Galveston Bay
Freshwater Inflow Study

Proposed Framework utilizing Salinity Area Zonation for Senate Bill 3 Bay & Estuary Approach

Sponsored by:

City of Dallas
City of Houston
NTMWD
TRWD
TRA

May 2009

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Presentation to
Trinity-San Jacinto and
Galveston Bay
BBEST

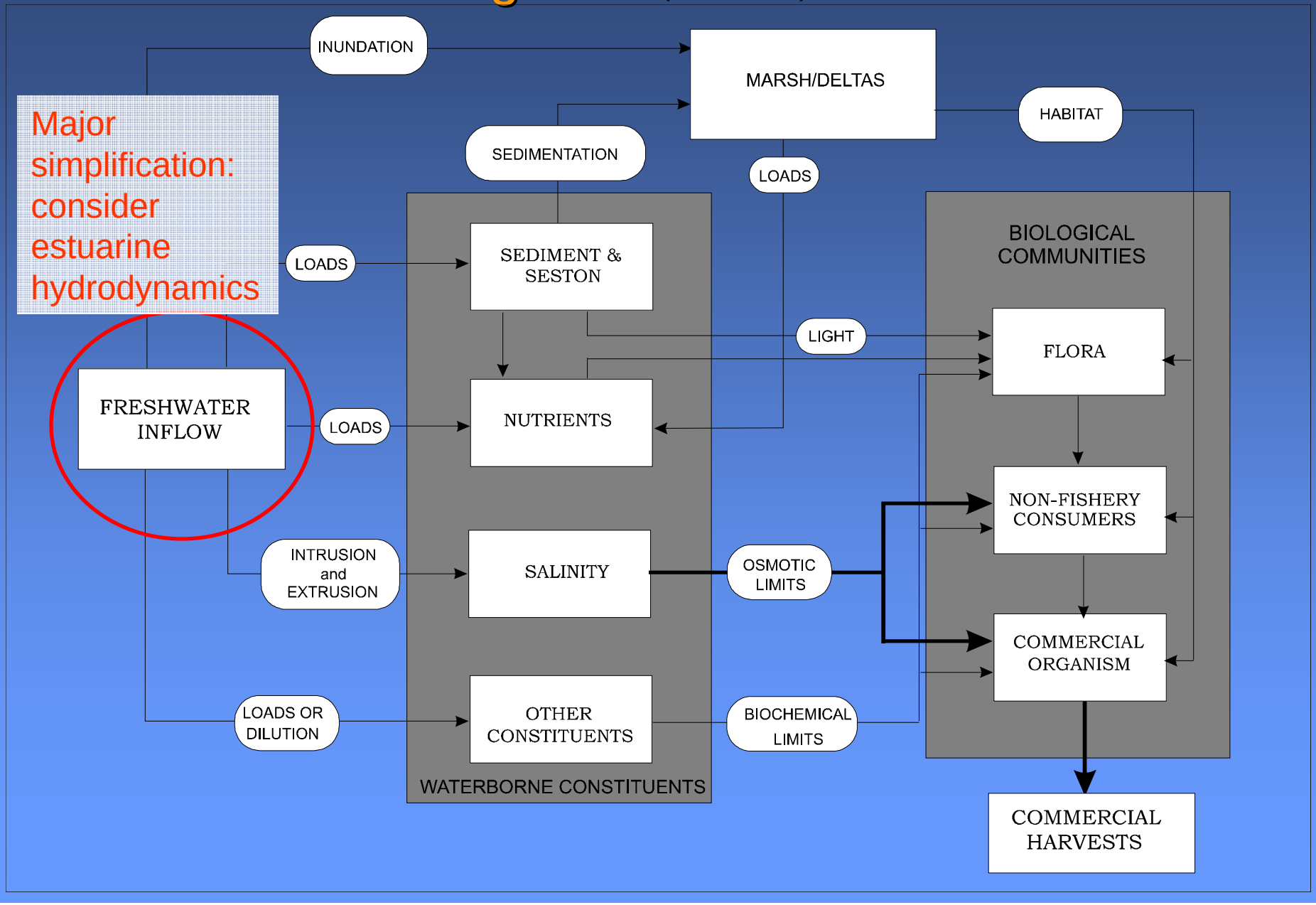
BBEST Mandate:

- Develop environmental flow analyses and a recommended environmental flow regime
- Must Achieve Consensus
- Must base answer on best available science
- SB3 defines "environmental flow regime" as:

"a schedule of flow quantities that reflects seasonal and yearly fluctuations that typically would vary geographically, by specific location in a watershed, and that are shown to be adequate to support a sound ecological environment and to maintain the productivity, extent, and persistence of key aquatic habitats in and along the affected water bodies".

Consensus via Witchcraft

Links with Inflows...
What We're Dealing With (Ward 1998)



Approach

- Fashion a toolbox
- Apply a suite of methods
- Characterize salinity regime necessary to "maintain the productivity, extent, and persistence of key aquatic habitats".

SB3 - Science Advisory Committee (SAC):

- SAC "Guidance" Document
  - B&E end of May
- The State Methodology is not just the resultant "Max H / MinQ" optimized solution
- Methodology is comprised of many <u>component tools</u> that play a role
  - What kind of ecological flow questions relevant to SB3 could each of these components be used to answer?
  - Identified Strengths/weaknesses

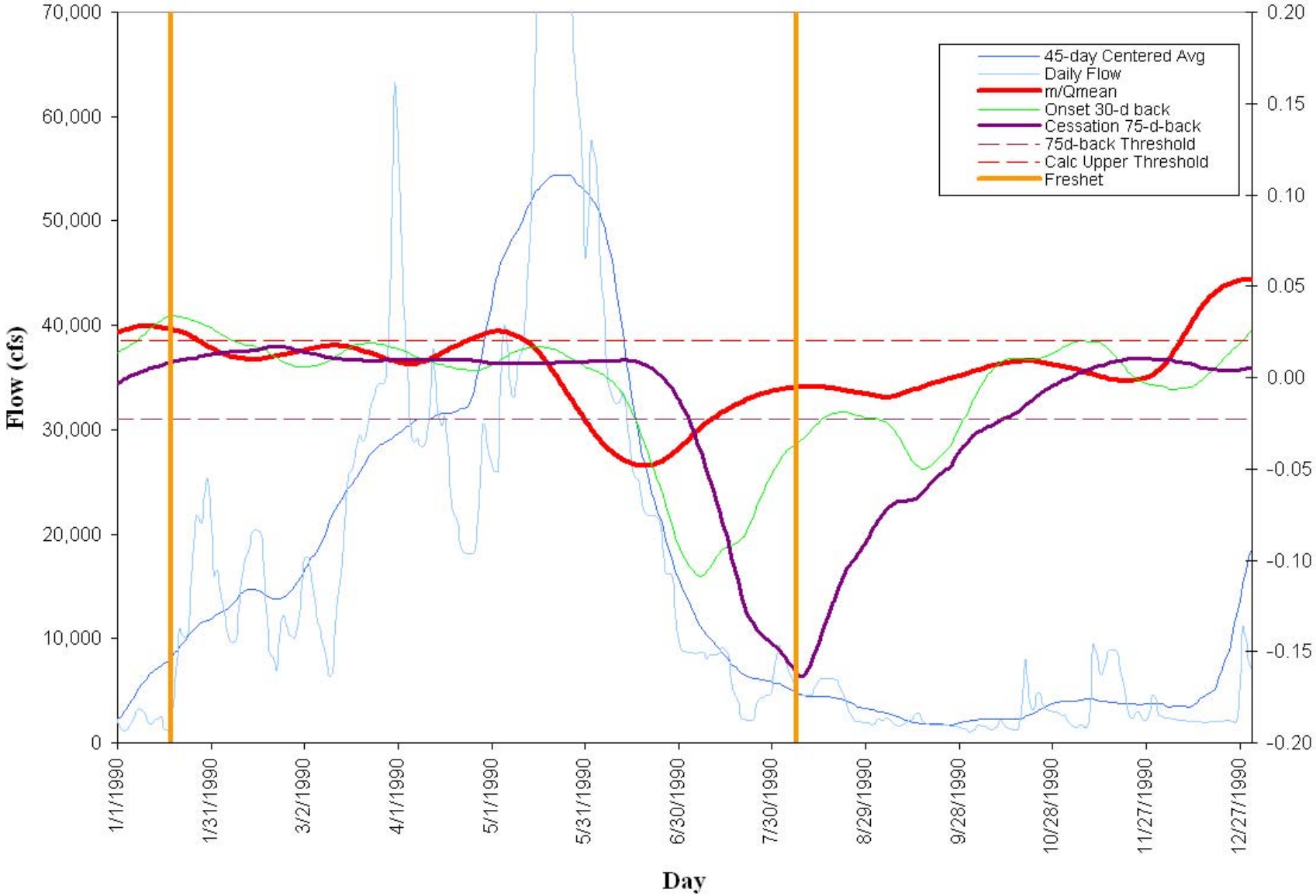
Trinity/SJ Galveston Bay BBEST

- BBEST has been in a “fact finding mode”
- Some salient points (to this observer):
  - FWI → Salinity → Biology
  - Texas has a natural freshwater inflow and salinity gradient along its coast.
  - It is important to understand where the bay ecosystem undergoes a regime change.
  - If it can be done, organisms are important to utilize as indicators.

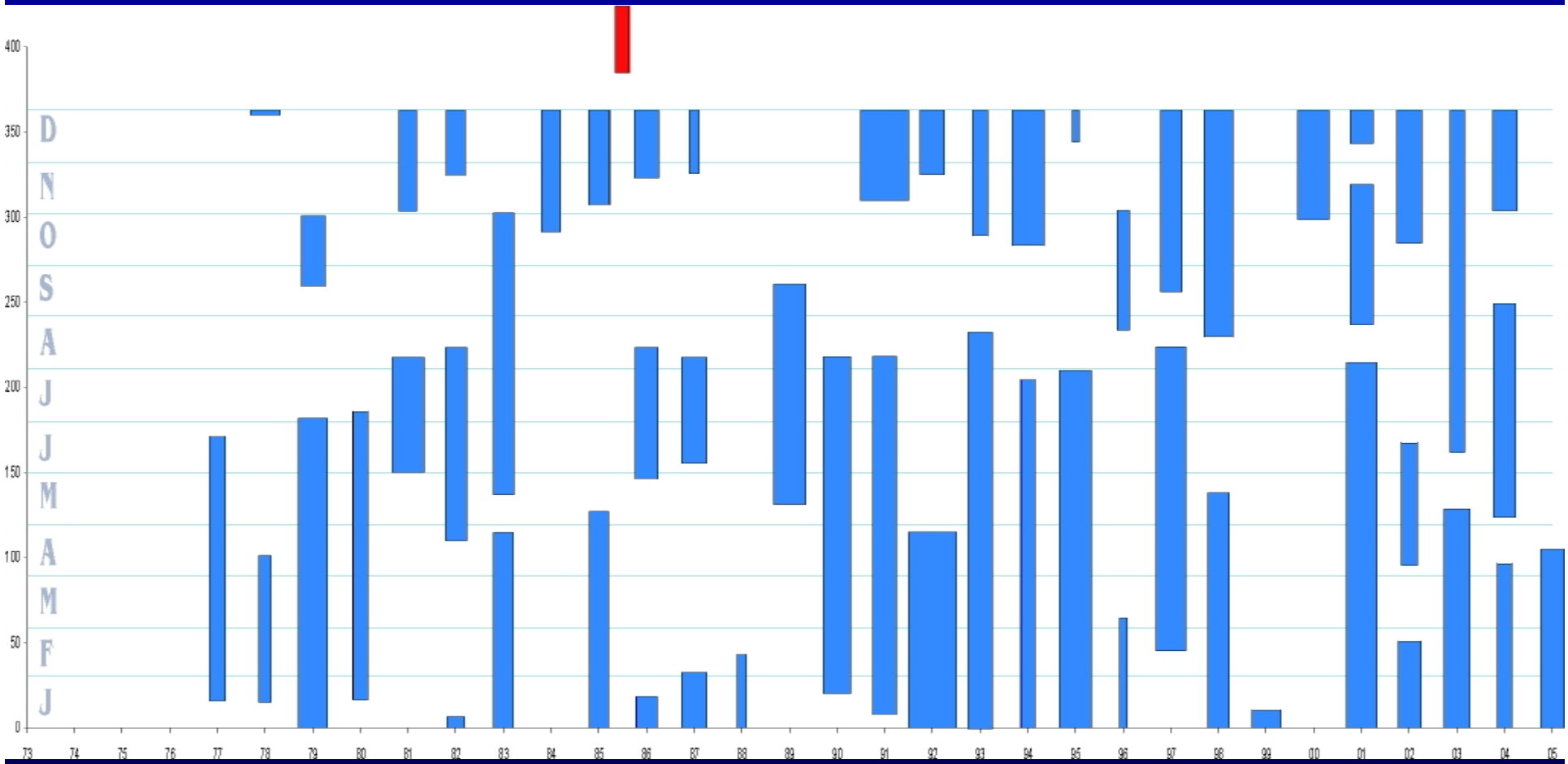
Hydrologic Characterization

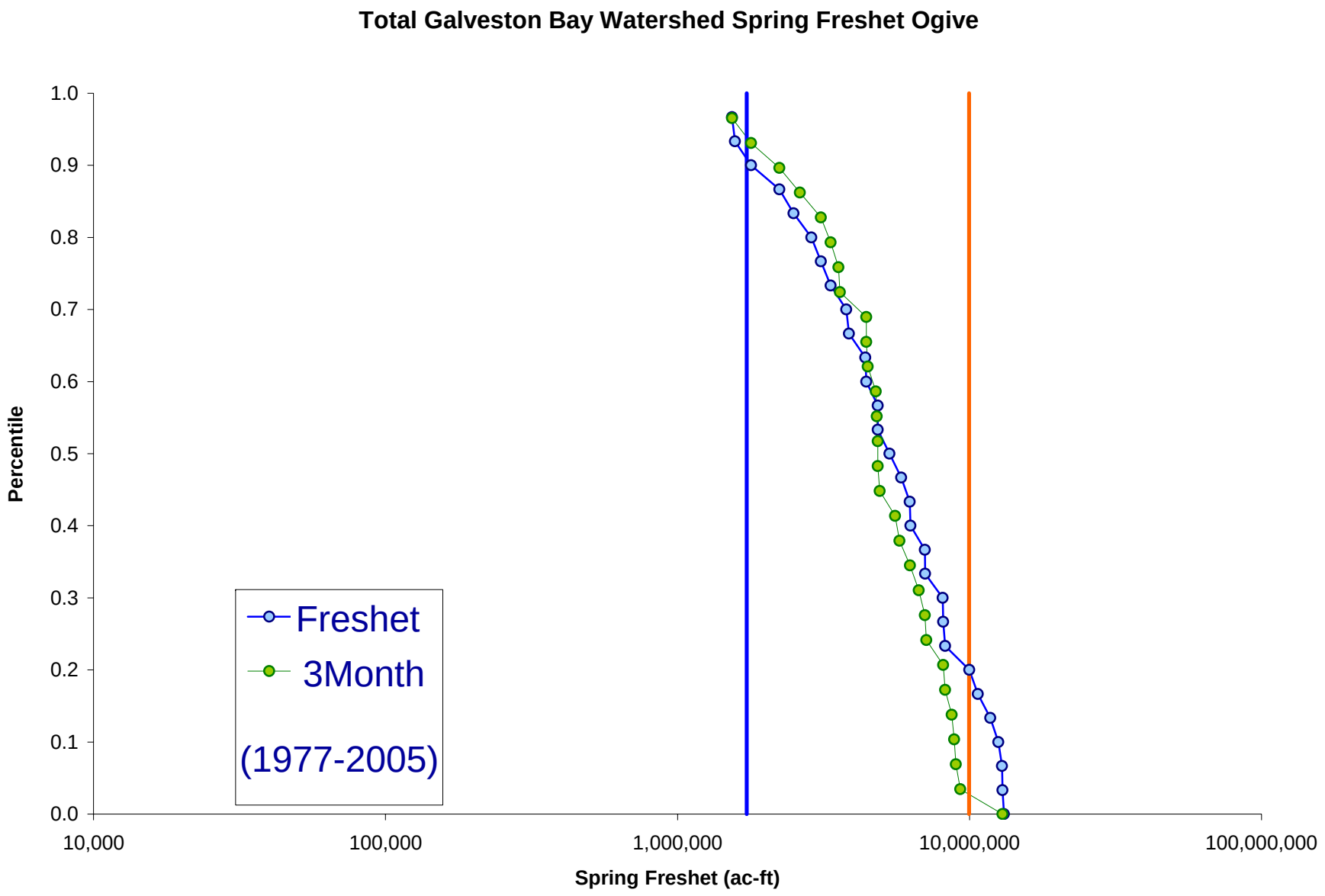
- The only driver of bay health that can possibly be influenced by basin water management
- Exhibits clear seasonal variation, spring & fall freshets and a summer “drought”
- Previously characterized in the State Methodology as six independent bi-monthly flow variables

Improved Representation of Flow via Freshets



Total Galveston Bay Inflows (1977-2005)




Total Galveston Bay Watershed Spring Freshet Ogive
Percentile
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
10,000
100,000
1,000,000
10,000,000
100,000,000
Spring Freshet (ac-ft)
Freshet
3Month
(1977-2005)

Salinity Analysis

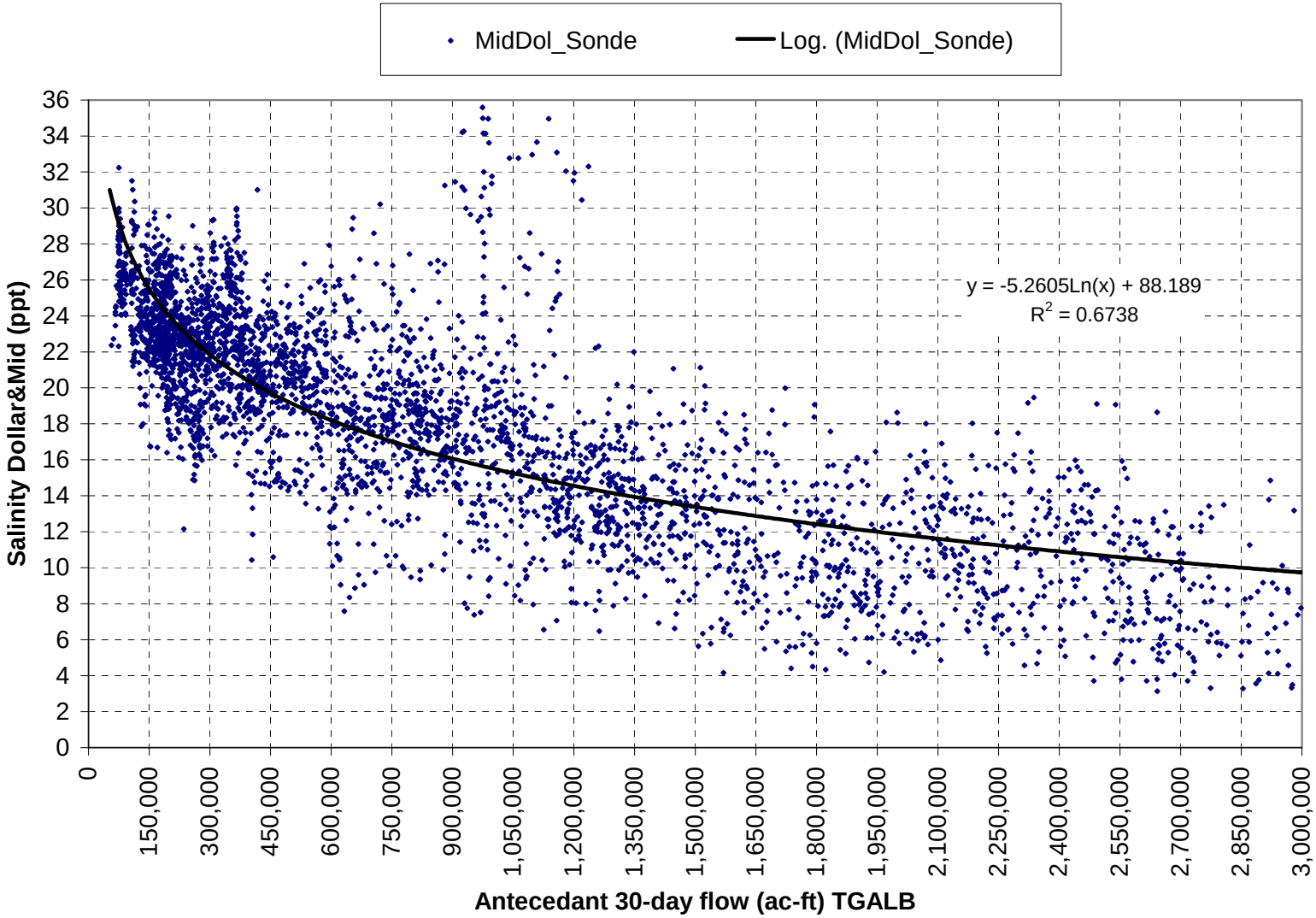
- TWDB Data Sonde Program
- Active since 1986
- 8 Sondes, intermittent sampling of WQ parameters

- Data Analyzed:
  - TRINITY BAY
  - RED BLUFF
  - MIDGAL & DOLLAR PT
  - BOLIVAR

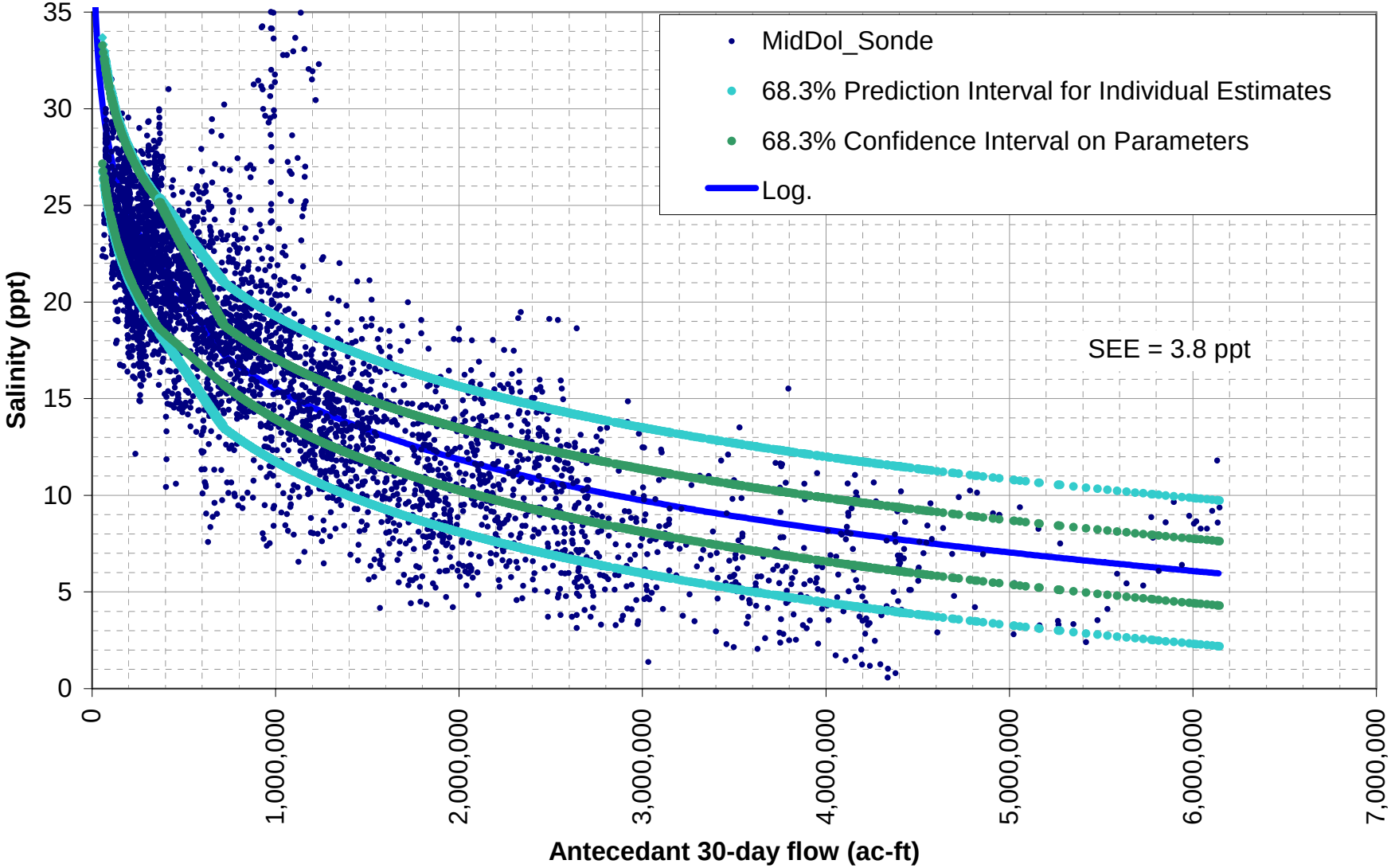
Salinity Analysis

- Salinity utilized as surrogate for habitat
- Salinity and habitat, along with flow, tie to organisms
- Utilize measurements at datasonde locations to assess freshwater inflow effects upon salinity zones within the entirety of the bay

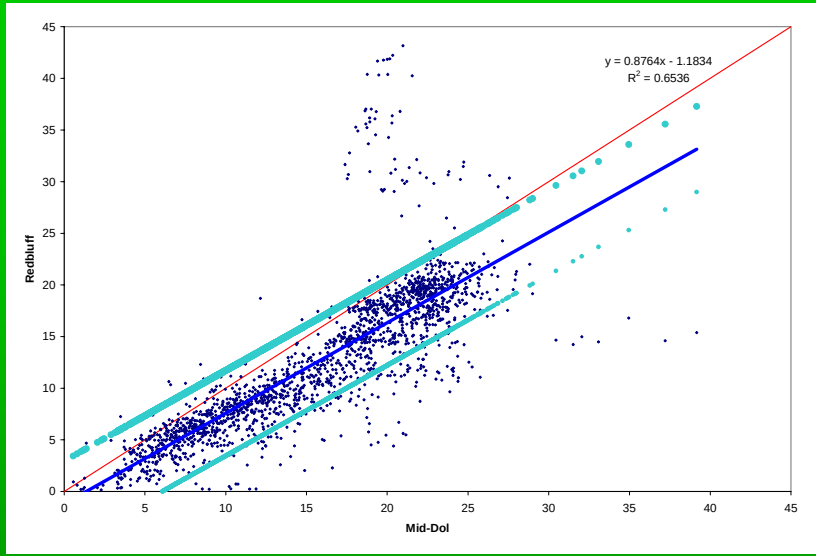
Total Galveston Bay Watershed – DOLLAR/MID Datasonde



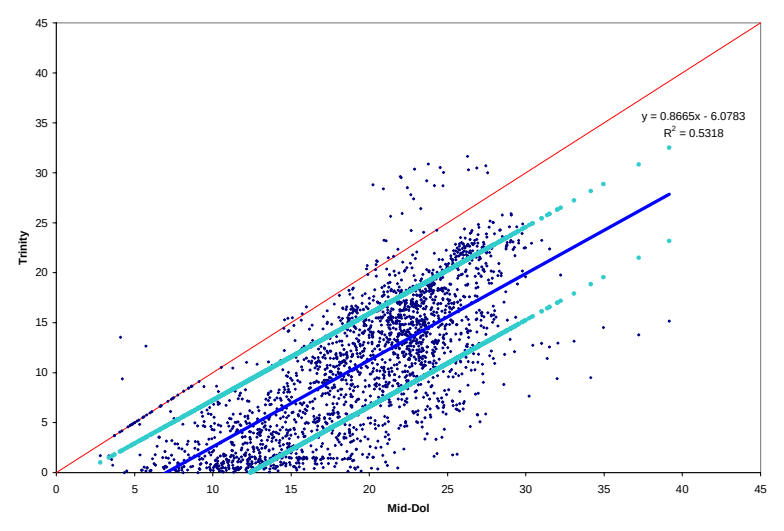
Must Account for Uncertainty



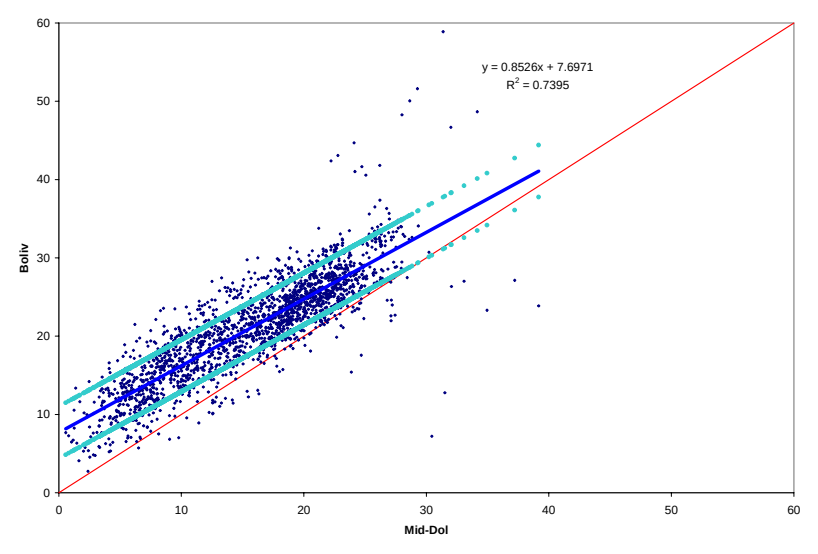
Linear Regressions of Salinity to Dollar/Mid Sonde



Red Bluff



Trinity



Bolivar

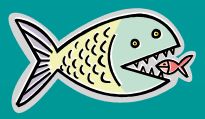
Comparison of POR Regression & Salinity vs. Salinity Regressions

	SEE	
Sonde	**POR Flow**	**DolarMidSal & Datasondes**
Trinity	6.3	4.6
Red Bluff	6.2	4.1
Dollar/Mid	3.8	3.8
Bolivar	4.8	3.3

TPWD Biological Data

- Our measure for organism “abundance”.
- To summarize, we have fashioned tools to aggregate specific organism data by space and time.
- These tools have been developed with adaptive capabilities for analyzing various gears, normalization techniques, and time periods.

Biological Parameterization

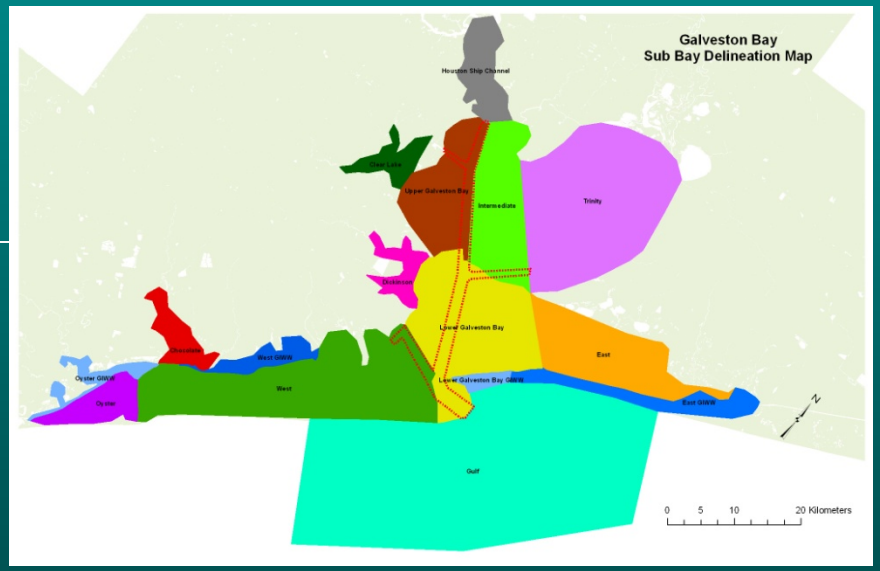


TPWD
Coastal Fisheries
Database

raw observations

$n(x_i, t_k)$ & $L_m(x_i, t_k)$

- Organism
- Gear type
- Space



Percentage of Regressions wherein Freshet Characterization Yields Greater Explained Variances

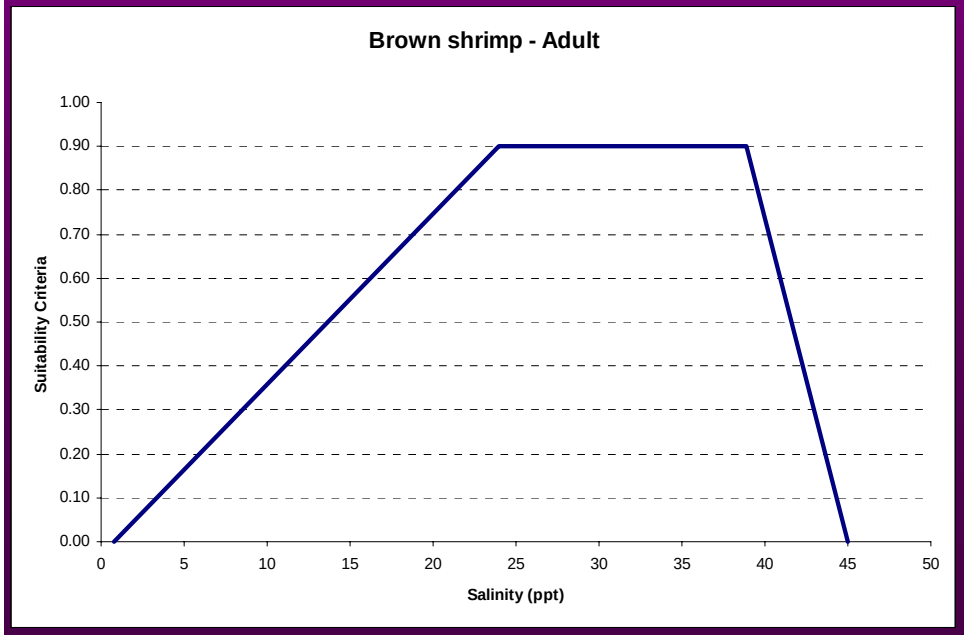
Total	Count	%
Freshet	74	73%
Annual	28	27%

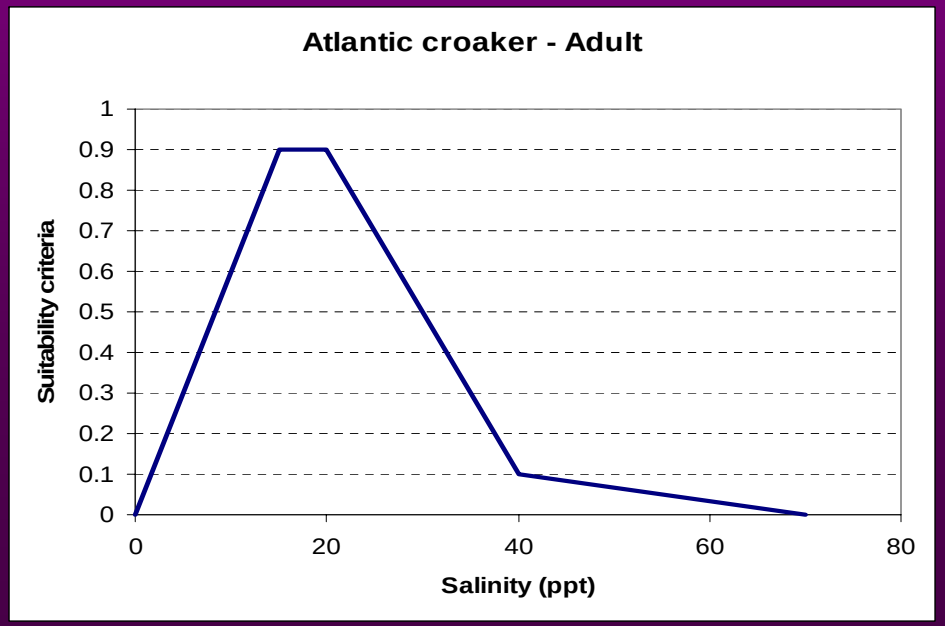
Literature

- NOAA's Estuarine Living Marine Resources (ELMR) Program
  - Species Life History Summaries
    - Pattillo, M.E., et al. 1997. Distribution and abundance of fishes and invertebrates in Gulf of Mexico estuaries, Vol. II: Species life history summaries. ELMR Rep. No. 11. NOAA/NOS SEA Division, Silver Spring, MD. 377 p.
  - Utilized in:
    - State Methodology
    - LSWP MBHE Approach

Salinity Suitability Curves:

- Organism salinity suitability (Ability to support organism)
- Suitability of 0.9-1 represents the best salinity conditions (e.g. preferred or optimal)
- Suitability of 0 indicates little tolerance to this salinity
- A drawback to this method is that how long an organism is exposed to a certain condition is not considered



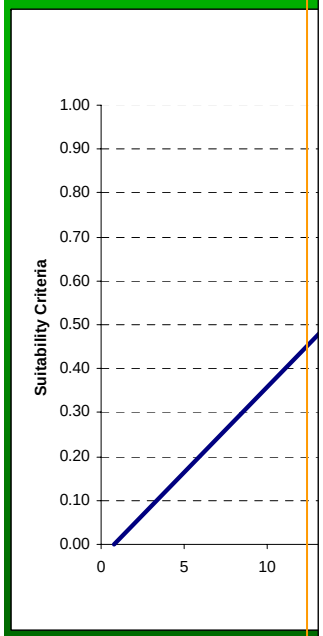


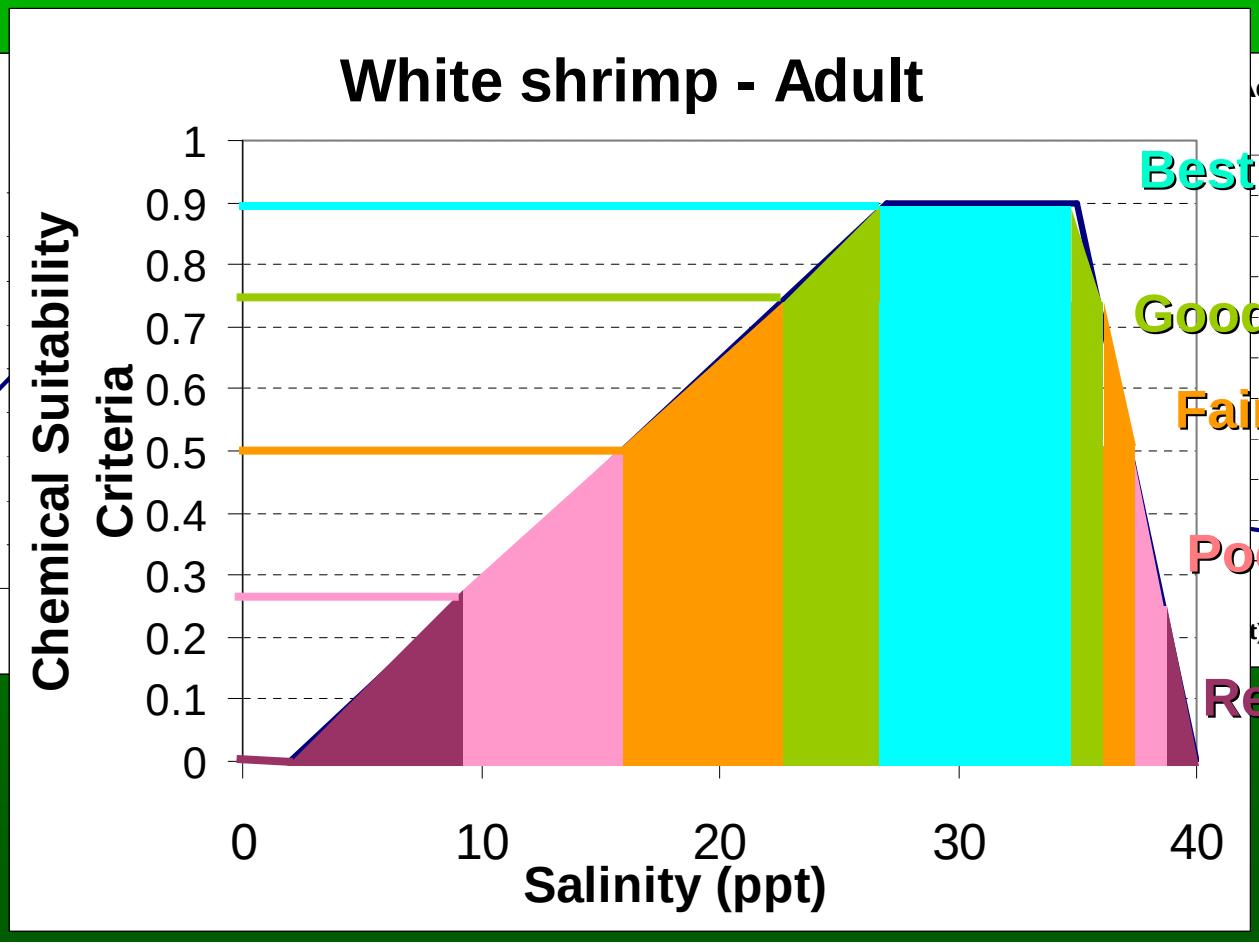
Now having developed:

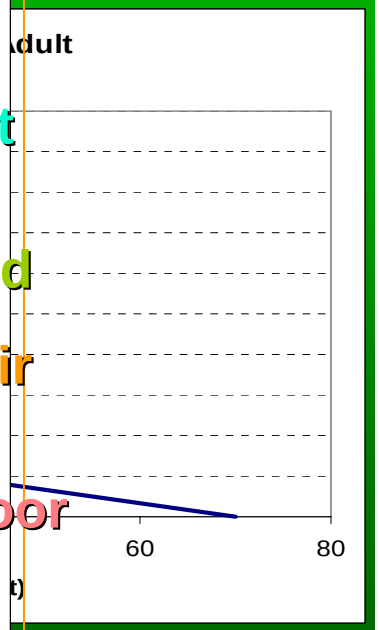
- Improved representations of hydrology
- Relations of salinity to flow based on actual data
- Relations of biology to hydrology
- Information on organism suitability to salinity
- How can we utilize this information?

Salinity Quality Zones:

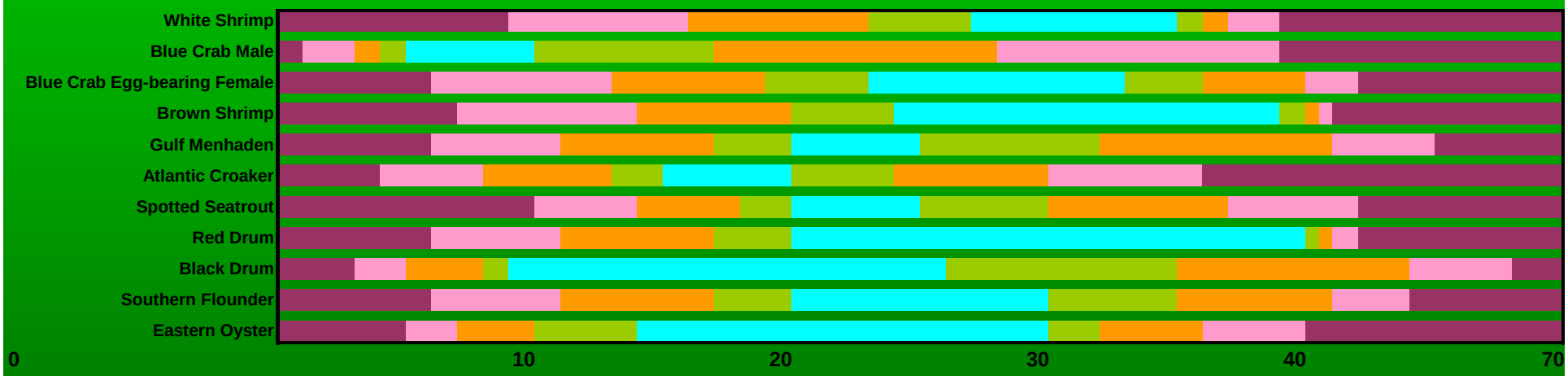
- Identify organism Salinity Quality zones
- This will yield ranges of salinities for each zone.





