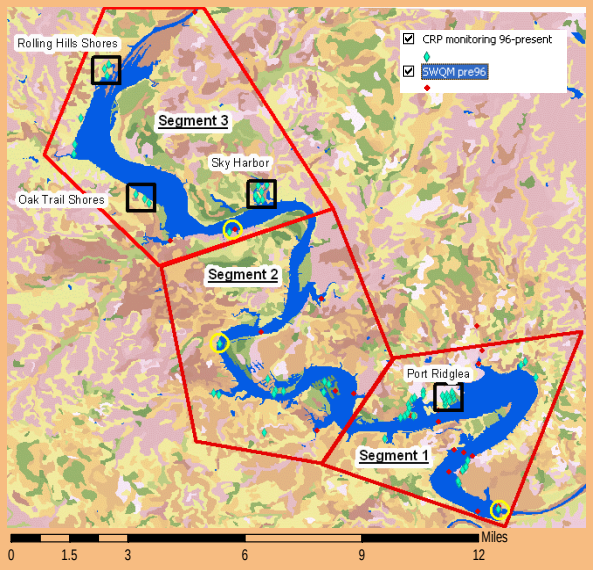
- Additional Data Collection Recommendations.
  - Additional nutrient sampling in the main body.
  - Circulation pattern field evaluation in selected canals.
  - Septic system dye injection in selected canals.
- Watershed Model Evaluation and Recommendation.
  - Numerous watershed models were evaluated.
  - Based on data availability and other factors, a simplified rainfall-runoff model is recommended for the watershed component of this project.

Summary of Study (Cont.)

- Lake and Cove Model Evaluation and Recommendation.
  - Numerous lake and cove models were evaluated.
  - Based on data availability, shallow depths, and other factors, a segmented well-mixed mass balance model is recommended.

Comments/Questions

Main Body Water Quality Data Evaluation

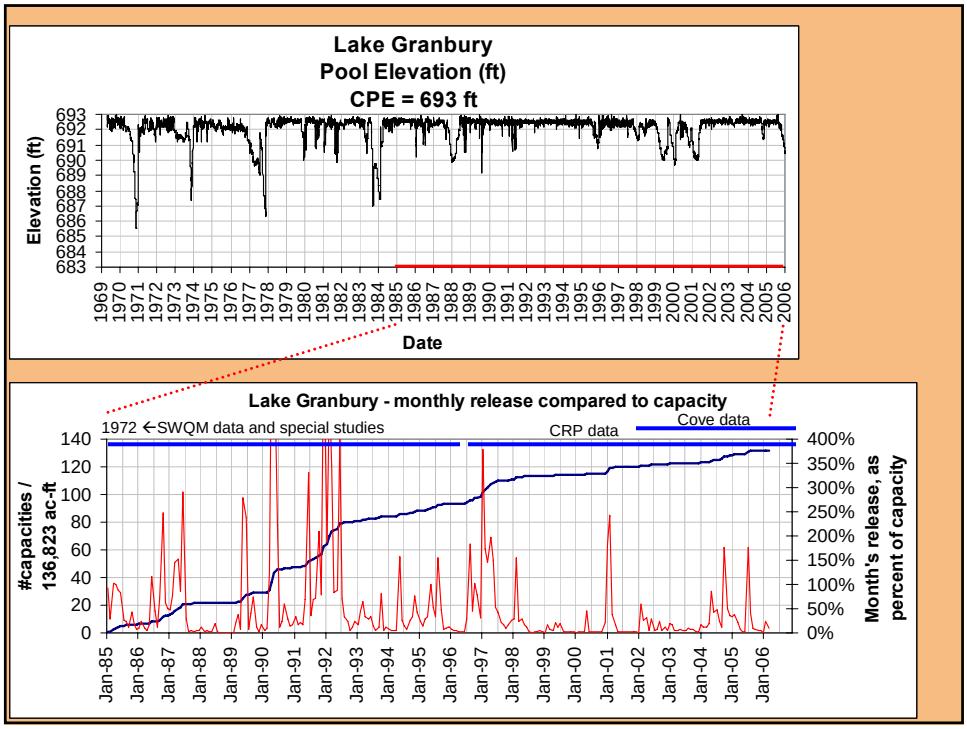


Main Body Data Evaluation

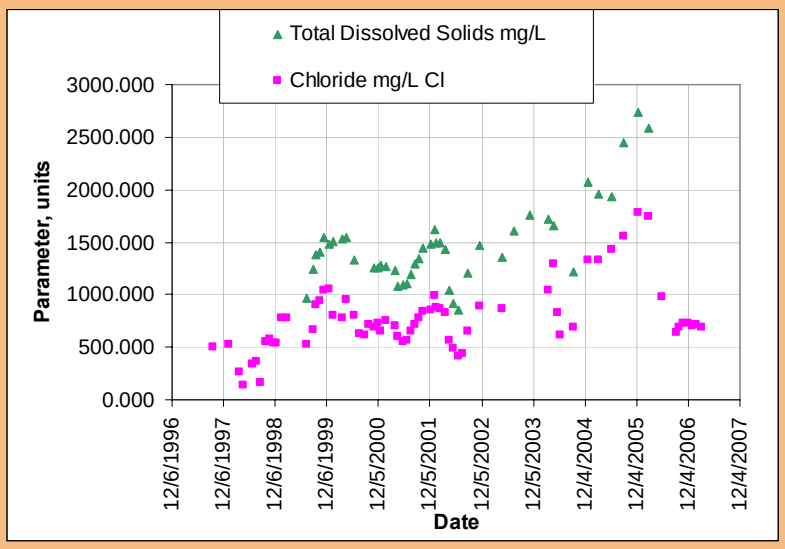
- Water quality data was evaluated at the three Clean Rivers Monitoring Stations.
- Water quality evaluation consisted of bacteria, DO, chlorophyll-*a*, and nutrient analysis.
- No immediate concerns at these locations based upon water quality standards.
- Some indication of trends in water quality data toward eutrophication (excess growth of aquatic plants – rooted of free moving).

