Salinity

Salinity Characterization of Galveston Bay

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The National Ocean Service is completing a comprehensive review of salinity and its hydrographic and meteorological controls in the eight estuarine systems of Texas, as an extension of the National Estuarine Inventory (NEI) (NOAA, 1985). This review is presented in a report (Orlando, *et al.*, 1991) that seeks a much more detailed depiction of salinity than that of the NEI. Two aspects of salinity are emphasized: first, the spatial *structure* of salinity, including its horizontal and vertical gradients, and the salinity characteristics of principal subsystems of each estuary; second, the *stability* of salinity, referring to the time variation of salinity on various scales. While the approach is descriptive, the philosophy is process-based, i.e., the basic physical controls affecting salinity are given explicit study. The approach used in this study will serve as a paradigm for analysis of the same 102 major U.S. estuaries considered in the NEI; therefore, a considerable effort was invested in establishing objective procedures of analysis.

The basic postulate of the analytical methodology is that estuarine hydrology is the prime control on salinity, and therefore canonical salinity regimes can be defined by examining the time-space variation of hydrology. Additional characteristics of salinity may be governed by other physical processes, which are quantified on an estuary-specific basis. Even in systems in which this postulate proves false, and there are some such systems in Texas, it provides the motivation for an objective procedural framework.

The first step in the analytical methodology is to delineate the normal range of variation in salinity, by identifying representative periods of high and low salinity. The term *representative period* is applied specifically to a period of three-month duration to focus on seasonal time scales. Generally, these periods will correspond to the low and high-inflow periods.

The next step is acquire and analyze salinity field data during these representative periods under the "usual" levels of inflow. This was approached by a two-tier statistical analysis of river inflow: (1) the long-term average inflow for the representative period; and (2) the period-of-record frequency of occurrence for various averaging windows ("durations") from 1 to 30 days. Candidate periods were required to be comparable in that (1) the period-mean flow agrees with the long-term average; and (2) the n-day average, for n from one to 30, agrees with the two-year return event at that duration. The field data were then plotted and mapped.