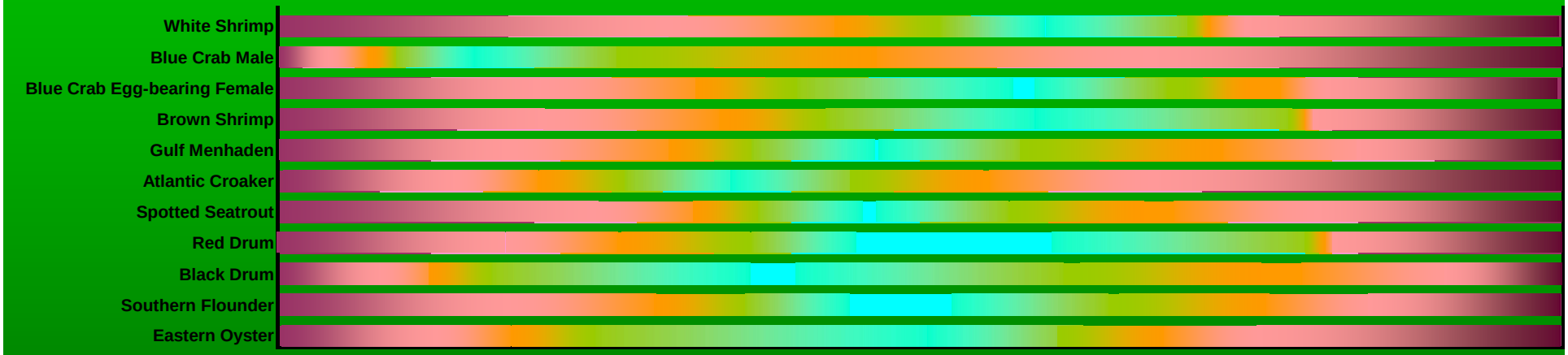


Salinity Quality Zones for each Euryhaline Organism within Study



0.9-1.0	0.75-0.9	0.5-0.75	0.25-0.5	<0.25
Best	Good	Fair	Poor	Refuge

Organisms likely behave more like this



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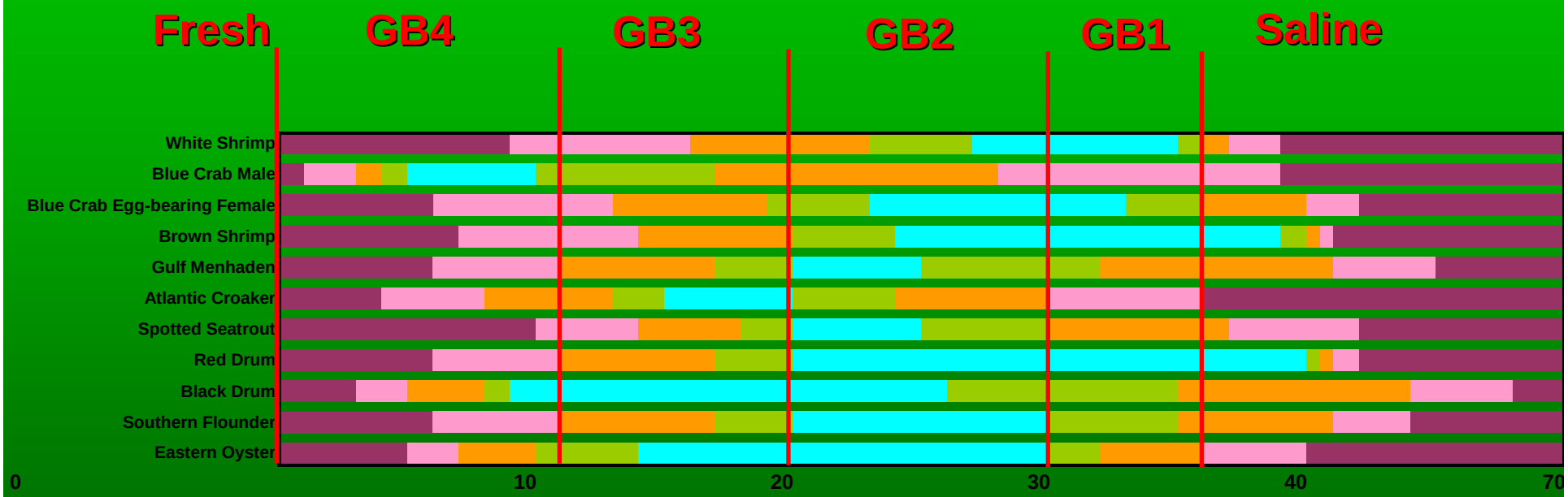
Salient points

- Approach is to characterize “salinity zones” to identify how often these salinity zones are maintained.
- Organisms may not differentiate a 1 ppt difference in salinity, would likely detect a 5-10 ppt. difference.
- Uncertainty in statistical relations has been ~ 4-5 ppt.
- Characterization of “best” salinity zone and breakpoints on the salinity curves are from ELMR, but the rest of the curve is interpolation.
- The salinity *quality* zones are an attempt to characterize the literature on the organisms preferences and tolerances.

Salinity Quality Zones for each Euryhaline Organism within Study



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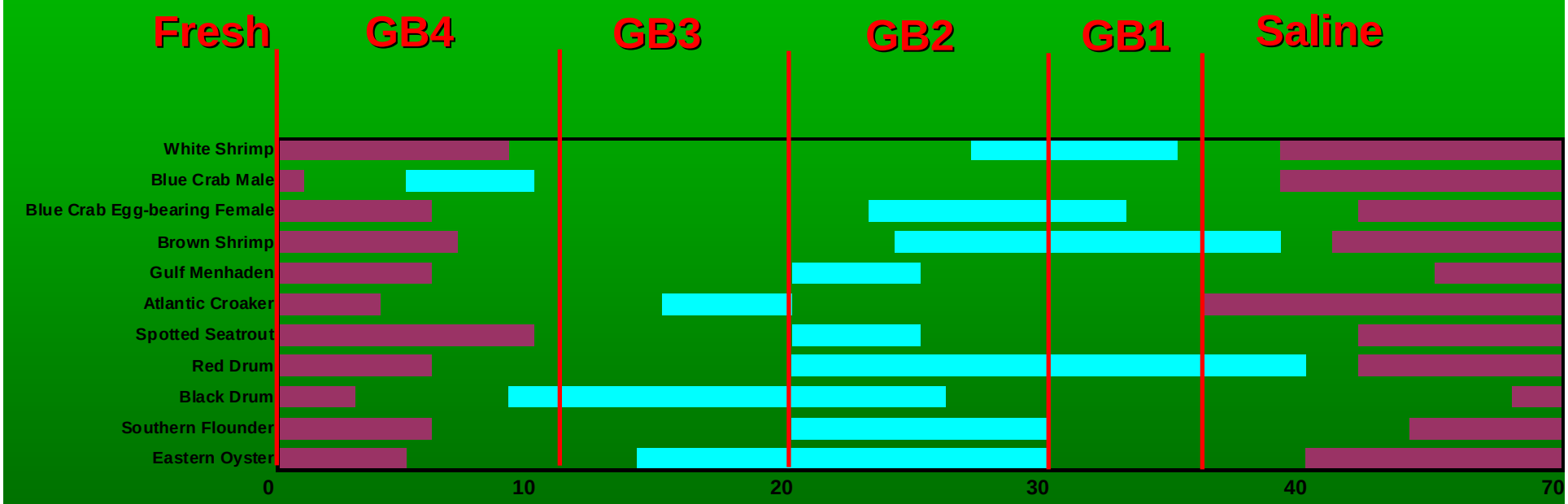
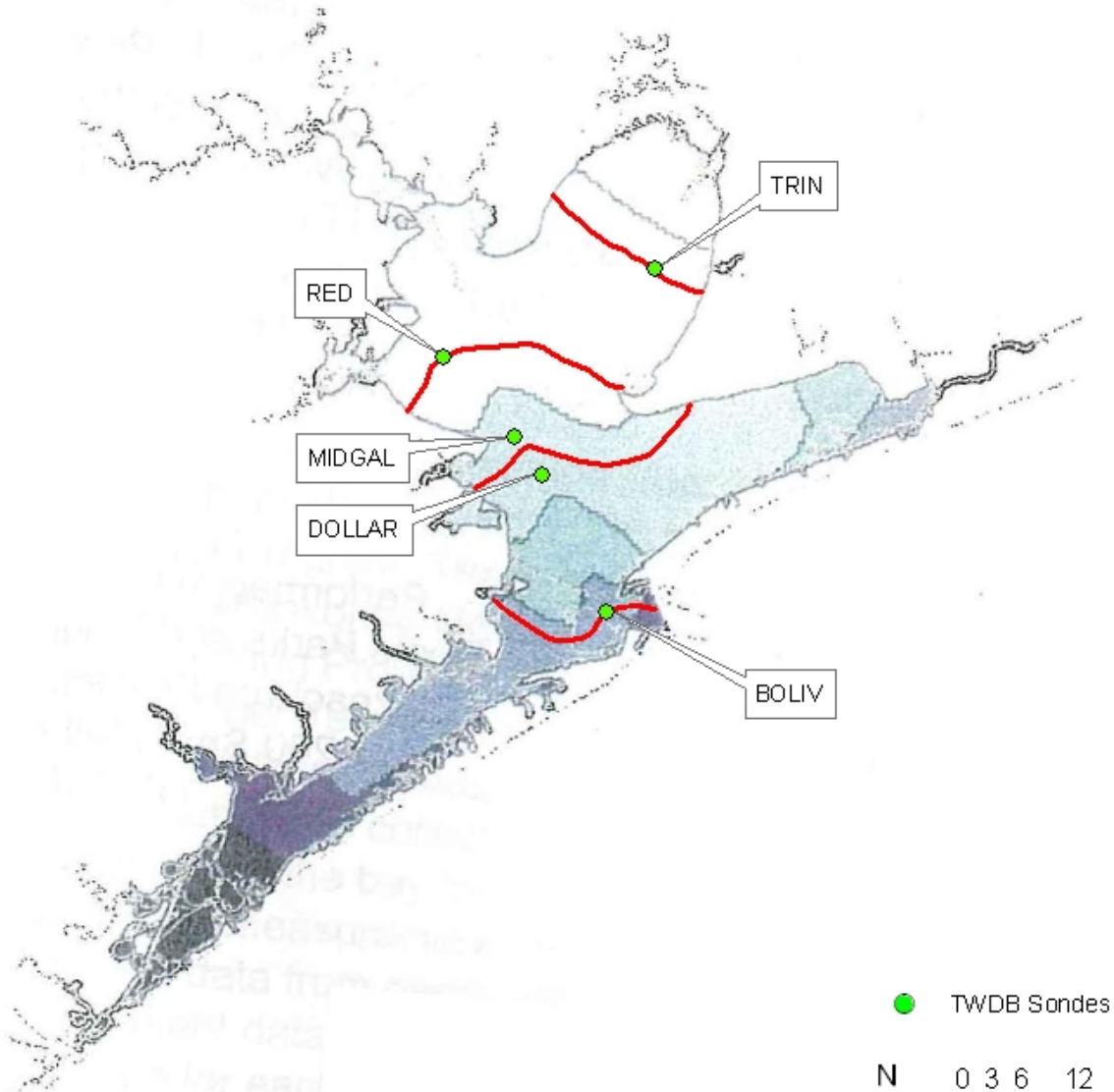


0.9-1.0	0.75-0.9	0.5-0.75	0.25-0.5	<0.25
Best	Good	Fair	Poor	Refuge

Salinity Zone Method

- Utilize Salinity/Flow Regressions to determine salinity at sonde locations for given flow conditions
- Utilize TxBLEND isohaline solely to interpolate shape of isohalines

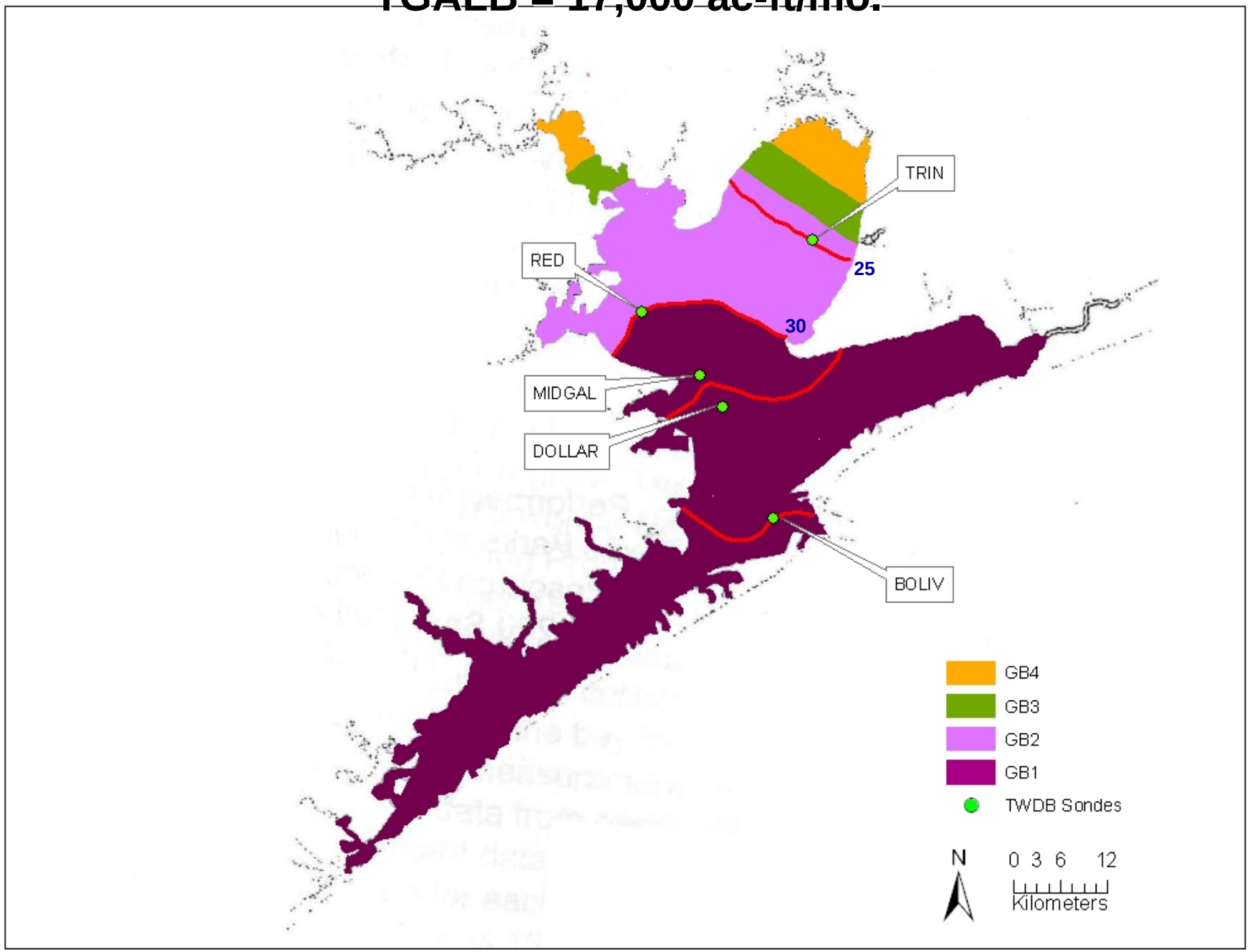


TxBLEND Modeled Salinity from Max H
March – August
(~median of 560,000 ac-ft/mo, TPWD 2001)

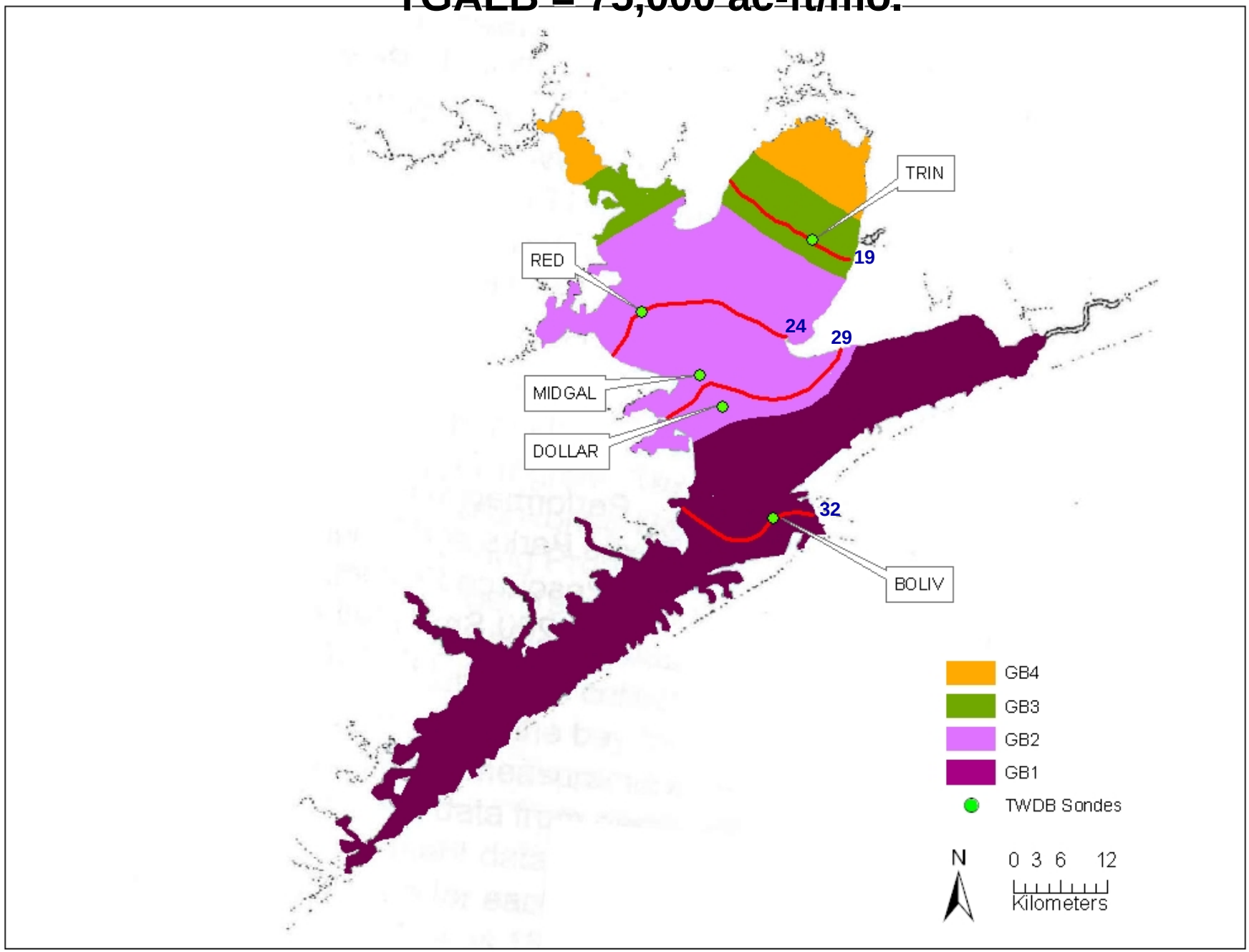
Salinity Zone Method

- Utilize Salinity/Flow Regressions to determine salinity at sonde locations for given flow conditions.
- Utilize TxBLEND isohaline solely to interpolate shape of isohalines
- Approximate where areas of GB(x) salinity zones would occur.

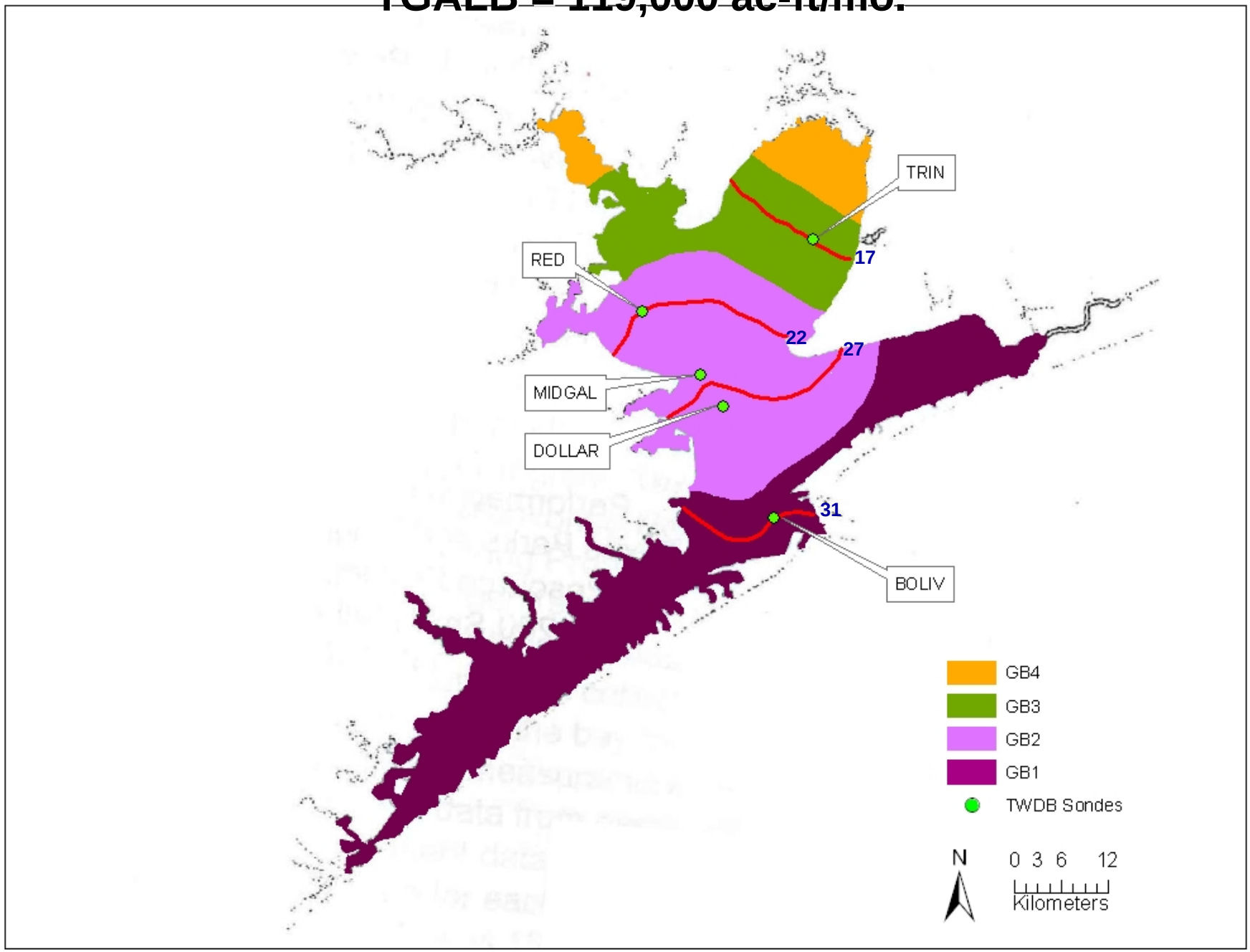
TGALB = 17,000 ac-ft/mo.



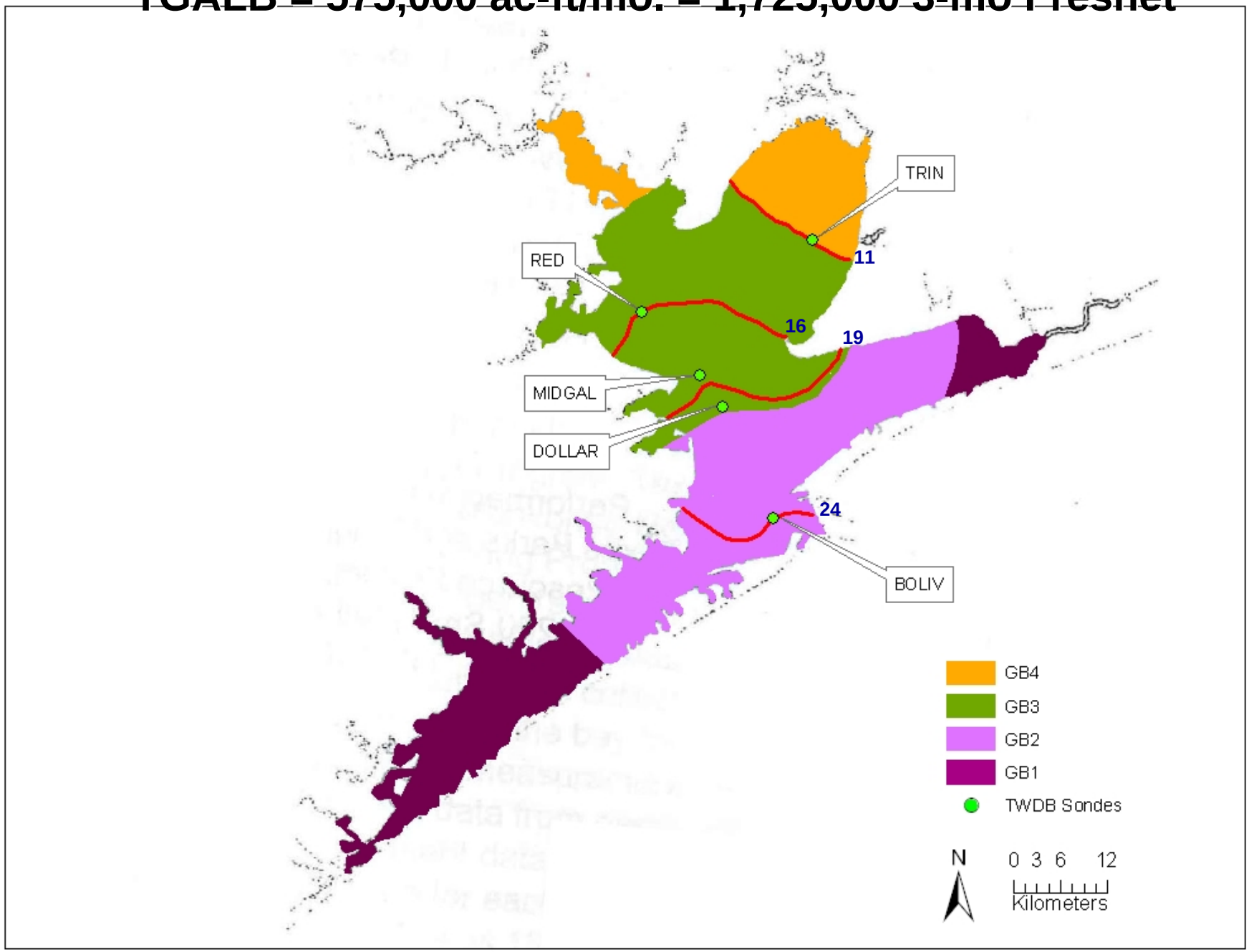
TGALB = 75,000 ac-ft/mo.



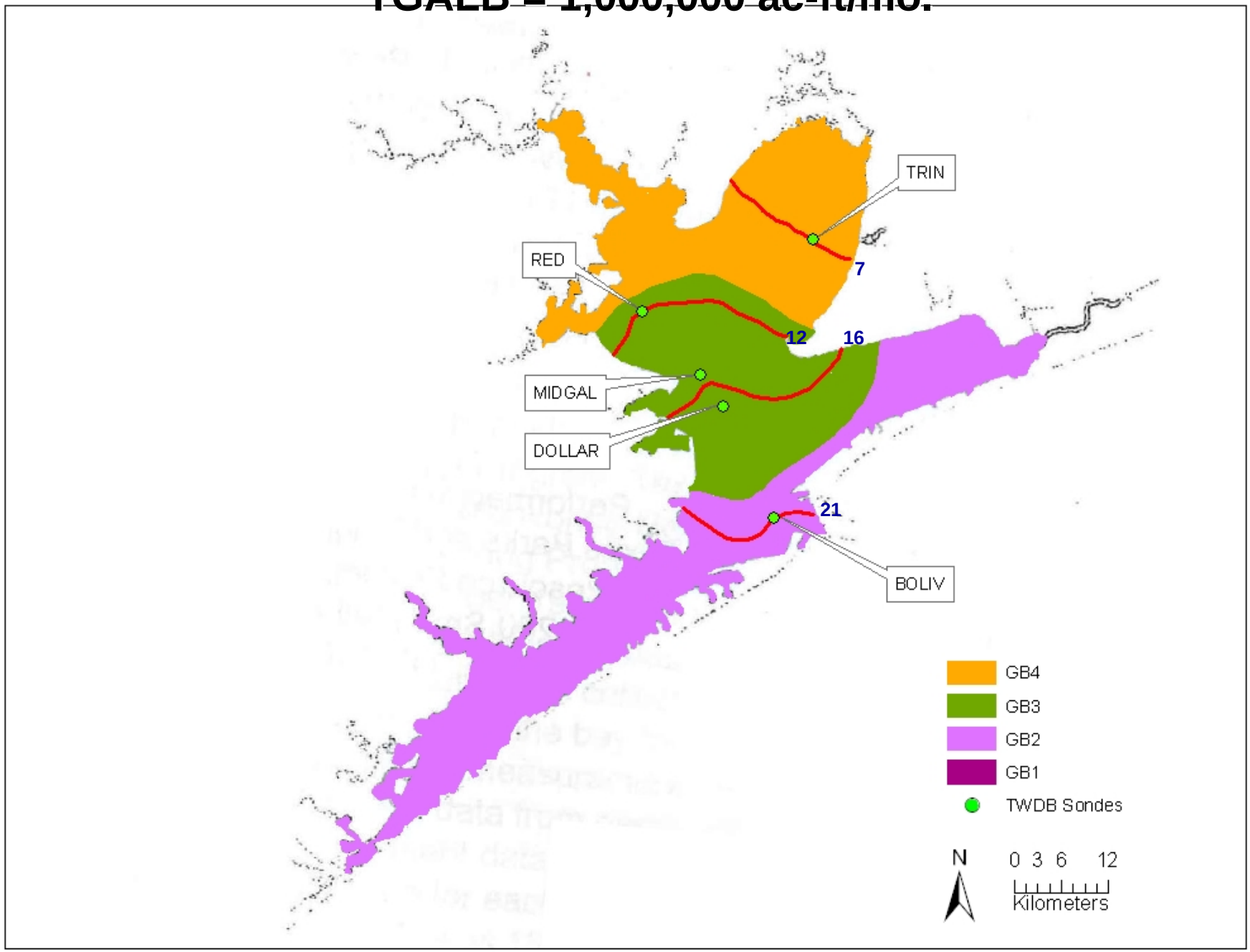
TGALB = 119,000 ac-ft/mo.



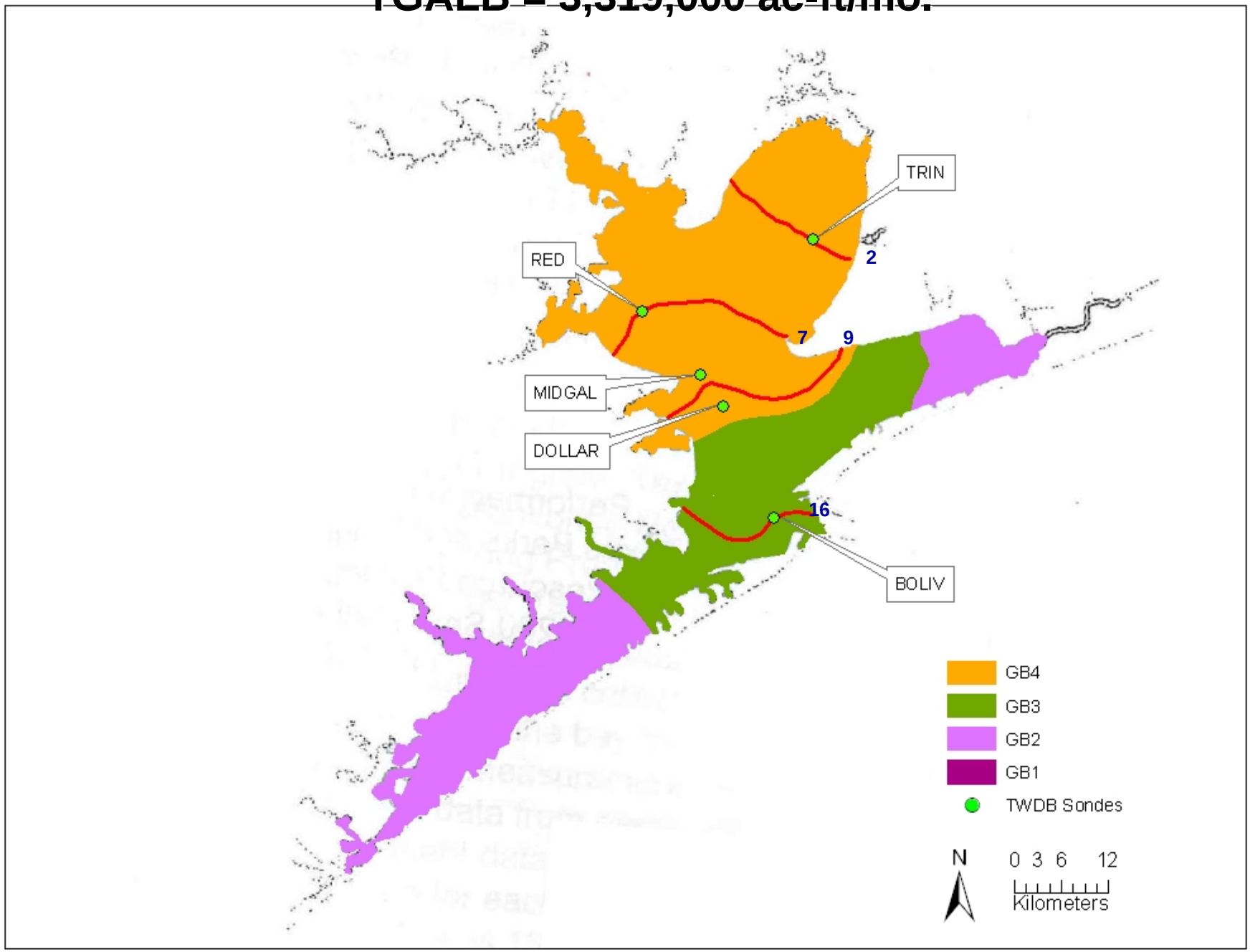
TGALB = 575,000 ac-ft/mo. = 1,725,000 3-mo Freshet



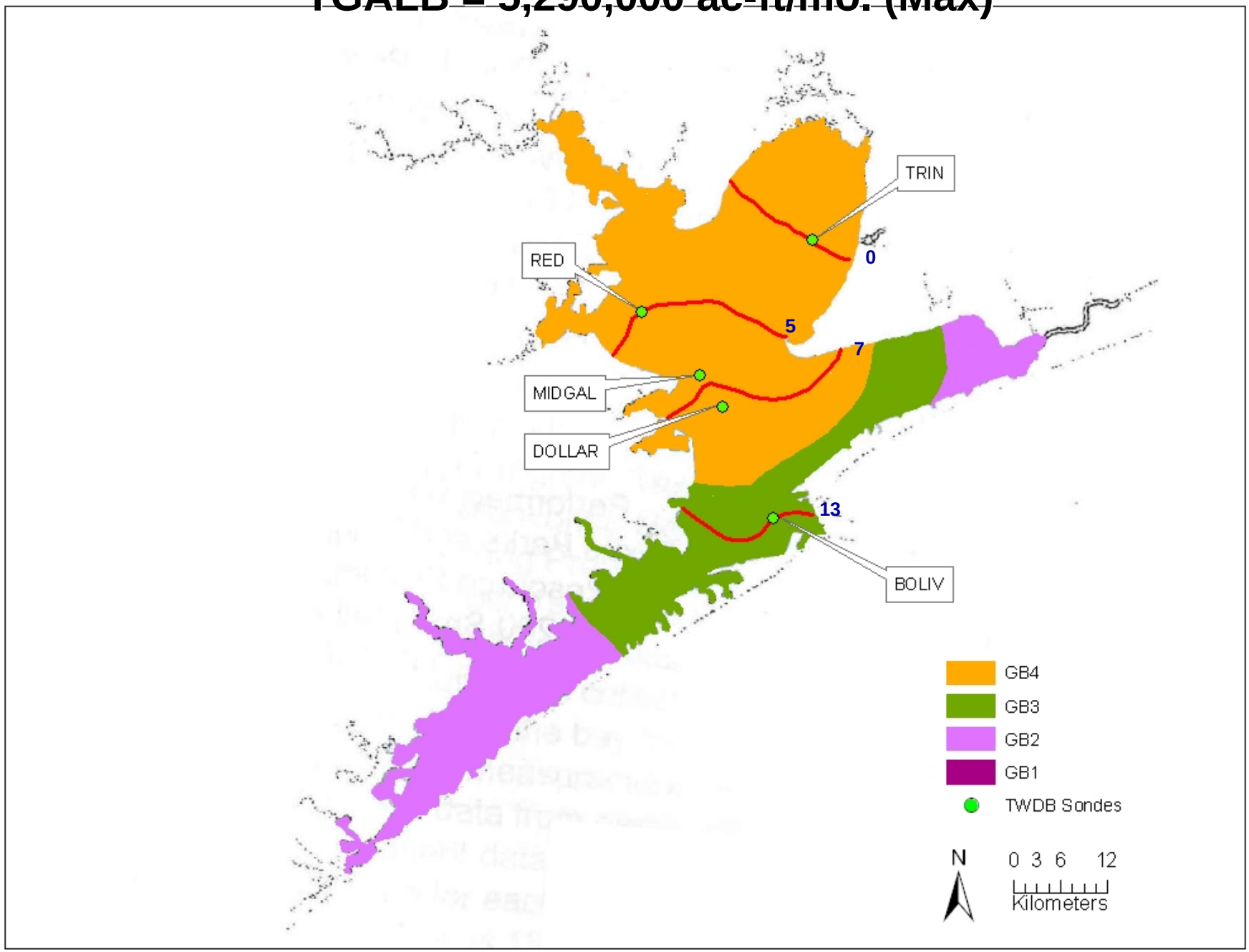
TGALB = 1,000,000 ac-ft/mo.



TGALB = 3,319,000 ac-ft/mo.



TGALB = 5,290,000 ac-ft/mo. (Max)

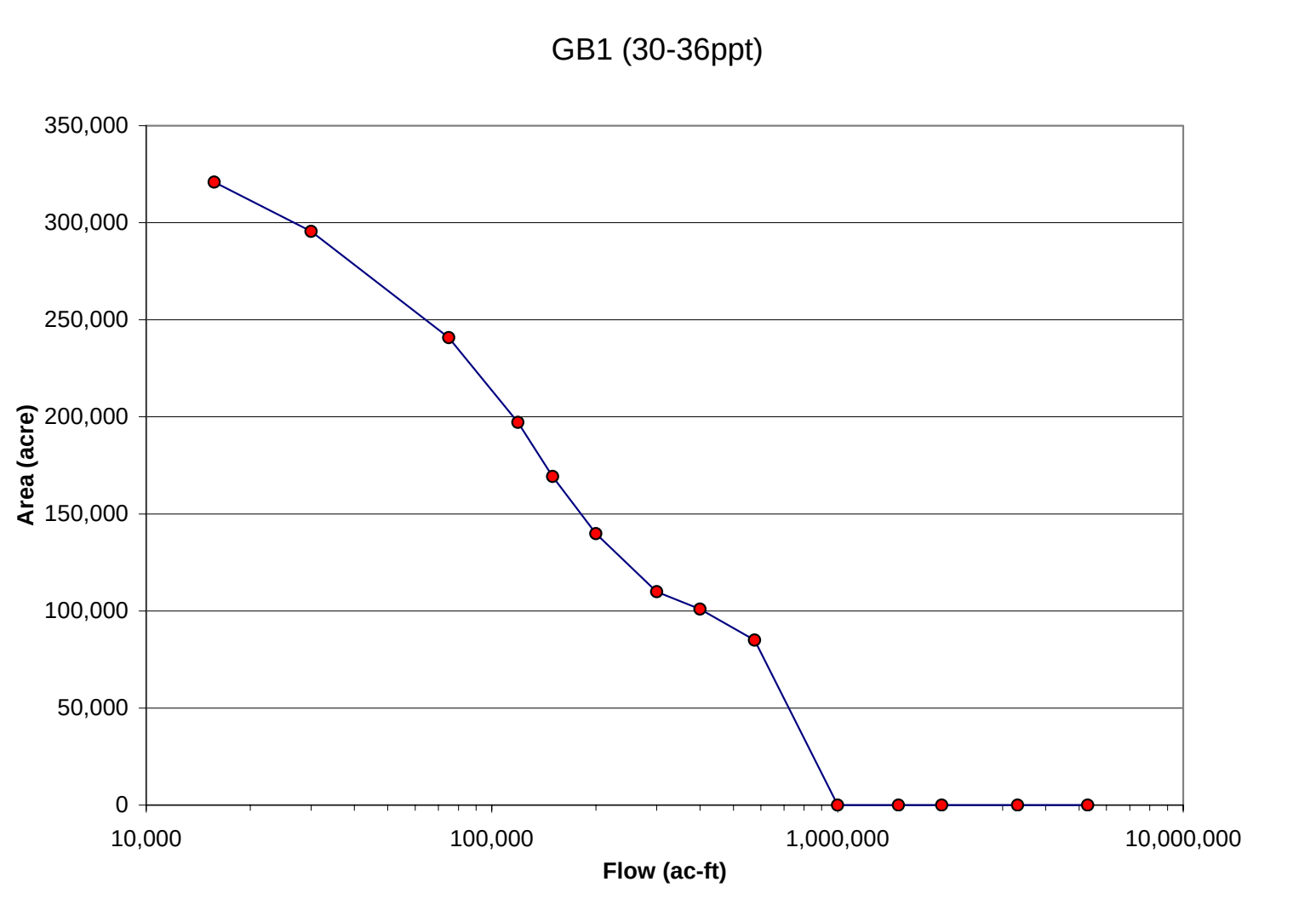


Salinity Zone Area vs. Flow Relations

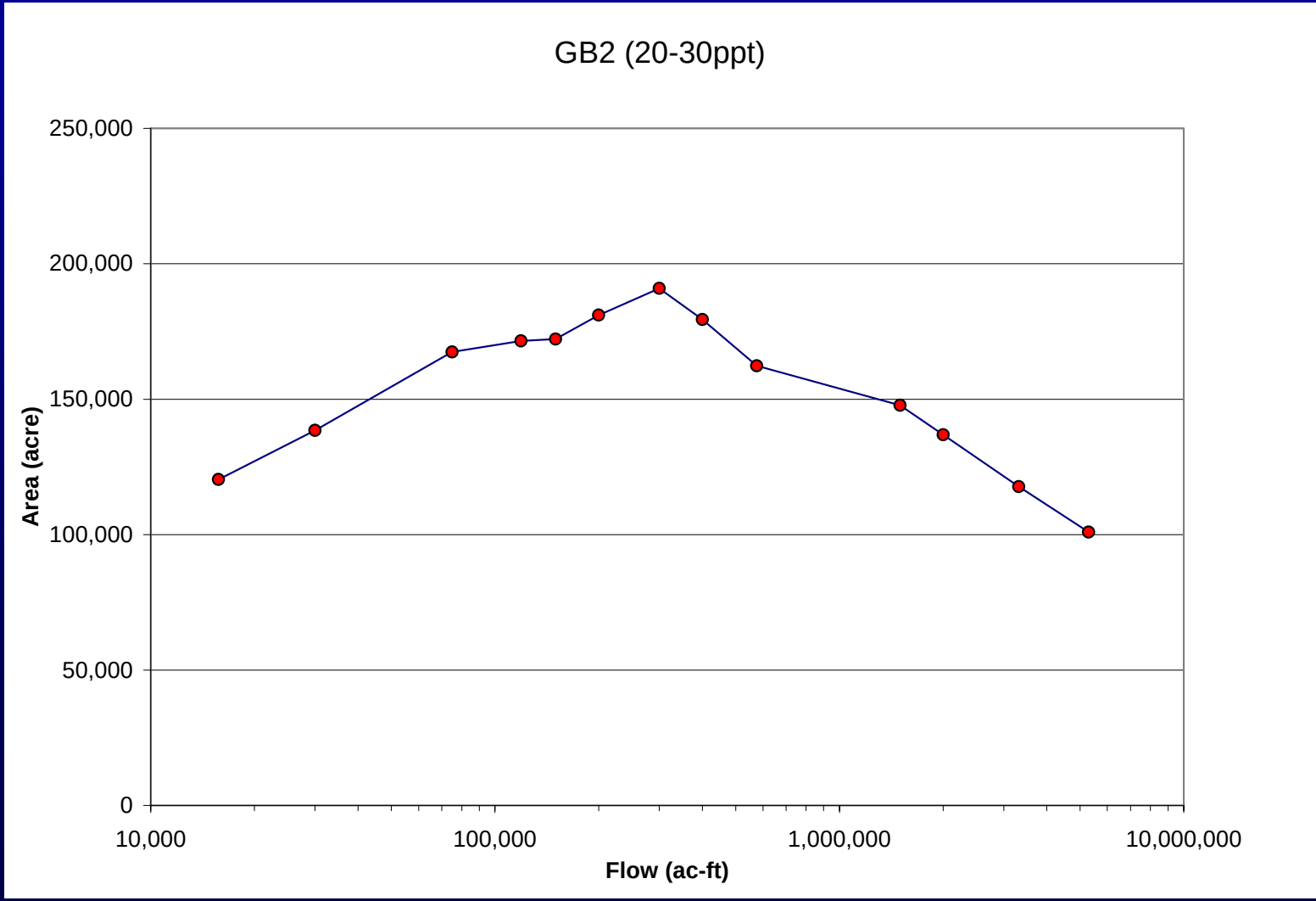
- Have now developed an ecological variable (Salinity Zone Area) that varies non-linearly with flow

- This variable can be depicted as a relation to flow

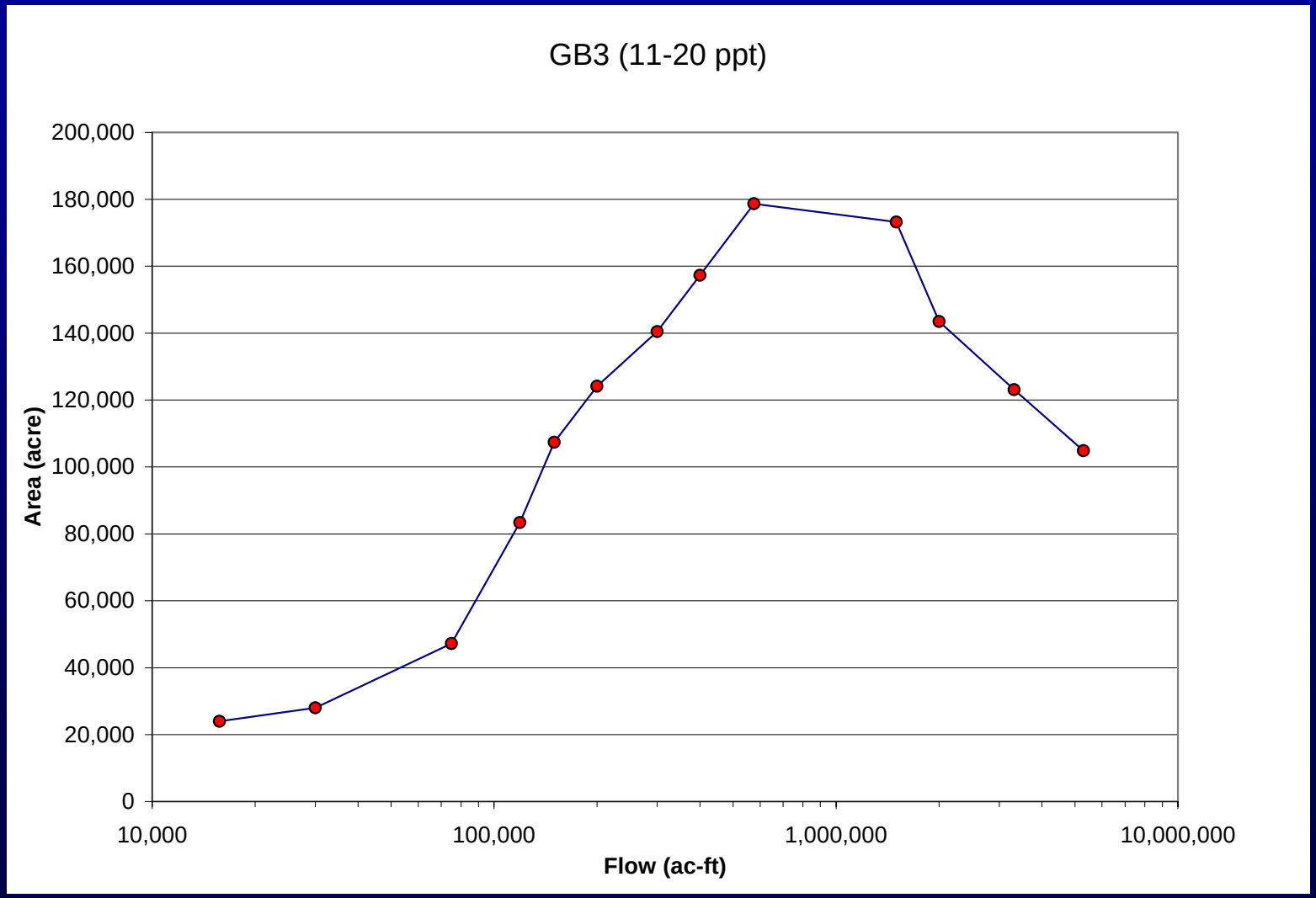
Relation of Total Galveston Bay Flow to Area of GB1 Salinity Zone