Main Body Trends

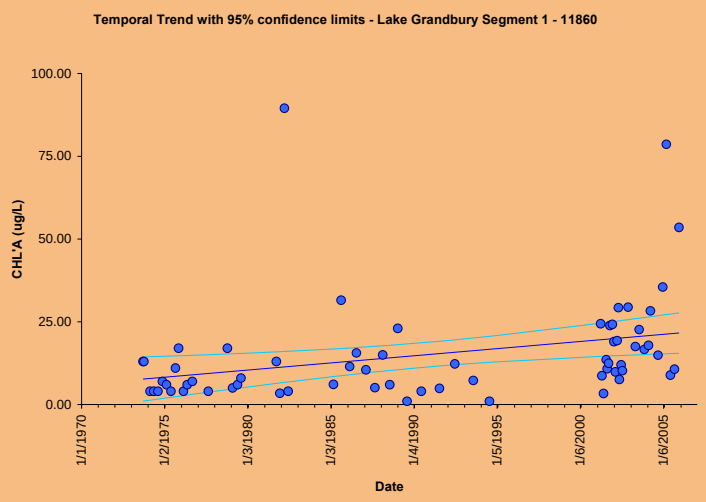
- Increasing nutrient and chlorophyll-a levels.
- Decreasing dissolved oxygen (DO) concentrations and secchi depth readings.
- Elevated bacteria levels did not appear regularly. Background bacteria levels less than 10 MPN per 100 mL.
- High Chlorides and Dissolved solids



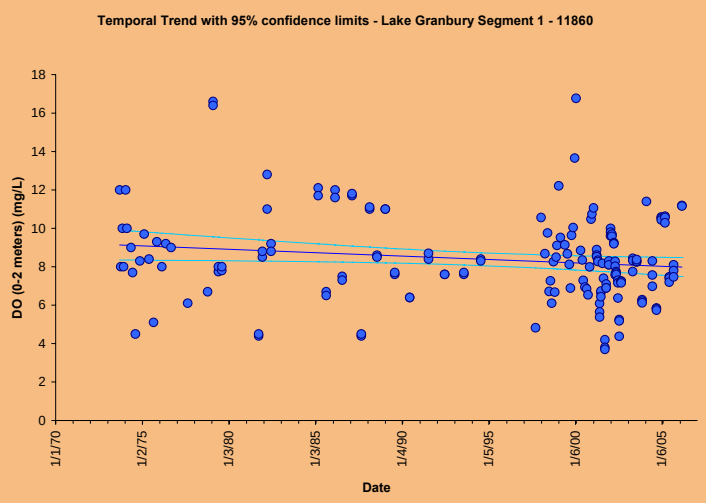
TDS and Chlorides (Main Body)