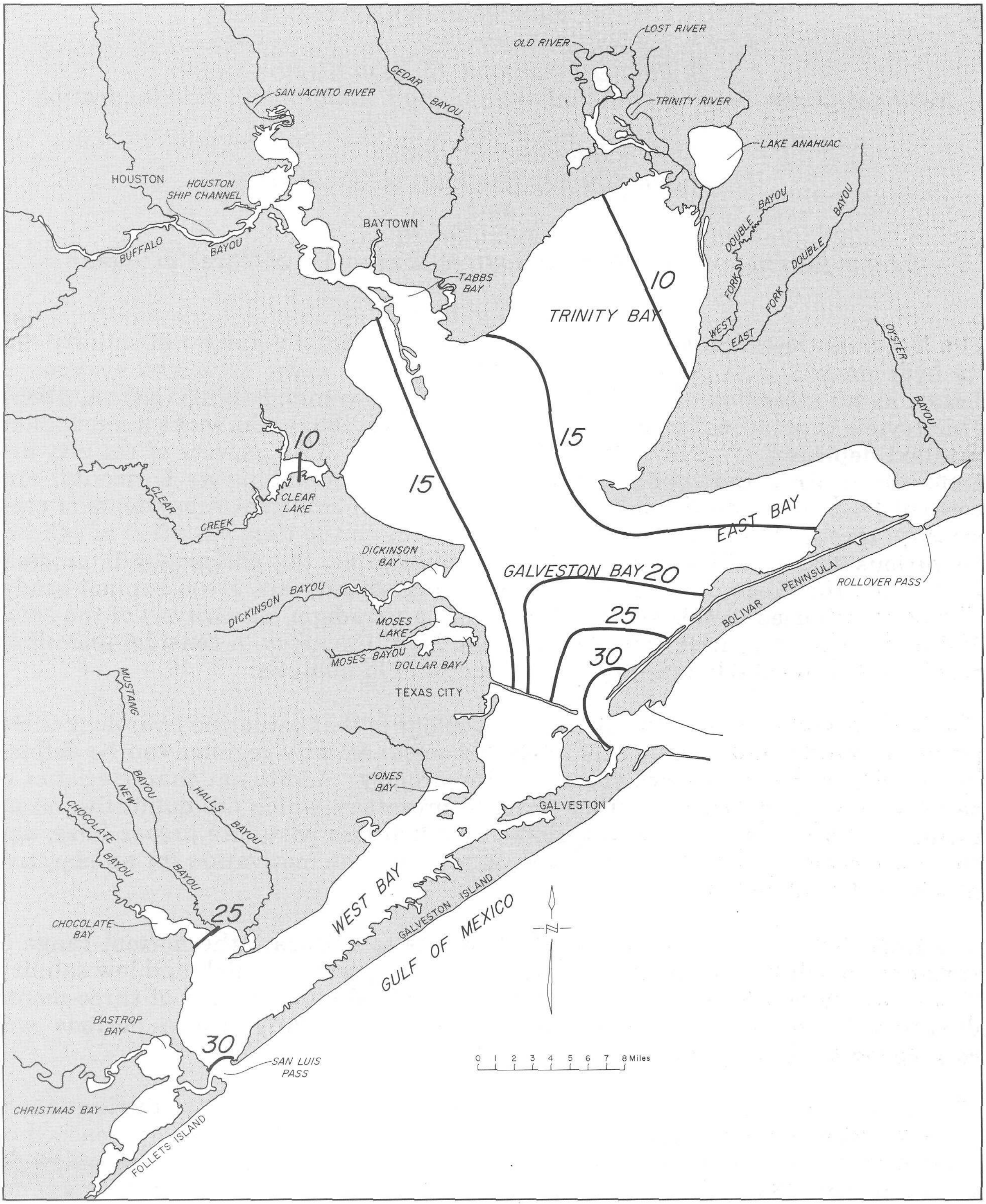

Figure 1. Surface salinity for a selected high salinity condition in Galveston Bay, August-October, 1986.