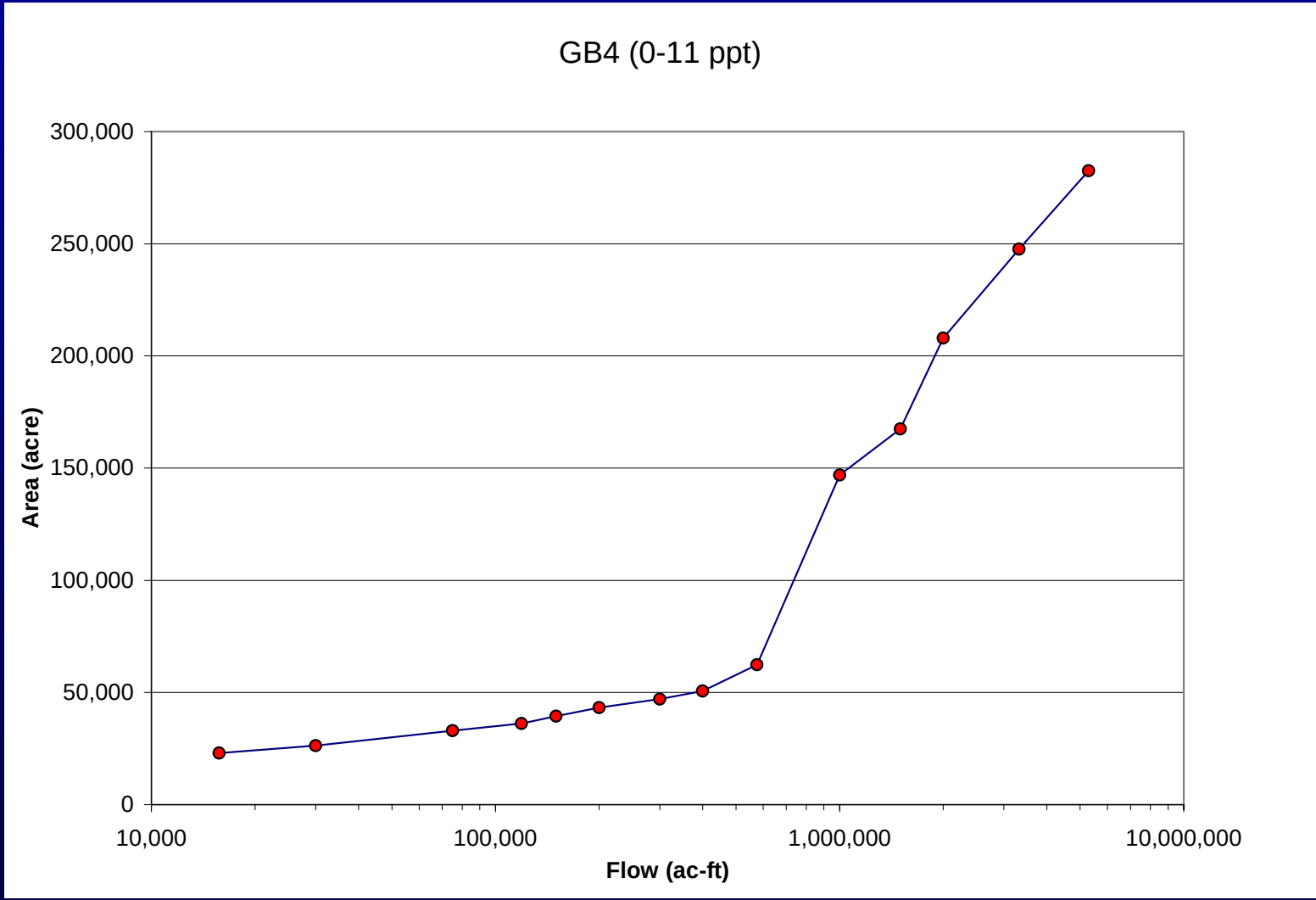
Relation of Total Galveston Bay Flow to Area of GB2 Salinity Zone



Relation of Total Galveston Bay Flow to Area of GB3 Salinity Zone



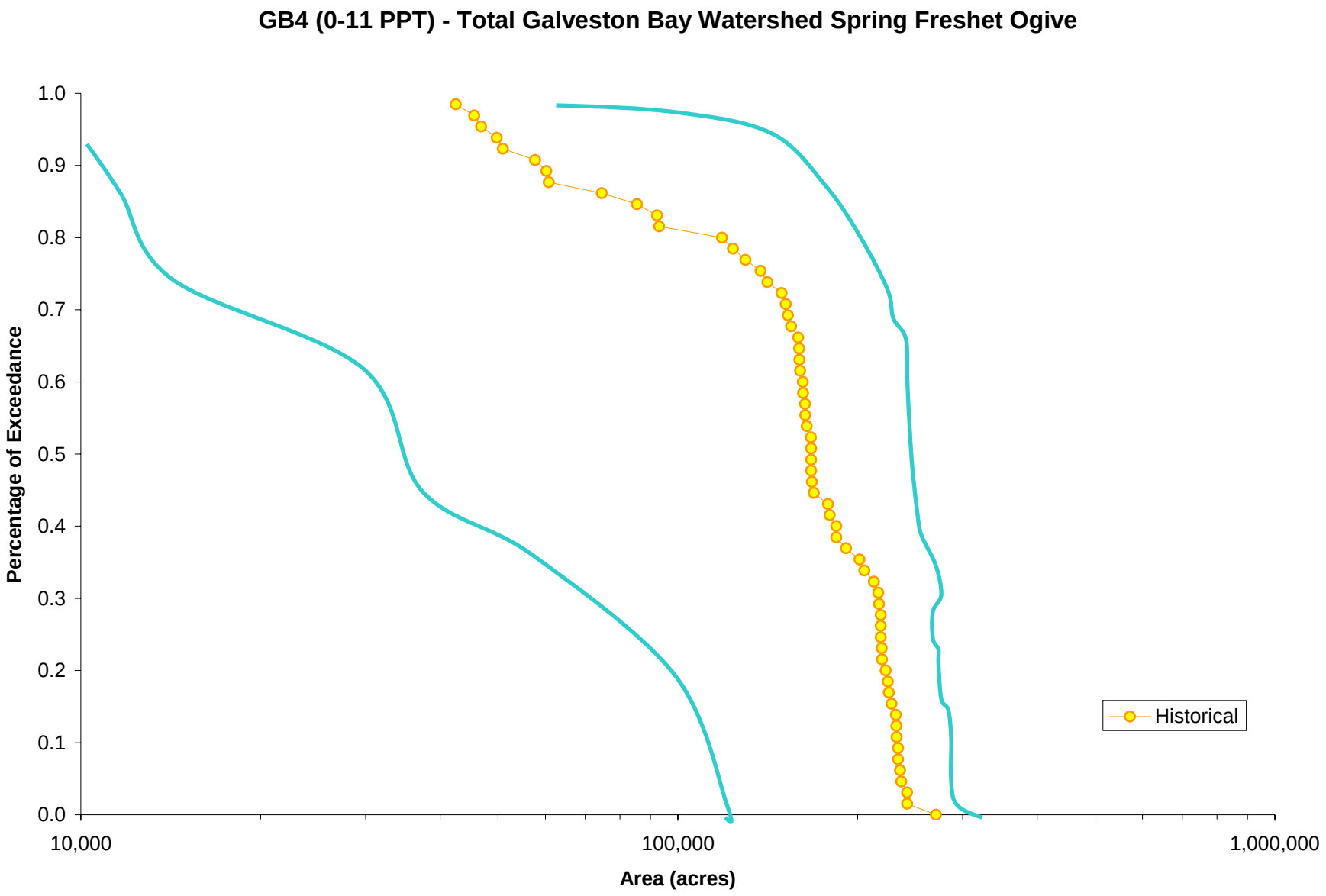
Relation of Total Galveston Bay Flow to Area of GB4 Salinity Zone



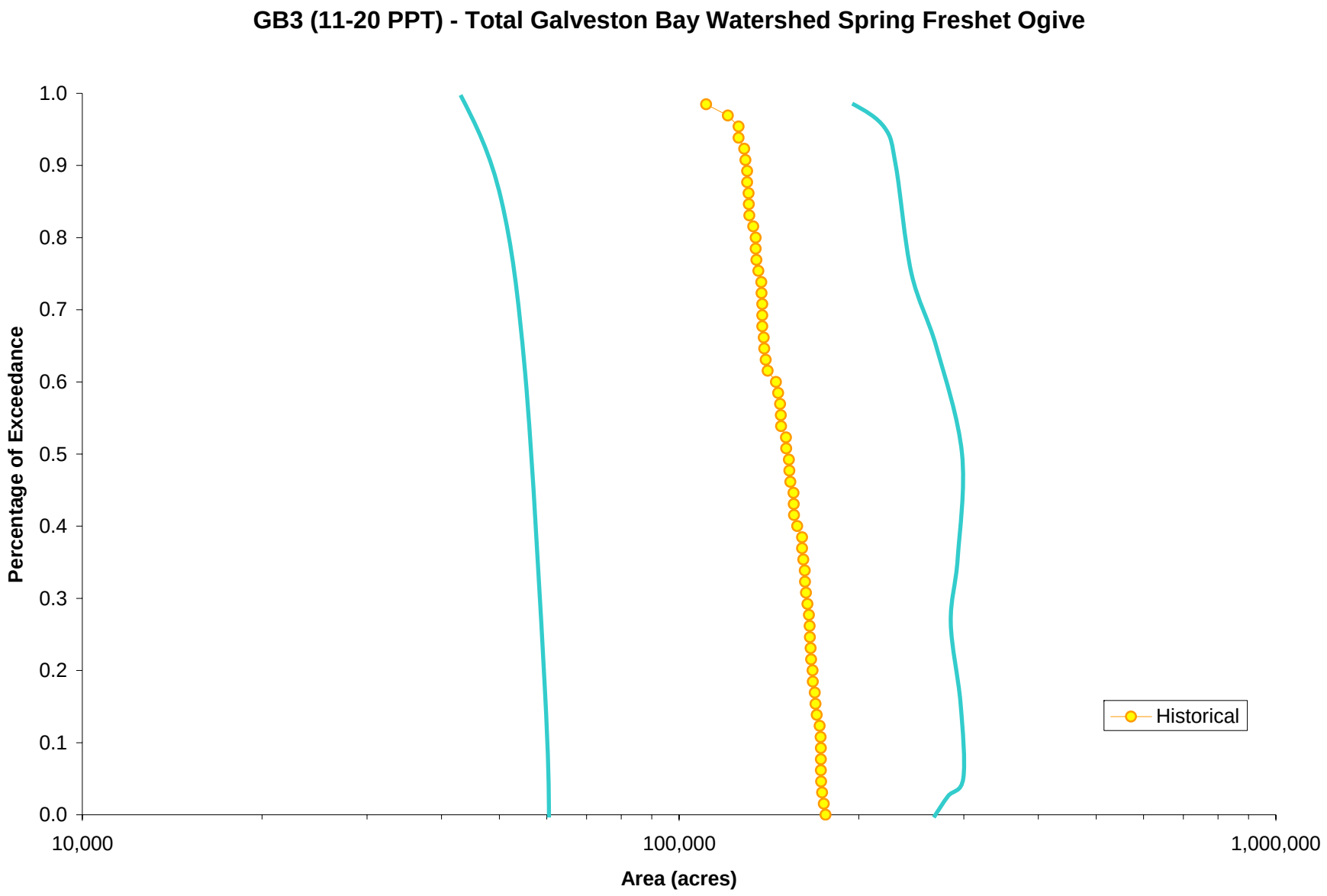
Historical Area Ogive

- The 1940-2005 historical conditions represent a range of flows from the flood of record to the drought of record
- Above relations of flow to area can be utilized to assess historical frequencies of occurrence of the Salinity Zones
- Do this by passing historical flows through these relations
- Estimate uncertainties of these predicted areas based upon the salinity regressions utilized.

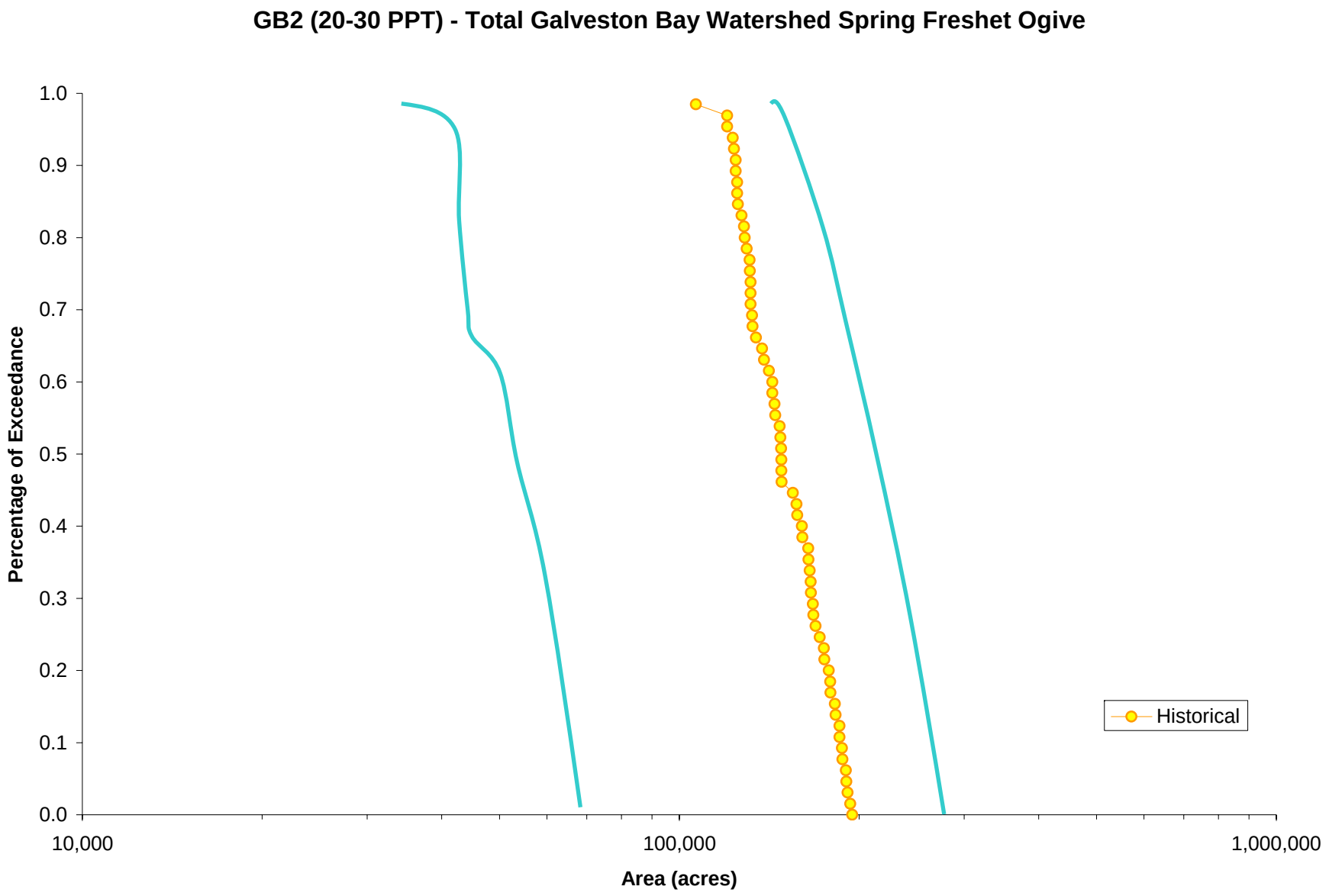
Spring Freshet Ogive – GB4



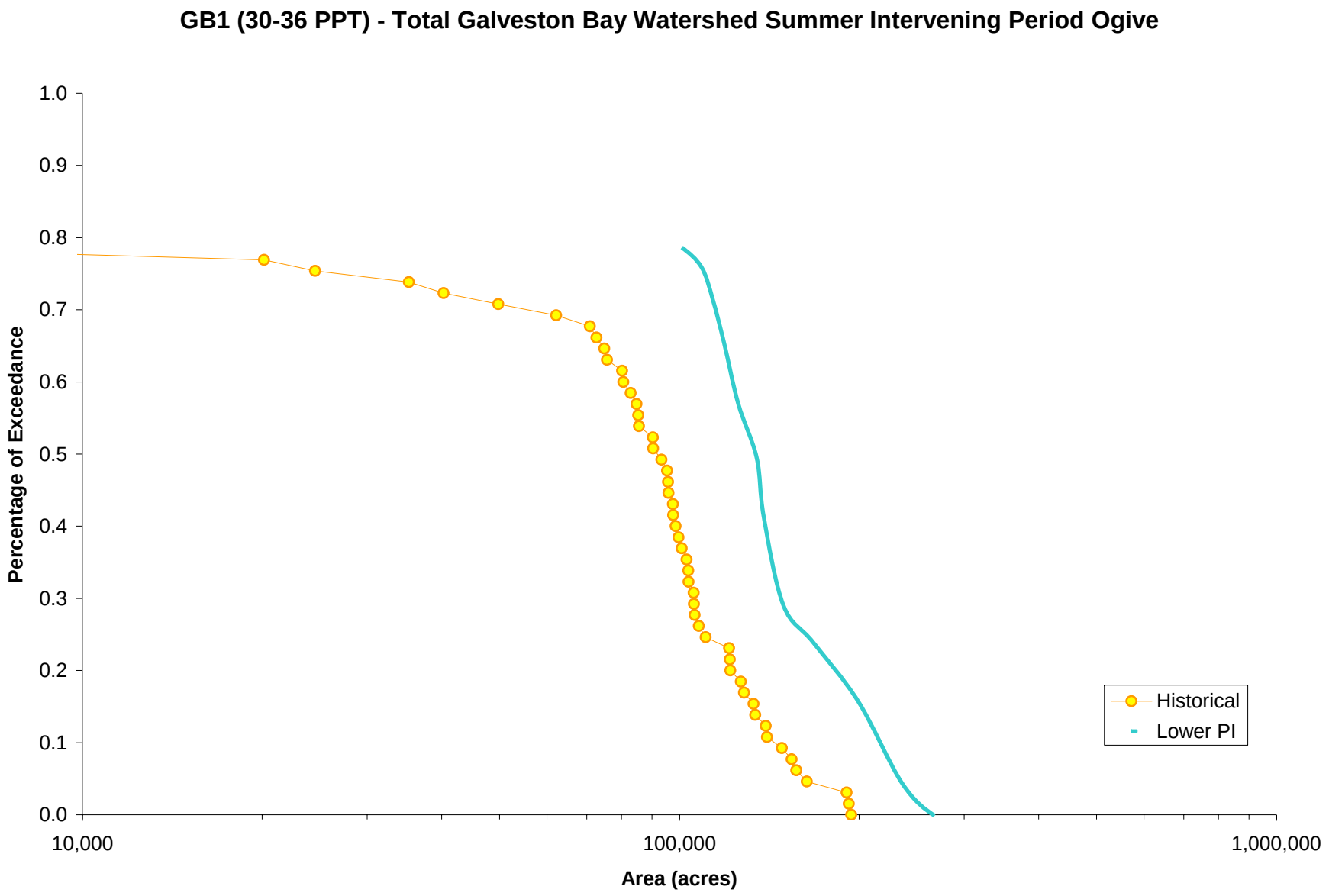
Spring Freshet Ogive – GB3



Spring Freshet Ogive – GB2



Summer Intervening Ogive – GB1



Maintain The Historical Frequencies of Salinity Zones

- Considers entirety of bay system
- Bay can tolerate some fluctuation of area within some bound within present ogive given latent uncertainty
- Utilize statistics of ogives to characterize these frequencies
- Capture associated flows using previous area/flow relations

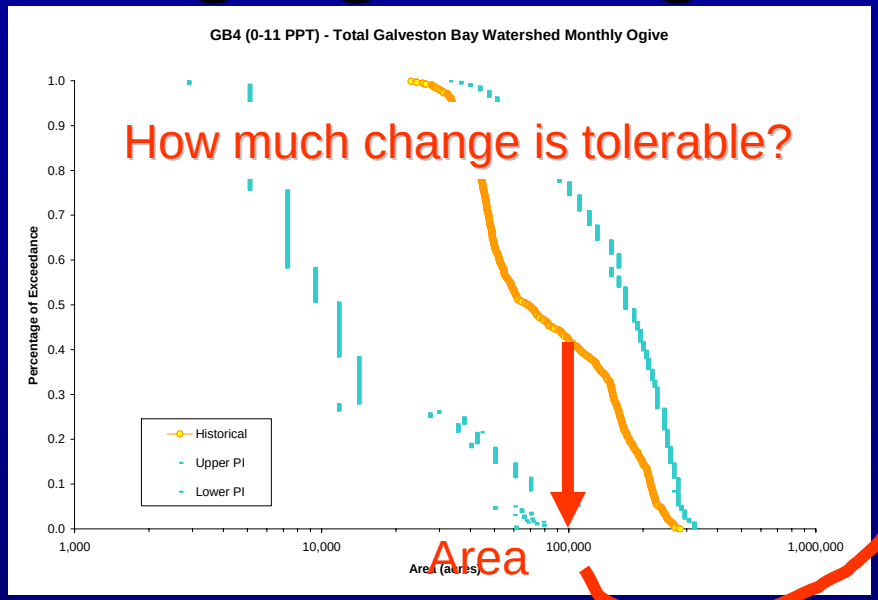
Flow Recommendation

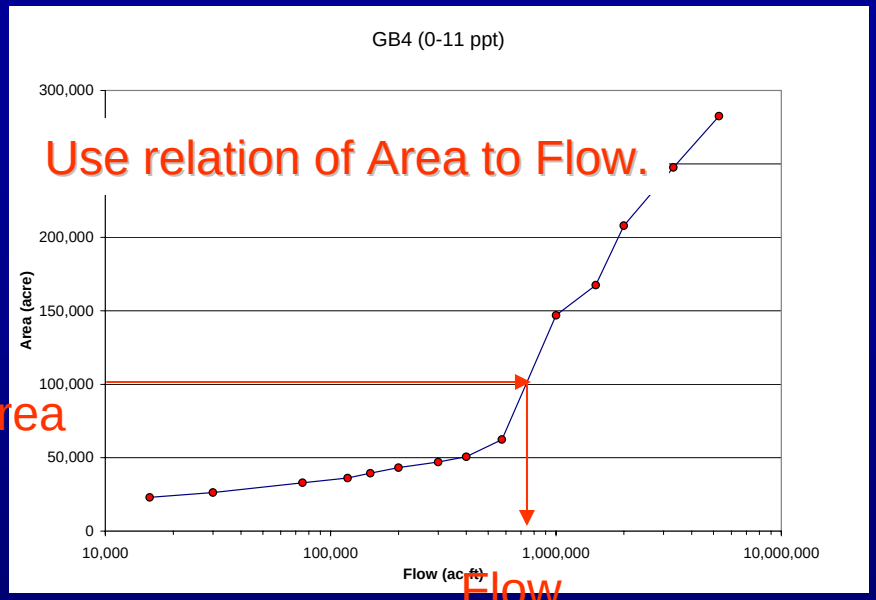
- BBEST develop assessment of impact within a salinity areal context

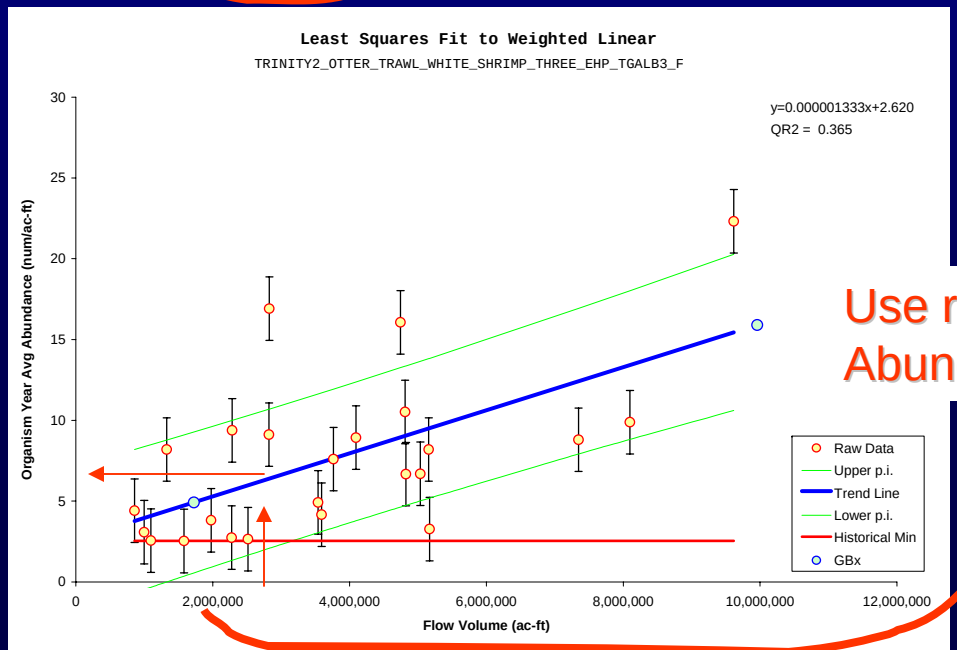
  "How much change in salinity area can the bay tolerate?"

- Leads to Flow Recommendation based on recommended frequency of areal salinity zones with uncertainties

Bringing It Together





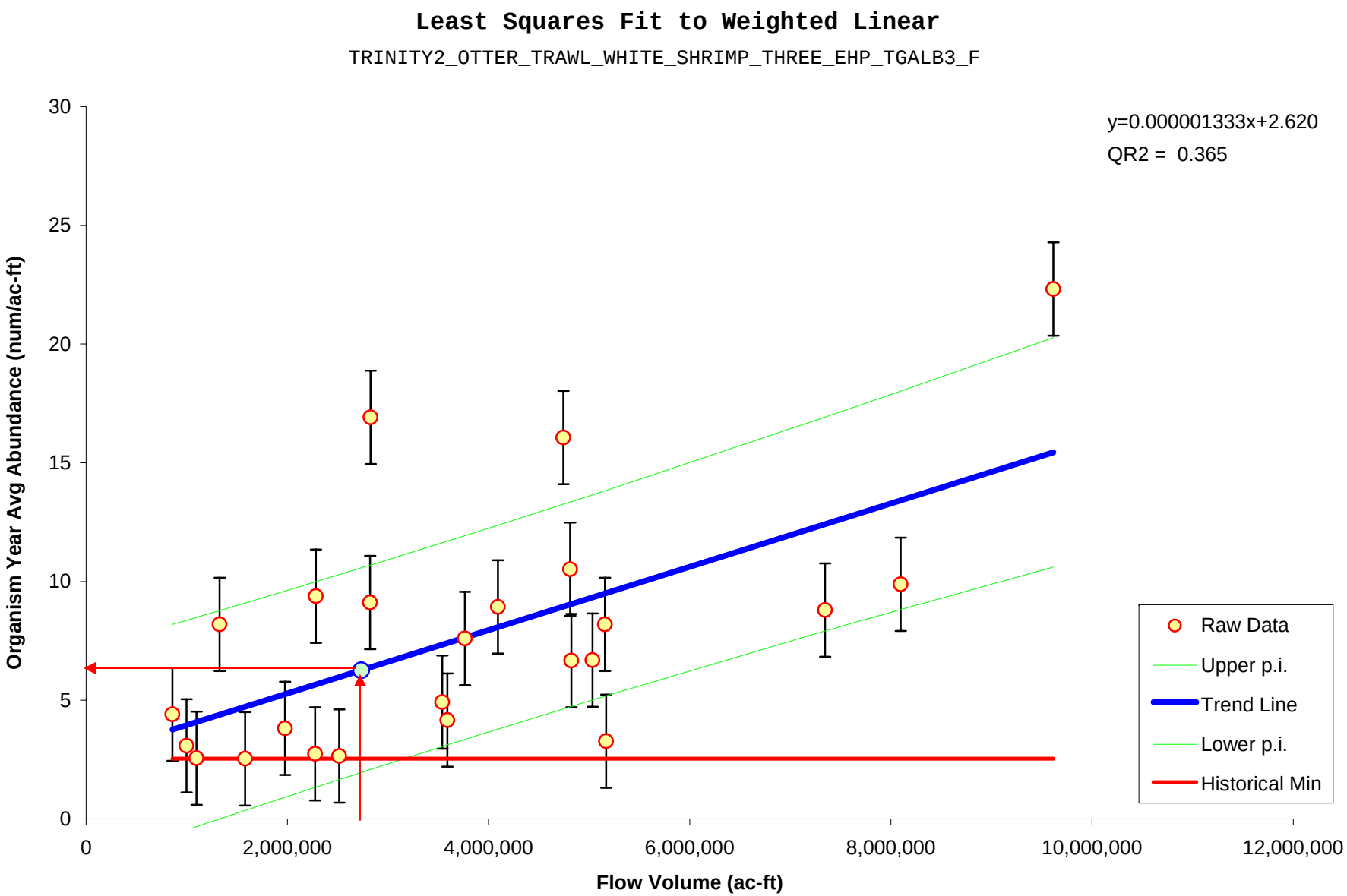


Use relation of Flow to Abundance.

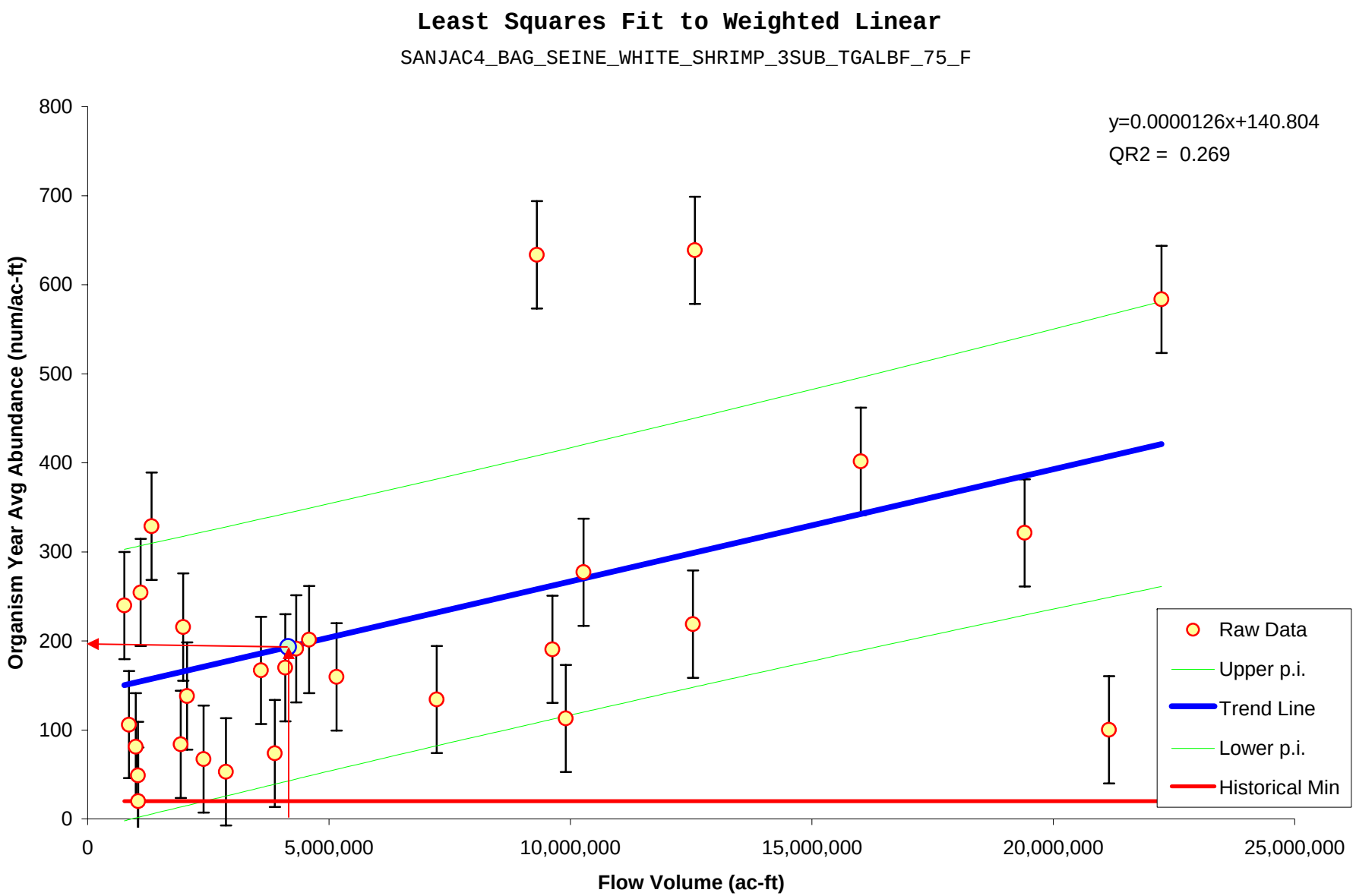
Abundance/Flow Regressions

- Utilize regressions of flow vs. abundance to validate recommendations
- Ensure not violating historical levels
- “Maintaining” the ecological health of the system

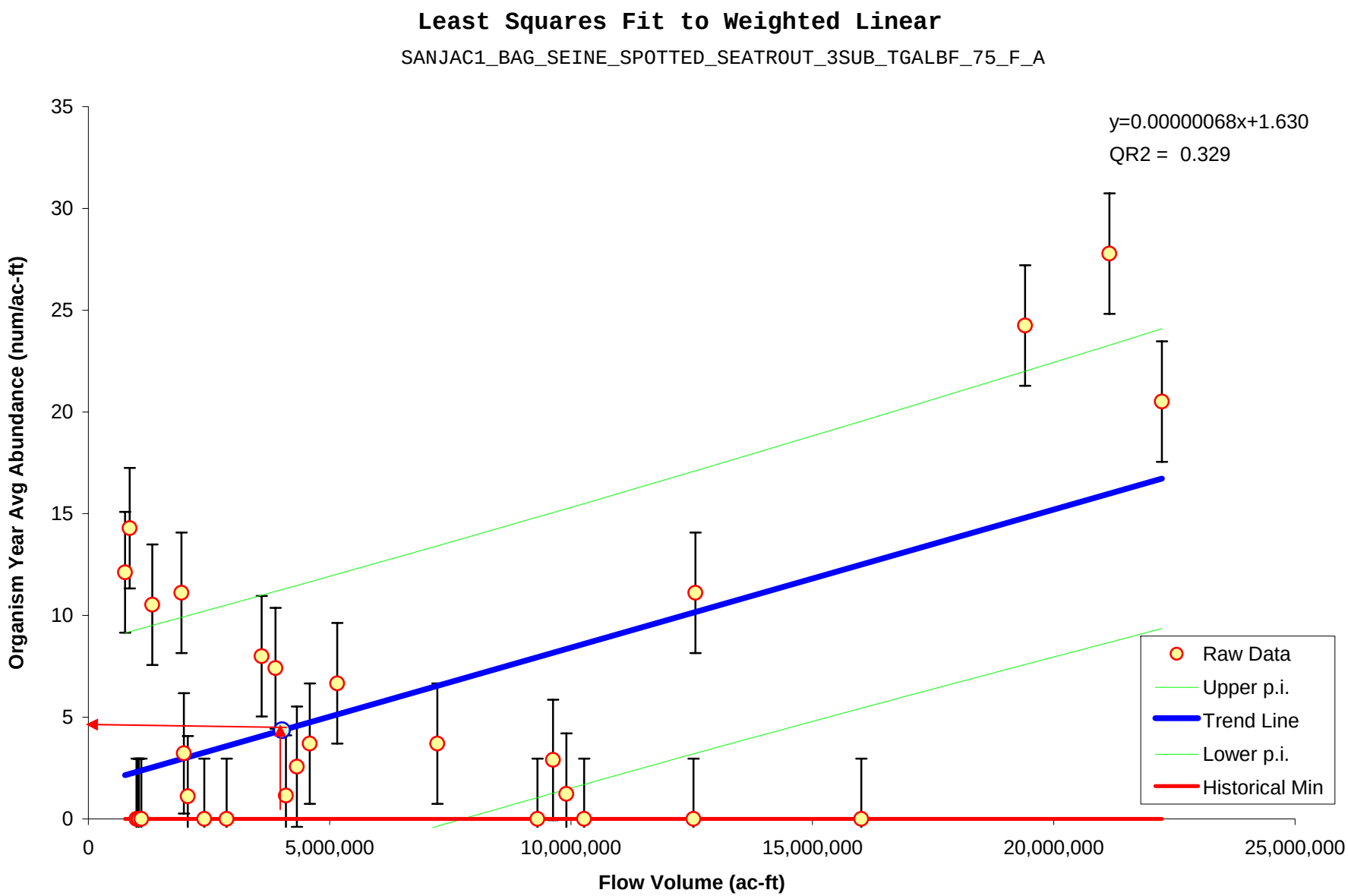
Total Galveston Bay Watershed
White Shrimp
Otter Trawl



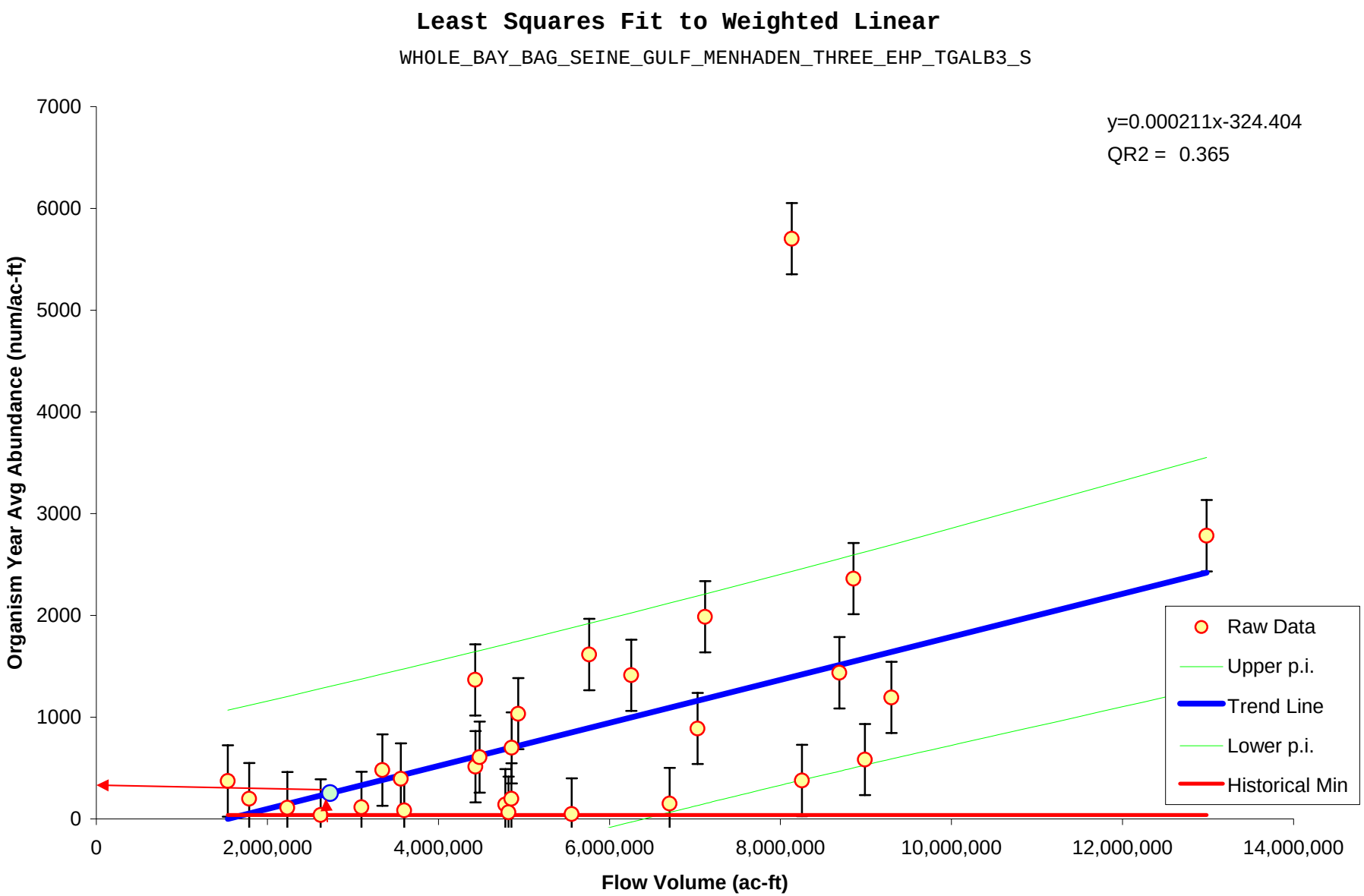
Total Galveston Bay Watershed
White Shrimp
Bag Seine



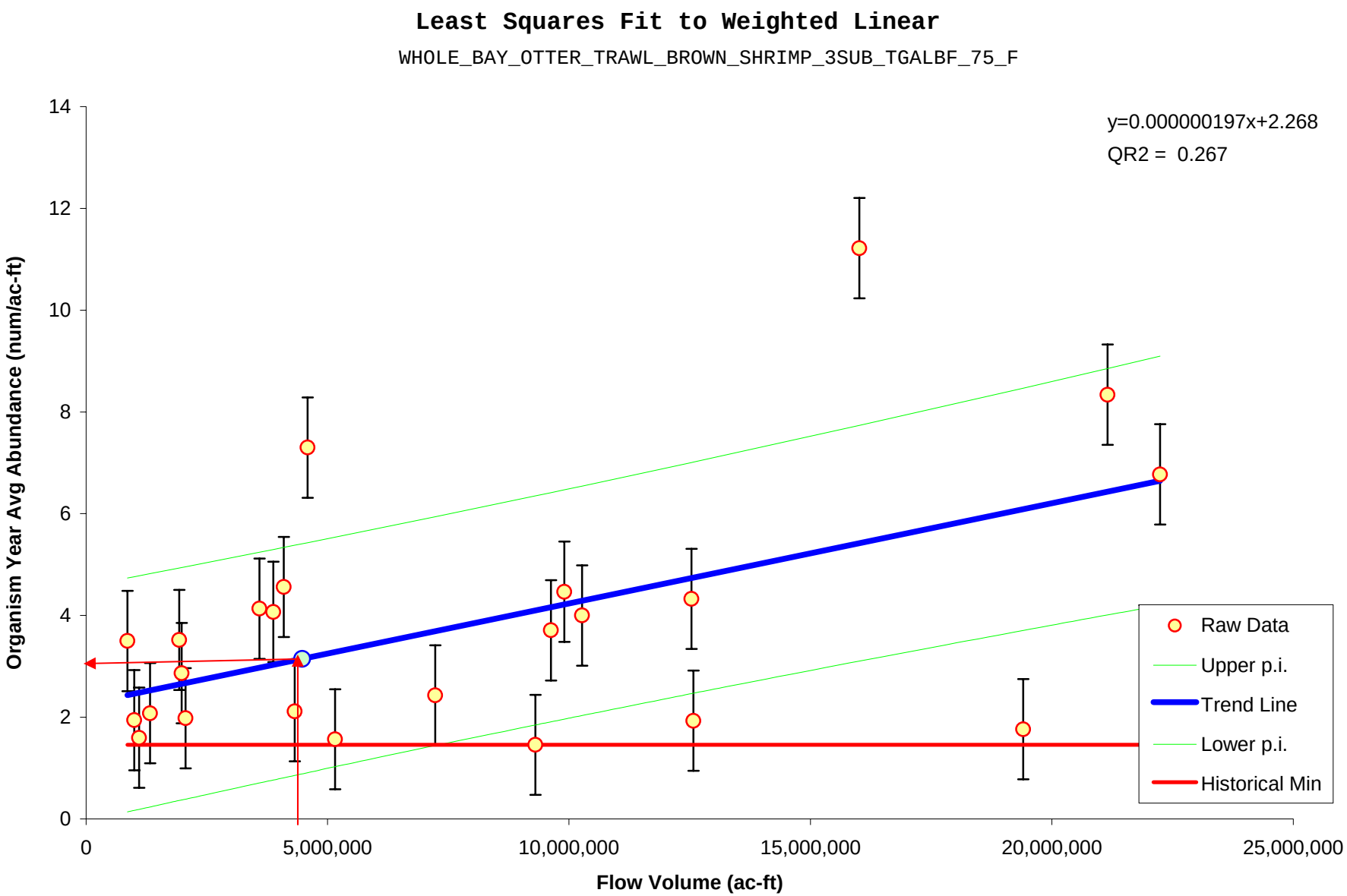
Total Galveston Bay Watershed
Spotted Seatrout
Bag Seine



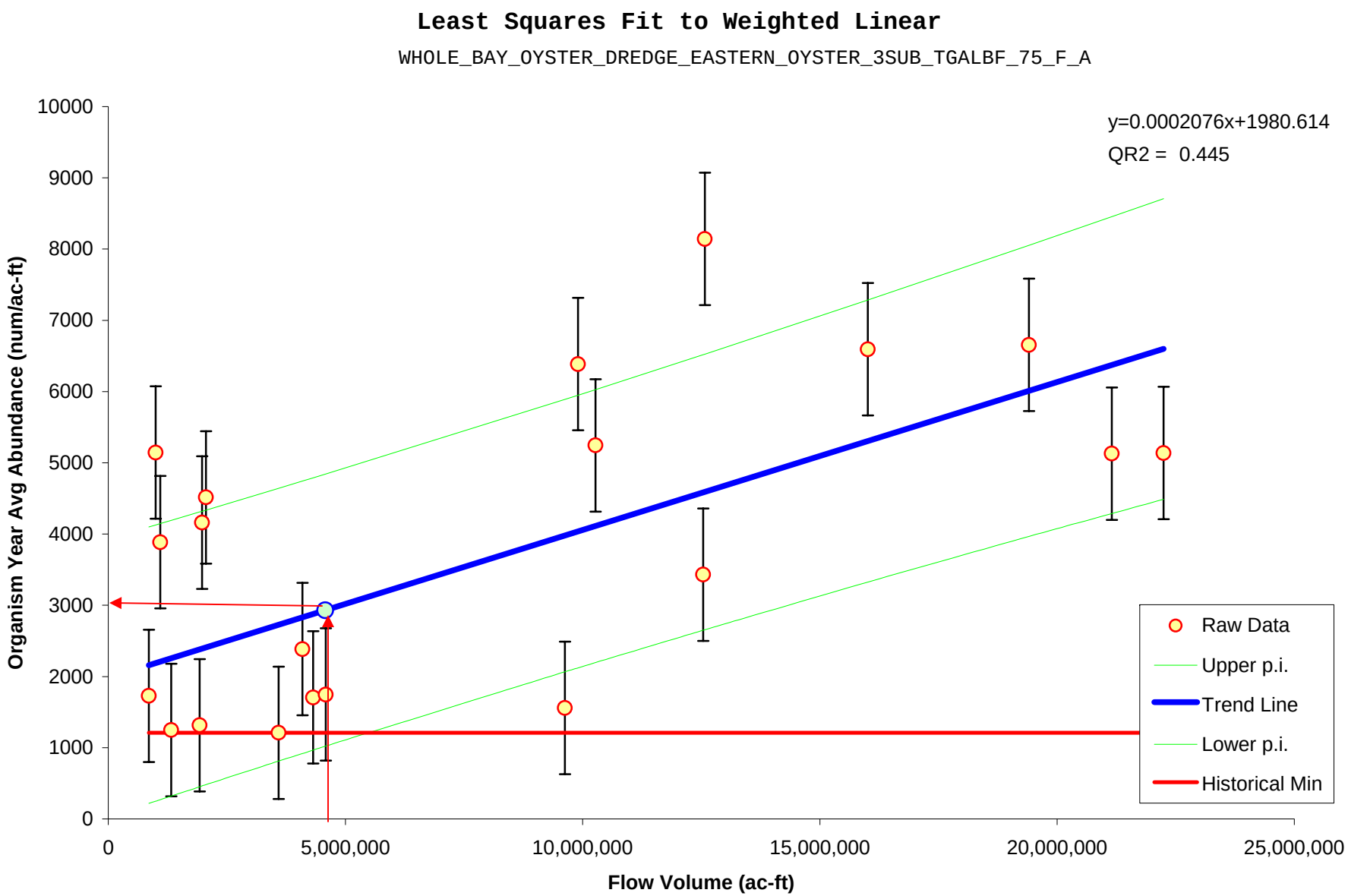
Total Galveston Bay Watershed
Gulf Menhaden
Bag Seine



Total Galveston Bay Watershed
Brown Shrimp
Otter Trawl



Total Galveston Bay Watershed
Eastern Oyster
Oyster Dredge



A Short List of Con's

- Specification of organism salinity classifications.
- No representation of exposure time to salinity
- Selection of salinity zones for characterization of system (i.e. 20-30, 10-20) remains somewhat subjective.
- Substantial uncertainty.
- Does not account for variation of isohaline shape with flow.