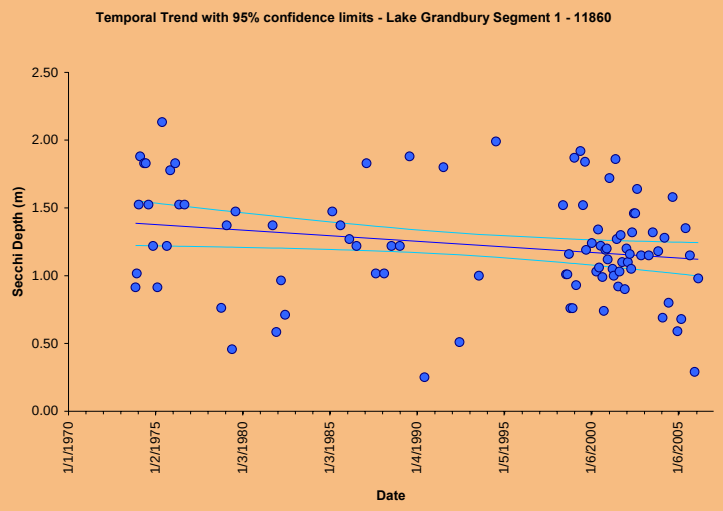
Chlorophyll-a Segment 1



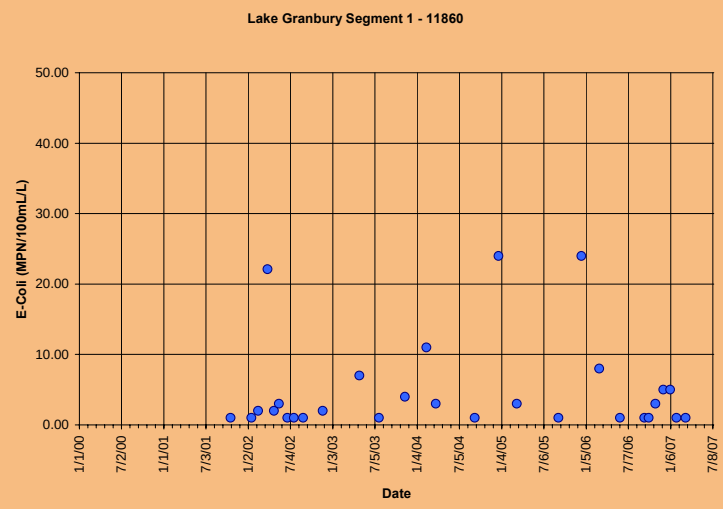
DO Segment 1



Secchi Depth Segment 1



E. Coli Segment 1



Why is Main Body Water Quality Important

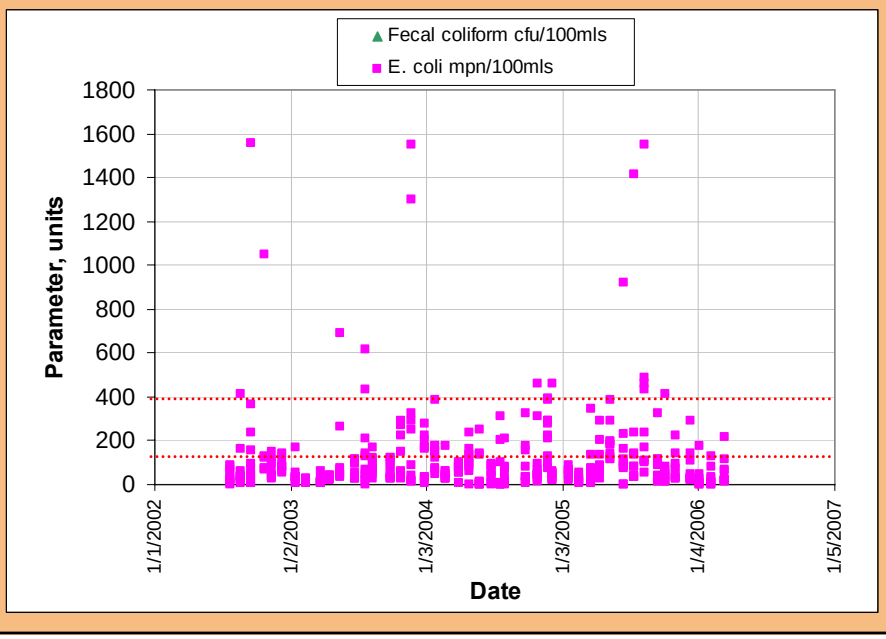
- Primary source of water for the coves.
- Nutrients are extremely important in the water quality of the lake and coves.
- Understanding the relationship of main body water quality to cove/canal water quality.
  - Nutrients are similar in main body and coves (volume greater, move flow movement),
  - Bacteria is consistently higher in coves (closer to source, less volume).
- Nutrients can also cause problems in cove areas (increased vegetation and algae growth).
- Bacteria issues may be dealt with but nutrient issues (eutrophication) could still be a problem.

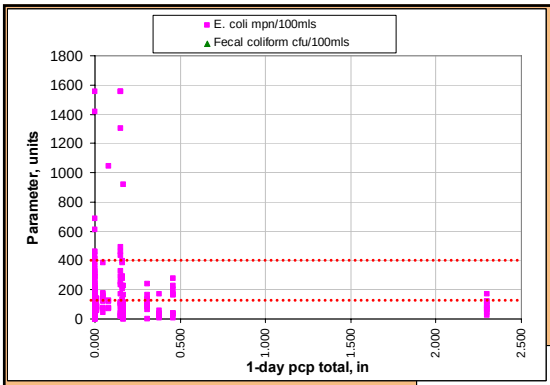
Comments/Questions

Canal/Cove Water Quality Evaluation

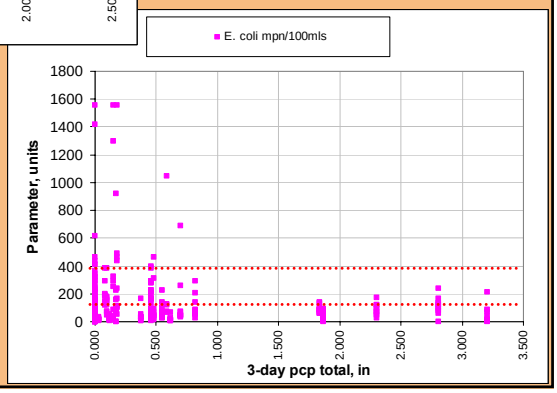
- Water quality data was evaluated at BRA's special study monitoring stations.
- Water quality evaluation consisted of bacteria, DO, chlorophyll-a, and nutrient analysis.
- Some indication of trends in water quality data toward eutrophication (excess growth of aquatic plants – rooted of free moving).
- Bacteria levels were high in many of the cove/canal areas.
- A Septic Index was developed for each subdivision.
- Subdivision in relation to river channel.