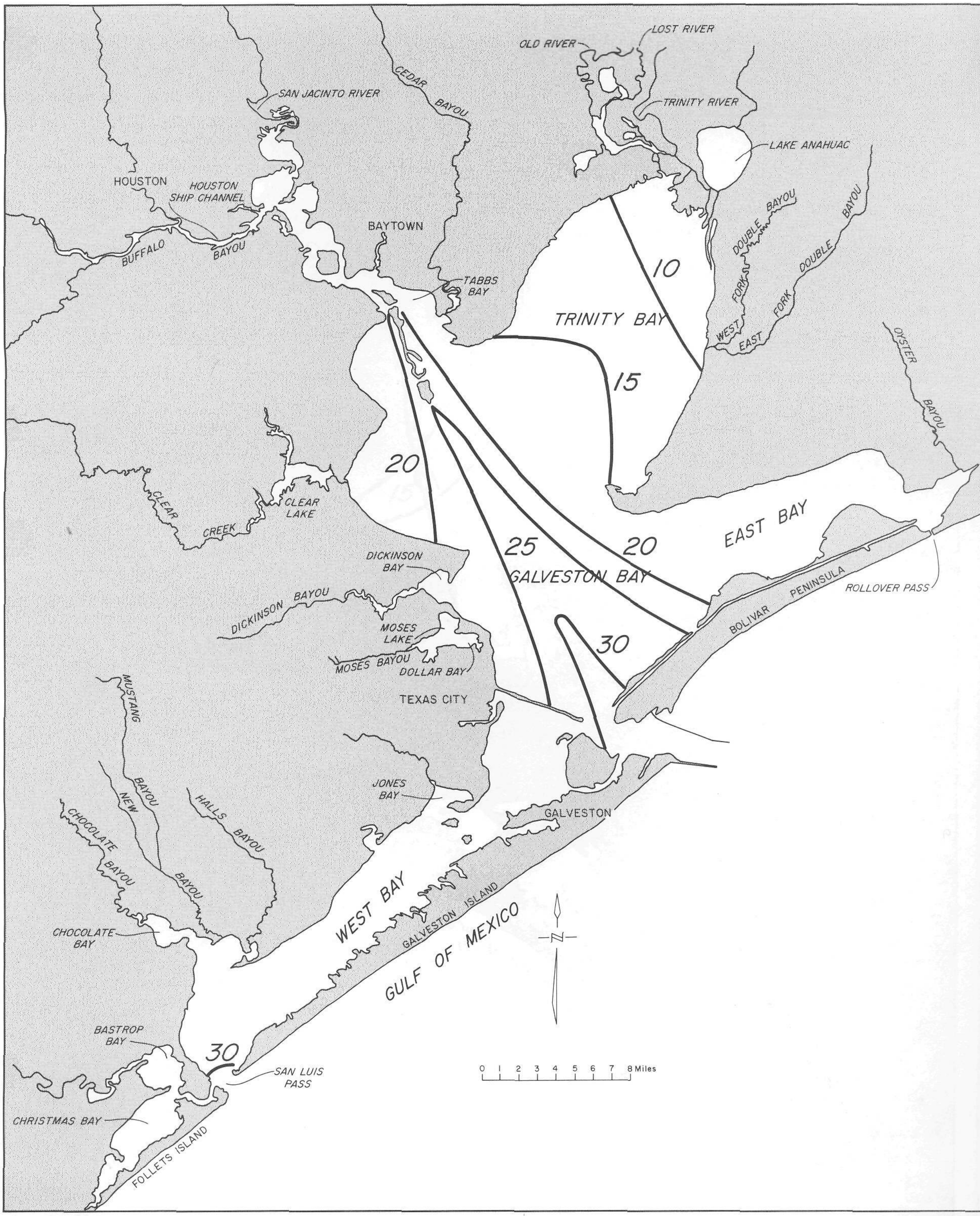

Figure 2. Bottom salinity for a selected high salinity condition in Galveston Bay, August-October, 1986.

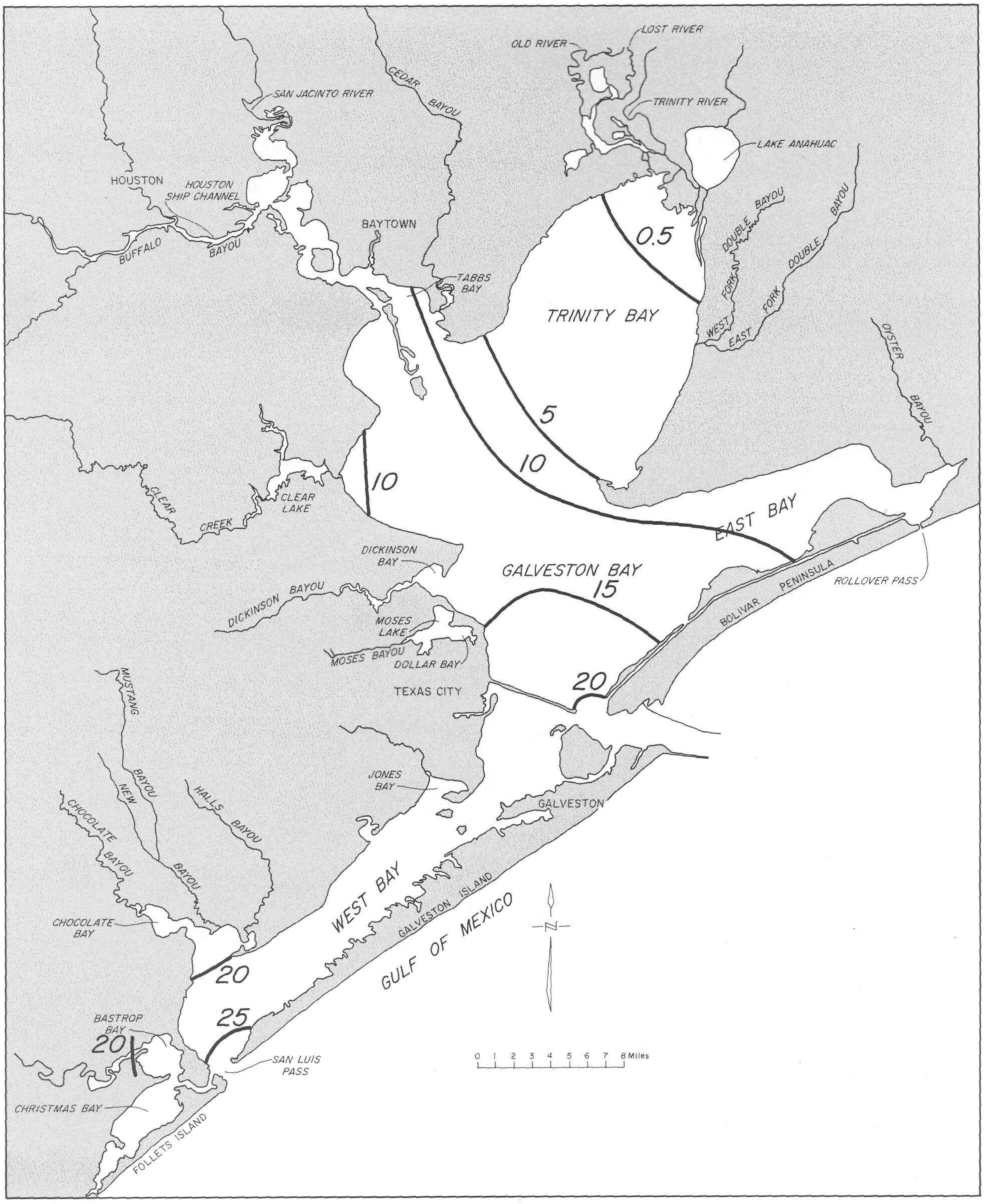

Figure 3. Surface salinity for a selected low salinity condition in Galveston Bay, April-June, 1985.