…and Pro's

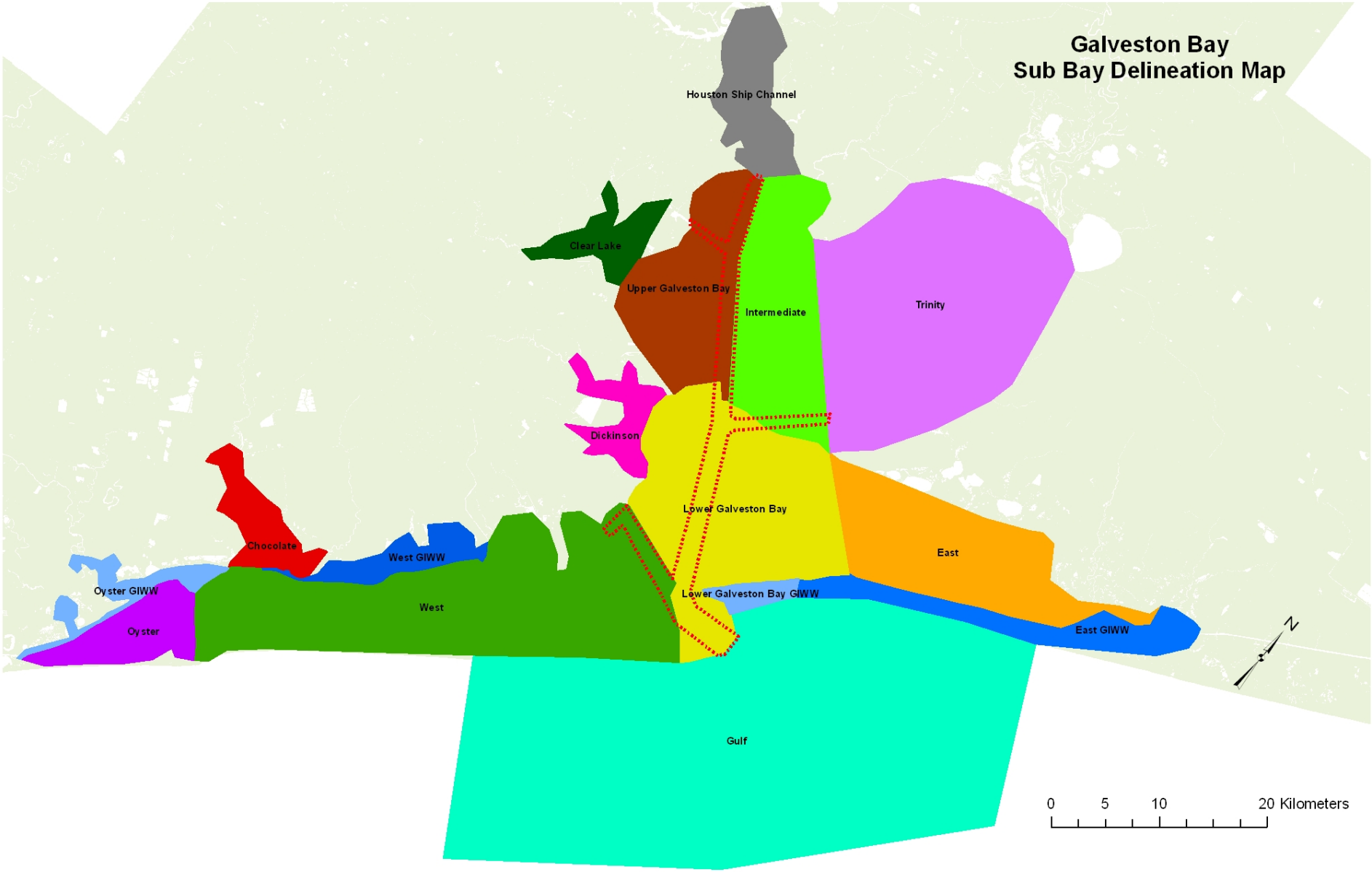
- Concept of

  Flow → Salinity/Habitat → Organism
- Concept of large scale salinity regime significance
- Method is similar to approach utilized by TPWD, thus there is precedent.
- Utilizes existing science, and is available.
- Subscribes to the notion of "maintaining" productivity of system.

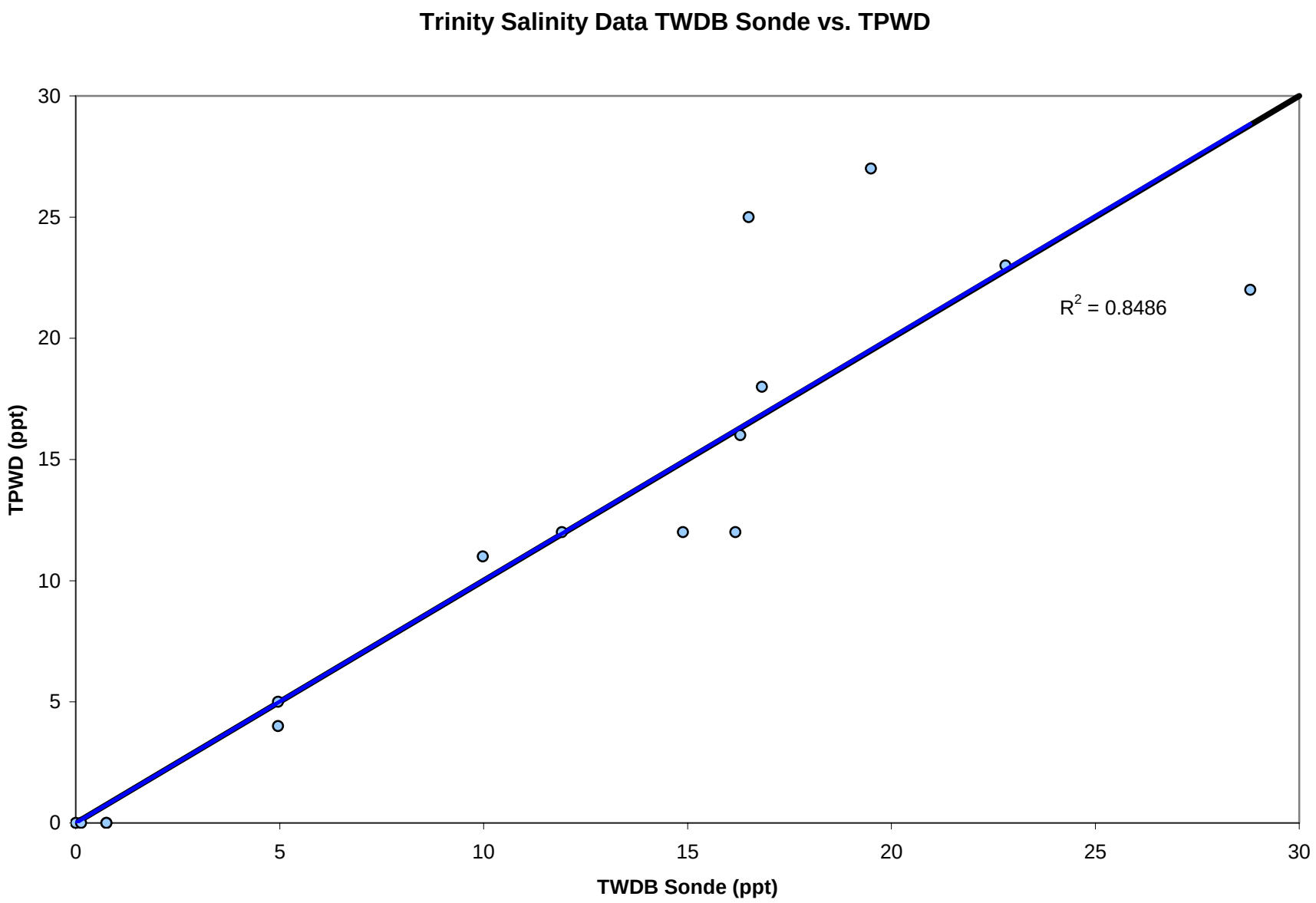
END

Spare Slides

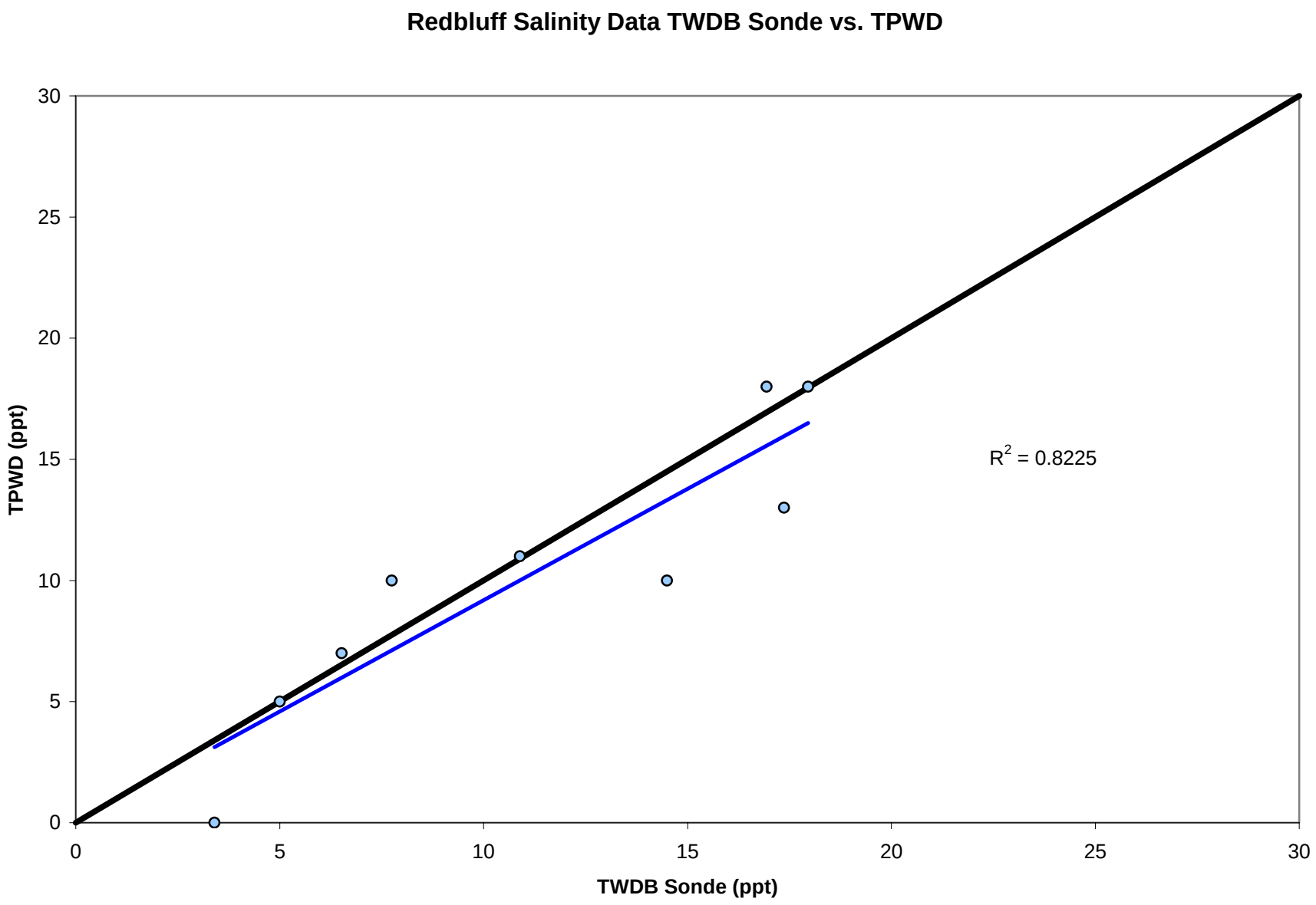
Spatial Aggregation



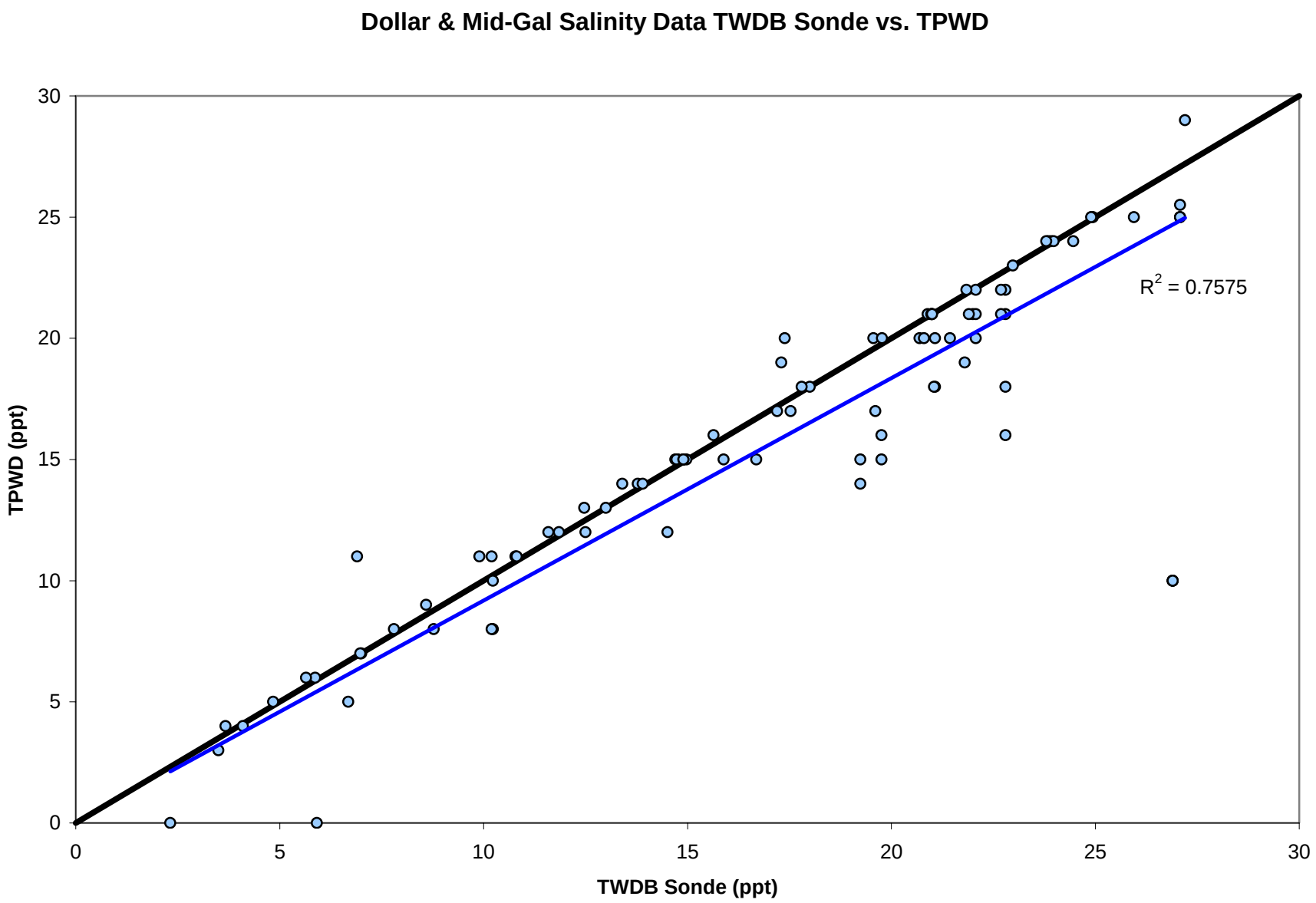
Validation to TPWD Data (2km)



Validation to TPWD Data (2km)



Validation to TPWD Data (2km)



Objective Freshet to Simplified 3-Month Regression Comparison By Organism

	Otter Trawl 75 RUNS	Otter Trawl		Bag Seine 75 RUNS	Bag Seine	
White Shrimp	**Total**	Counts	Percentage	**Total**	Counts	Percentage
	Freshet	2	20.0%	Freshet	8	88.9%
	Three Months	7	70.0%	Three Months	1	11.1%
	Annual	1	10.0%	Annual	0	0.0%
Spotted Seatrout	**Total**	Counts	Percentage	**Total**	Counts	Percentage
	Freshet	1	50.0%	Freshet	15	100.0%
	Three Months	1	50.0%	Three Months	0	0.0%
	Annual	0	0.0%	Annual	0	0.0%
Red Drum	**Total**	Counts	Percentage	**Total**	Counts	Percentage
	Freshet	4	40.0%	Freshet	1	16.7%
	Three Months	6	60.0%	Three Months	5	83.3%
	Annual	0	0.0%	Annual	0	0.0%
Gulf Menhaden	**Total**	Counts	Percentage	**Total**	Counts	Percentage
	Freshet	0	0.0%	Freshet	3	33.3%
	Three Months	1	100.0%	Three Months	6	66.7%
	Annual	0	0.0%	Annual	0	0.0%
Southern Flounder	**Total**	Counts	Percentage	**Total**	Counts	Percentage
	Freshet	1	12.5%	Freshet	0	#DIV/0!
	Three Months	5	62.5%	Three Months	0	#DIV/0!
	Annual	2	25.0%	Annual	0	#DIV/0!
Brown Shrimp	**Total**	Counts	Percentage	**Total**	Counts	Percentage
	Freshet	9	32.1%	Freshet	1	25.0%
	Three Months	4	14.3%	Three Months	3	75.0%
	Annual	15	53.6%	Annual	0	0.0%
Blue Crab	**Total**	Counts	Percentage	**Total**	Counts	Percentage
	Freshet	5	23.8%	Freshet	2	33.3%
	Three Months	12	57.1%	Three Months	4	66.7%
	Annual	4	19.0%	Annual	0	0.0%
Black Drum	**Total**	Counts	Percentage	**Total**	Counts	Percentage
	Freshet	3	37.5%	Freshet	18	64.3%
	Three Months	1	12.5%	Three Months	8	28.6%
	Annual	4	50.0%	Annual	2	7.1%
Atlantic Croaker	**Total**	Counts	Percentage	**Total**	Counts	Percentage
	Freshet	1	100.0%	Freshet	0	#DIV/0!
	Three Months	0	0.0%	Three Months	0	#DIV/0!
	Annual	0	0.0%	Annual	0	#DIV/0!

Statistical Regression Selection:

Org	Gear	Methods	Bay	External Consistancy: Watershed	External Consistancy: NFMethods	FQ Included	Adj. R^2	SEE	Unique Regression
White Shrimp	Otter Trawl	Standard	WHOLE_BAY	1	2	Y2	0.436	2.733104	WHOLE_BAY_OTTER_TRAWL_WHITE_SHRIMP_THREE_EHP_TGALB3_F
		Curvilinear	WHOLE_BAY	0	1	Y1	0.439	2.725	WHOLE_BAY_OTTER_TRAWL_WHITE_SHRIMP_3SUB_SNJACF_75_F
		TimeLags	WHOLE_BAY	0	3	Y1	0.436	2.731934	WHOLE_BAY_OTTER_TRAWL_WHITE_SHRIMP_LAG3_3SUB_TGALBF_7
	Bag Seine	Standard	TRINITY2	0	0	Y1	0.354	160.9625	TRINITY2_BAG_SEINE_WHITE_SHRIMP_3SUB_TGALBF_75_S
			SANJAC3	0	0	Y3	0.433	127.8812	SANJAC3_BAG_SEINE_WHITE_SHRIMP_3SUB_SNJACF_75_S
		Curvilinear		-	-	-	-		-
		TimeLags	WHOLE_BAY	1	0	Y3	0.518	105.1128	WHOLE_BAY_BAG_SEINE_WHITE_SHRIMP_LAG6_3SUB_COSTLF_75_F
	Bag Seine A	Standard	TRINITY3	1	0	Y1	0.358	374.6916	TRINITY3_BAG_SEINE_WHITE_SHRIMP_TPC_TRNTY_75_A
			TRINITY3	1	0	Y2	0.31	388.2781	TRINITY3_BAG_SEINE_WHITE_SHRIMP_THREE_EHP_TRNTY3_S_A
			TRINITY2	0	0	N	0.397	369.3326	TRINITY2_BAG_SEINE_WHITE_SHRIMP_TPC_TGALB_75_A
			SANJAC3	0	0	N	0.302	313.5676	SANJAC3_BAG_SEINE_WHITE_SHRIMP_TPC_TGALB_75_A
		Curvilinear		-	-	-	-		-
		TimeLags	WHOLE_BAY	3	4	Y1	0.433	326.0043	WHOLE_BAY_BAG_SEINE_WHITE_SHRIMP_LAG6_THREE_EHP_TGALB
SeaTrout	Otter Trawl	Standard	WHOLE_BAY	0	3	N	0.492	0.022826	WHOLE_BAY_OTTER_TRAWL_SPOTTED_SEATROUT_TPC_COSTL_75
			WHOLE_BAY	0	2	Y1	0.473	0.02286	WHOLE_BAY_OTTER_TRAWL_SPOTTED_SEATROUT_TPC_TRNTY_75
		Curvilinear	WHOLE_BAY	2	0	Y1	0.422	0.024	WHOLE_BAY_OTTER_TRAWL_SPOTTED_SEATROUT_TPC_TRNTY_75
			WHOLE_BAY	2	0	Y1	0.394	0.025	WHOLE_BAY_OTTER_TRAWL_SPOTTED_SEATROUT_THREE_EHP_TRN
		TimeLags	WHOLE_BAY	0	2	Y2	0.486	0.022954	WHOLE_BAY_OTTER_TRAWL_SPOTTED_SEATROUT_LAG1_3SUB_TRNT
	Bag Seine	Standard	SANJAC4	0	0	Y2	0.346	2.885025	SANJAC4_BAG_SEINE_SPOTTED_SEATROUT_3SUB_SNJACF_75_S
			SANJAC3	0	0	Y2	0.367	3.131006	SANJAC3_BAG_SEINE_SPOTTED_SEATROUT_3SUB_SNJACF_75_S
		Curvilinear		-	-	-	-		-
		TimeLags		-	-	-	-		-
	Bag Seine A	Standard	SANJAC2	0	1	Y1	0.388	5.663519	SANJAC2_BAG_SEINE_SPOTTED_SEATROUT_3SUB_TGALBF_75_F_A
		Curvilinear		-	-	-	-		-
		TimeLags		-	-	-	-		-
Flounder	Otter Trawl	Standard	WHOLE_BAY	3	6	Y1	0.503	0.041113	WHOLE_BAY_OTTER_TRAWL_SOUTHERN_FLOUNDER_TPC_TGALB_75
		Curvilinear	WHOLE_BAY	0	3	Y1	0.588	0.037	WHOLE_BAY_OTTER_TRAWL_SOUTHERN_FLOUNDER_TP_TGALB_75
		TimeLags	WHOLE_BAY	3	2	Y1	0.441	0.046063	WHOLE_BAY_OTTER_TRAWL_SOUTHERN_FLOUNDER_LAG3_THREE_E
	Bag Seine	Standard		-	-	-	-		-
		Curvilinear		-	-	-	-		-
		TimeLags	WHOLE_BAY	0	0	N	0.343	1.559717	WHOLE_BAY_BAG_SEINE_SOUTHERN_FLOUNDER_LAG1_THREE_EHP_
	Bag Seine A	Standard		-	-	-	-		-
		Curvilinear		-	-	-	-		-
		TimeLags		-	-	-	-		-
Red Drum	Otter Trawl	Standard	WHOLE_BAY	0	1	Y2	0.409	0.010336	WHOLE_BAY_OTTER_TRAWL_RED_DRUM_TPC_TRNTY_75
			WHOLE_BAY	0	1	Y1	0.395	0.01046	WHOLE_BAY_OTTER_TRAWL_RED_DRUM_TPC_TGALB_75
			TRINITY3	0	2	Y3	0.784	0.005547	TRINITY3_OTTER_TRAWL_RED_DRUM_TPC_TRNTY_75
			TRINITY			Y1	0.353	0.007362	TRINITY_OTTER_TRAWL_RED_DRUM_3SUB_TRNTYF_75_S
		Curvilinear	WHOLE_BAY	2	1	Y1	0.483	0.01	WHOLE_BAY_OTTER_TRAWL_RED_DRUM_TPC_COSTL_75
			WHOLE_BAY	0	0	Y1	0.371	0.011	WHOLE_BAY_OTTER_TRAWL_RED_DRUM_3SUB_SNJACF_75_F
		TimeLags	WHOLE_BAY	0	0	Y3	0.3	0.012322	WHOLE_BAY_OTTER_TRAWL_RED_DRUM_LAG5_THREE_EHP_TRNTY3
		Standard		-	-	-	-		-
									-
								07	WHOLE_BAY_BAG_SEINE_RED_DRUM_LAG6_THREE_EHP_SNJAC3_S
								95	SANJAC1_BAG_SEINE_RED_DRUM_TPC_TGALB_75_A
									-
									-

not realistic
TPC
COSTL

Statistical Regression Selection:

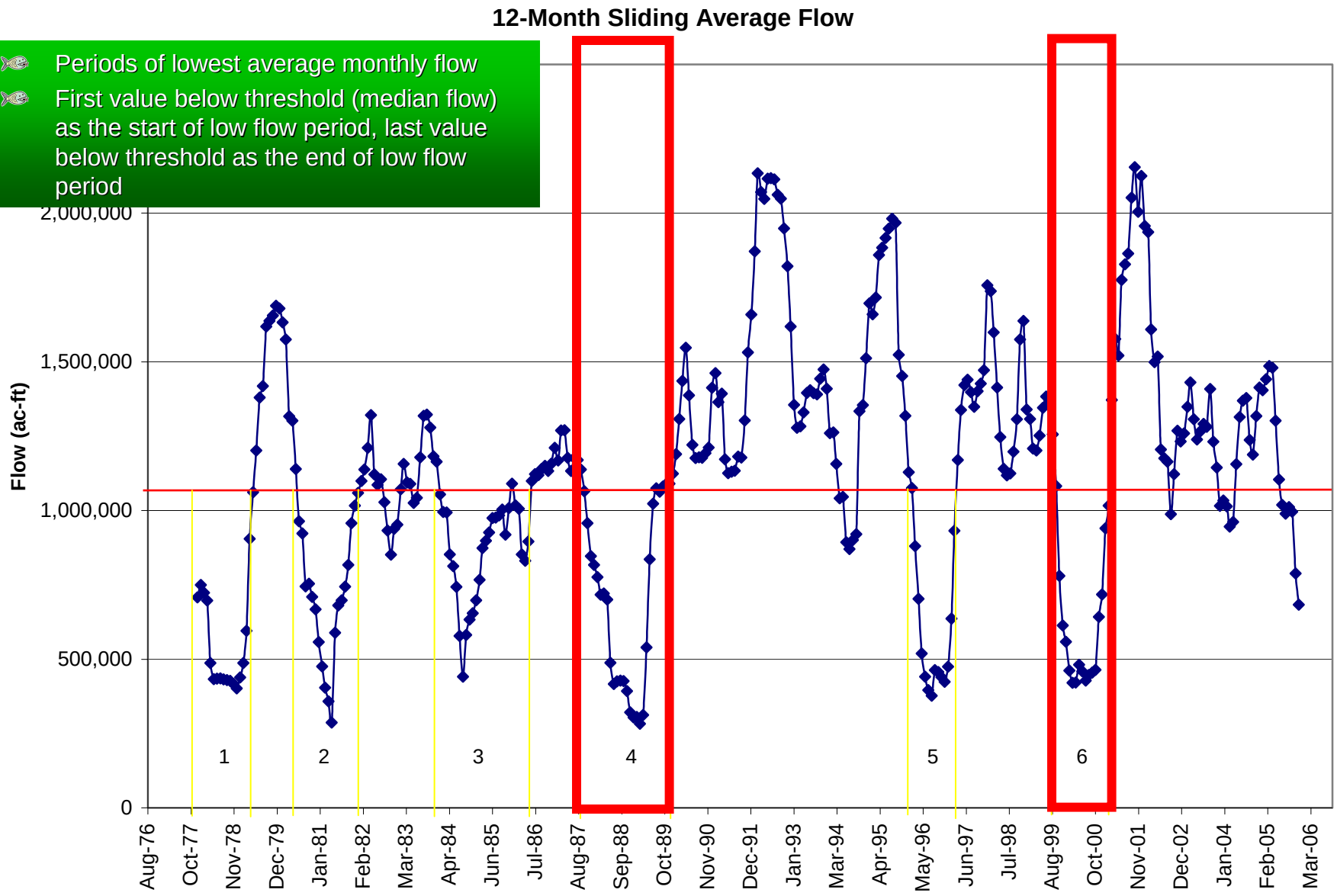
Org	Gear	Methods	Bay	External Consistancy		FQ	Adj. R^2	SEE	Unique Regression
				Watershed	NFMethods	Included			
Gulf Menhaden	Otter Trawl	Standard	TRINITY3	1	1	Y1	0.334	1.353655	TRINITY3_OTTER_TRAWL_GULF_MENHADEN_TPC_TRNTY_75
			TRINITY3	1	1	Y1	0.304	1.384061	TRINITY3_OTTER_TRAWL_GULF_MENHADEN_TP_TRNTY_75
		Curvilinear		-	-	-	-		
		TimeLags	WHOLE_BAY	0	0	N	0.315	1.321012	WHOLE_BAY_OTTER_TRAWL_GULF_MENHADEN_LAG6_3SUB_TRNTYF
	Bag Seine	Standard	WHOLE_BAY	0	2	Y1	0.359	796.5638	WHOLE_BAY_BAG_SEINE_GULF_MENHADEN_THREE_EHP_TGALB3_S
			TRINITY4	0	0	Y1	0.353	1137.739	TRINITY4_BAG_SEINE_GULF_MENHADEN_TPC_TRNTY_75
		Curvilinear		-	-	-	-		-
		TimeLags	WHOLE_BAY	0	4	Y1	0.564	657.0087	WHOLE_BAY_BAG_SEINE_GULF_MENHADEN_LAG1_3SUB_SNJACF_75_
	Bag Seine A	Standard	WHOLE_BAY	0	0	Y1	0.308	3025.322	WHOLE_BAY_BAG_SEINE_GULF_MENHADEN_THREE_EHP_SNJAC3_S_
			TRINITY4	0	0	Y1	0.324	4587.148	TRINITY4_BAG_SEINE_GULF_MENHADEN_TPC_TRNTY_75_A
			TRINITY2	0	1	Y2	0.412	5395.416	TRINITY2_BAG_SEINE_GULF_MENHADEN_TPC_TGALB_75_A
			TRINITY1	0	1	Y2	0.405	6657.661	TRINITY1_BAG_SEINE_GULF_MENHADEN_TPC_TRNTY_75_A
			TRINITY1	0	1	Y2	0.386	6763.72	TRINITY1_BAG_SEINE_GULF_MENHADEN_TPC_TGALB_75_A
		Curvilinear	WHOLE_BAY	0	0	Y	0.36	2858.988	WHOLE_BAY_BAG_SEINE_GULF_MENHADEN_THREE_EHP_SNJAC3_S_
		TimeLags	WHOLE_BAY	0	4	Y1	0.554	2427.036	WHOLE_BAY_BAG_SEINE_GULF_MENHADEN_LAG1_3SUB_SNJACF_75_
Brown Shrimp	Otter Trawl	Standard	WHOLE_BAY	0	1	Y2	0.369	1.997472	WHOLE_BAY_OTTER_TRAWL_BROWN_SHRIMP_TPC_TGALB_75
			SANJAC2	0	1	Y1	0.567	2.177911	SANJAC2_OTTER_TRAWL_BROWN_SHRIMP_3SUB_SNJACF_75_F
			SANJAC1	2	1	Y1	0.37	1.854149	SANJAC1_OTTER_TRAWL_BROWN_SHRIMP_TP_SNJAC_75
		Curvilinear	WHOLE_BAY	1	2	Y1	0.397	1.952	WHOLE_BAY_OTTER_TRAWL_BROWN_SHRIMP_THREE_EHP_TGALB3_
		TimeLags	WHOLE_BAY	1	2	N	0.463	1.860012	WHOLE_BAY_OTTER_TRAWL_BROWN_SHRIMP_LAG7_3SUB_SNJACF_
			WHOLE_BAY	0	2	Y3	0.352	2.025184	WHOLE_BAY_OTTER_TRAWL_BROWN_SHRIMP_LAG1_3SUB_COSTLF_7
	Bag Seine	Standard		-	-	-	-		-
		Curvilinear		-	-	-	-		-
		TimeLags		-	-	-	-		-
	Bag Seine A	Standard		-	-	-	-		-
		Curvilinear		-	-	-	-		-
		TimeLags	WHOLE_BAY	0	0	N	0.354	141.5186	WHOLE_BAY_BAG_SEINE_BROWN_SHRIMP_LAG2_3SUB_TRNTYF_75_F
Blue Crab	Otter Trawl	Standard		-	-	-	-		-
		Curvilinear		-	-	-	-		-
		TimeLags	WHOLE_BAY	0	0	Y2	0.442	0.993843	WHOLE_BAY_OTTER_TRAWL_BLUE_CRAB_LAG7_THREE_EHP_TRNTY:
	Bag Seine	Standard		-	-	-			
		Curvilinear		-	-	-	-		-
		TimeLags	WHOLE_BAY	0	0	Y2	0.32	14.66696	WHOLE_BAY_BAG_SEINE_BLUE_CRAB_LAG1_3SUB_TRNTYF_75_S
	Bag Seine A	Standard		-	-	-	-		-
		Curvilinear		-	-	-	-		-
		TimeLags	WHOLE_BAY	0	4	Y2	0.363	26.33381	WHOLE_BAY_BAG_SEINE_BLUE_CRAB_LAG6_3SUB_TGALBF_75_F_A
			WHOLE_BAY	0	3	Y2	0.303	25.64505	WHOLE_BAY_BAG_SEINE_BLUE_CRAB_LAG1_3SUB_TRNTYF_75_S_A
Black Drum	Otter Trawl	Standard	WHOLE_BAY	4	2	Y1	0.464	0.018284	WHOLE_BAY_OTTER_TRAWL_BLACK_DRUM_3SUB_SNJACF_75_F
			TRINITY4	6	2	Y1	0.601	0.012874	TRINITY4_OTTER_TRAWL_BLACK_DRUM_THREE_EHP_COSTL3_S
		Curvilinear	WHOLE_BAY	1	0	Y1	0.406	0.017	WHOLE_BAY_OTTER_TRAWL_BLACK_DRUM_TP_SNJAC_75
		TimeLags	WHOLE_BAY	0	2	Y1	0.477	0.018376	WHOLE_BAY_OTTER_TRAWL_BLACK_DRUM_LAG1_3SUB_COSTLF_75_F
			WHOLE_BAY	1	2	Y3	0.459	0.019796	WHOLE_BAY_OTTER_TRAWL_BLACK_DRUM_LAG5_THREE_EHP_TGAL
	Bag Seine	Standard	TRINITY3	0	0	Y1	0.736	1.580528	TRINITY3_BAG_SEINE_BLACK_DRUM_3SUB_COSTLF_75_F
			TRINITY3	0	0	Y2	0.453	2.274749	TRINITY3_BAG_SEINE_BLACK_DRUM_TP_TRNTY_75
			SANJAC1	0	1	Y2	0.328	2.479426	SANJAC1_BAG_SEINE_BLACK_DRUM_THREE_EHP_SNJAC3_S
		Curvilinear		-	-	-	-		-

Statistical Regression Selection:

Org	Gear	Methods	Bay	External Consistancy		FQ	Adj. R^2	SEE	Unique Regression
				Watershed	NFMethods	Included			
Black Drum	Otter Trawl	Standard	WHOLE_BAY	4	2	Y1	0.464	0.018284	WHOLE_BAY_OTTER_TRAWL_BLACK_DRUM_3SUB_SNJACF_75_F
			TRINITY4	6	2	Y1	0.601	0.012874	TRINITY4_OTTER_TRAWL_BLACK_DRUM_THREE_EHP_COSTL3_S
		Curvilinear	WHOLE_BAY	1	0	Y1	0.406	0.017	WHOLE_BAY_OTTER_TRAWL_BLACK_DRUM_TP_SNJAC_75
		TimeLags	WHOLE_BAY	0	2	Y1	0.477	0.018376	WHOLE_BAY_OTTER_TRAWL_BLACK_DRUM_LAG1_3SUB_COSTLF_75_F
			WHOLE_BAY	1	2	Y3	0.459	0.019796	WHOLE_BAY_OTTER_TRAWL_BLACK_DRUM_LAG5_THREE_EHP_TGALB3_S
	Bag Seine	Standard	TRINITY3	0	0	Y1	0.736	1.580528	TRINITY3_BAG_SEINE_BLACK_DRUM_3SUB_COSTLF_75_F
			TRINITY3	0	0	Y2	0.453	2.274749	TRINITY3_BAG_SEINE_BLACK_DRUM_TP_TRNTY_75
			SANJAC1	0	1	Y2	0.328	2.479426	SANJAC1_BAG_SEINE_BLACK_DRUM_THREE_EHP_SNJAC3_S
		Curvilinear		-	-	-	-		-
		TimeLags	WHOLE_BAY	0	1	Y3	0.393	1.829396	WHOLE_BAY_BAG_SEINE_BLACK_DRUM_LAG7_3SUB_TRNTYF_75_S
	Bag Seine A	Standard	TRINITY3	0	0	Y1	0.704	3.709371	TRINITY3_BAG_SEINE_BLACK_DRUM_3SUB_COSTLF_75_F_A
			TRINITY3	0	0	Y2	0.452	5.050819	TRINITY3_BAG_SEINE_BLACK_DRUM_TP_TRNTY_75_A
			SANJAC4	0	0	Y1	0.648	3.4289	SANJAC4_BAG_SEINE_BLACK_DRUM_3SUB_COSTLF_75_F_A
			SANJAC4	0	0	N	0.43	4.364582	SANJAC4_BAG_SEINE_BLACK_DRUM_TP_TGALB_75_A
		Curvilinear		-	-	-	-		-
		TimeLags	WHOLE_BAY	0	1	Y2	0.447	3.665669	WHOLE_BAY_BAG_SEINE_BLACK_DRUM_LAG7_3SUB_TGALBF_75_F_A
Atlantic Croaker	Otter Trawl	Standard	WHOLE_BAY	1	1	Y1	0.636	3.220683	WHOLE_BAY_OTTER_TRAWL_ATLANTIC_CROAKER_TPC_TRNTY_75
			WHOLE_BAY	1	1	Y1	0.403	4.124037	WHOLE_BAY_OTTER_TRAWL_ATLANTIC_CROAKER_TP_TRNTY_75
		Curvilinear	WHOLE_BAY	1	1	Y1	0.451	3.953	WHOLE_BAY_OTTER_TRAWL_ATLANTIC_CROAKER_TPC_TRNTY_75
			WHOLE_BAY	1	1	Y1	0.405	4.116	WHOLE_BAY_OTTER_TRAWL_ATLANTIC_CROAKER_TP_TRNTY_75
		TimeLags	WHOLE_BAY	0	1	Y1	0.423	4.32388	WHOLE_BAY_OTTER_TRAWL_ATLANTIC_CROAKER_LAG6_THREE_EHP_TRNTY3
	Bag Seine	Standard		-	-	-	-		-
		Curvilinear		-	-	-	-		-
		TimeLags		-	-	-	-		-
	Bag Seine A	Standard		-	-	-	-		-
		Curvilinear		-	-	-	-		-
		TimeLags	WHOLE_BAY	0	0	Y1	0.343	164.1263	WHOLE_BAY_BAG_SEINE_ATLANTIC_CROAKER_LAG5_3SUB_TGALBF_75_F_A
Eastern Oyster	Oyster Dredge	Standard	SANJAC1	0	2	Y3	0.534	1623.273	SANJAC1_OYSTER_DREDGE_EASTERN_OYSTER_3SUB_SNJACF_75_S_A
			WHOLE_BAY	0	1	Y2	0.543	1471.857	WHOLE_BAY_OYSTER_DREDGE_EASTERN_OYSTER_TP_COSTL_75_A
			WHOLE_BAY	0	2	Y2	0.527	1496.896	WHOLE_BAY_OYSTER_DREDGE_EASTERN_OYSTER_3SUB_SNJACF_75_S_A
		LongerTime	WHOLE_BAY	0	0	Y1	0.43	1643.519	WHOLE_BAY_OYSTER_DREDGE_EASTERN_OYSTER_THREE_EHP_TRNTY3_3yr_A
		Curvilinear	WHOLE_BAY	0	0	Y1	0.383	1709.323	WHOLE_BAY_OYSTER_DREDGE_EASTERN_OYSTER_3SUB_TGALBF_75_F_A
		TimeLags	WHOLE_BAY	4	4	Y2	0.454	1607.62	WHOLE_BAY_OYSTER_DREDGE_EASTERN_OYSTER_LAG2_3SUB_TGALBF_75_F_

Identify Low Flow Periods

- Periods of lowest average monthly flow
- First value below threshold (median flow) as the start of low flow period, last value below threshold as the end of low flow period



Tabular Aggregation of Salinity Quality Zones for Associated Organisms

	Best	Good	Fair	Poor	Refuge
	0.9-1.0	0.75-0.9	0.5-0.75	0.25-0.5	<0.25
Shell Fish					
White Shrimp	27-35	22.8-27,35-35.8	15.9-22.8,35.8-37.2	8.9-15.9,37.2-38.6	<8.9,>38.6
Blue Crab male	5-10	4.2-5,10-16.7	2.8-4.2,16.7-27.8	1.4-2.8,27.8-38.9	<1.4,>38.9
Blue Crab Egg-bearing Female	23-33	19.1-23,33-35.8	12.8-19.1,35.8-40.6	6.4-12.8,40.6-45.3	<6.4,>45.3
Brown Shrimp	24-38.9	20.1-24,38.9-39.9	13.7-20.1,39.9-41.6	7.2-13.7,41.6-43.3	<7.2,>43.3
Forage Fish					
Gulf Menhaden	20-25	16.7-20,25-32	11.1-16.7,32-43.7	5.6-11.1,43.7-55.3	<5.6,>55.3
Atlantic Croaker	15-20	12.5-15,20-23.8	8.3-12.5,23.8-30	4.2-8.3,30-36.3	<4.2,>36.3
Spotted Seatrout	20-25	17.7-20,25-29.6	13.8-17.7,29.6-37.3	10-13.8,37.3-45	<10,>45
Red Drum	20-40	16.7-20,40-40.9	11.1-16.7,40.9-42.4	5.6-11.1,42.4-43.8	<5.6,>43.8
Black Drum	9-26	7.5-9,26-35	5-7.5,35-50	2.5-5,50-65	<2.5,>65
Southern Flounder	20-30	16.7-20,30-35	11.1-16.7,35-43.3	5.6-11.1,43.3-51.7	<5.6,>51.7
Eastern Oyster	14-30	10-14,30-32.3	7.3-10,32.3-36	4.7-7.3,36-39.8	<4.7,>39.8