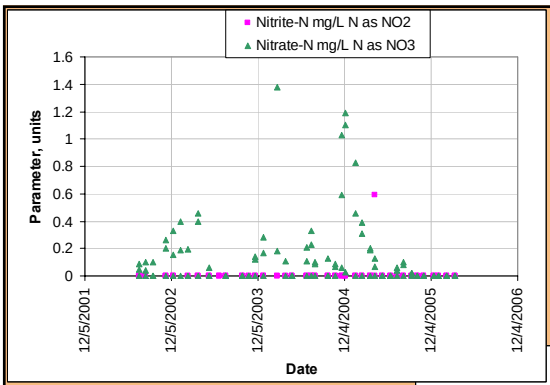
Port Ridglea – all stations 18031 to 18040



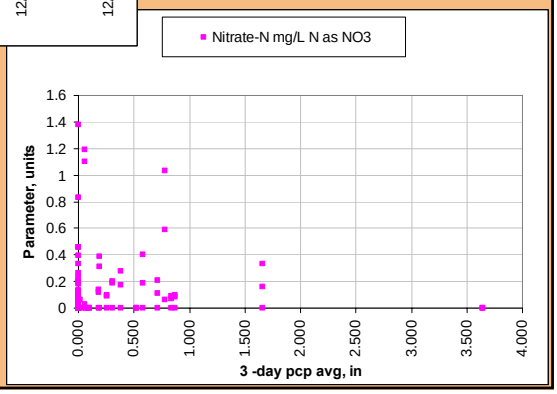


Port Ridglea
all stations 18031
to 18040



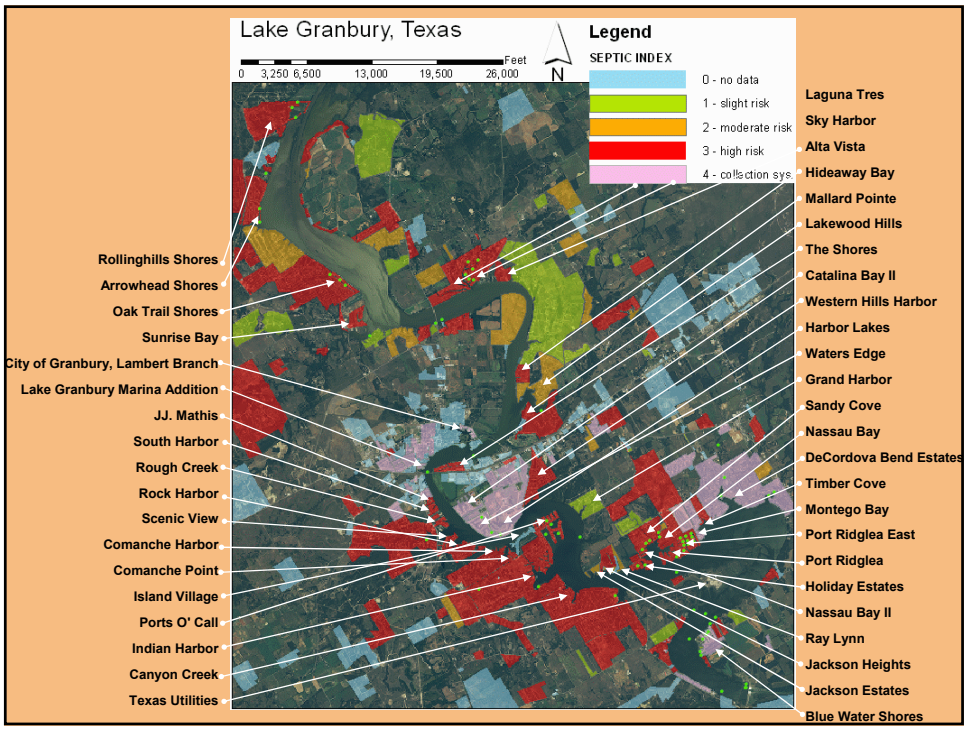


Oak Trail Shores
all stations 18008
to 18009



Septic Index

- The Septic Index (SI) was developed for each canal system to evaluate each subdivisions.
- The SI is a ranking of risk based on septic age, SCS absorption suitability, soils maps, and water table depth.
- Risk is classified in four categories:
  - 0 – No data
  - 1 – Slight Risk
  - 2 – Moderate Risk
  - 3 – High Risk



Canal/Cove Data Evaluation

- 27 canals were classified as high risk based on the SI.
- Based on the monitoring data, 10 of those subdivisions were found to have consistently elevated bacteria readings.
- 4 canals nearing bacteria impairments, 1 site impaired
  - Concentration is high and is persistent
  - Watershed source not indicated
- 4 canal/cove sites do not meet DO standard
- 1 canal/cove site near Nitrogen screening level

High Risk Subdivisions

- Canyon Creek
- Laguna Tres
- Sky Harbor
- Alta Vista
- Hideaway Bay
- Lakewood Hills
- The Shores
- Western Hills Harbor
- Jackson Heights
- Holiday Estates
- Port Ridglea
- Port Ridglea East
- Sandy Cove
- Nassau Bay
- Timber Cove
- Rolling Hills Shores
- Arrowhead Shores
- Oak Trail Shores
- Sunrise Bay
- South Harbor
- Rough Creek
- Rock Harbor
- Scenic View
- Comanche Harbor
- Comanche Point
- Ports O' Call
- Indian Harbor

Bacteria Consistently High

- Rolling Hills Shores
- Arrowhead Shores
- Oak Trail Shores
- Ports O' Call
- Indian Harbor (<100)
- Nassau Bay
- Sky Harbor
- Port Ridglea
- Port Ridglea East
- Blue Water Shores