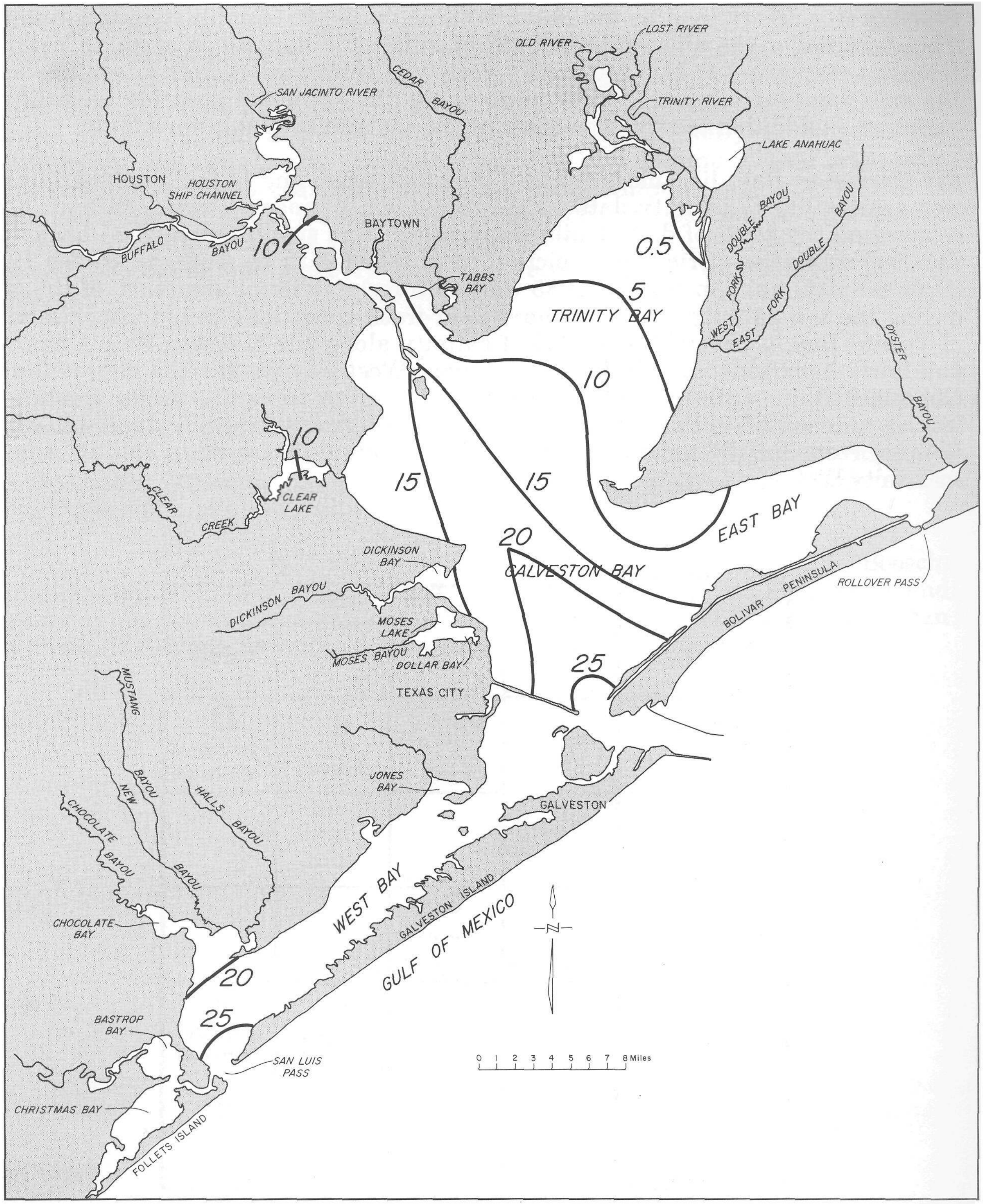

Figure 4. Bottom salinity for a selected low salinity condition in Galveston Bay, April-June, 1985.