Tabular Aggregation of Salinity Ranges and Conditions

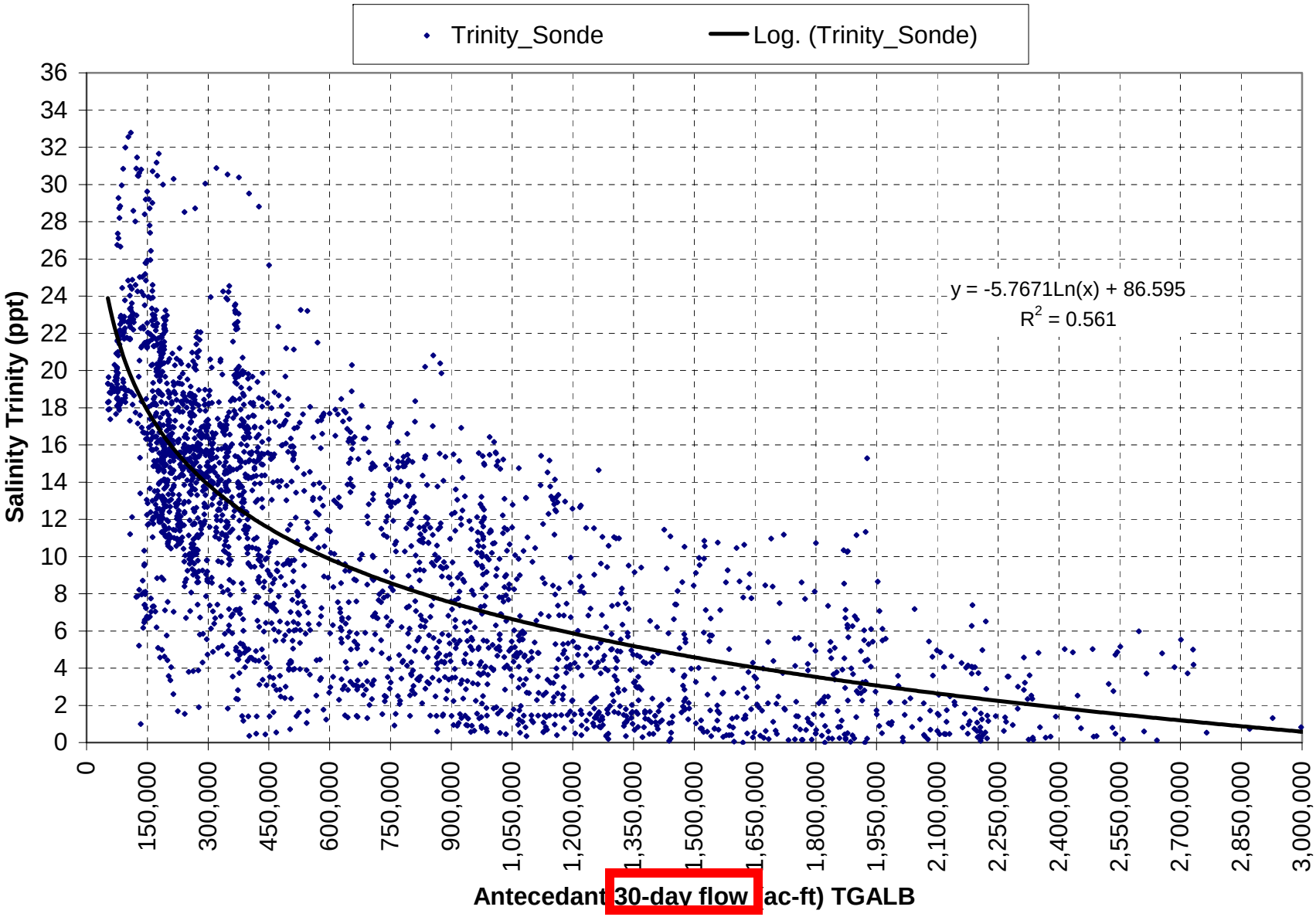
	GB4	GB3	GB2	GB1	Saline
Salinity Range	0-11	11-20	20-30	30-36	>36
Shell Fish					
White Shrimp	Refuge/Poor	Poor/Fair	Fair/Good/Best	Best/Good	Fair/Poor/Refuge
Blue Crab male	Refuge/Poor/Fair/Good/Best	Good/Fair	Fair/Poor	Poor	Poor/Refuge
Blue Crab Egg-bearing Female	Refuge/Poor	Poor/Fair/Good	Good/Best	Best/Good	Fair/Poor/Refuge
Brown Shrimp	Refuge/Poor	Poor/Fair	Good/Best	Best	Best/Good/Fair/Poor/Refuge
Forage Fish					
Gulf Menhaden	Refuge/Poor	Fair/Good	Good/Best	Good/Fair	Fair/Poor/Refuge
Atlantic Croaker	Refuge/Poor/Fair	Fair/Good/Best	Good/Fair	Poor	Refuge
Spotted Seatrout	Refuge/Poor	Poor/Fair/Good	Good/Best	Fair	Fair/Poor/Refuge
Red Drum	Refuge/Poor	Fair/Good	Best	Best	Best/Good/Fair/Poor/Refuge
Black Drum	Refuge/Poor/Fair/Good/Best	Best	Good/Best	Good/Fair	Fair/Poor/Refuge
Southern Flounder	Refuge/Poor	Fair/Good	Best	Good/Fair	Fair/Poor/Refuge
Eastern Oyster	Refuge/Poor/Fair/Good	Good/Best	Best	Good/Fair	Poor/Refuge

Comparison of Predicted vs. Minimum Historical Abundances

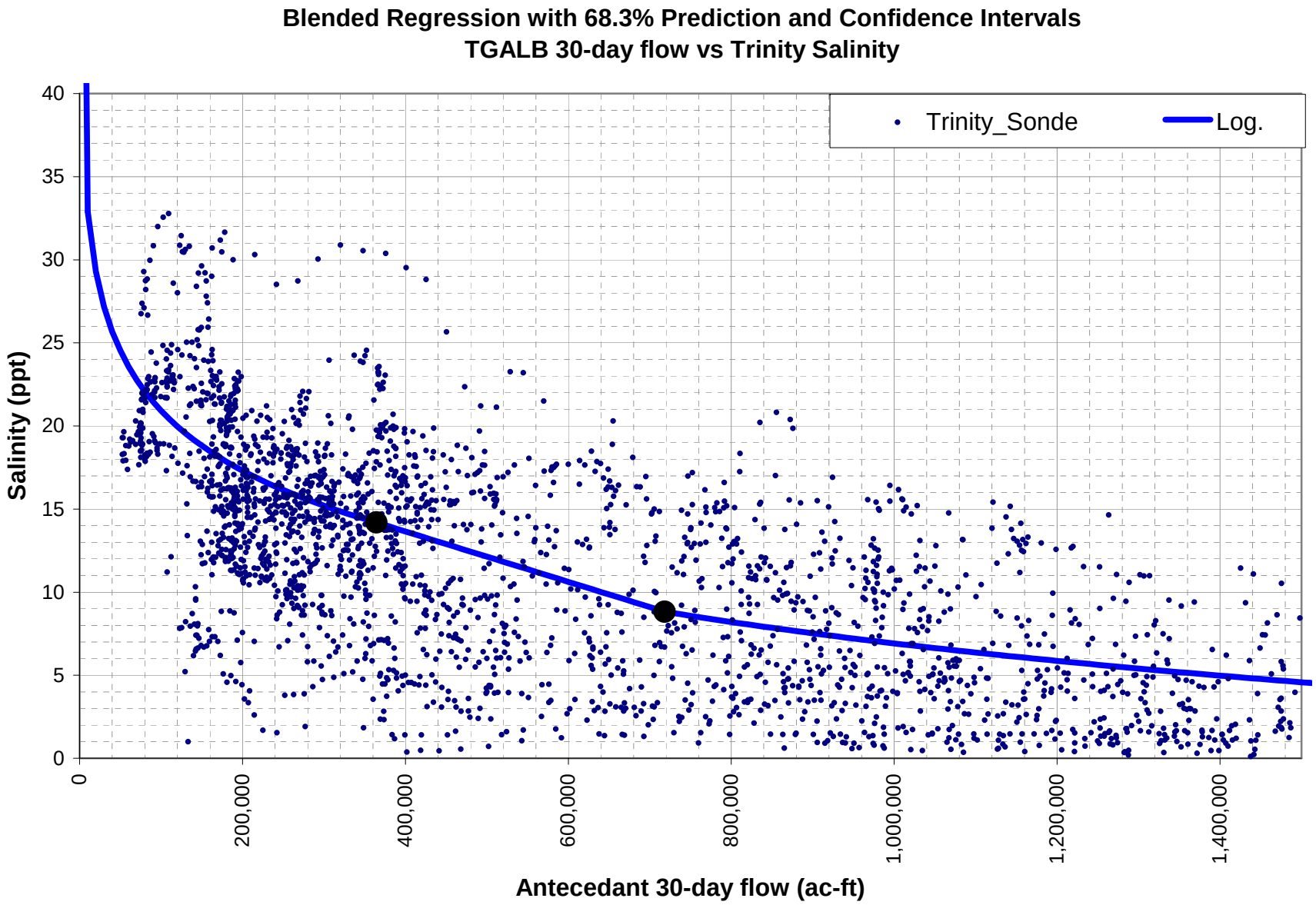
TOTAL GALVESTON BAY

	White Shrimp		Sea Trout	Southen Flounder	Red Drum	Gulf Menhaden	Brown Shrimp		Blue Crab		Black Drum	Atlantic Croaker	Eastern Oyster
	Bag Seine	Otter Trawl	Bag Seine	Bag Seine	Bag Seine	Bag Seine	Bag Seine	Otter Trawl	Bag Seine	Otter Trawl	Bag Seine	Bag Seine	Oyster Dredge
GB4	173.80	4.91	3.38			39.57		2.82					2,581.01
Fresh	331.28	15.86	11.76			1,776.52		5.48					5,446.18
Historical Min.	20.03	2.53	0.00			38.77		1.46					1,210.11

TGALB Watershed - TRINITY Sonde

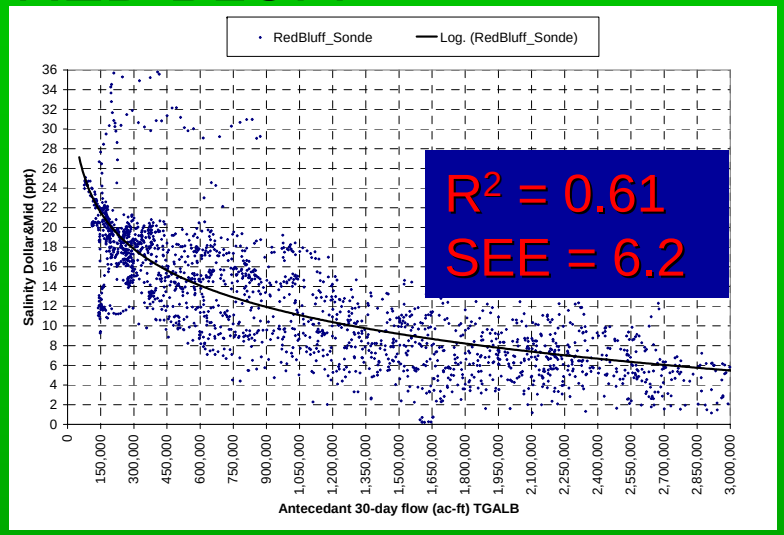


Refined Integrated Low Flow Salinity Regressions

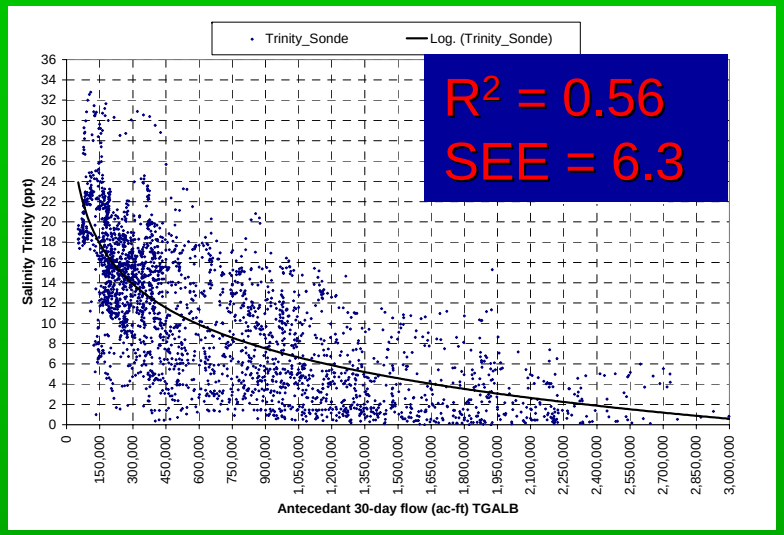


WATERSHED: TOTAL GALVESTON BAY

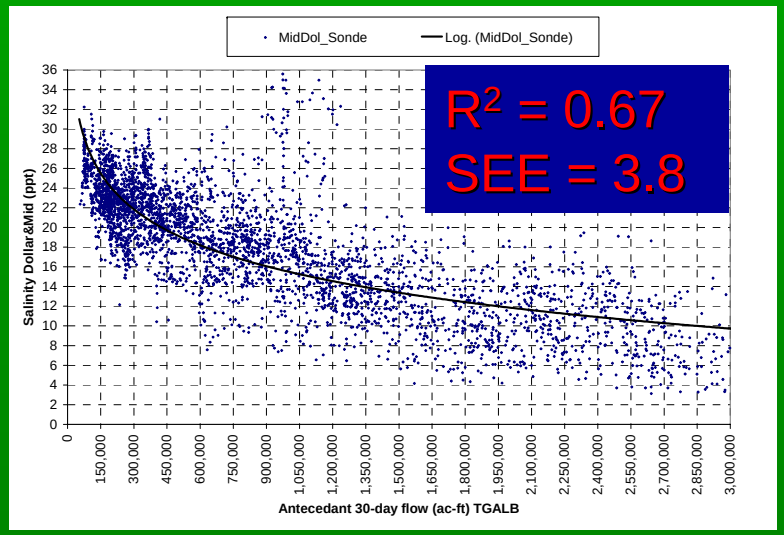
RED BLUFF



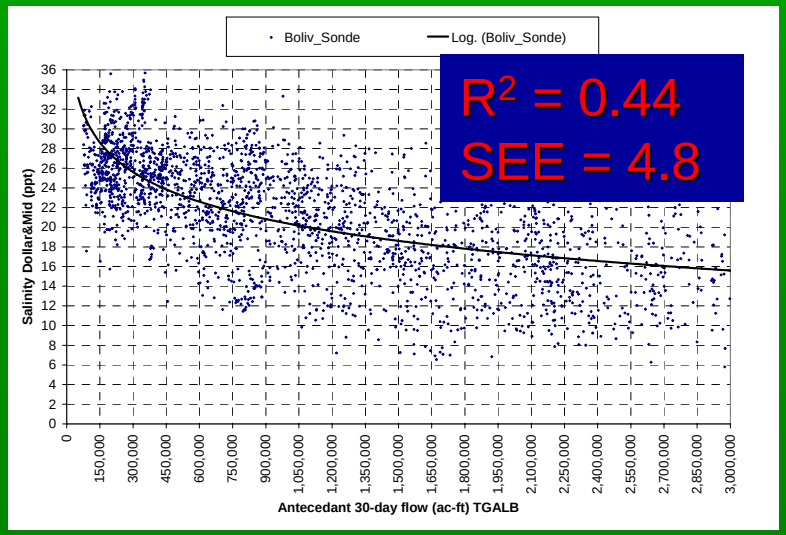
TRINITY



DOLLAR/MID



BOLIVAR



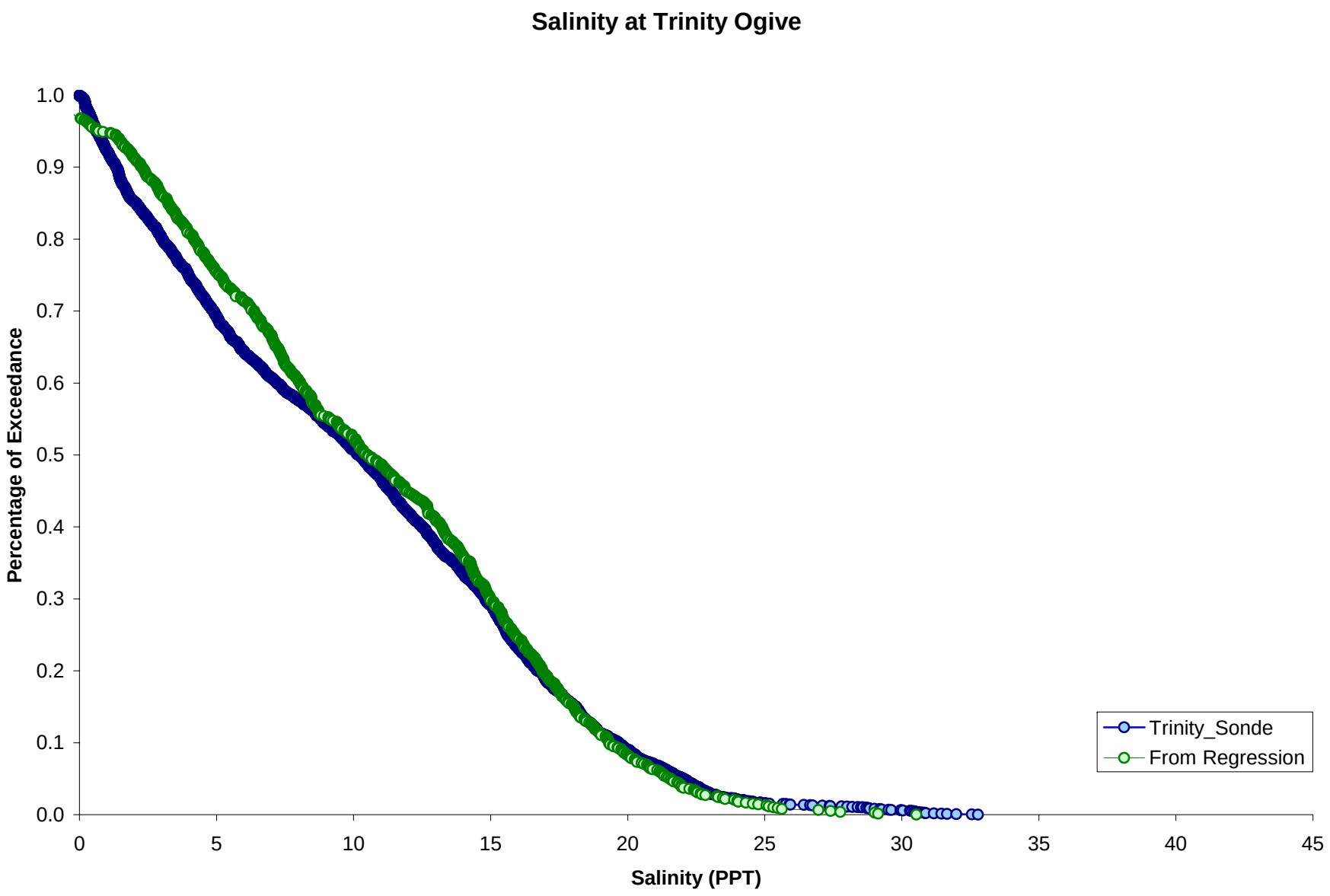
Comparison of POR Regression & Piecewise Regressions

Sonde	Old SEE (ppt)	New SEE (ppt)
Trinity	6.3	4.7
Red Bluff	6.2	4.3
Dollar/Mid	3.8	3.8
Bolivar	4.8	4.8

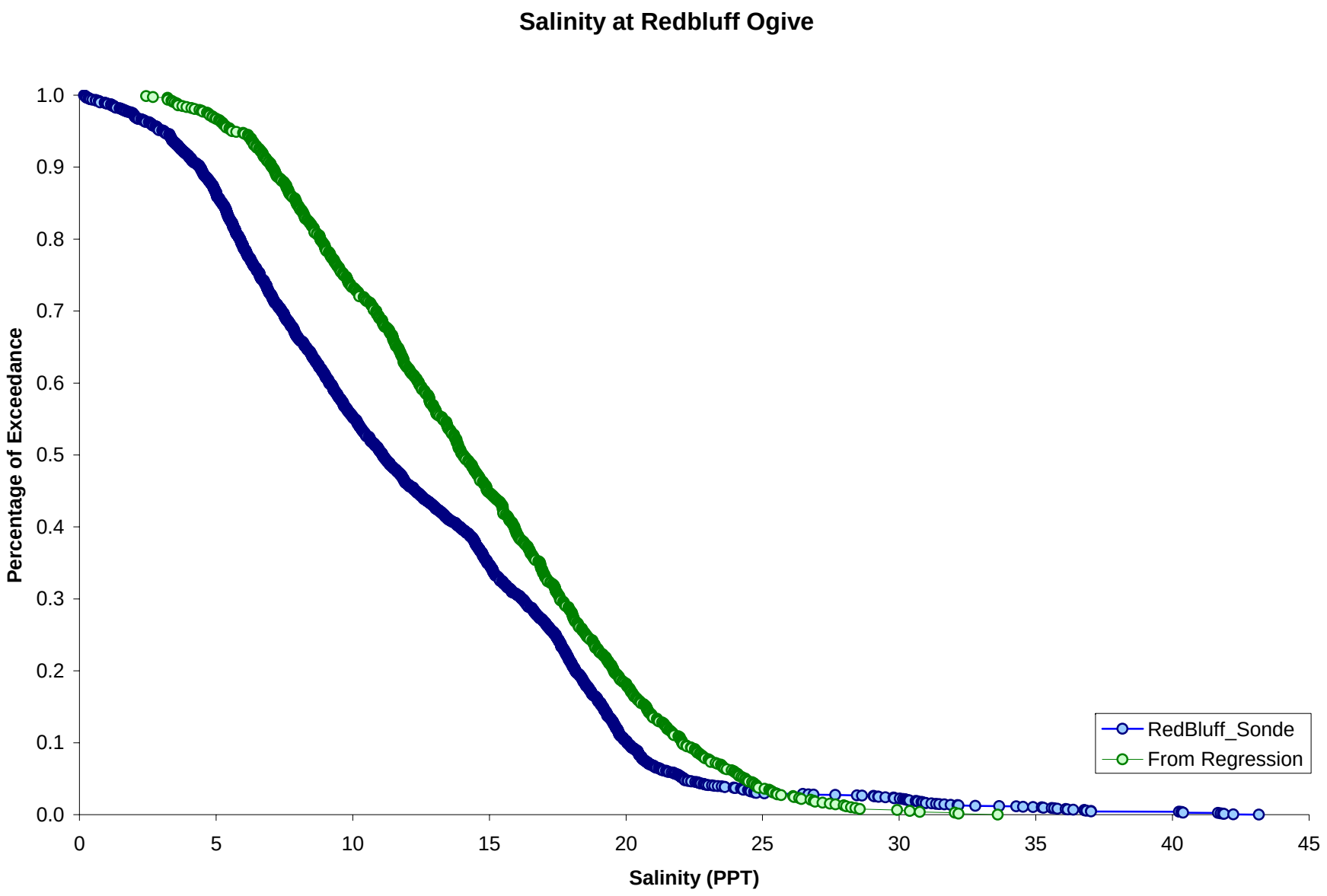
Validation of salinity regression dataset

- Comparison of ogives from actual data (1986-2005) and from regression predictions (1940-2005) compare well