E. Coli and DO summary

				E. coli (MPN/100mL)				Dissolved Oxygen (DO, mg/L)		
Site	Subdivision	Bank	Septic Index	N	≤ 394 25% exc.	≤ 126 gMean	≤ 394 Max	N	≥ 5 Average	≥ 3 Min
70031	Lake Country Acres - BR	<--		7	39	9	126	7	9.29	6.98
70020	Long Creek	<--	3	7	135	67	178	7	7.11	4.31
17930	Rolling Hills Shores	-->	3	36	50	12	770	33	4.22	0.63
17931	Rolling Hills Shores	-->	3	50	22	7	142	47	6.72	1.25
18004	Rolling Hills Shores	-->	3	55	56	19	816	52	4.83	0.18
70010	Rolling Hills Shores	-->	3	11	27	9	131	11	6.14	3.07
18005	The Live Oaks	-->	3	6	64	29	210	6	5.19	1.94
18006	Arrowhead Shores	-->	3	49	22	10	548	46	7.16	3.06
18007	Arrowhead Shores	-->	3	51	31	13	1733	48	7.26	2.9
70027	Arrowhead Shores - Robinson Creek	-->	3	7	76	41	91	7	6.95	4.75
18008	Oak Trail Shores	-->	3	55	99	32	2419	52	7.22	2.83
18009	Oak Trail Shores - Tee	-->	3	55	68	28	866	51	6.88	1.43
18010	Oak Trail Shores - Tee	-->	3	57	166	63	1733	53	6.68	1.78
70028	Thorp Spring - Strouds Creek	-->		7	59	43	148	7	7.57	4.47
11862	**Lake Granbury Segment 3**			**336**	**0**	**3**	**17**	**70**	**8.73**	**3.85**
18011	Sky Harbor	<--	3	50	52	27	1733	45	8.67	4.54
18012	Sky Harbor	<--	3	50	30	15	2419	45	8.93	4.99
18013	Sky Harbor	<--	3	46	57	23	2419	45	8.86	2.69
18014	Sky Harbor - Tributary	<--	3	51	96	57	1733	48	7.00	1.42
18015	Sky Harbor - Tributary	<--	3	51	249	118	2419	46	7.22	3.27
18016	Sky Harbor - Tributary	<--	3	46	128	47	2420	42	8.49	1.27

= less than 10 samples
= screening
= standard violation

E. Coli and DO summary

Site	Subdivision	Bank	Septic Index	E. coli (MPN/100mL) N	≤ 394 25% exc.	≤ 126 gMean	≤ 394 Max	Dissolved Oxygen (DO, mg/L) N	≥ 5 Average	≥ 3 Min
70021	Mallard Pointe	<--	2	7	100	24	158	7	10.15	7.15
70022	Mallard Pointe	<--	2	7	238	70	461	7	8.77	6.64
70019	Lambert Branch - COG	-->	OSCS	7	102	30	148	7	9.91	7.43
11861	**Lake Granbury Segment 2**			**470**	**0**	**5**	**31**	**71**	**8.90**	**3.52**
70014	Rough Creek Cove	-->	3	7	51	16	249	7	9.97	7.12
18017	Waters Edge - COG WWTP	<--	OSCS	25	35	21	727	22	9.32	7.76
18018	Waters Edge - COG WWTP	<--	OSCS	32	76	24	1986	29	9.62	7.17
18019	Waters Edge	<--	OSCS	18	43	13	91	14	8.63	7.01
18020	Waters Edge	<--	OSCS	17	39	19	145	14	10.12	6.5
18021	Ports O' Call	-->	3	22	39	18	649	18	8.77	6.2
18022	Indian Harbor - Lagoon	-->	3	22	59	23	260	18	9.16	6.01
18023	Indian Harbor - Lagoon	-->	3	22	23	9	81	18	8.72	5.94
18024	Indian Harbor - Lagoon	-->	3	26	17	7	122	22	9.06	5.88
70015	Indian Harbor - Canal	-->	3	7	749	266	1414	7	9.86	6.89
70016	Indian Harbor - Canal	-->	3	7	708	167	1733	7	9.88	6.9
70017	Indian Harbor - Canal	-->	3	7	142	38	2420	7	9.85	6.72
70018	Indian Harbor - Canal	-->	3	7	355	89	435	7	9.52	7.15
18025	Holiday Estates	<--	3	59	81	29	2419	52	8.62	5.27
18026	Nassau Bay II	<--	3	26	27	20	2419	21	8.60	6.3
18027	Nassau Bay II	<--	3	26	29	16	770	22	8.42	5.45
18028	Nassau Bay II	<--	3	26	22	15	142	22	8.59	6.29
90029	Nassau Bay II	<--	3	20	75	34	921	20	9.07	5.91
18029	Sandy Beach	<--	3	27	118	37	2419	23	8.13	4.91
18030	Sandy Beach	<--	3	26	50	21	411	22	8.27	6.36

= less than 10 samples
= screening
= standard violation

E. Coli and DO summary

Site	Subdivision	Bank	Septic Index	E. coli (MPN/100mL) N	≤ 394 25% exc.	≤ 126 gMean	≤ 394 Max	Dissolved Oxygen (DO, mg/L) N	≥ 5 Average	≥ 3 Min
70023	Port Ridglea	<--	3	7	164	66	1120	7	10.19	7.33
70024	Port Ridglea	<--	3	7	143	38	613	7	10.31	8.02
70025	Port Ridglea	<--	3	7	183	41	727	7	10.13	7.71
70026	Port Ridglea	<--	3	7	207	73	488	7	10.24	7.14
18031	Port Ridglea East, West canals	<--	3	58	153	68	2420	53	8.50	5.64
18032	Port Ridglea East, West canals	<--	3	50	94	35	1553	44	8.15	5.68
18033	Port Ridglea East, West canals	<--	3	58	128	53	2420	53	8.13	5.19
18034	Port Ridglea East, West canals	<--	3	58	144	57	2419	53	7.91	4.31
18035	Port Ridglea East, West canals	<--	3	58	126	61	1120	53	7.92	4.52
18036	Port Ridglea East, West canals	<--	3	50	101	44	613	45	8.22	5.5
18037	Port Ridglea East, West canals	<--	3	57	144	58	921	52	8.44	5.81
18038	Port Ridglea East, East canals	<--	3	58	231	110	1553	53	8.48	5.48
18039	Port Ridglea East, East canals	<--	3	56	164	75	866	51	8.36	5.34
18040	Port Ridglea East, East canals	<--	3	50	96	49	687	45	8.33	5.73
18739	Canyon Creek Cove	-->	3	19	12	6	461	18	9.14	6.3
70029	Cordova Bend Estates - Walnut Creek	<--	OSCS	7	105	86	185	7	11.31	5.92
18041	Lusk Branch	<--	OSCS	25	15	6	117	22	7.79	4.34
18042	Lusk Branch	<--	OSCS	25	17	8	613	22	7.55	4.37
18043	Blue Water Shores, N	<--	OSCS	53	111	31	2420	49	8.74	5.36
18044	Blue Water Shores, N	<--	OSCS	53	172	38	2420	49	8.48	4.74
18738	Blue Water Shores, S	<--	OSCS	32	16	10	225	31	8.49	4.5
18740	Blue Water Shores, N	<--	OSCS	32	33	15	228	31	8.85	5.69
18741	Blue Water Shores, N	<--	OSCS	32	239	74	2420	31	8.44	4.58
18742	Blue Water Shores, S	<--	OSCS	25	30	12	86	24	8.60	6.06
11860	**Lake Granbury Segment 1**			**551**	**0**	**3**	**24**	**70**	**8.60**	**4.2**

= less than 10 samples
= screening
= standard violation

Recommendations for Modeling

- Rolling Hills Shores – Restricted lagoon, unique
- Arrowhead Shores – T-Canal
- Oak Trail Shores – T-Canal
- Ports O' Call – Deep finger canal
- Indian Harbor (<100) – Eastern most lagoon
- Nassau Bay – Deep cove and canals with tribs.
- Sky Harbor – Deep cove and canals with tribs.
- Waters Edge – finger canal, to validate model at low concentrations
- Port Ridglea East – Shallow finger canals
- Blue Water Shores – Determine source

Summary of modeling considerations

Subdivision	Concern	Type	Bank	Orientation	Depth (ft)
Rolling Hills Shores	Bacteria, DO	Lagoon	-->	N	est. 4 to 5
The Live Oaks	Bacteria, DO	Cove	-->	W	
Arrowhead Shores	Bacteria, DO	Tee Canal	-->	W	5 to 7
Arrowhead Shores	-	Trib-Cove	-->	W	5 to 7
Oak Trail Shores	Bacteria, DO	Trib-Cove	-->	W	4
Oak Trail Shores	Bacteria, DO	Tee Canal	-->	W	4
Sky Harbor	Bacteria	Canal-Cove	<--	N	4 to 15
Sky Harbor	Bacteria, DO	Trib-Cove	<--	N	4 to 10
Mallard Pointe	(Bacteria)	Cove	<--	E	4 to 15
Lambert Branch - COG	-	Trib-Cove	-->	W	15
Rough Creek Cove	-	Trib-Cove	-->	W	10
Waters Edge - COG WWTP	Bacteria	Canal	<--	E	8 to 10
Waters Edge	None	Canal	<--	E	8 to 10
Ports O' Call	Bacteria	Canal	-->	S	8 to 10
Indian Harbor	None	Lagoon	-->	W	8 to 10
Indian Harbor	None	Lagoon	-->	N	5 to 8
Indian Harbor	(Bacteria)	Canal-Cove	-->	W	5 to 8
Holiday Estates	Bacteria	Canal	<--	N	8 to 10
Nassau Bay II	Bacteria	Canal-Cove	<--	N	4 to 5
Nassau Bay II	Bacteria	Canal-Cove	<--	W	4 to 5
Sandy Beach	Bacteria	Trib-Cove	<--	N	8 to 10
Port Ridglea	(Bacteria)	Canal-Cove	<--	S	8 to 10
Port Ridglea East, West canals	Bacteria	Canal	<--	N	5 to 8
Port Ridglea East, East canals	Bacteria	Canal	<--	N	5 to 8
Canyon Creek Cove	Bacteria	Trib-Cove	-->	S	5 to 8
DeCordova Bend Estates - Walnut Creek	-	Trib-Cove	<--	N	4 to 5
Lusk Branch	Bacteria	Trib-Cove	<--	N	8 to 10
Blue Water Shores	Bacteria	Canal	<--	S	4 to 5
Blue Water Shores	Bacteria	Canal	<--	E	4 to 5

On right bank, looking downstream = -->
On left bank, looking downstream = <--

Data for Canal/Cove Modeling

- Existing data
  - Canal depth,
  - Sample data,
  - Canal width and mouth opening,
  - Wind data, and
  - Precipitation data,

- Additional data needed for modeling
  - Circulation patterns,
  - Longer period of records for WQ data,
  - Shorter sampling intervals,
  - Biologic kinetics (respiration, growth rate, decay, settling, etc.), and
  - Nutrient kinetics (decay rates, settling, mineralization rates, etc.)