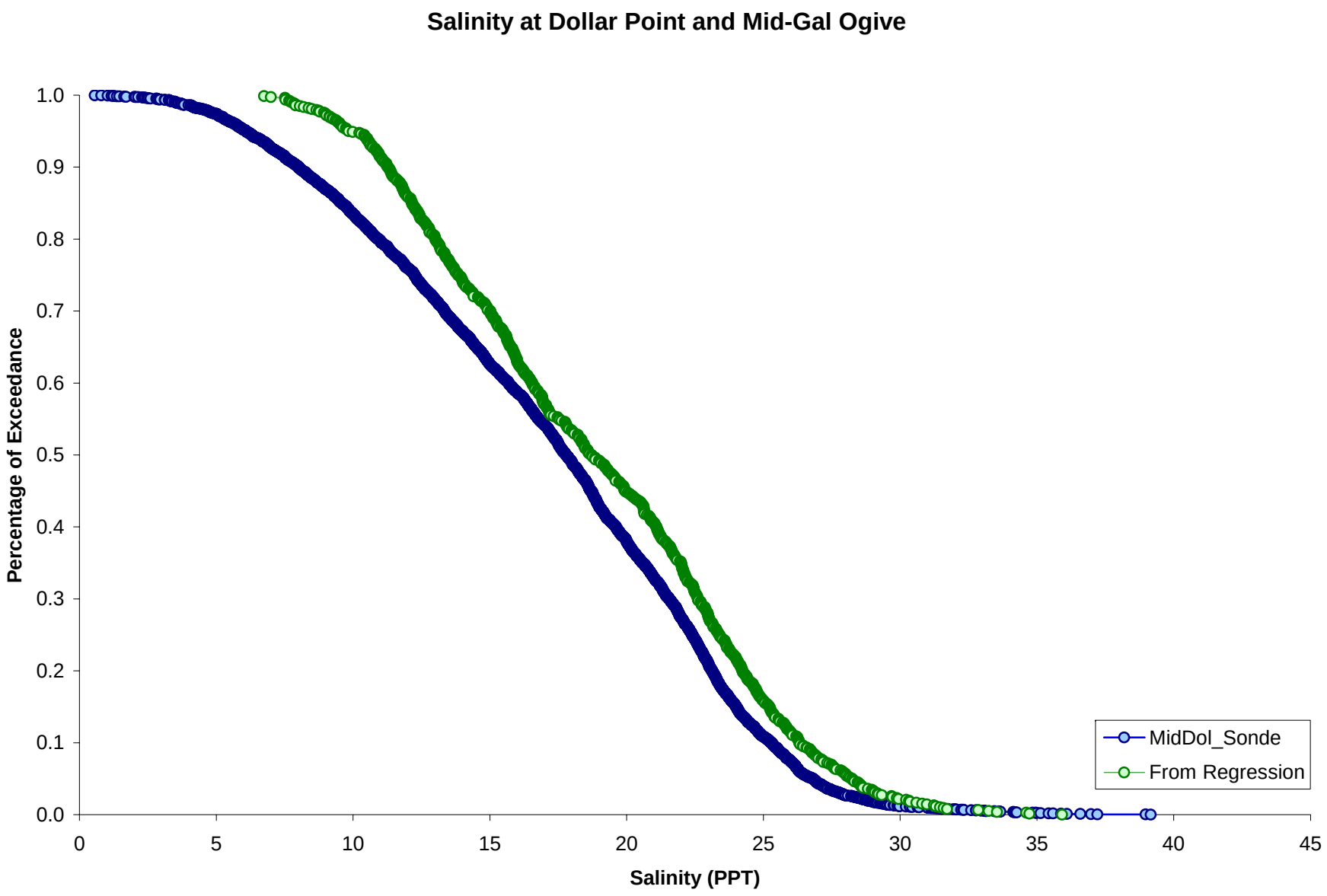
Comparison @ Trinity



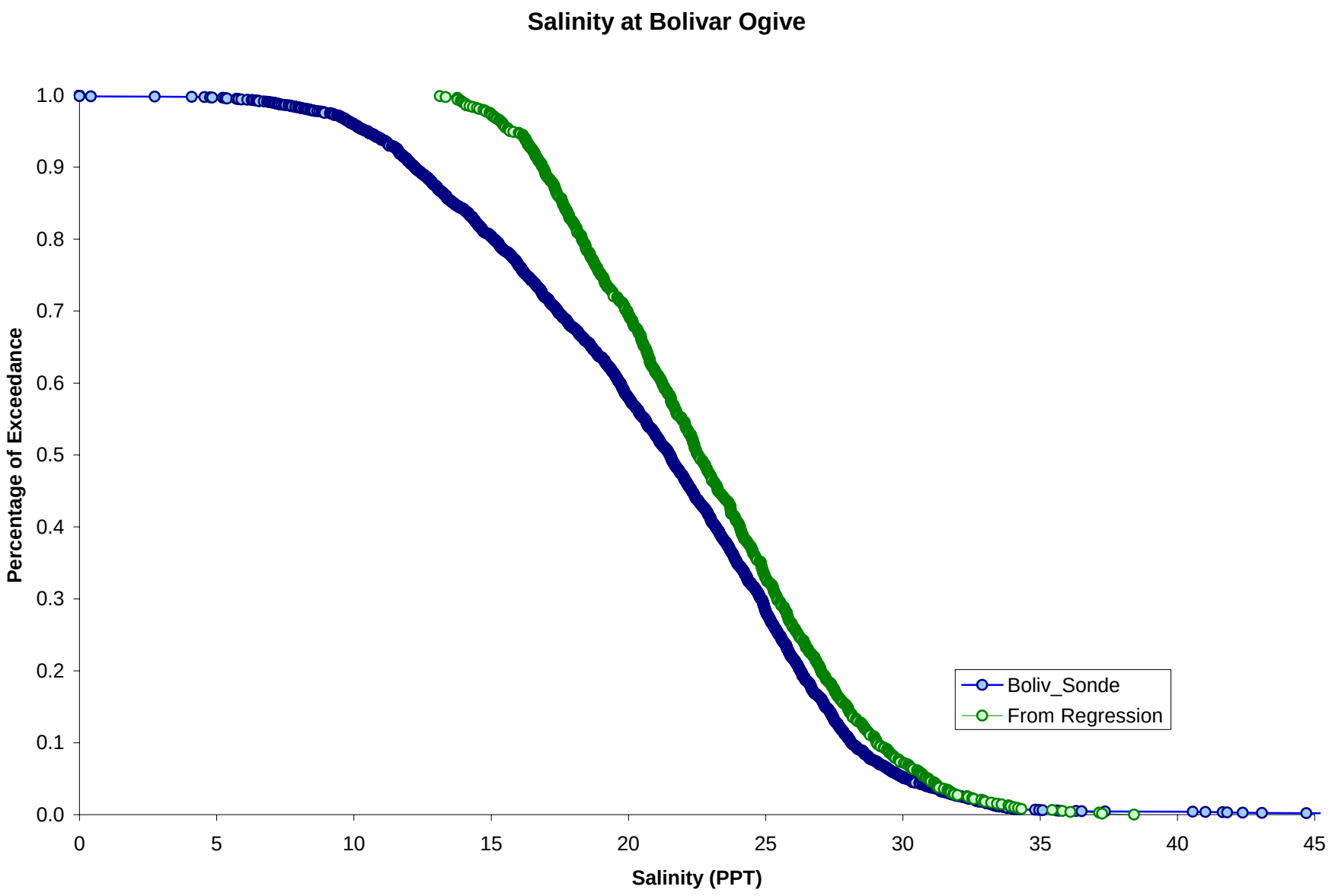
Comparison @ Red Bluff



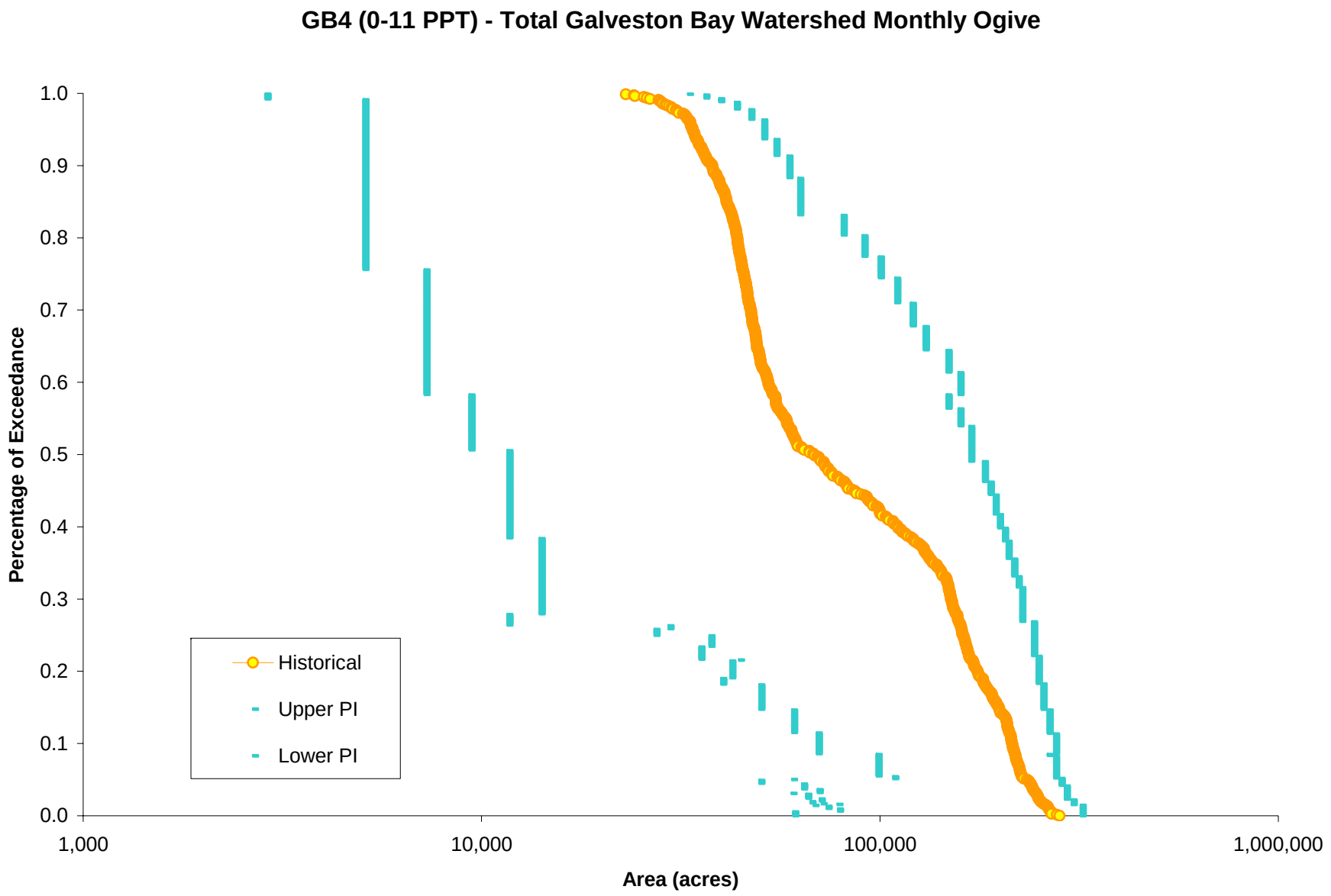
Comparison @ Dollar/Mid



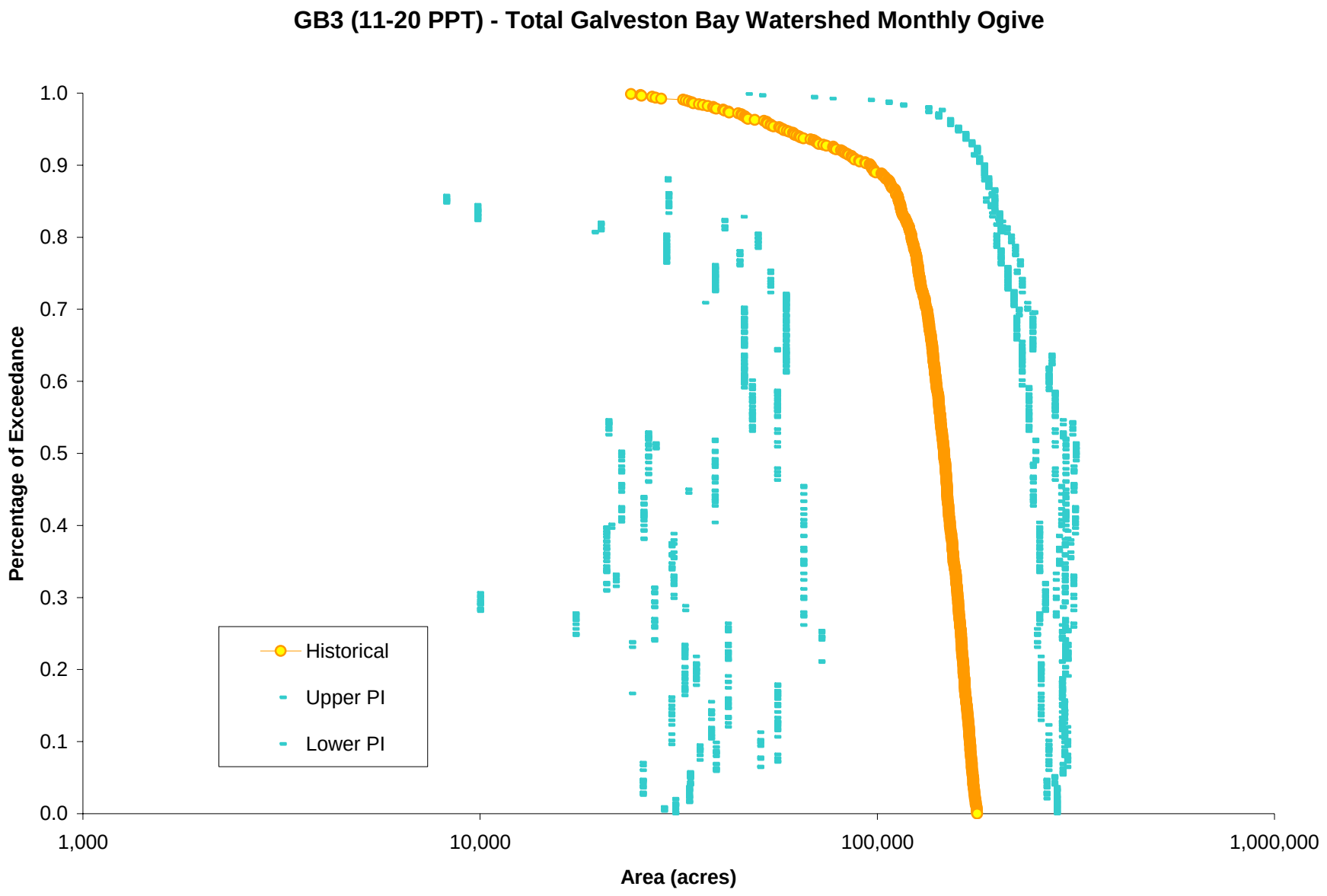
Comparison @ Bolivar



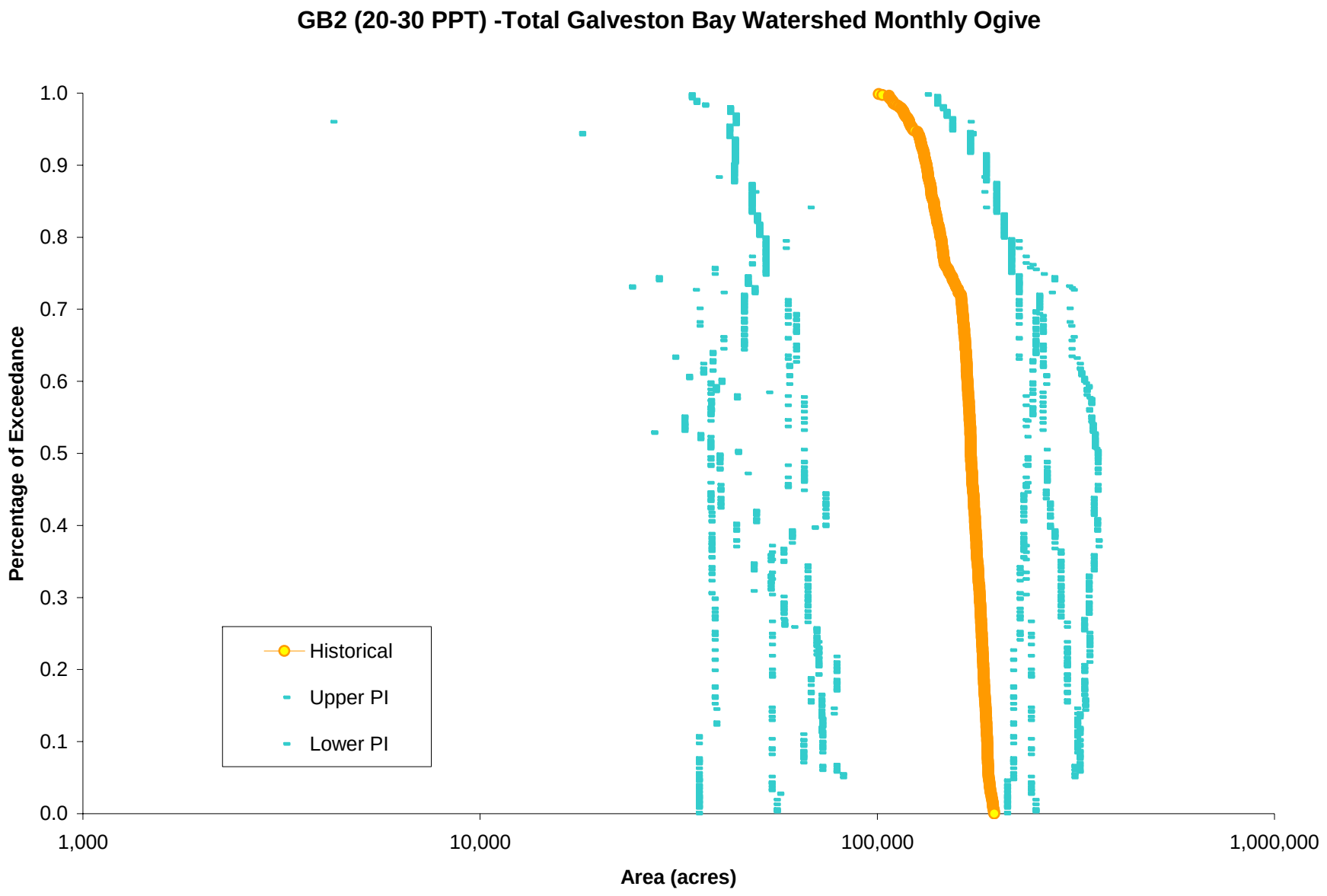
Monthly Ogive – GB4



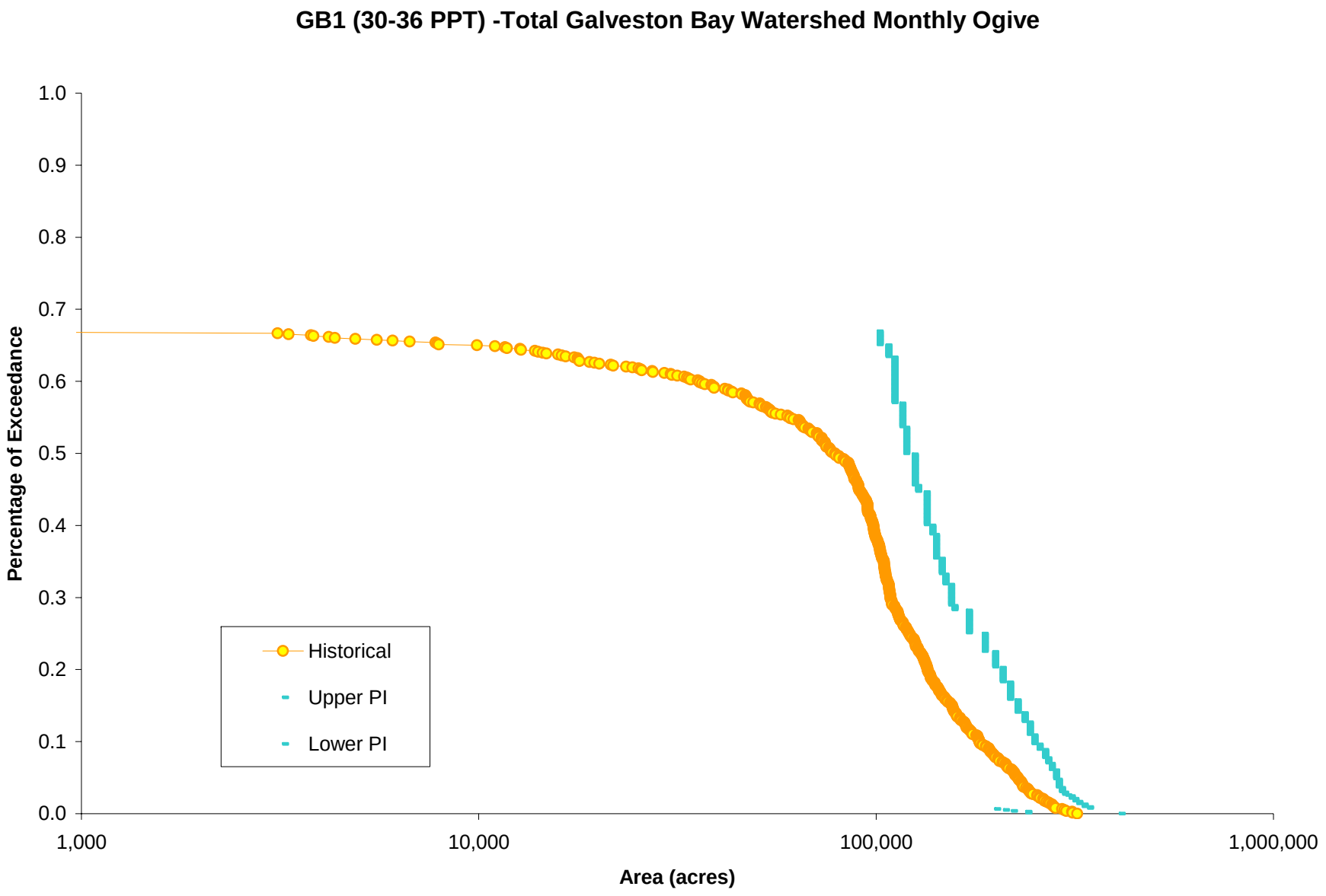
Monthly Ogive – GB3



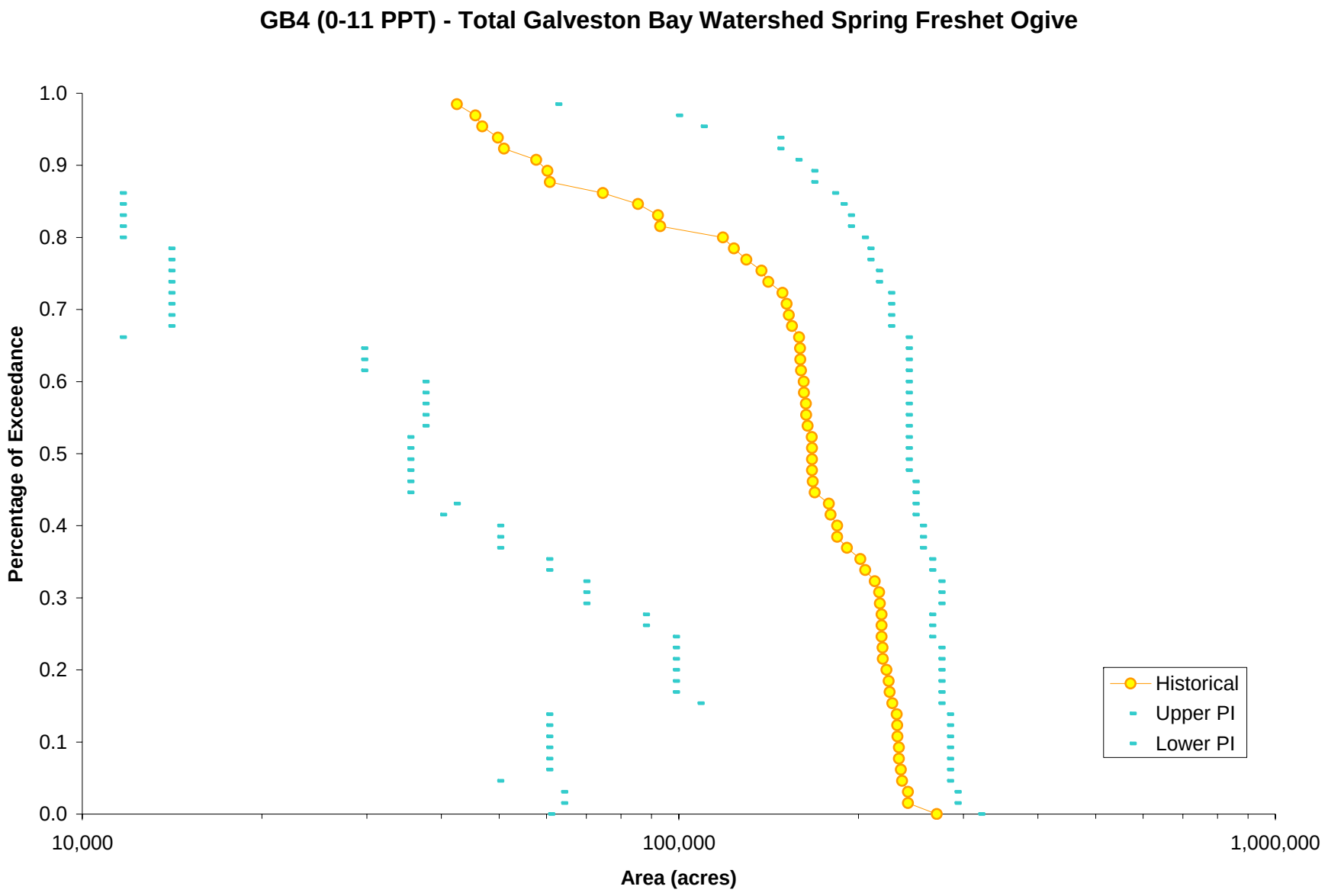
Monthly Ogive – GB2



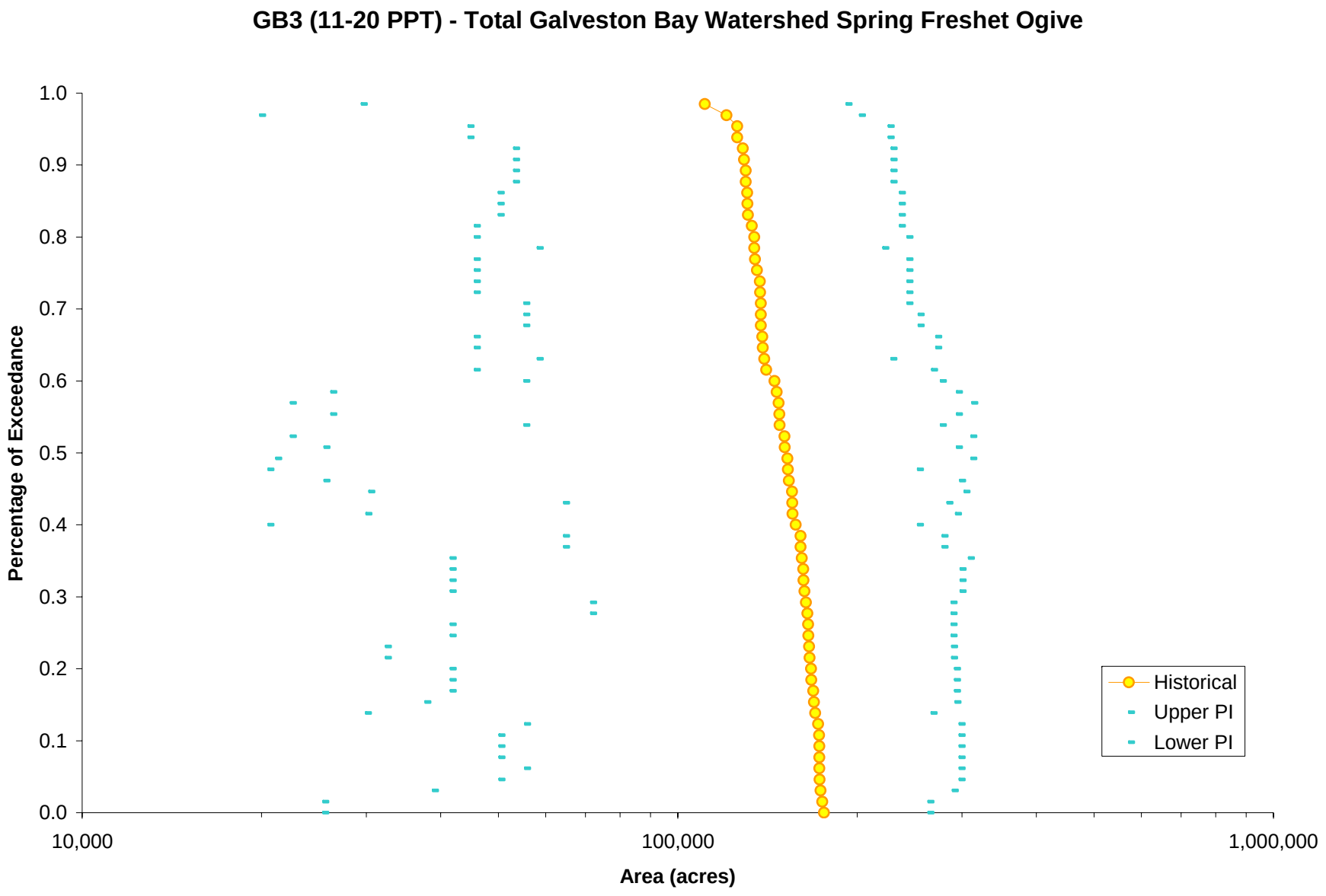
Monthly Ogive – GB1



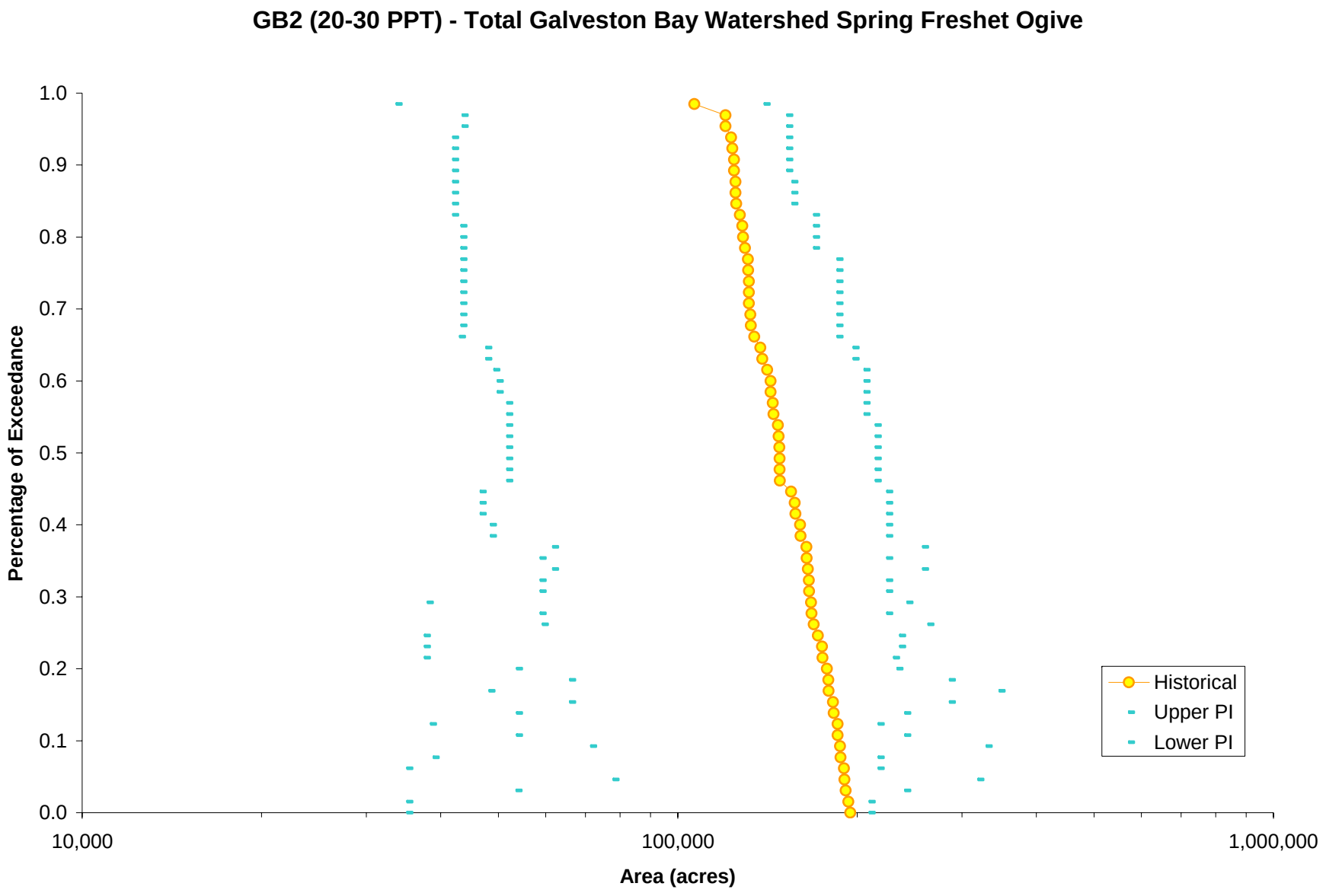
Spring Freshet Ogive – GB4



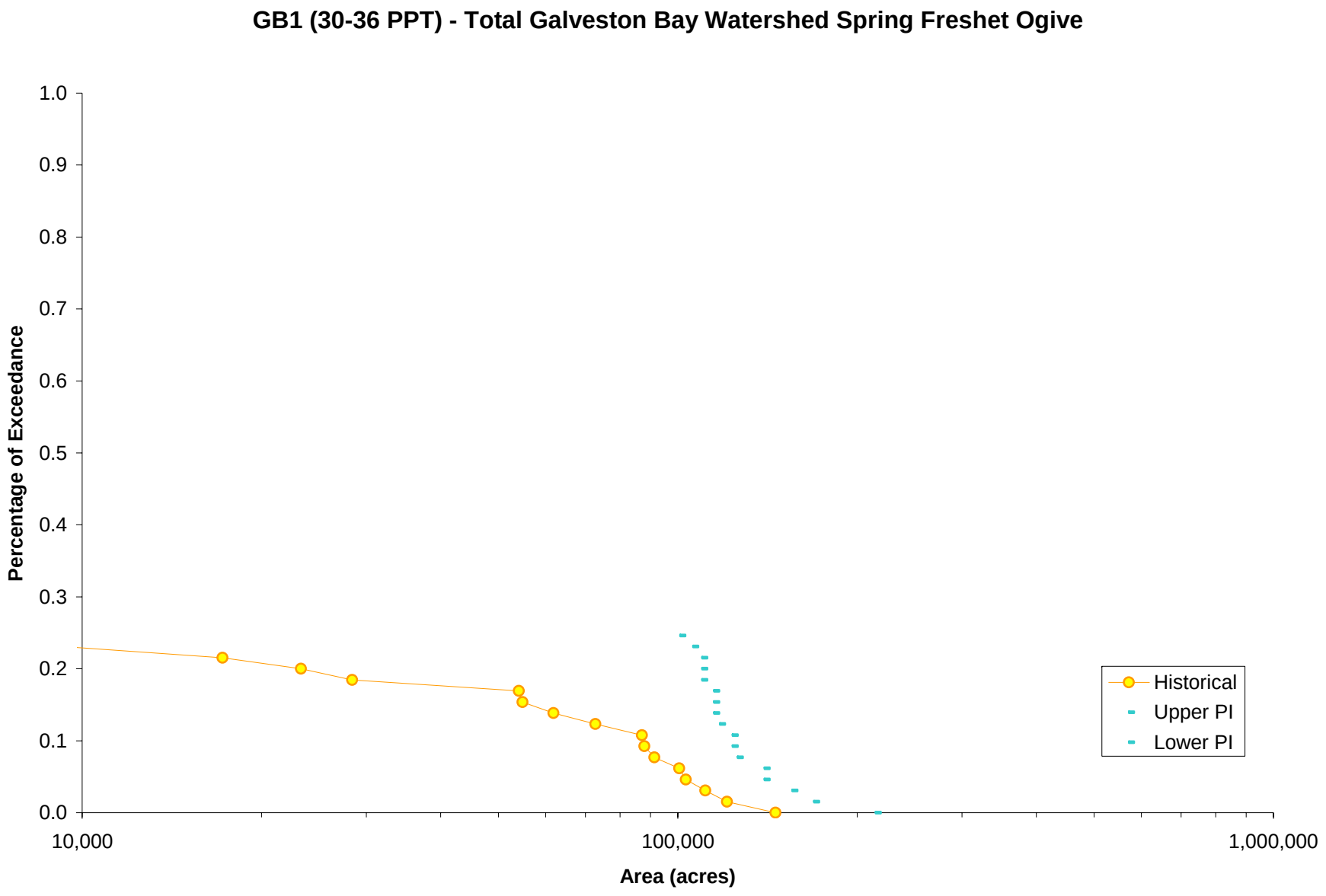
Spring Freshet Ogive – GB3



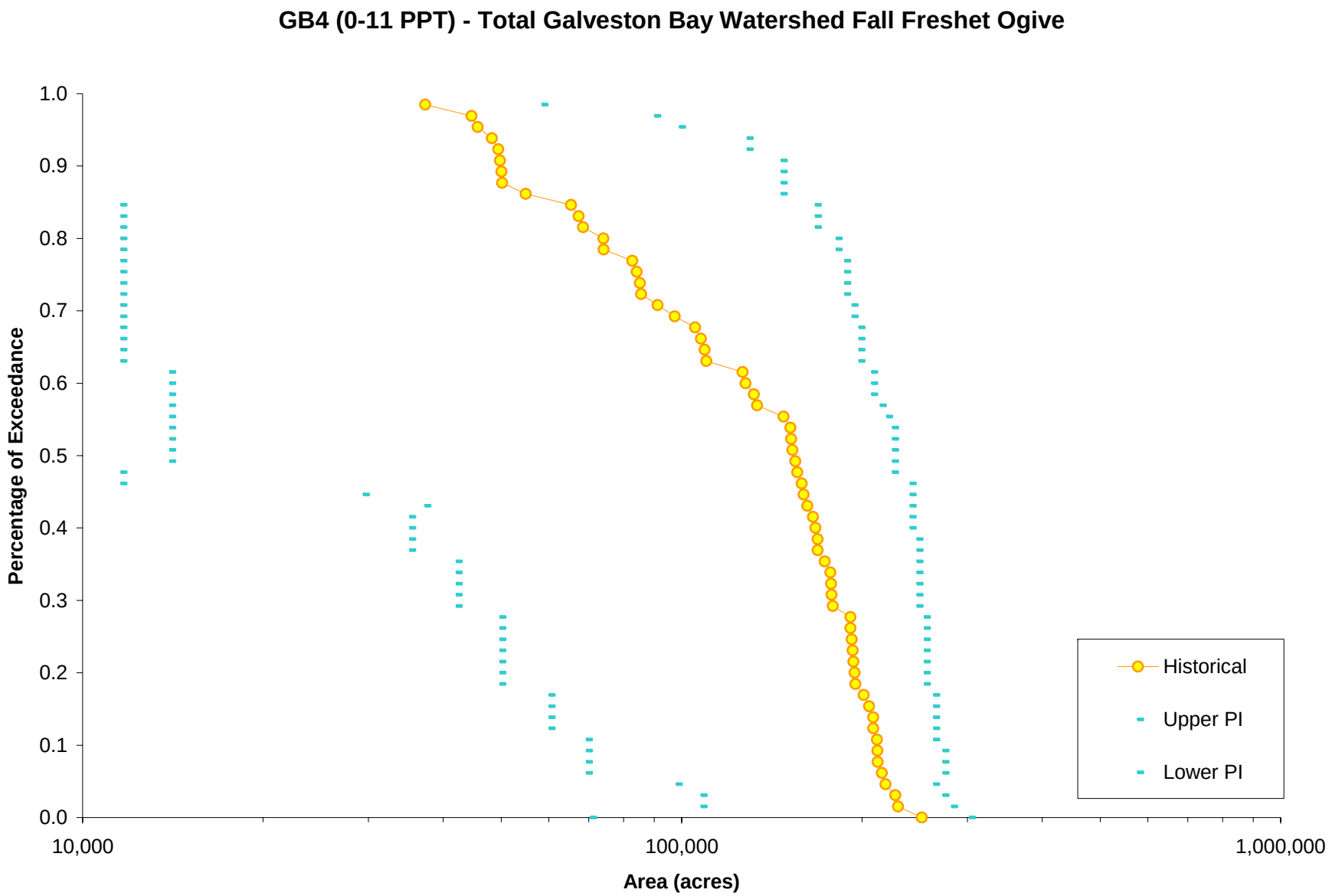
Spring Freshet Ogive – GB2



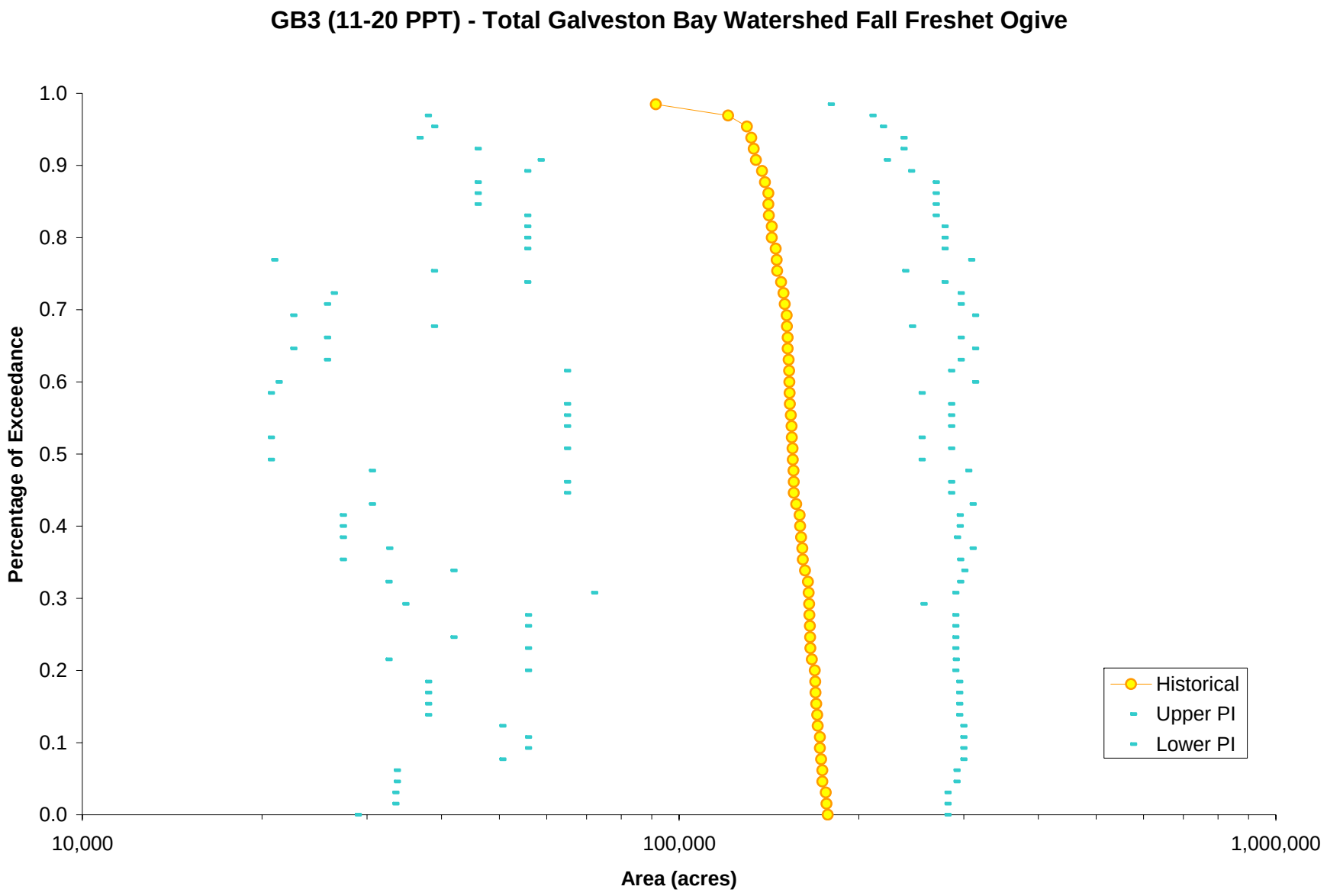
Spring Freshet Ogive – GB1



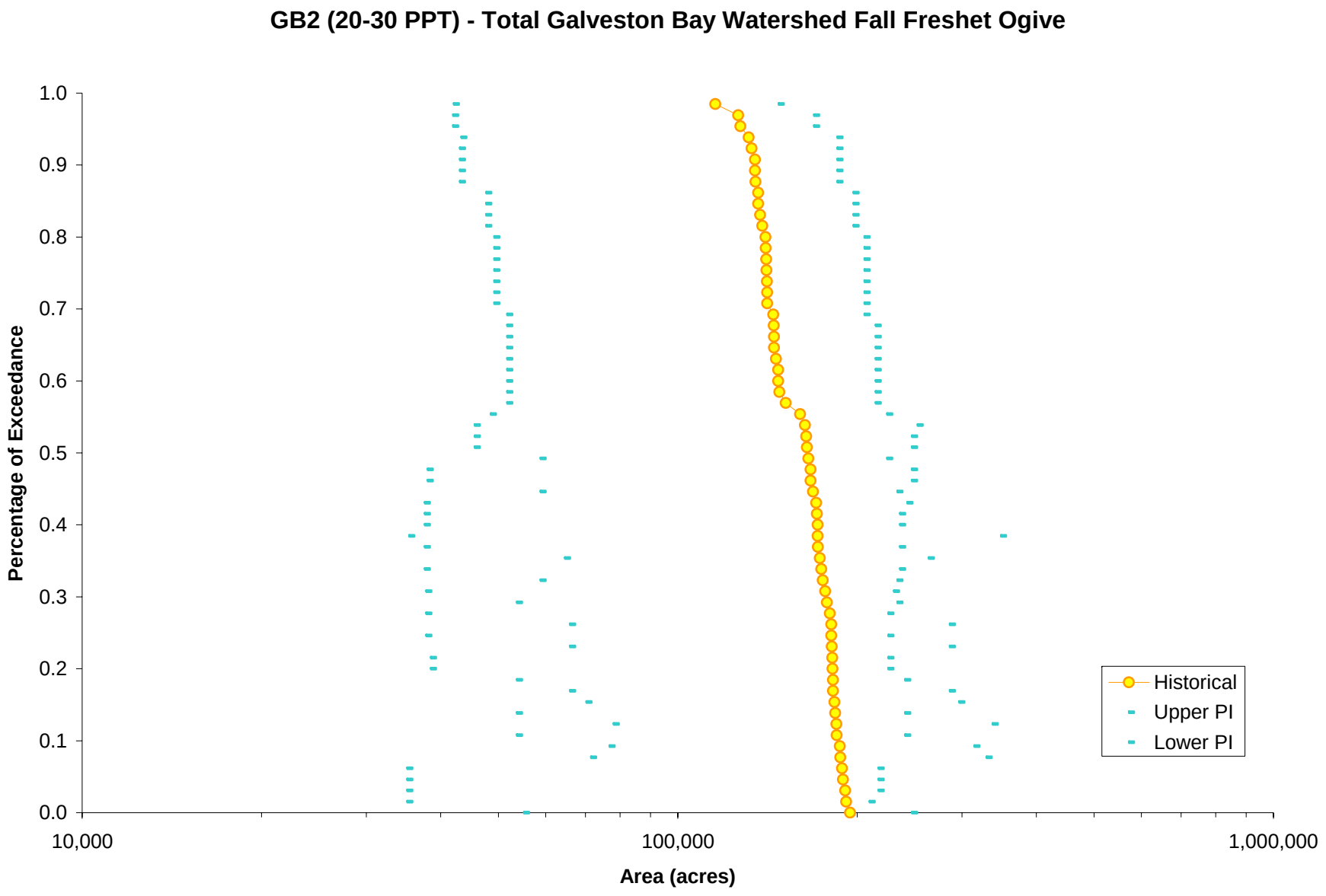
Fall Freshet Ogive – GB4



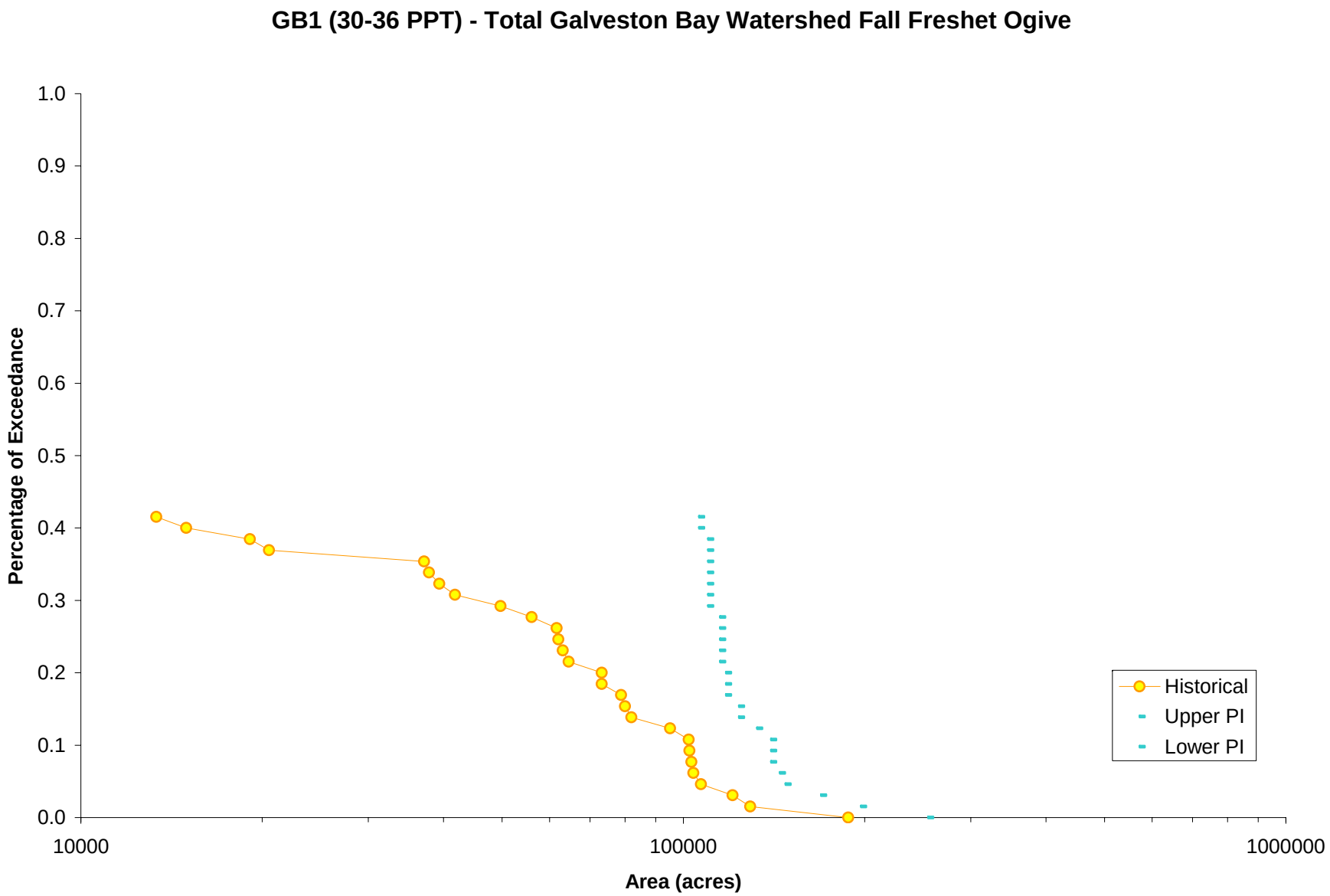
Fall Freshet Ogive – GB3



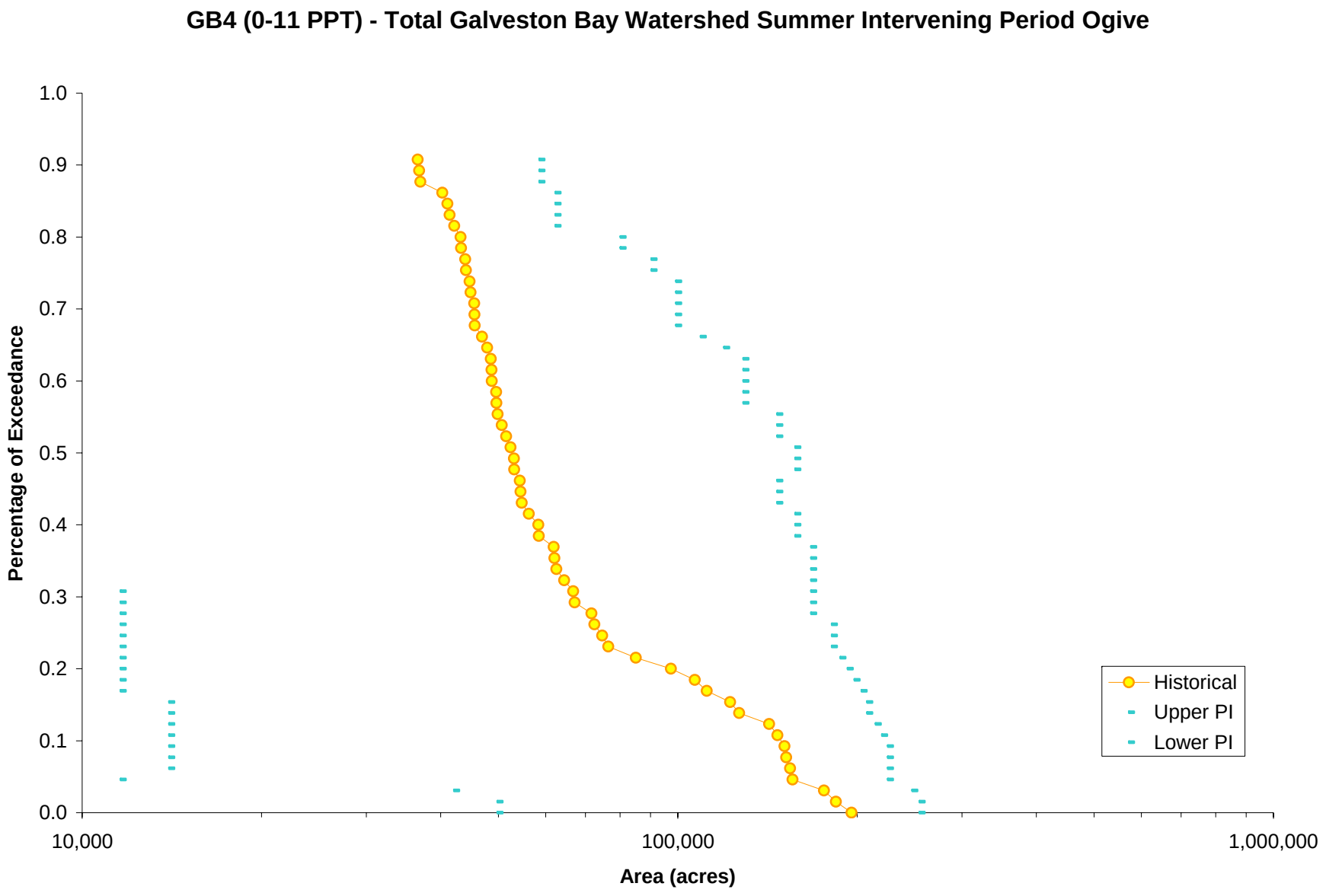
Fall Freshet Ogive – GB2



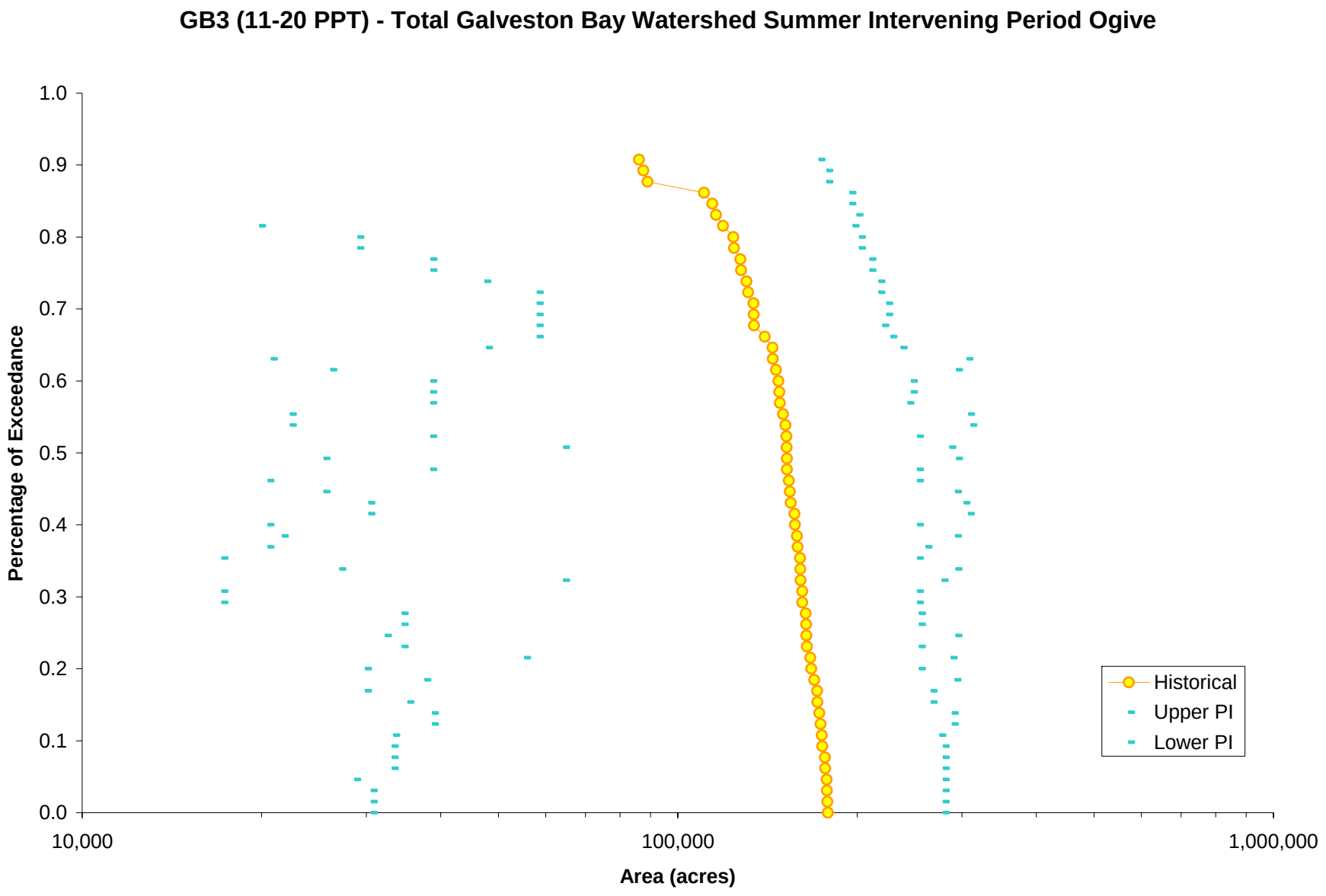
Fall Freshet Ogive – GB1



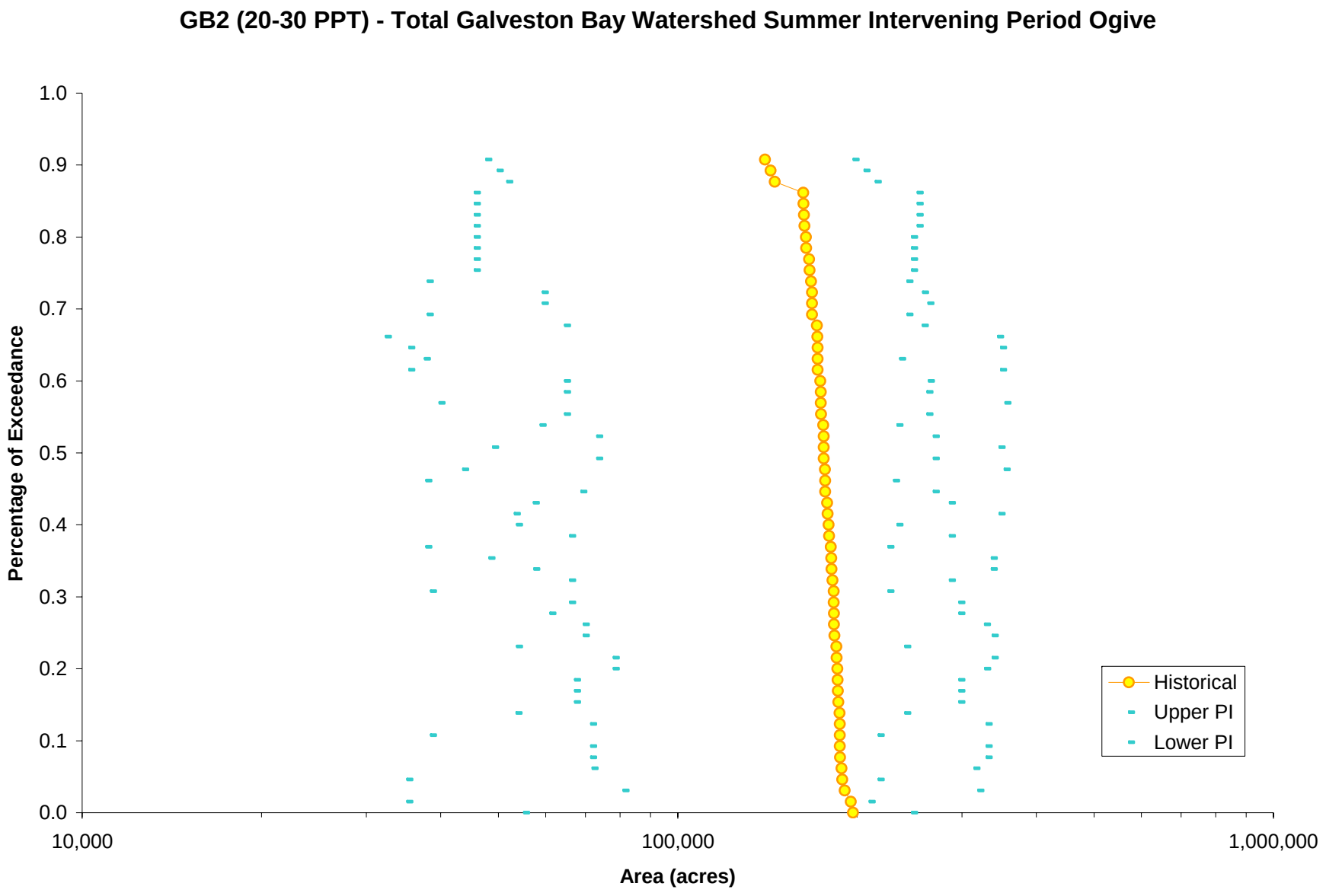
Summer Intervening Ogive – GB4



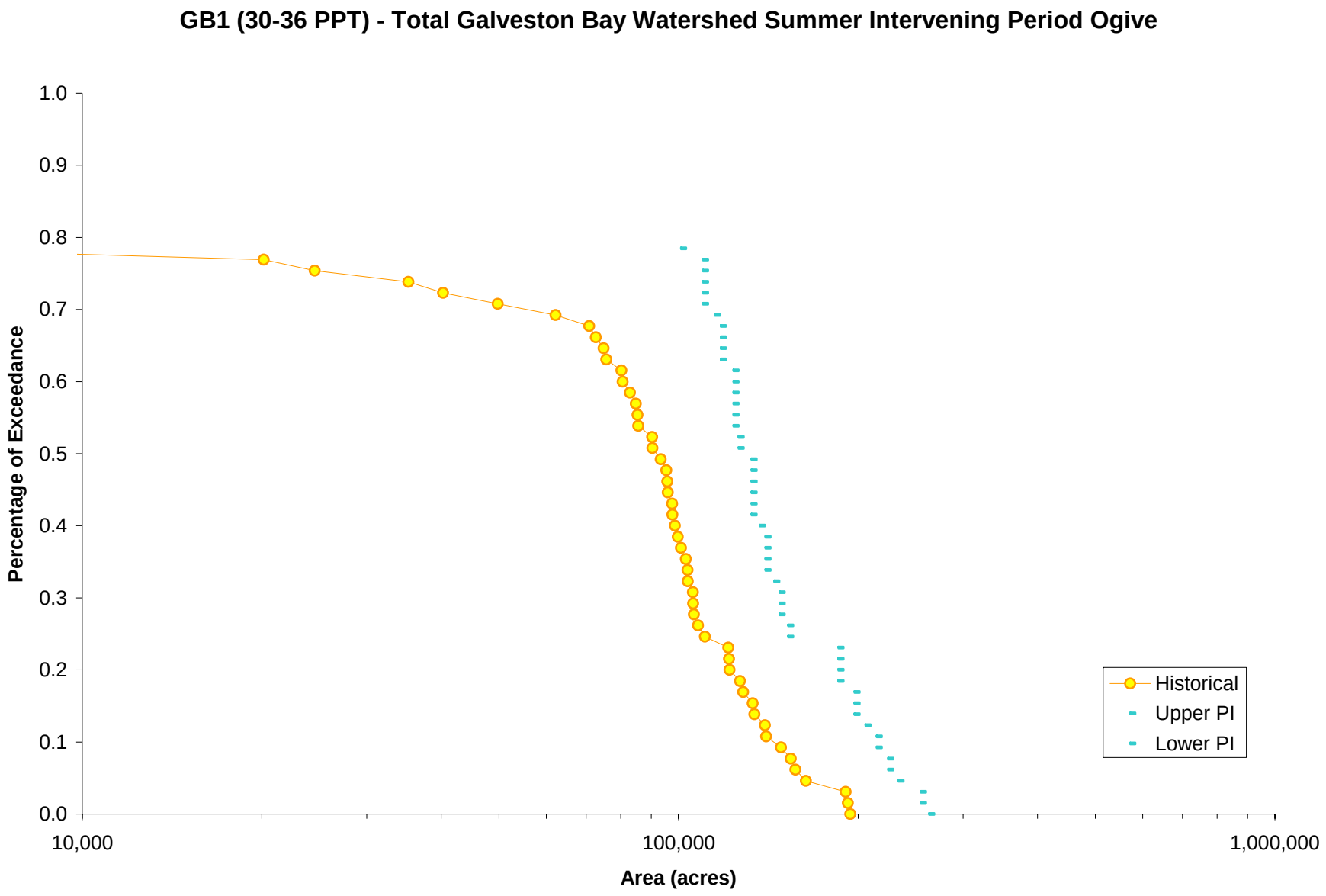
Summer Intervening Ogive – GB3



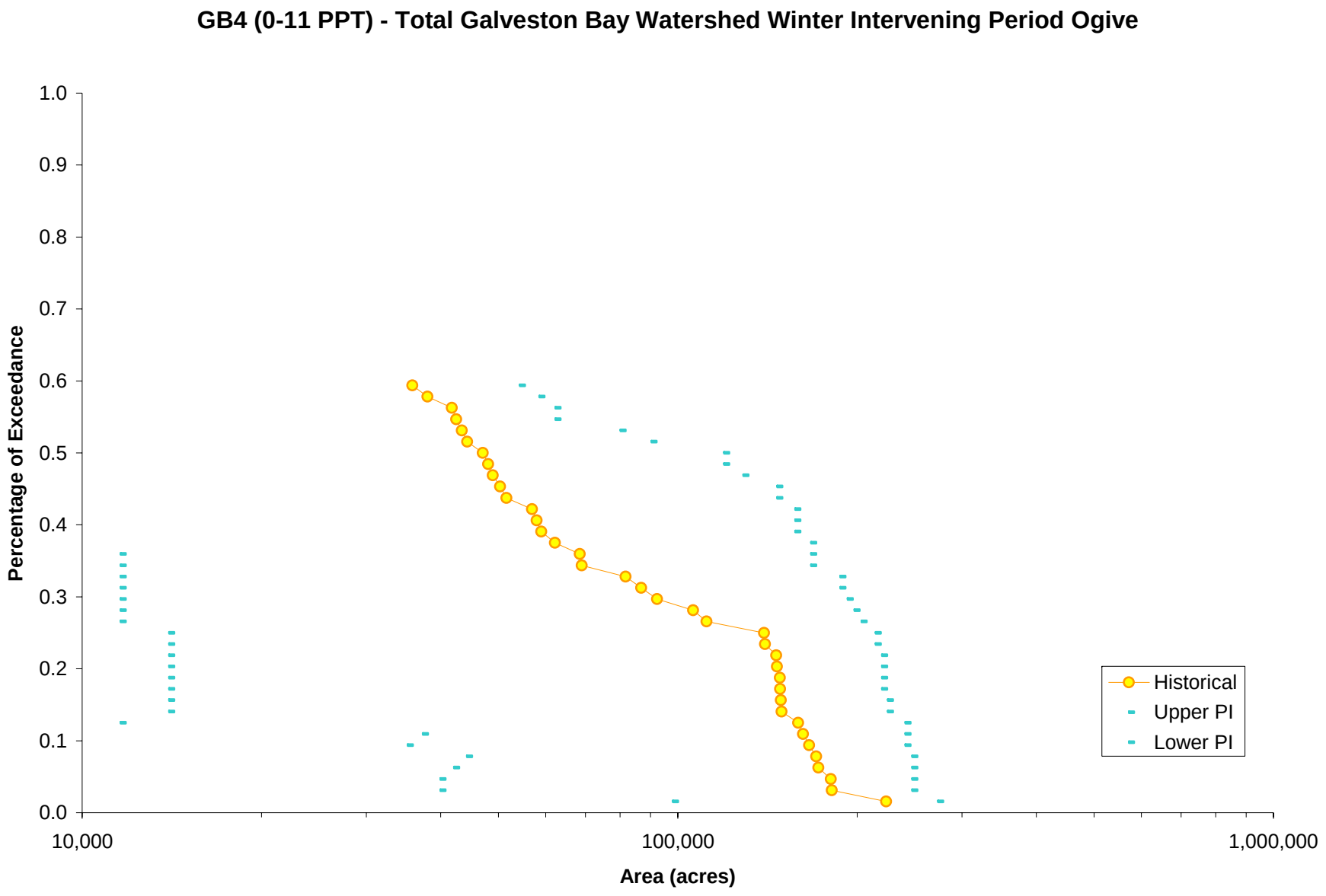
Summer Intervening Ogive – GB2



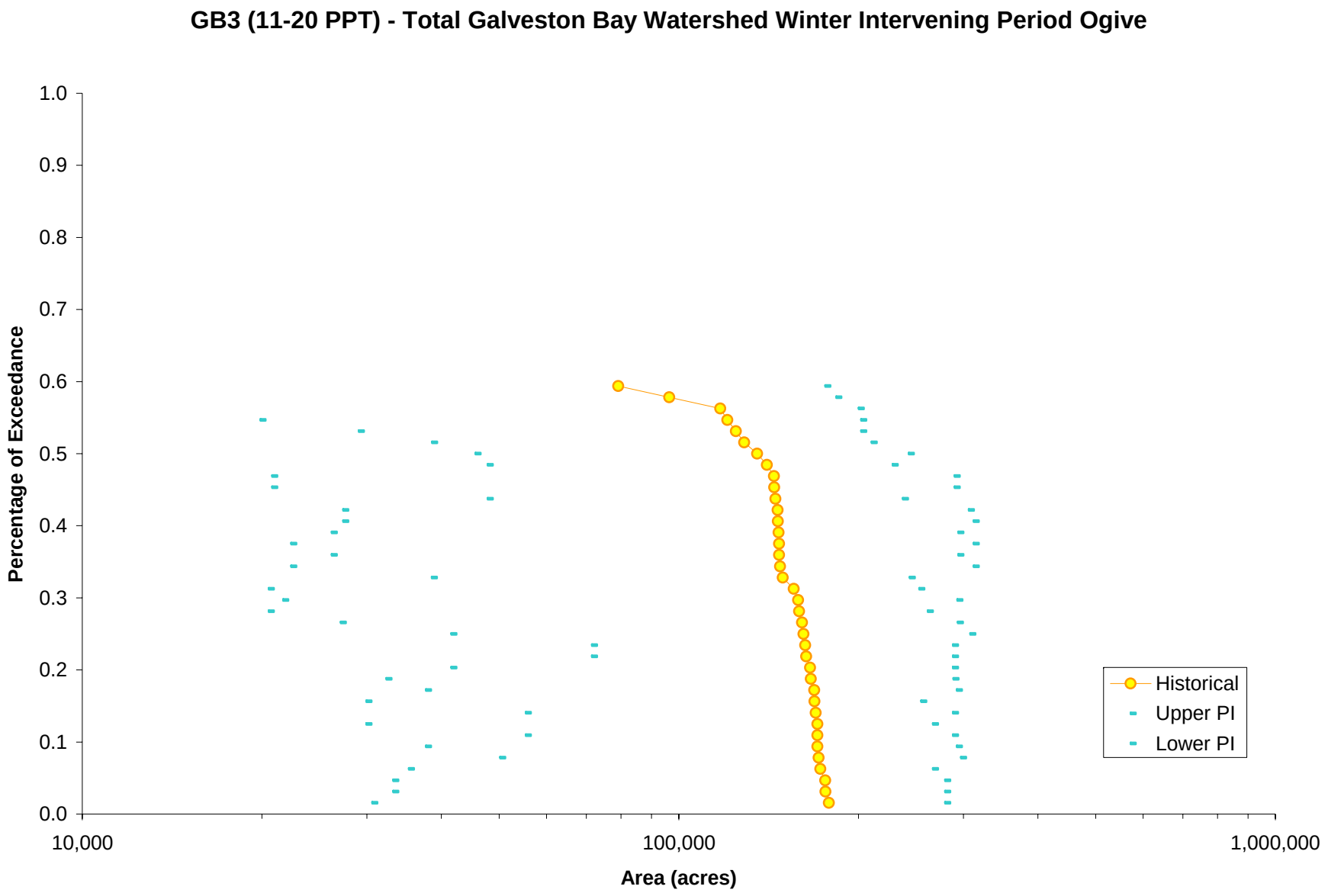
Summer Intervening Ogive – GB1



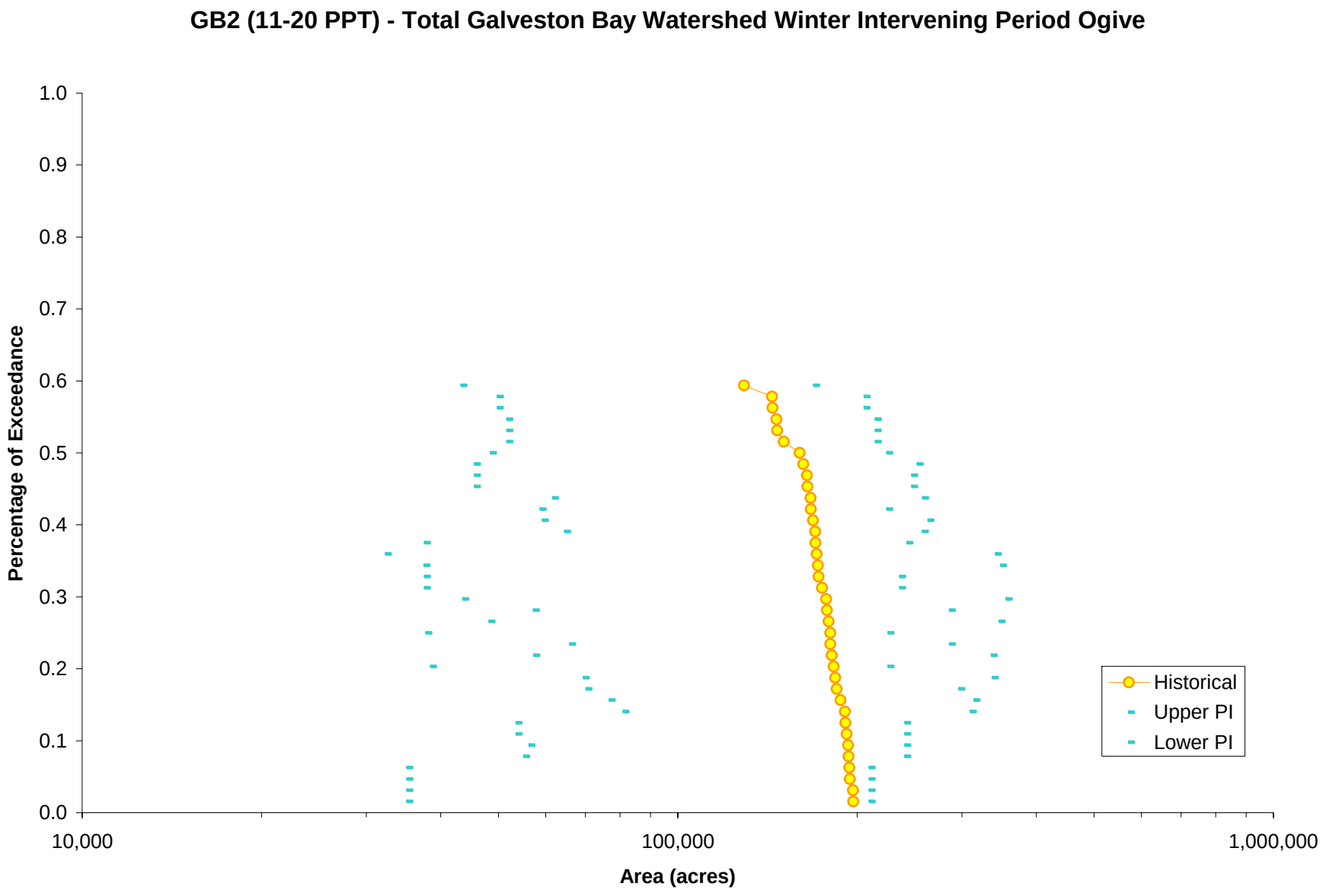
Winter Intervening Ogive – GB4



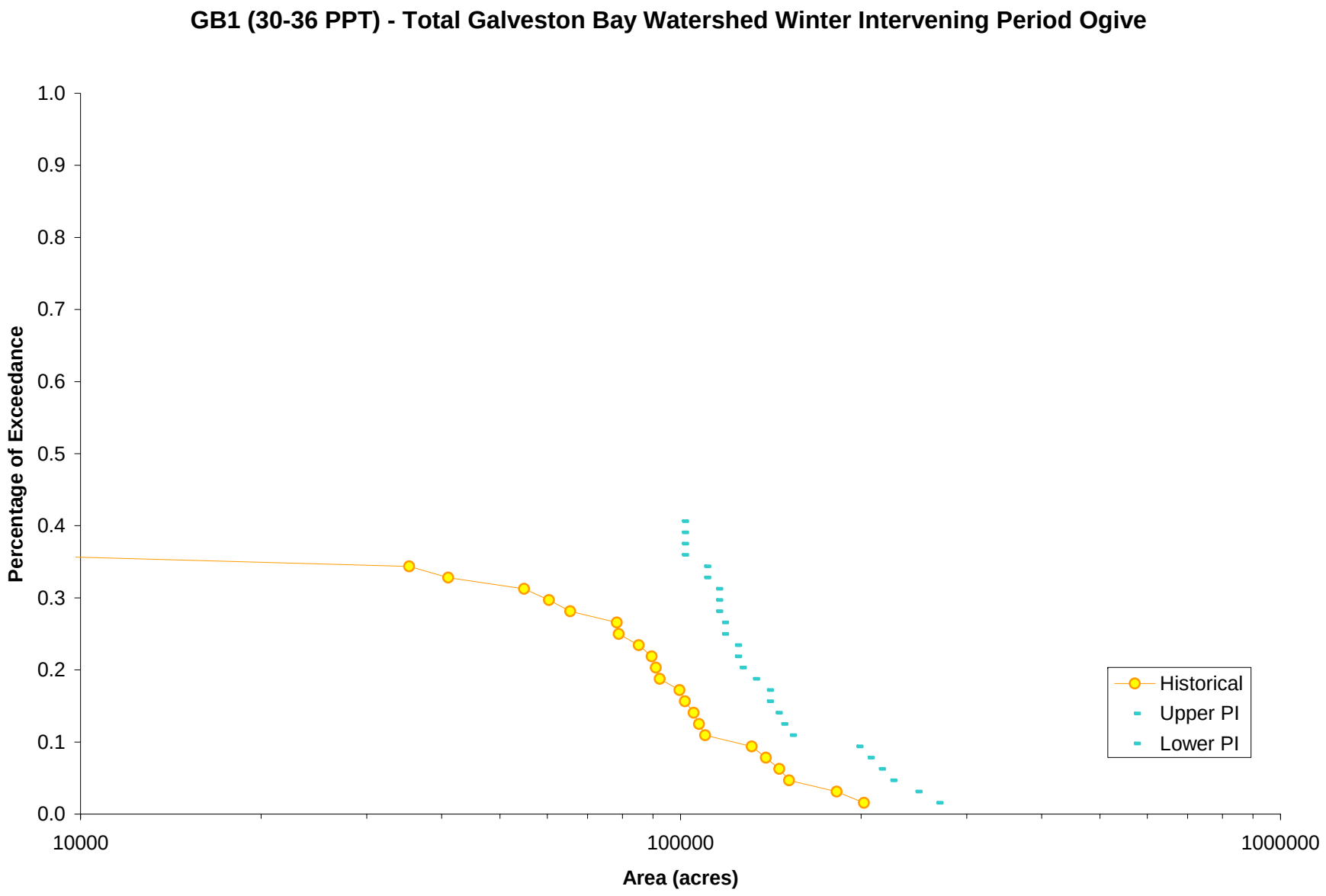
Winter Intervening Ogive – GB3



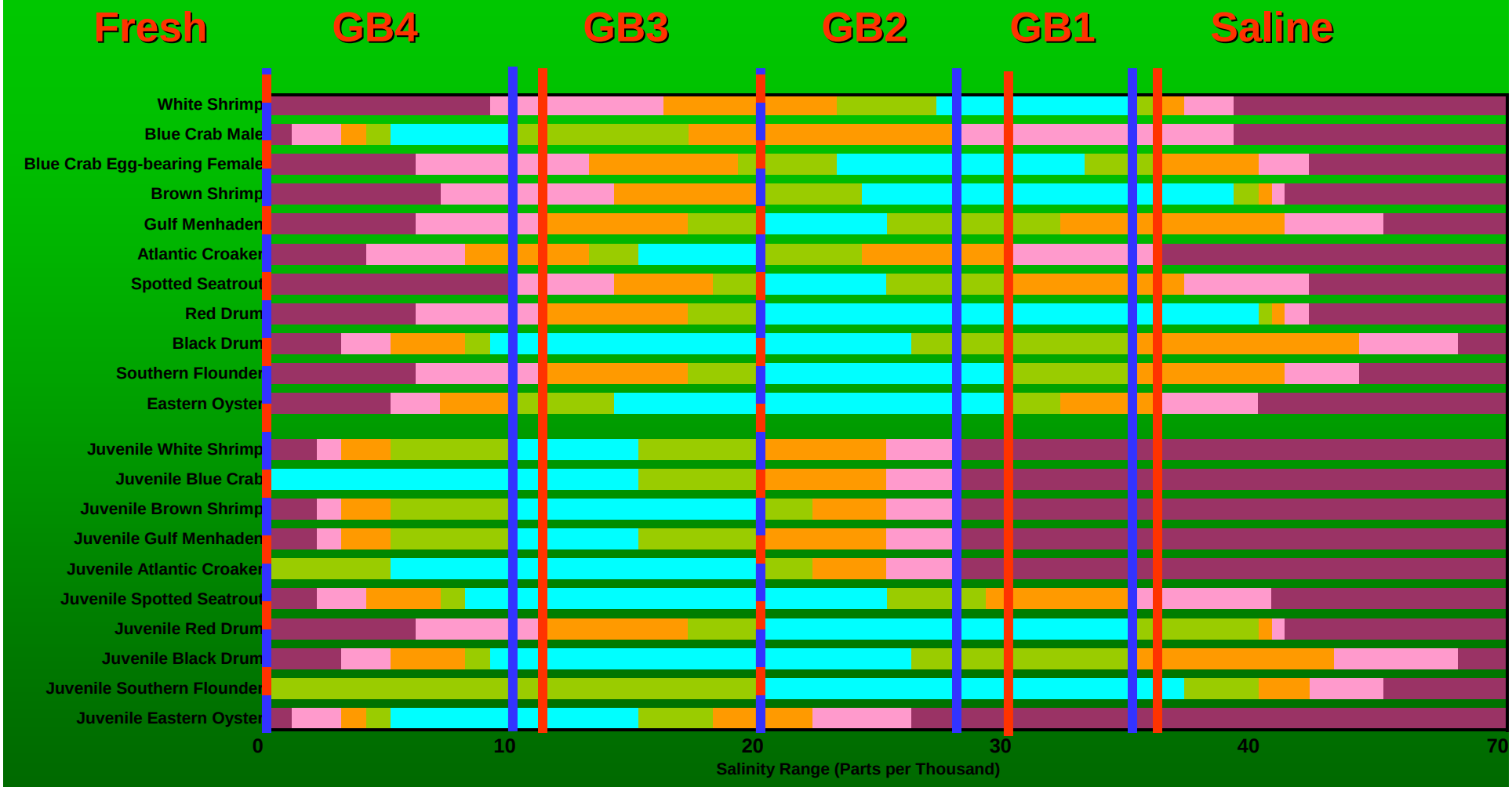
Winter Intervening Ogive – GB2



Winter Intervening Ogive – GB1

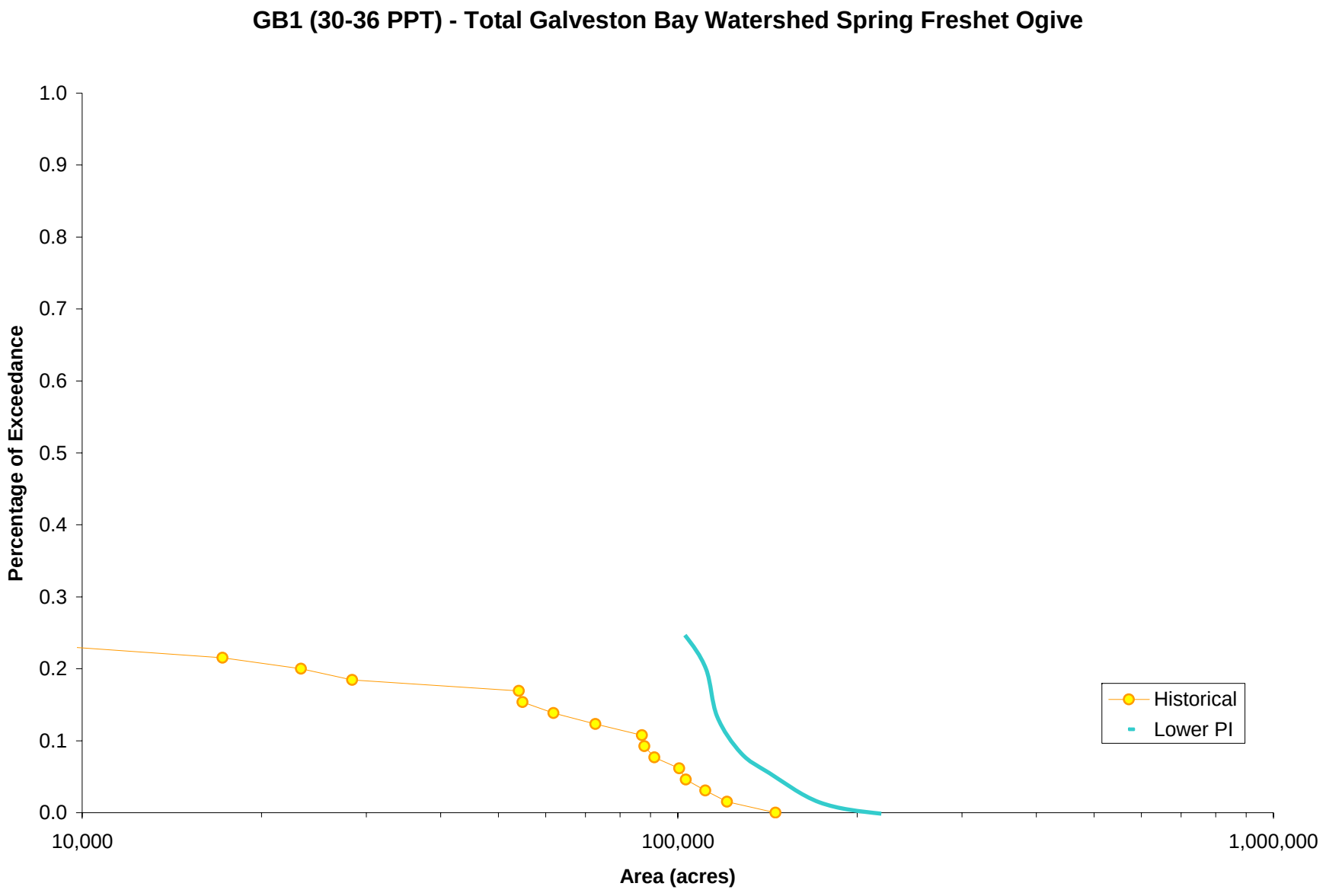


Adult & Juvenile Combined

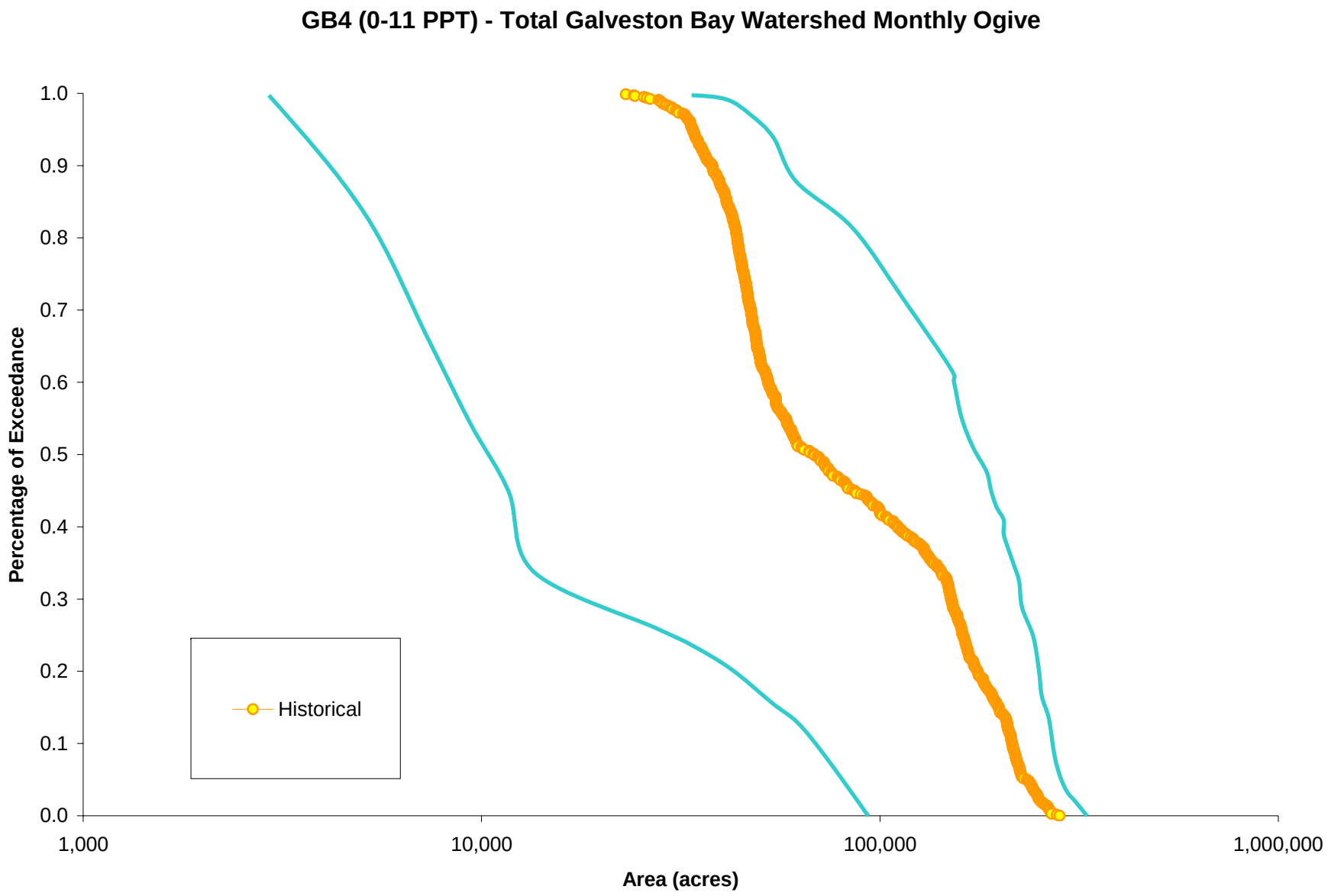


0.9-1.0	0.75-0.9	0.5-0.75	0.25-0.5	<0.25
Best	Good	Fair	Poor	Refuge

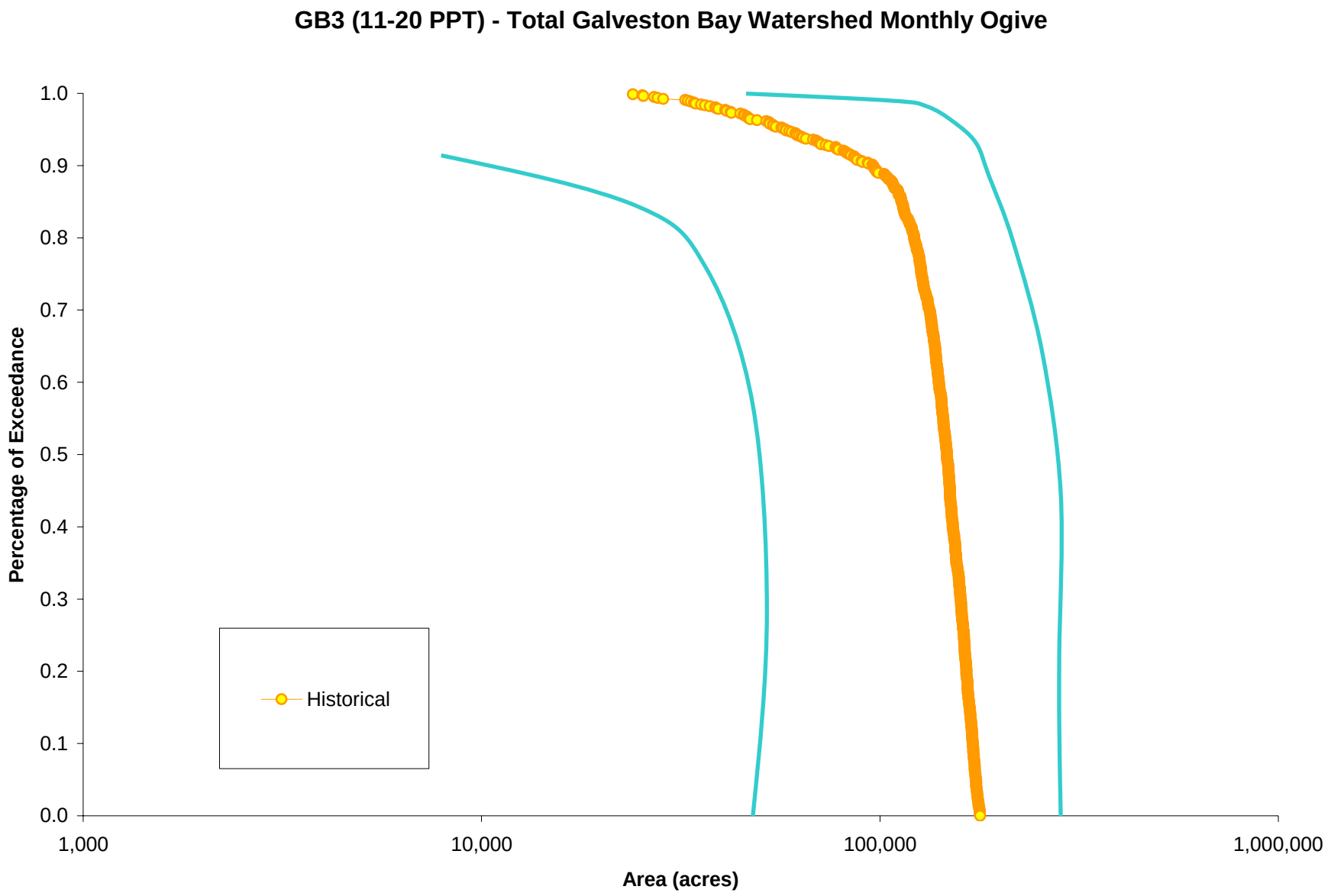
Spring Freshet Ogive – GB1



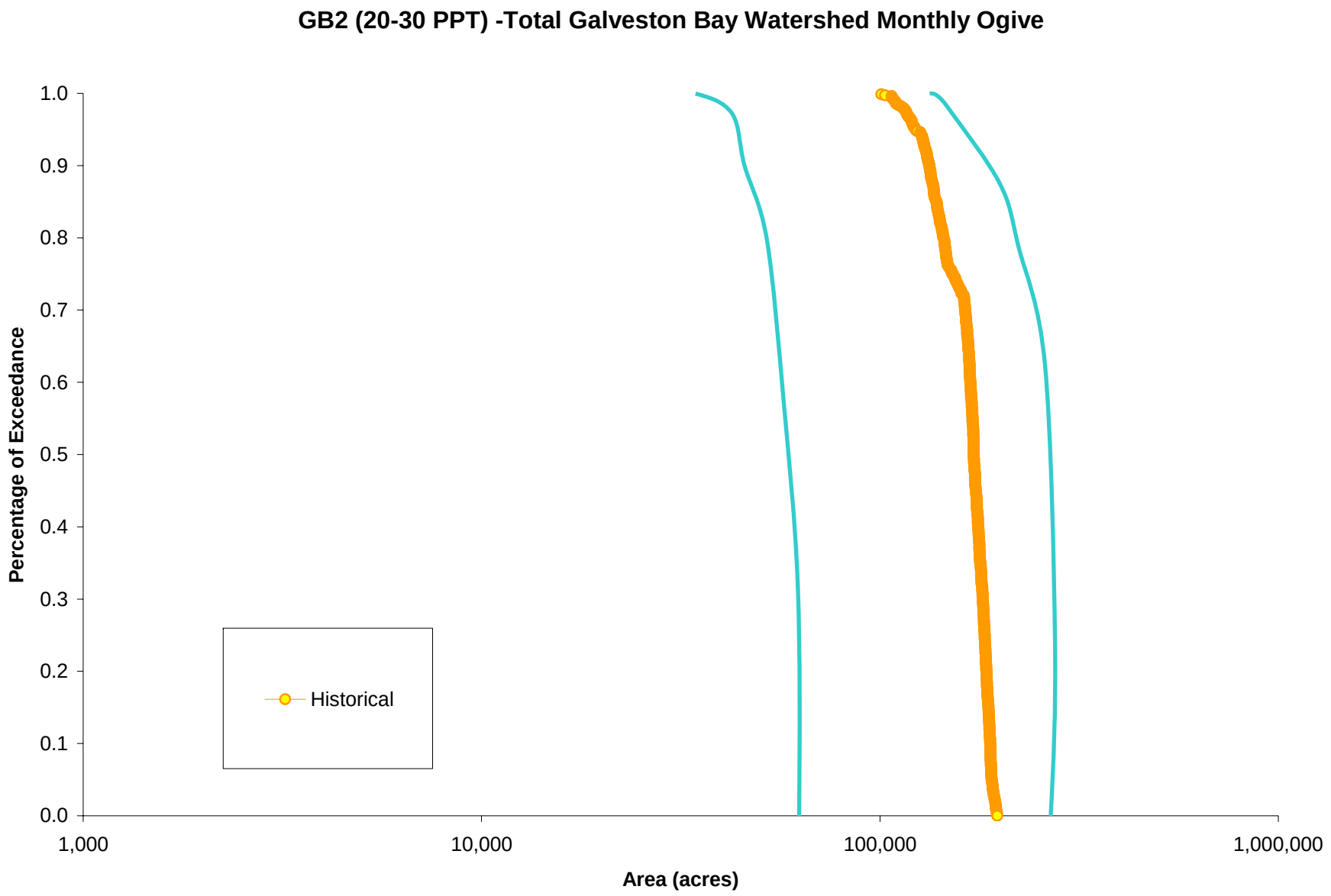
Monthly Ogive – GB4



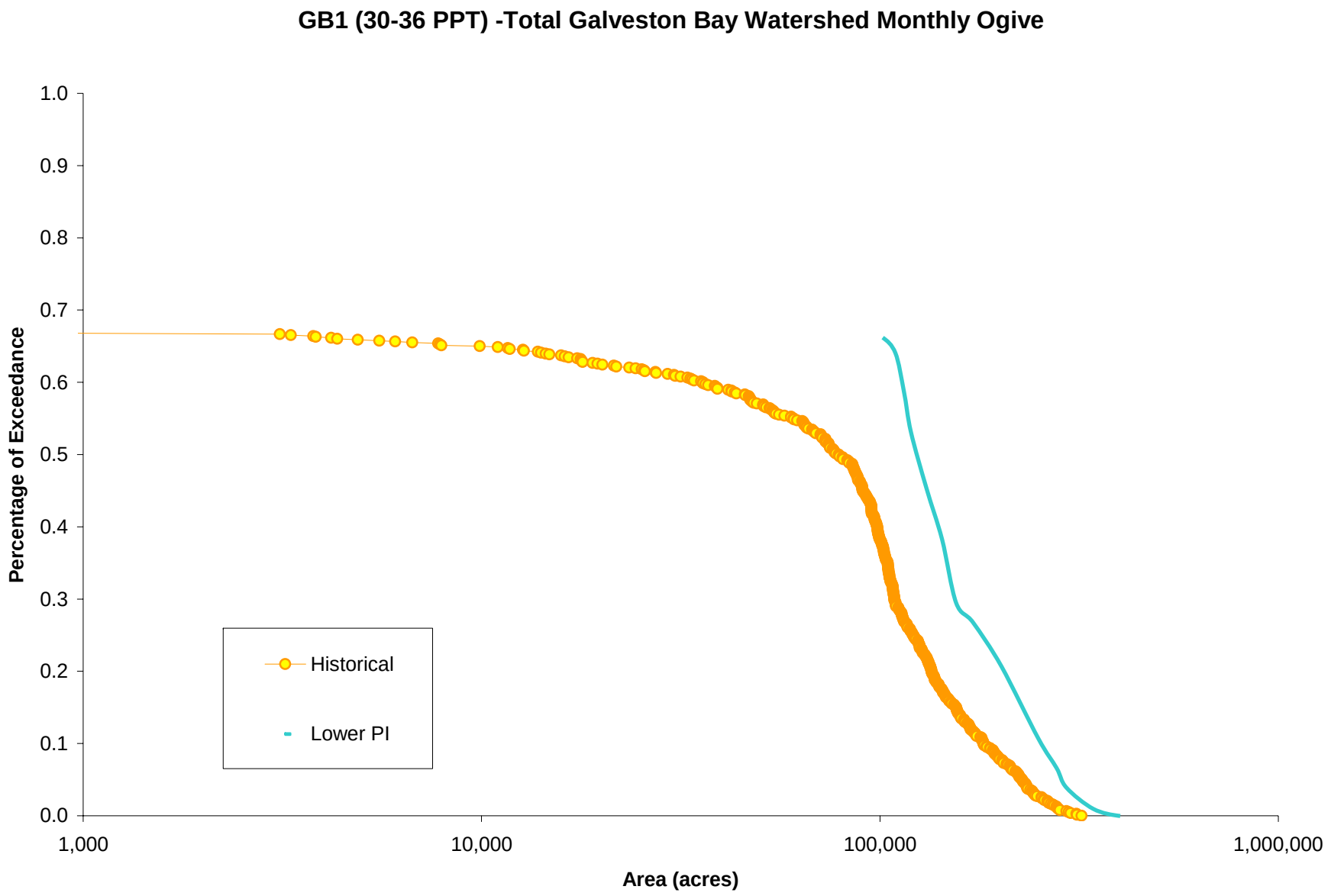
Monthly Ogive – GB3



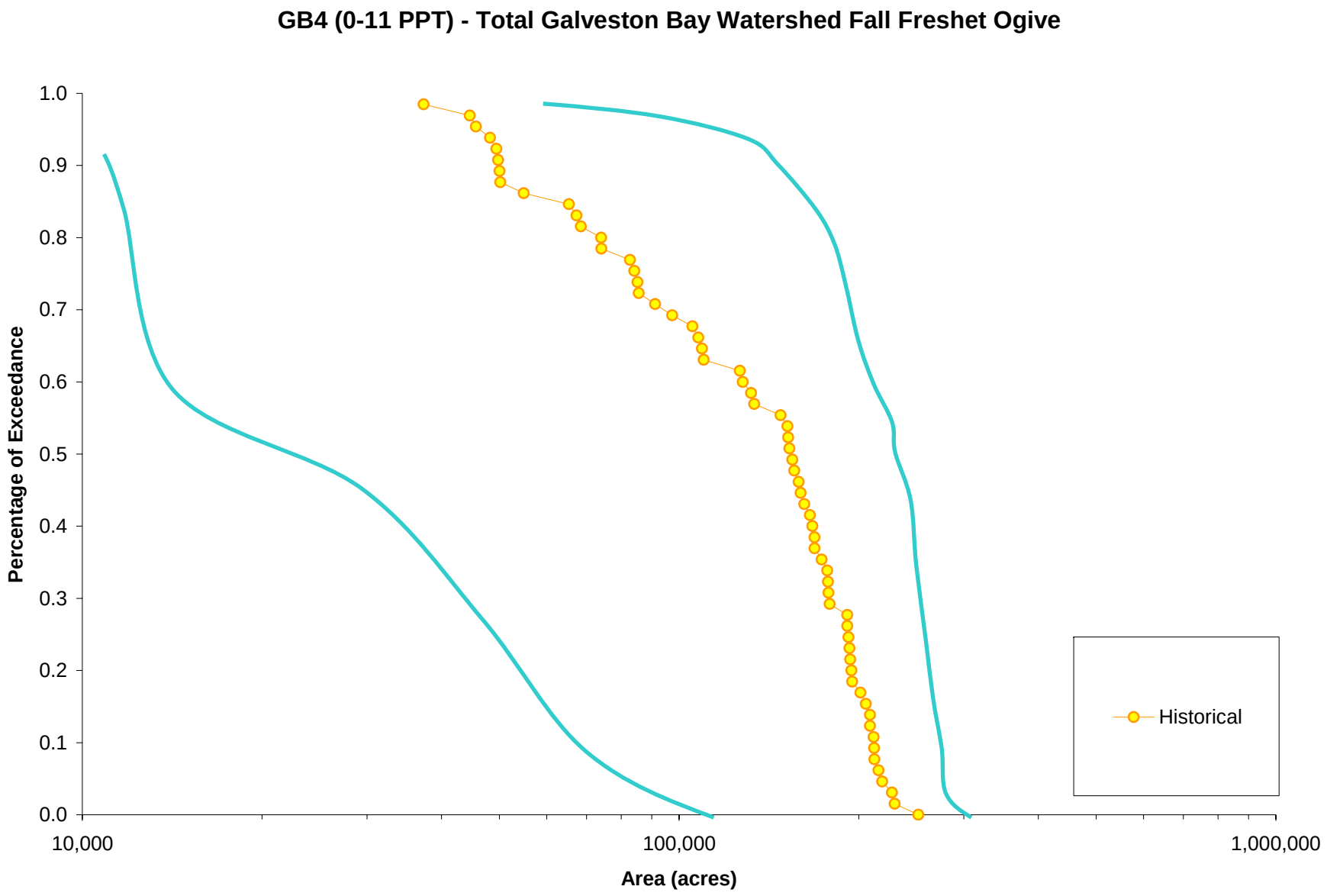
Monthly Ogive – GB2



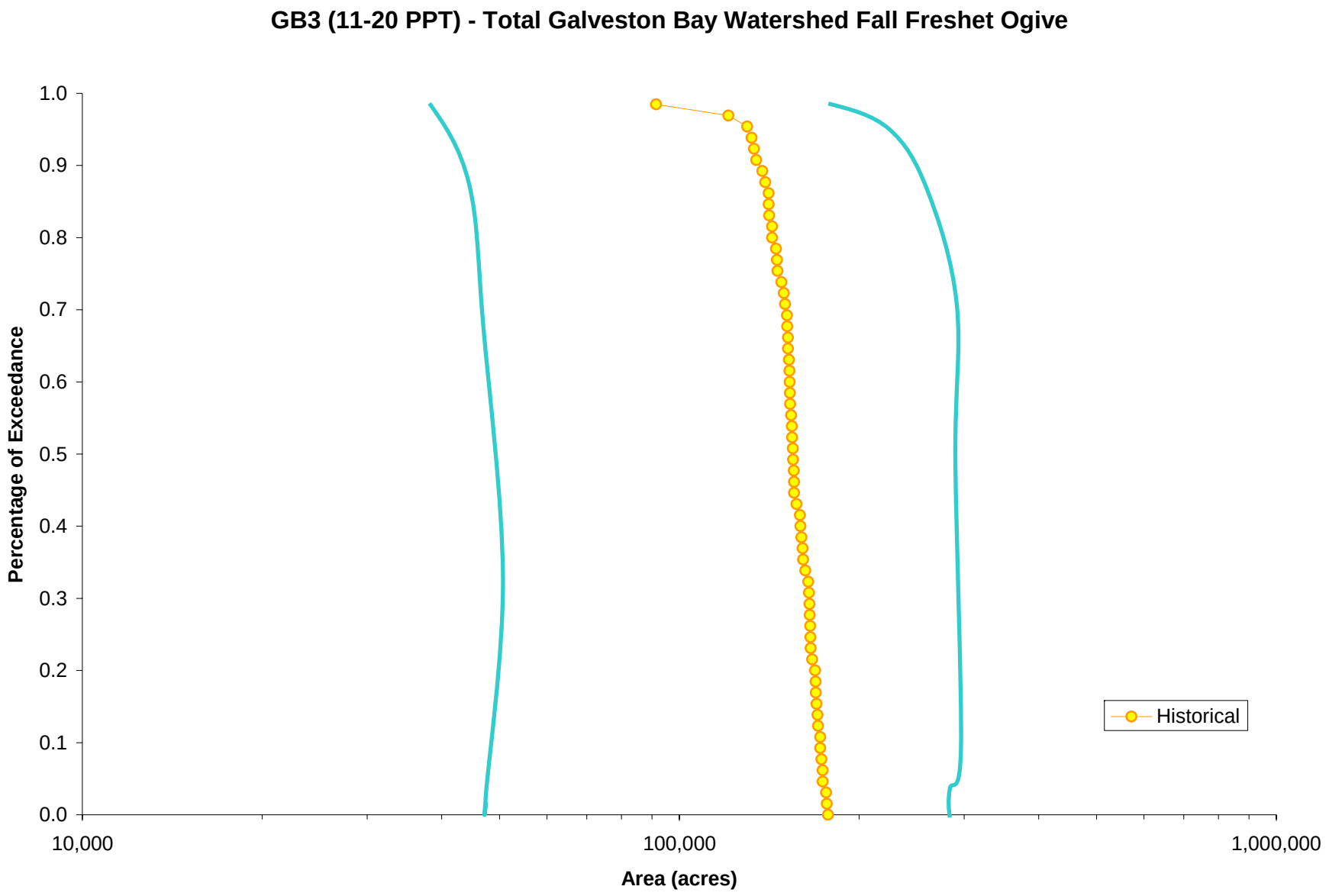