Example Input

WASP Kinetic Constant Type	*Avg. Range*	*Units*
Nitrification Rate @ 20º C	0.001 – 0.2	day^{-1}
Nitrification Temp Coeff.	1.02 – 1.08	NA
Half Saturation: Nitrification Oxygen Limit	0.5 – 2.0	mg O_2/L
Denitrification Rate @ 20º C	0 – 0.09	day^{-1}
Denitrification Temp Coeff.	1.02 – 1.09	NA
Half Saturation: Denitrification Oxygen Limit	0 – 2.0	mg O_2/L
Phytoplankton Growth Rate @ 20º C	1.0 – 3.0	day^{-1}
Phytoplankton Growth Temp Coeff.	0 – 1.07	NA
Phytoplankton Light Formulation Switch (1 = DiToro)	NA	NA
Phytoplankton Max Quantum Yield Constant	NA	NA
Phytoplankton Self Shading Extinction	NA	NA
Phytoplankton Carbon::Chlorophyll Ration	0 – 200	mg carbon/mg chla
Phytoplankton Optimal Light Saturation	0 – 350	Ly/day
Phytoplankton Half Saturation Constant: Nitrogen	0.01 – 0.06	mg-N/L
Phytoplankton Half Saturation Constant: Phosphorus	0.0005 – 0.05	PO_4-P/L
Phytoplankton Endogenous Respiration Rate @ 20º C	0 – 0.5	day^{-1}
Phytoplankton Respiration Temp Coeff.	1.0 – 1.08	NA
Phytoplankton Death Rate Non-Zooplankton Predation	0 – 0.25	day^{-1}
Phytoplankton Zooplankton Grazing Rate	0 – 5	L/cell-day
Nutrient Limitation Option (0 = Min; 1 = Multiplicative)	0, 1	NA
Phytoplankton Decay Rate in Sediments @ 20º C	0 – 0.02	day^{-1}
Phytoplankton Decay Rate Temp Coeff.	1.0 – 1.08	NA
Phytoplankton Phosphorus::Carbon Ratio	0 – 0.24	mg P/mg C
Phytoplankton Nitrogen::Carbon Ratio	0 – 0.43	mg N/mg C
Phytoplankton Half Saturation for N and P	0 – 1.0	NA

Example Input (Cont.)

WASP Kinetic Constant Type	*Avg. Range*	*Units*
BOD Decay Rate @ 20º C	0.05 – 0.4	day $^{-1}$
BOD Decay Rate Temp Correction	1.0 – 1.07	NA
BOD Decay Rate in Sediments @ 20º C	0.0004 – 1.0	day $^{-1}$
BOD Decay Rate in Sediments Temp Coeff.	1.0 – 1.08	NA
BOD Half Saturation Oxygen Limit	0.5 – 1.0	NA
Waterbody Type for Wind Driven Aeration	1.0 – 3.0	NA
Oxygen::Carbon Stoichiometeric Ratio	0 – 2.67	mg O_2/mg C
Reaeration Rate Constant @ 20º C	0.5 – 3.0	day $^{-1}$
Reaeration Rate Option (sums Wind and Hydraulic Ka)	0 – 1.0	NA
Dissolved Organic N Mineraliztion Rate @ 20º C	0.02 – 0.075	day $^{-1}$
Dissolved Organic N Mineraliztion Temp Coeff.	1.0 – 1.08	NA
Organic N Decay in Sediments @ 20º C	0.0004 – 0.01	day $^{-1}$
Organic N Decay in Sediments Temp Coeff.	1.0 – 1.08	NA
Fraction of Phytoplankton Death Recycled to Organic N	0 – 1.0	NA
Dissolved Organic P Mineraliztion Rate @ 20º C	0 – 0.22	day $^{-1}$
Dissolved Organic P Mineraliztion Temp Coeff.	1.0 – 1.08	NA
Organic P Decay in Sediments @ 20º C	0.0004 – 0.01	day $^{-1}$
Organic P Decay in Sediments Temp Coeff.	1.0 – 1.08	NA
Fraction of Phytoplankton Death Recycled to Organic P	0 – 1.0	NA

Data Evaluation Conclusions

- Lake-cove water exchange not well-understood.
- Bacteria.
  - Problems in some canals, not in main body,
  - Watershed source is not likely
- Nutrients.
  - DO, chl a and clarity (secchi depth) show trends,
  - Similar in main body and canals.
- Need additional nutrient data in main body.
- Data for modeling effort is limited.

Watershed Models

- To determine what drains into lake waters
  - Stormwater runoff
    - Watershed, size, topography/drainage patterns and soil characteristics
    - No runoff data
  - Constituent of concern (bacteria, nutrients)
    - Monthly in-lake concentration data
    - Source location and interval between release not known

Watershed modeling

SWAT Soil Water Assessment Tool	Comprehensive runoff and constituent model, process-based Agricultural
HSPF Hydrologic Simulation Program - FORTRAN	Comprehensive runoff and constituent model, process-based Sediment
SWMM5 Storm Water Management Model v5	Comprehensive runoff and constituent model, process-based Urban
PRMS Precipitation-Runoff Modeling System	Comprehensive runoff-only
WEPP Water Erosion Prediction Project	Comprehensive runoff-only Small-watersheds
Soil Conservation Service Curve Numbers	Standard runoff-only
Load Duration Curves	Statistical characterization of bacteria concentration

INPUT DATA REQUIREMENTS

Standard	**Comprehensive**
Drainage area	Rainfall time-series
Topography/drainage patterns	Infiltration
Soil characteristics	Evapotranspiration
Rainfall	Wind
Pollutant source and concentration	Temperature
	Tillage
	Erosion/deposition

CALIBRATION AND VALIDATION DATA

Standard	**Comprehensive**
Flow	Flow time-series
Concentration	Concentration time-series