Monthly Ogive – GB1



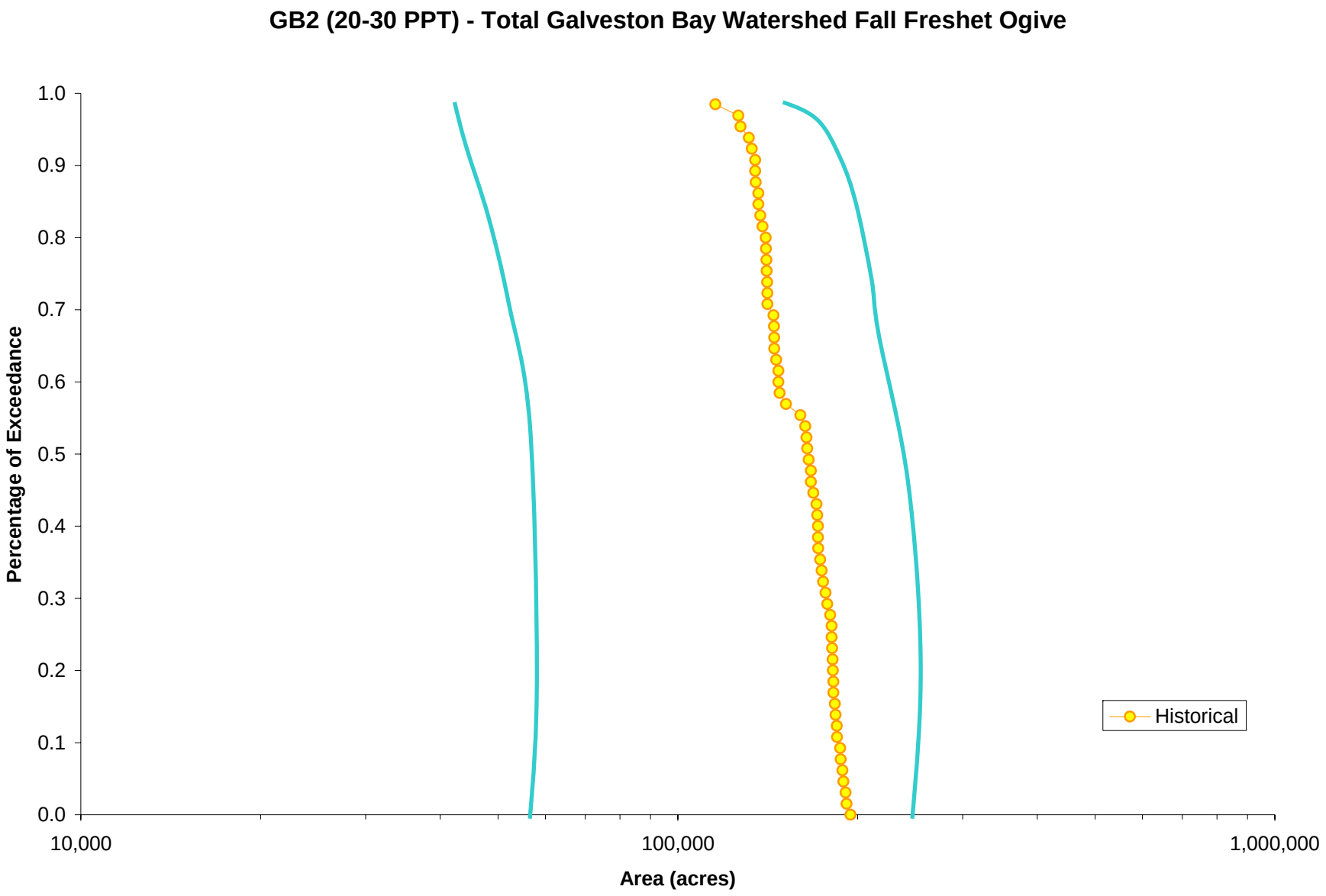
Fall Freshet Ogive – GB4



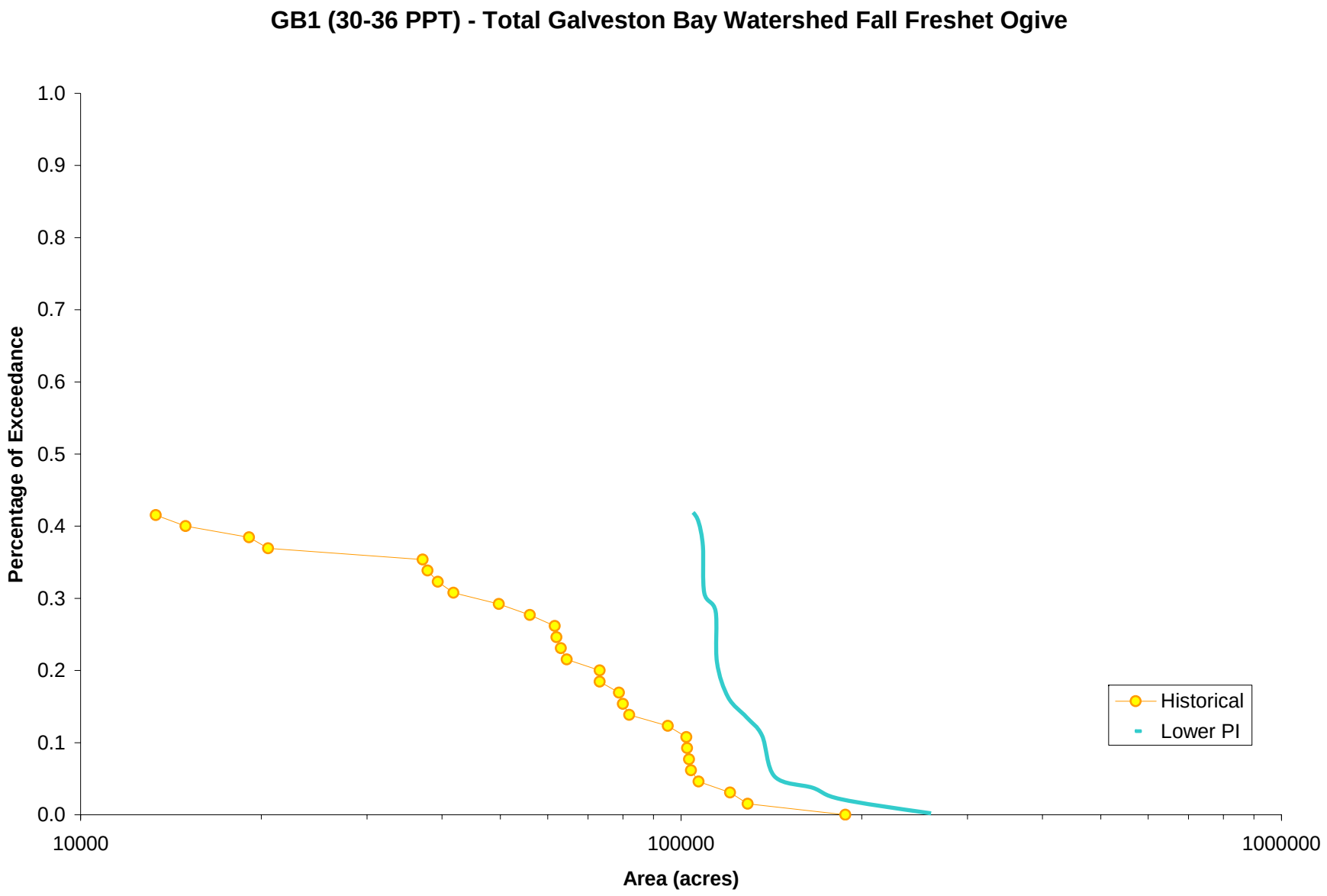
Fall Freshet Ogive – GB3



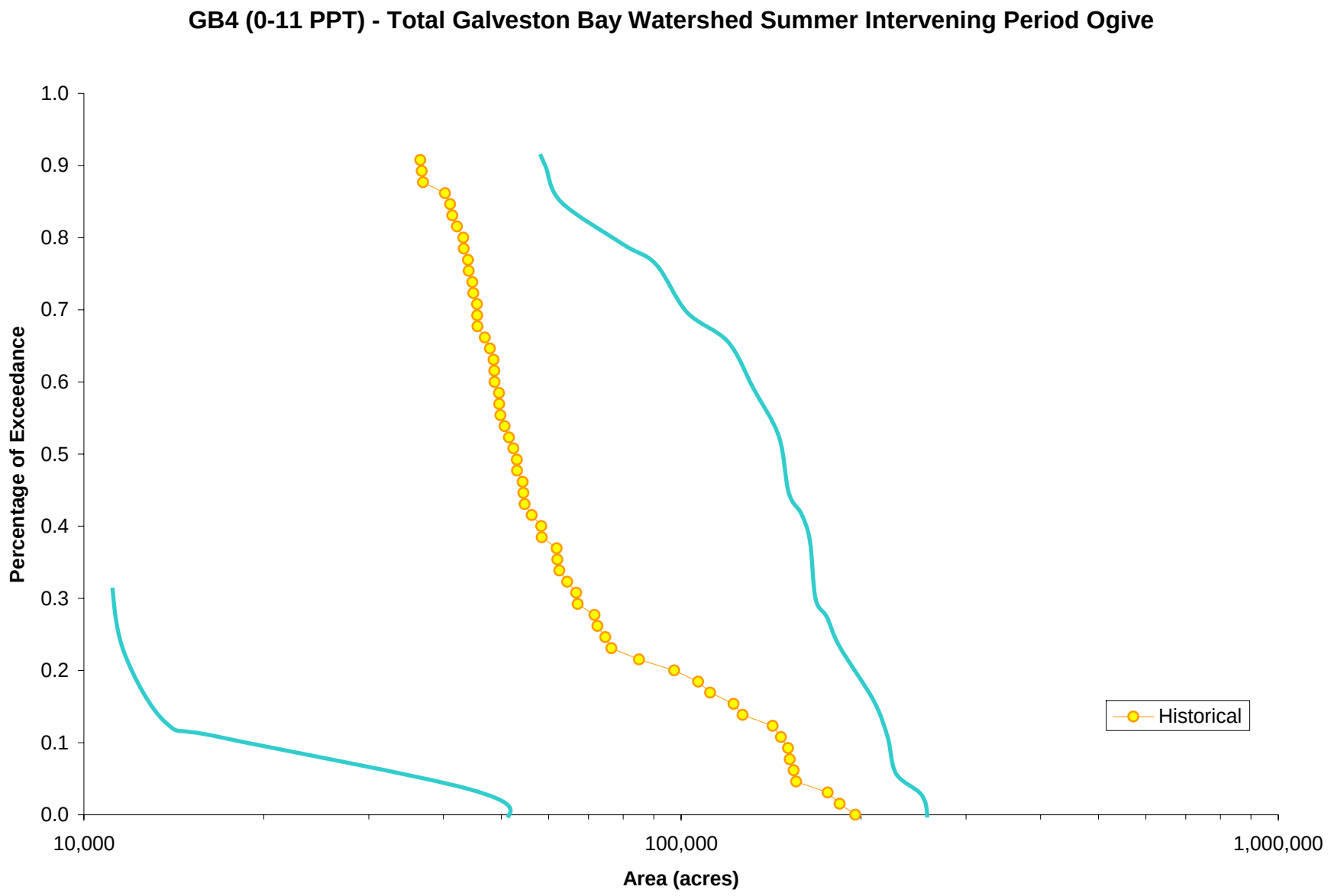
Fall Freshet Ogive – GB2



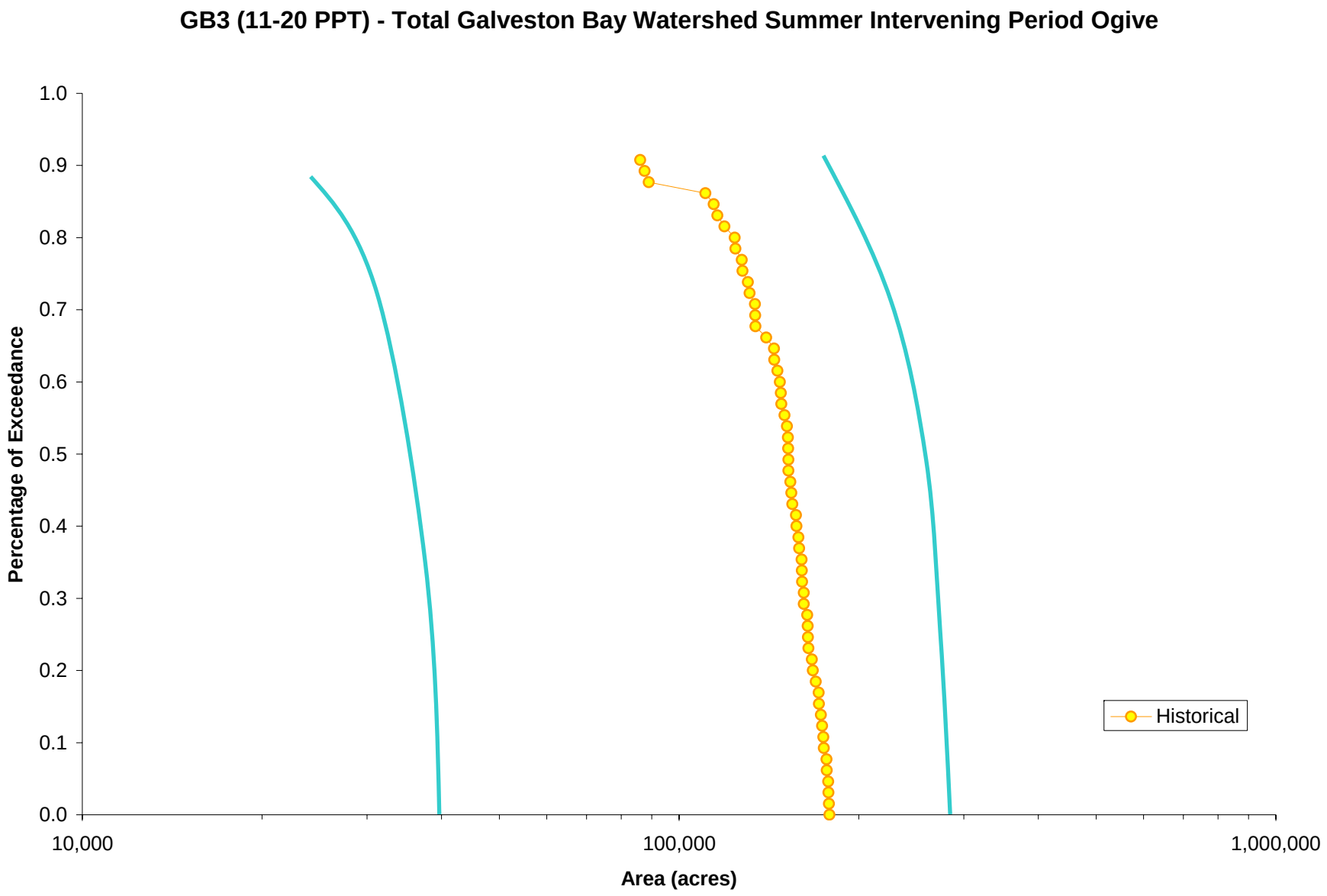
Fall Freshet Ogive – GB1



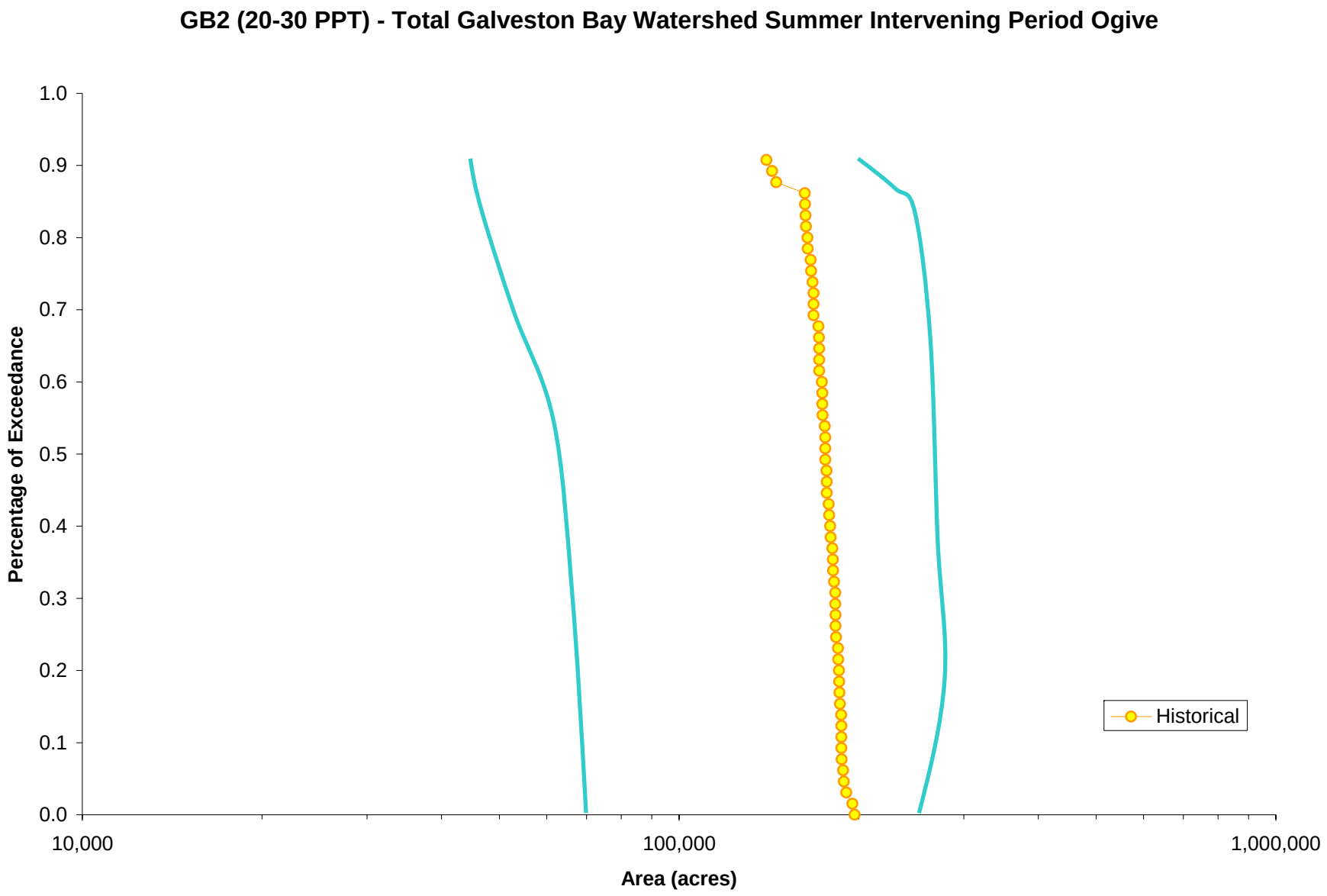
Summer Intervening Ogive – GB4



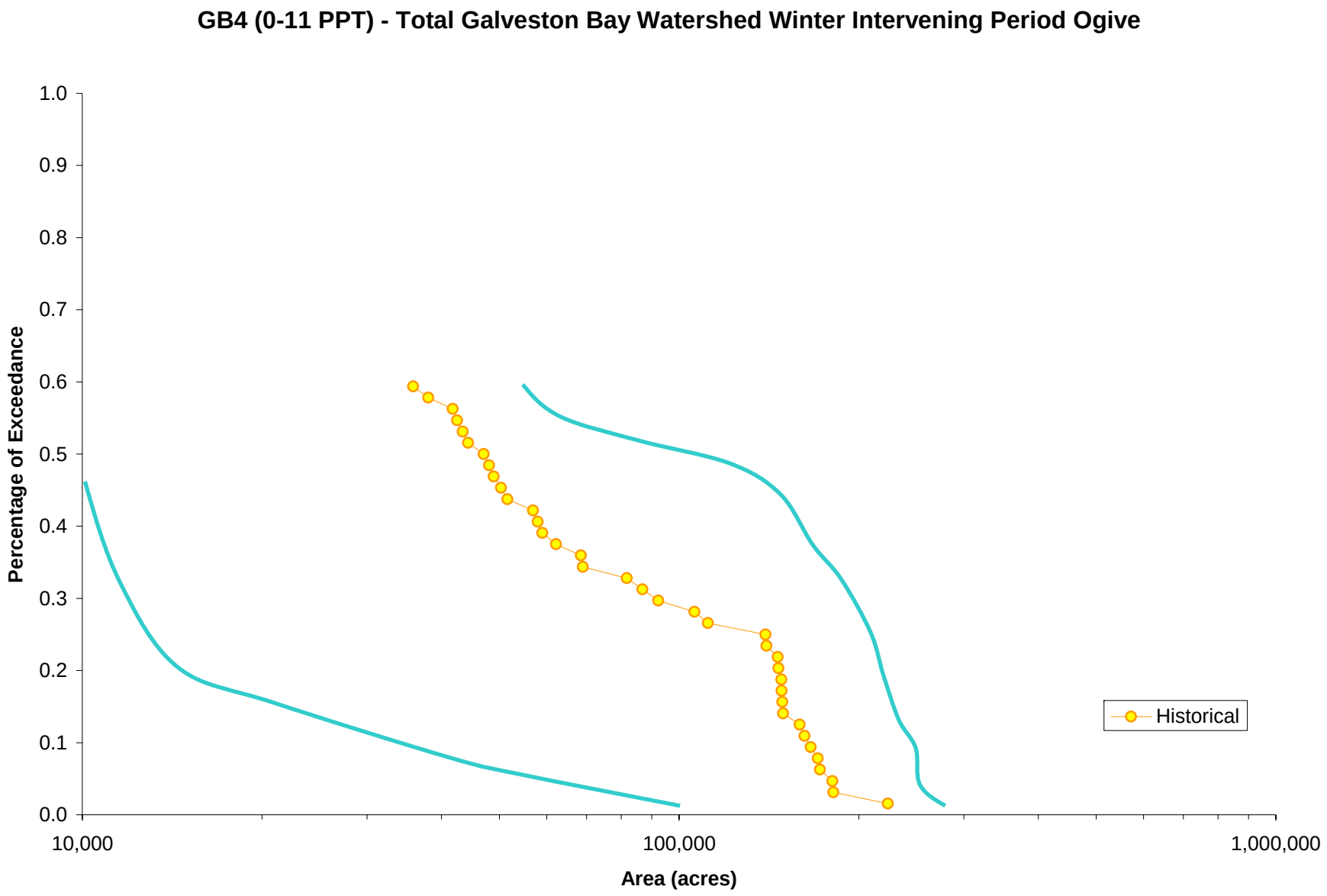
Summer Intervening Ogive – GB3



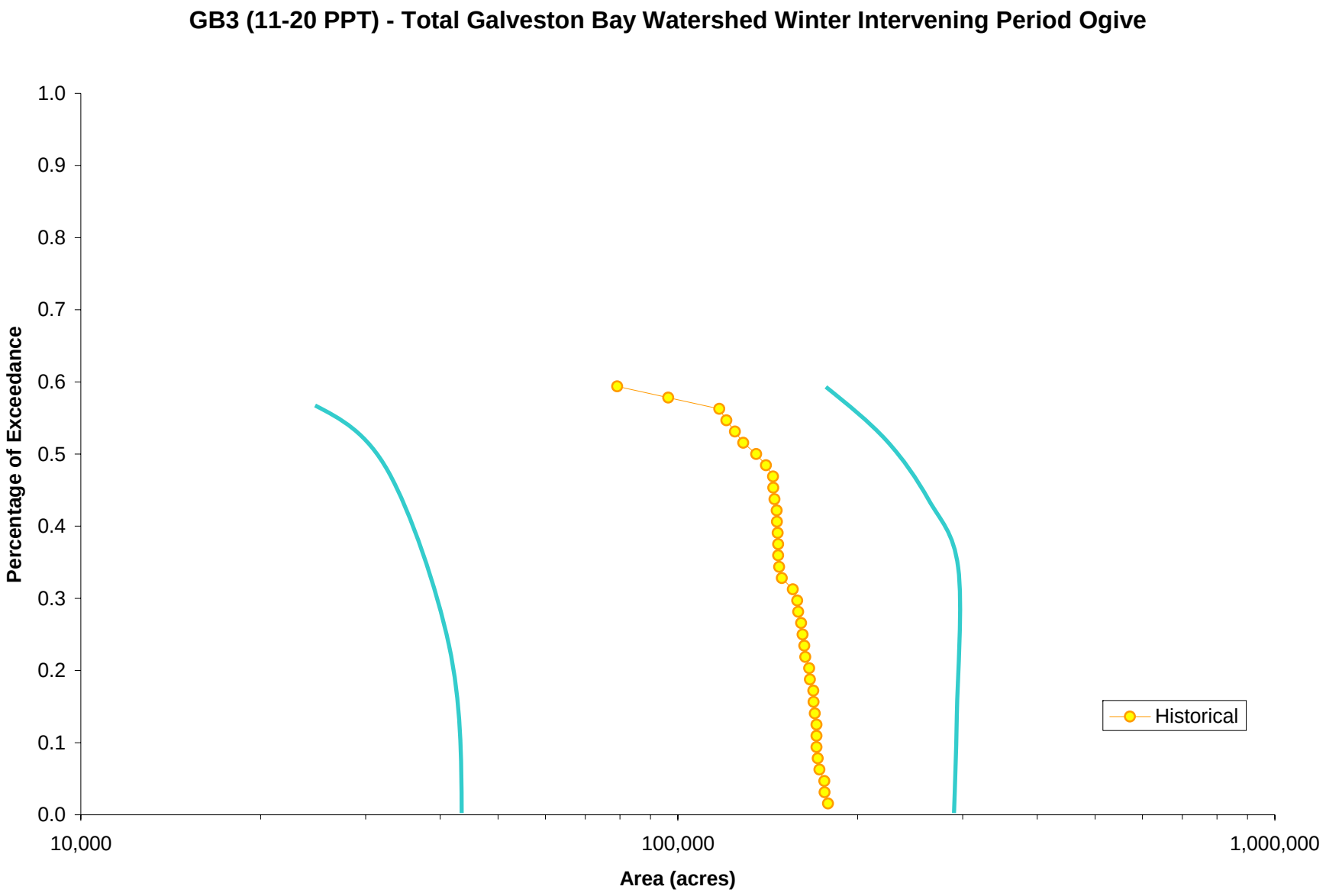
Summer Intervening Ogive – GB2



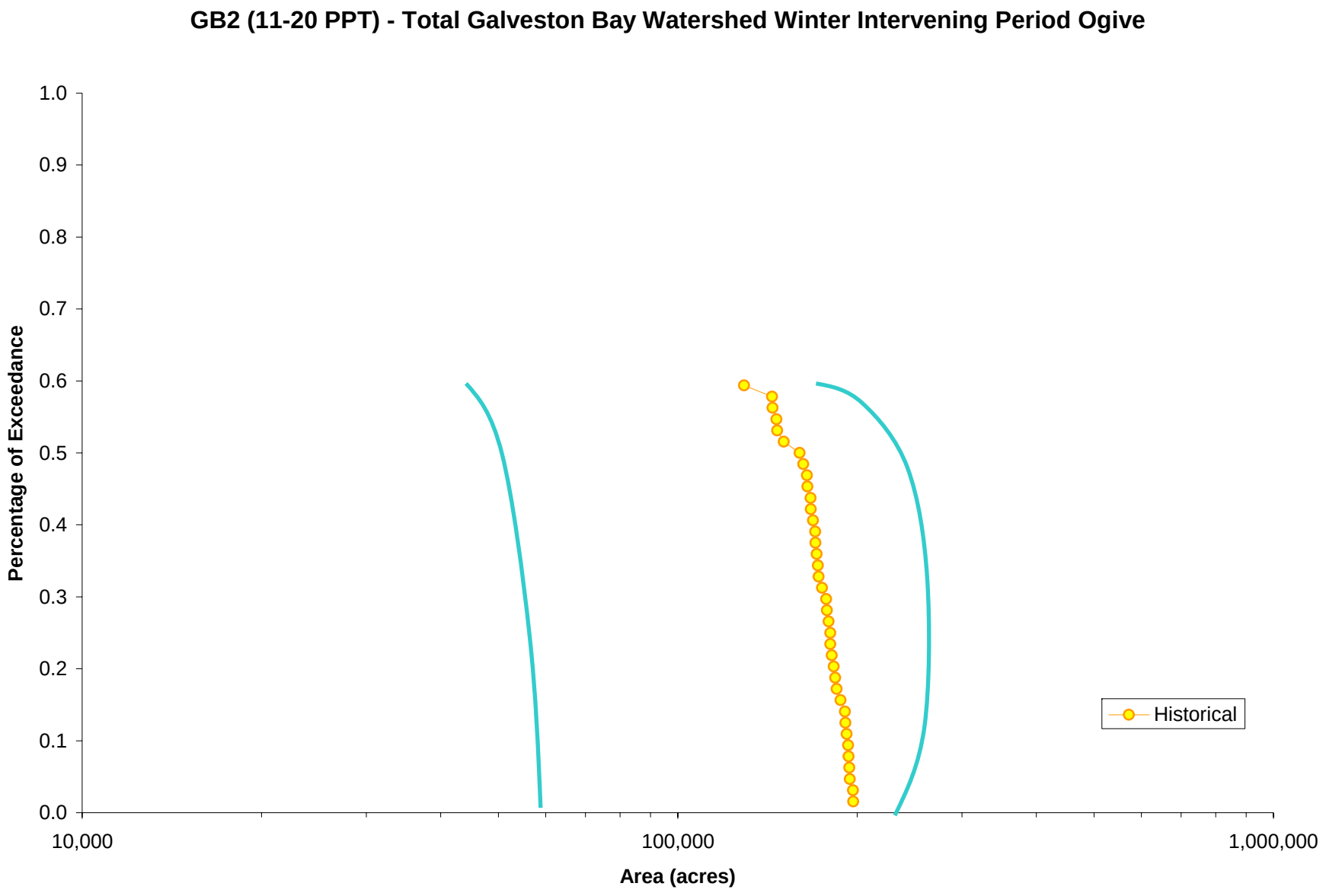
Winter Intervening Ogive – GB4



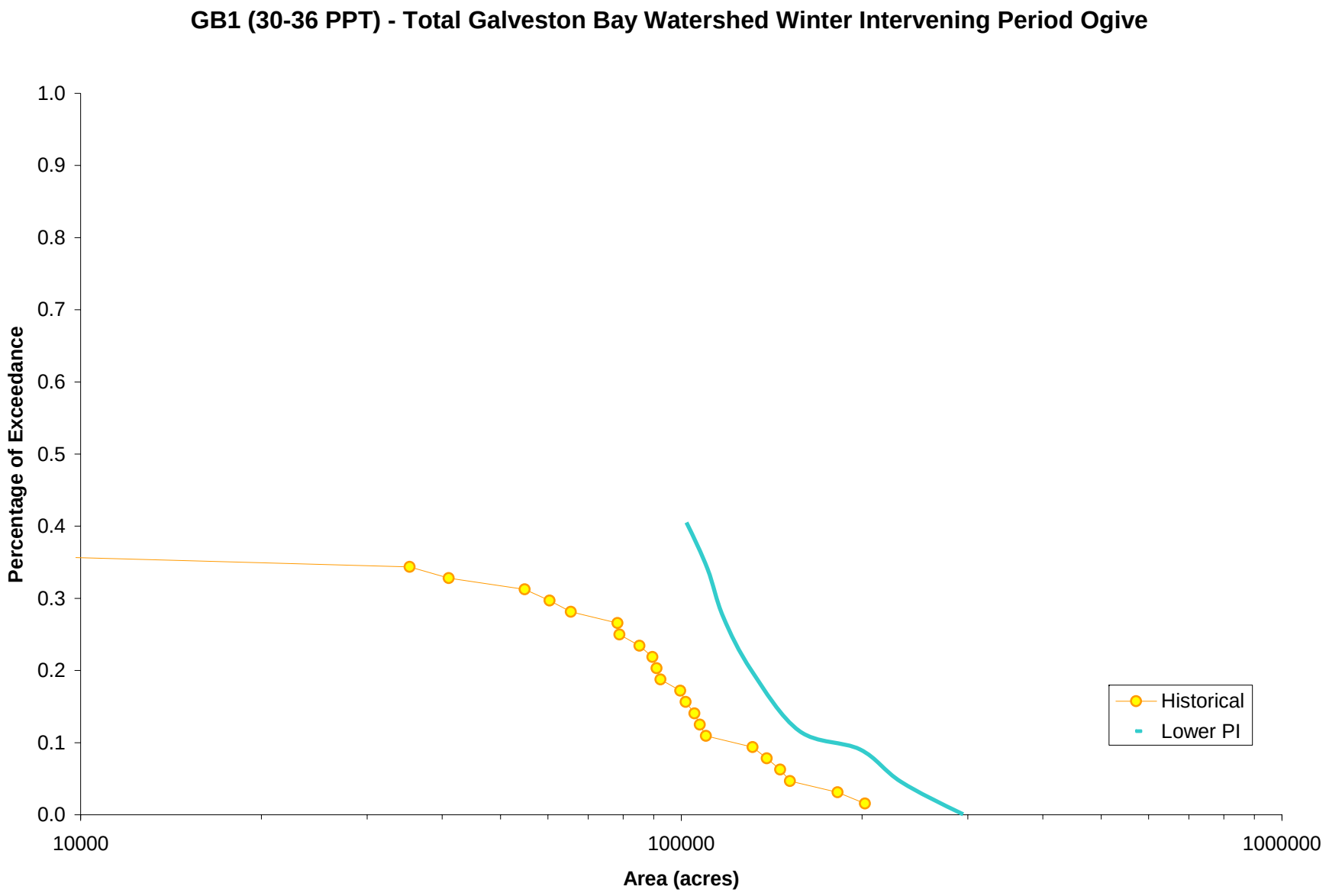
Winter Intervening Ogive – GB3



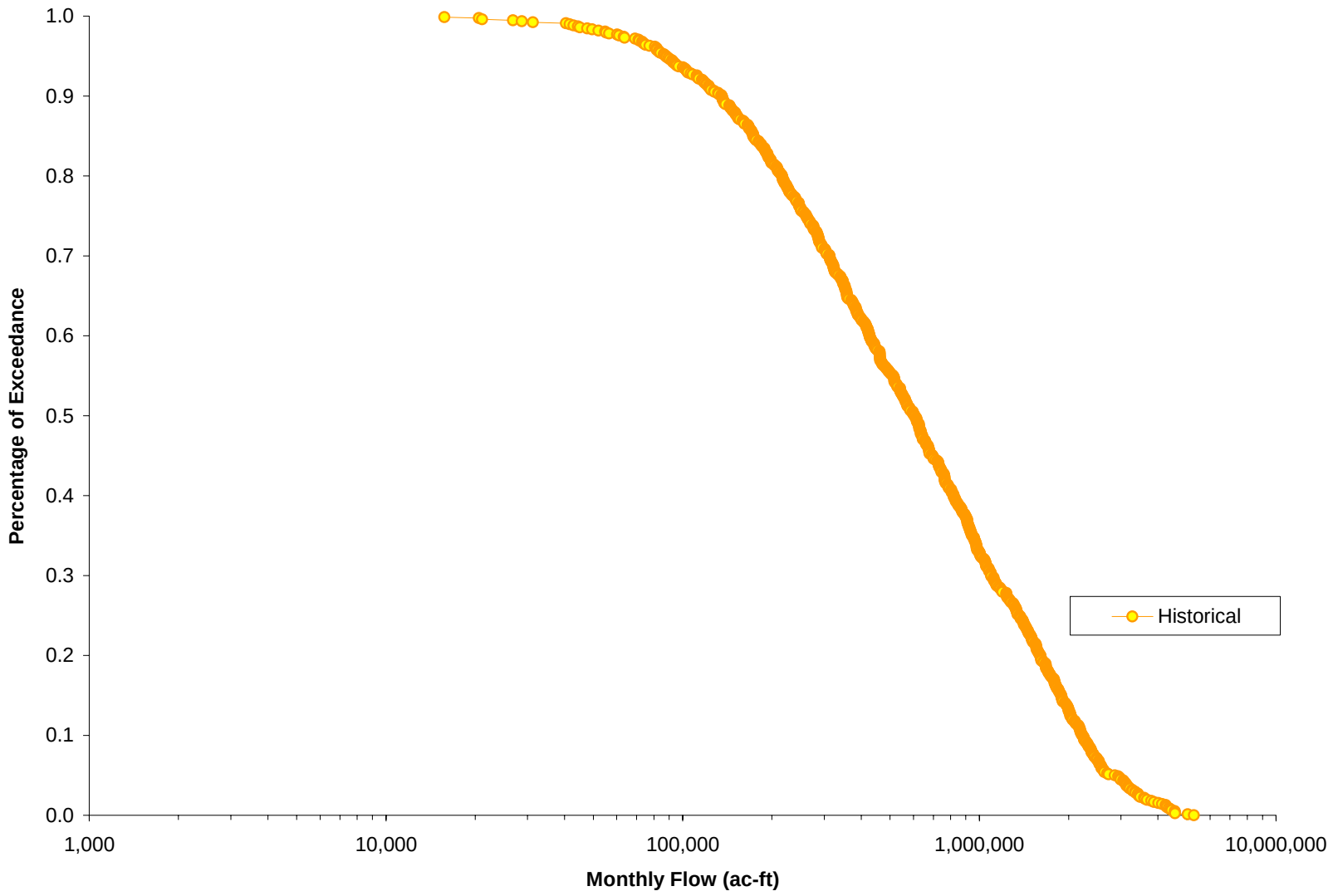
Winter Intervening Ogive – GB2



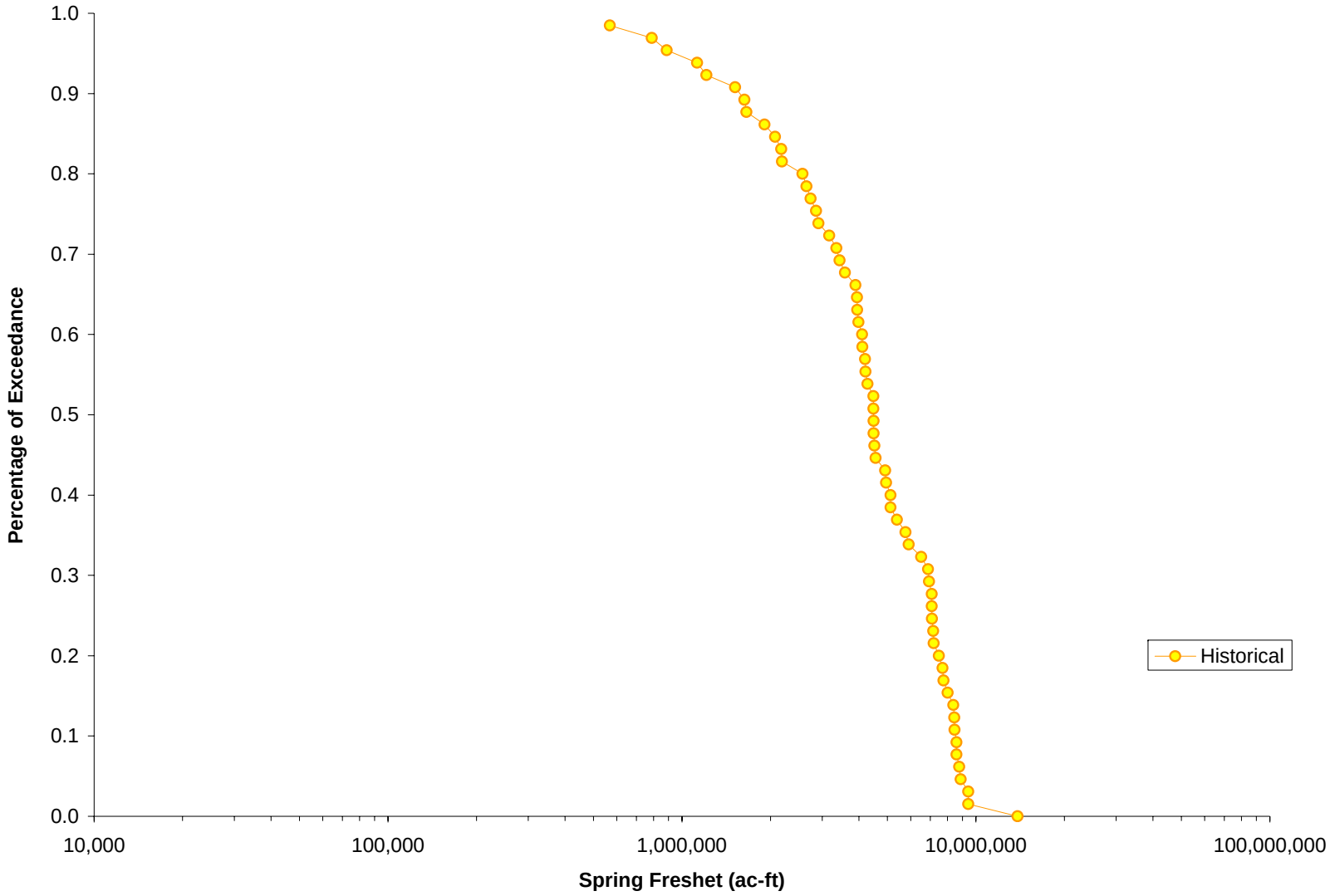
Winter Intervening Ogive – GB1



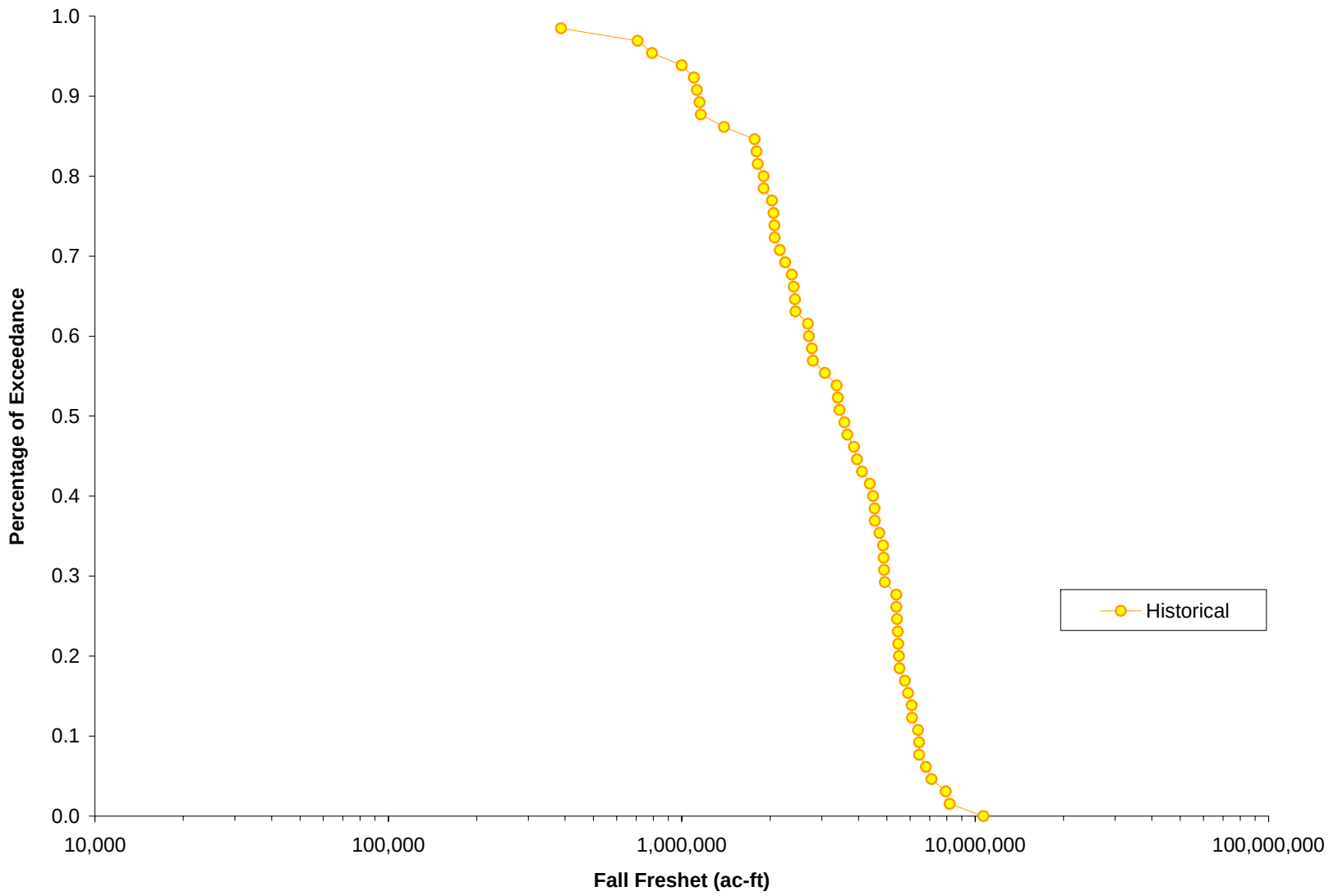
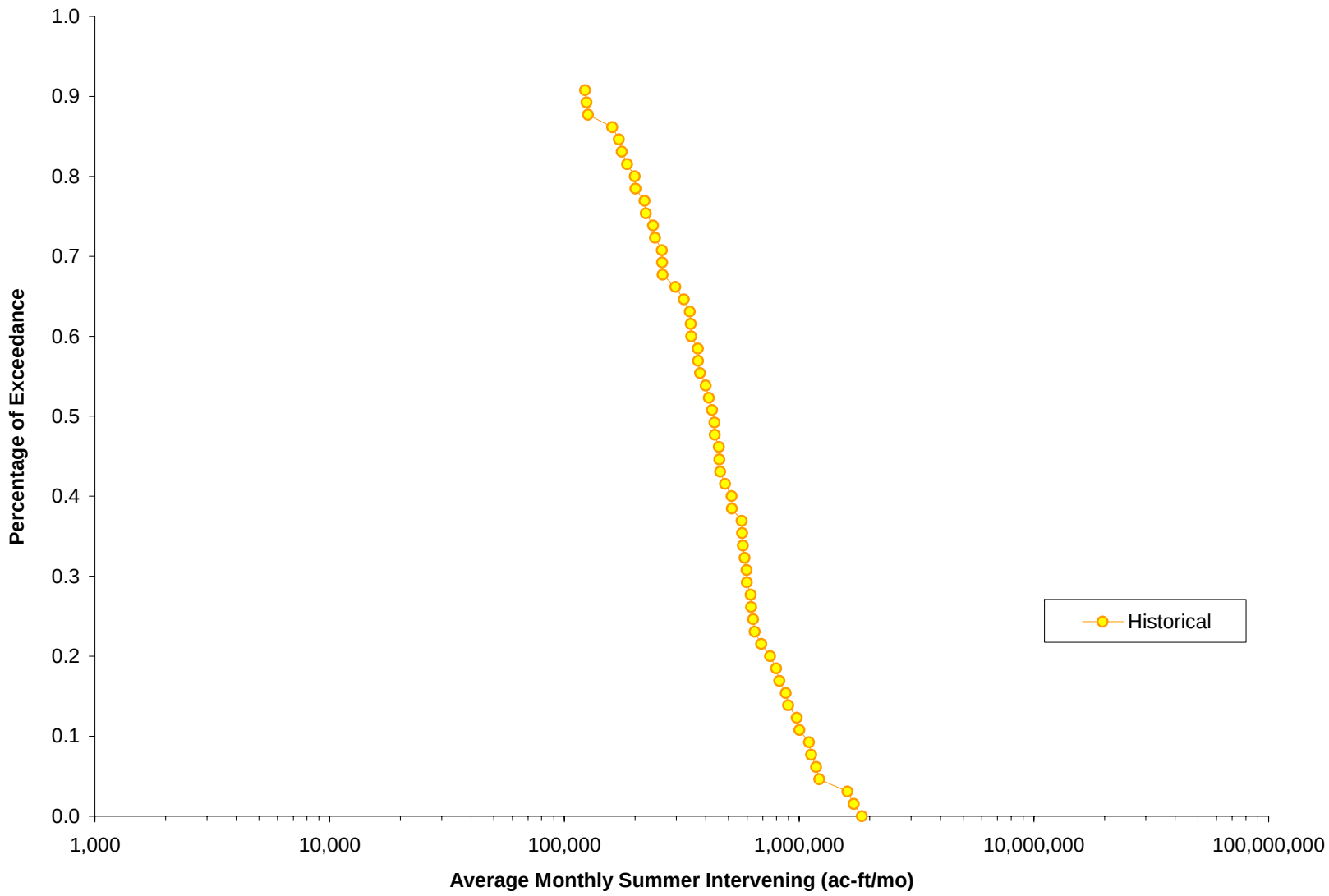
Total Galveston Bay Monthly Flow Ogive



Total Galveston Bay Spring Freshet Ogive



Total Galveston Bay
Fall Freshet Ogive



Total Galveston Bay Summer Intervening Ogive