Watershed modeling

	Available Data	SCS CN	Load Duration Curves	SWAT	HSPF	SWMM5	PRMS	WEPP
Input Data								
Drainage Area	1	•		•	•	•	•	•
Topography and drainage patterns	1	•		•	•	•	•	•
Soil characteristics	1	•		•	•	•	•	•
Rainfall	2	•		•	•	•	•	•
Pollutant load	3		•	•	•	•		
Pollutant change or decay	3			•	•	•		
Rainfall time-series	2	•		•	•	•	•	•
Infiltration	3	•			•	•	•	•
Evapotranspiration	3			•	•	•	•	•
Temperature	2			•	•	•	•	•
Tillage	2			•	•	•	•	•
Erosion and deposition	3			•	•	•	•	•
Calibration and Validation Data								
Flow	3	•	•					
Pollutant concentration	1		•					
Flow time-series	3			•	•	•	•	•
Pollutant concentration time-series	3			•	•	•		

1 = Detailed site-specific data
2 = Less detailed regional data
3 = Can be estimated from literature or modeling

Lake modeling

- What happens in the water body?
- Bacteria
  - Consider each canal/coves system individually,
  - Source and amount of bacteria contributions,
  - Decay rate,
  - Concentration influenced by rainfall and circulation.
- Nutrients
  - Characterize current status
    - water and nutrient balance
    - identify major sources
  - WASP, CE-QUAL-W2 – multidimensional models
    - Wind, temperature, water balance
    - Temporal and spatial relationships need to be explicitly quantified

Lake modeling

BATHTUB	Steady-state, statistical nutrient model Lakes
HSPF Hydrologic Simulation Program - FORTRAN	Comprehensive runoff and constituent model, process-based Well-mixed receiving water model; first-order decay; river; 1D
QUALTX	Steady-state flow and water quality model Segmented; first-order decay; river; 1D
WASP Water Analysis and Simulation Package	Comprehensive multidimensional water quality analysis Requires external hydrodynamic model
CE-QUAL-W2	Comprehensive multi-dimensional water quality analysis Includes hydrodynamics, stratification; Estuaries and lakes
CSTR Continuously-stirred tank reactor	Standard mass-balance model of a well-mixed segment Custom formulation and spreadsheet implementation

INPUT DATA REQUIREMENTS

Standard	Comprehensive
Inflow	Inflow and conc. time-series
Depth	Bathymetry
Surface area	Circulation patterns
Water exchange	Wind
Segmentation	Temperature
Pollutant concentration input	Solar radiation
Pollutant change or decay	Profiles
Pollutant concentration output	Processes causing change

CALIBRATION AND VALIDATION DATA

Standard	Comprehensive
Concentration	Concentration time-series
Water movements	Tracers
	Flow measurements

Lake modeling

	Available Data	CSTR-MB	HSPF	QUALTX	WASP	CE-QUAL-W2
Input Data						
Inflow	3	•	•	•	•	•
Outflow	3	•	•	•	•	•
Water exchange	-	•			•	•
Depth	1*	•	•	•	•	•
Suface area	1	•	•	•	•	•
Segmentation	3	•		•	•	•
Pollutant load	3	•	•	•	•	•
Pollutant change or decay	3	•	•	•	•	•
Inflow time-series	3		•		•	•
Pollutant load time-series	1*		•		•	•
Bathymetry	1*				•	•
Circulation patterns	-				•	•
Wind	2				•	•
Temperature	2	•	•	•	•	•
Solar radiation	2,3				•	•
Vertical variation	3				•	•
Processes causing change	3				•	•
Calibration and Validation Data						
Pollutant concentration	1	•	•	•	•	•
Water exchange, inflow, outflow	3*	•	•	•	•	•
Pollutant concentration time-series	-		•		•	•

1 = Detailed site-specific data
2 = Less detailed regional data
3 = Can be estimated from literature or modeling
* = Data only available for some areas

Watershed Modeling Recommendations

- Utilize a simple watershed modeling approach (rainfall-runoff method).

- Reasons:
  - Small (or no) drainage areas for the coves/canals,
  - Limited data on runoff water quality,
  - Limited data on runoff volumes, and
  - Limited time series data.

Canal/Cove Modeling Recommendations

- Utilize a segmented well-mixed mass balance model (steady-state conditions).

- Reasons:
  - Shallow depths in coves,
  - Limited data on biologic and nutrient kinetics,
  - Limited time series for existing data (period of record and timing of data), and
  - Limited hydrodynamic data.

Additional Data needs

- Septic tracer studies
  - Understanding movement of bacteria into coves.
- Lake-to-canal water exchange
  - Dye tracer with atmospheric and WQ measurements
  - Understanding movement and interaction of water from main body to coves/canals.
- Bacterial Source Tracking (utilized for verification).
- Monitoring
  - Additional nutrient data in main body,
  - Phosphorus tested to low detection limits, at 3 long-term lake stations

Recommendations for Modeling

- Rolling Hills Shores – Restricted lagoon, unique
- Arrowhead Shores – T-Canal
- Oak Trail Shores – T-Canal
- Ports O' Call – Deep finger canal
- Indian Harbor (<100) – Eastern most lagoon
- Nassau Bay – Deep cove and canals with tribs.
- Sky Harbor – Deep cove and canals with tribs.
- Waters Edge – finger canal, to validate model at low concentrations
- Port Ridglea East – Shallow finger canals
- Blue Water Shores – Determine source

Comments/Questions?