Stability was determined by the observed time variation of salinity in the system. This required a set of historical data of sufficient density in time to exhibit temporal response. It also required a review of information, both literature and the experience of local scientists, concerning the principal controls on salinity variation, in addition to river flow, that might contribute to this variability.

For Galveston Bay, like most of the Texas estuaries, one of the limiting factors was availability of salinity data. Less-than-ideal periods of depiction had to be selected on the basis of data availability rather than strict hydrological behavior. The representative periods of depiction were selected to be August-October 1986 (high salinity) and April-June 1985 (low salinity). General structure of the bay during the low salinity period displays near-fresh conditions in the upper section of Trinity Bay, a prominent tongue of salinity along the Houston Ship Channel, and fairly homogeneous salinities throughout West Bay, with some depression in Chocolate Bay. Inflows during this period decline from the major freshet in March, antecedent to the period of depiction, with surges in early April and May. Salinity response throughout is a generally monotonic increase in salinity except in Trinity Bay.

	TIME SCALE			
MECHANISM	Hours	Days	Weeks	Months to seasons
Freshwater inflow			M (freshet)	D (seasonal discharge)
Tides				
Wind		S (frontal passages)		
Other: Channels			M (density currents)	S (density currents)
Shelf river plumes				S

D: Dominant factor accounting for the preatest range in salinity variability
S: Secondary factor having an influence on salinity variability
M: Minor factor having a detectable influence on salinity variability

Figure 3. Salinity response matrix and those associations considered to characterize Galveston Bay

Based upon the specific analyses of the periods of depiction, as well as the cumulative information from literature review and the analysis of other periods of data, a general characterization was formulated and displayed as a response matrix (Fig. 3). This indicates the most important time scales of variability of salinity in the system and the forcing mechanism(s) chiefly responsible for variations on this time scale. In Galveston Bay, the dominant time scale over which salinity varies is seasonal. However, this dominant seasonal pattern is further modified by small freshets, wind (especially in association with frontal passages), the salinity in the Gulf of Mexico as influenced by freshwater plumes from the Louisiana and East Texas rivers, and density currents due to ship channels.

Literature Cited

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Orlando, P., J. Klein, S. Holliday, F. Shirzad, D. Bontempo, L. Rozas, D. Boesch, C. Brantley, B. Pollock and G. Ward. 1991. Analysis of salinity structure and stability for Texas estuaries. Strategic Assessment Branch, National Ocean Service, U.S. Dept. Commerce, Rockville, MD. 92 pp.

Paleoecological Evidence of Salinity Changes in Galveston Bay

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Paleoecological and geochemical methods were used to study changes occurring in Galveston Bay over the time period of *circa* 1850 to 1988. The purposes of the study were:

1. To examine changes in foraminiferal species distribution in space and time;

2. To measure changes in geochemical variables within the sediments; and

3. To determine if human actions such as the dredging of the Houston Ship Channel and the impounding of the Trinity River have affected the distribution of the foraminiferal fauna.

Sixteen gravity cores were collected during 1987 and 1988 from the *R V Matagorda*, Rice University. The study area included Trinity Bay and portions of upper and lower Galveston Bay. The cores were initially examined by x-radiography to assure that the samples were relatively undisturbed so that the chronology of various subsampled horizons could be established. ^{210}Pb isotope measurements were performed on six cores and sediment accumulation rates were calculated for four of these cores. An average of ten horizons were subsampled within each of the sixteen cores. These horizons were analyzed for particle size, total organic carbon, various elements, and foraminifera. A suite of elements including Al, Ba, Ca, Cd, Cr, Cu, Fe, Mg, Mn, Na, Ni, Sn, Sr, V, and Zn were analyzed using inductively coupled plasma emission spectroscopy (ICP). Foraminifera were identified to species and data were presented as percent relative abundance (%RA) based on 200 to 300 counts per horizon subsample.

The sediment accumulation rate, as calculated from the ^{210}Pb data, ranged from 0.44 to 1.16 cm/yr in Trinity Bay to 0.29 cm/yr in the center of Galveston Bay. The lower two values compare favorably with previous estimates of the sediment accumulation rate for Galveston Bay (Shephard, 1953; Rehkemper, 1969). Inspection of the geochemical results revealed recurring depth-related trends for barium. Barium increased logarithmically to the surface at collection sites throughout the bay. A regression of year before present (ybp) against Log_{10} of barium showed a constant slope for all three cores measured by ^{210}Pb analysis. Thus, sediment accumulation rate and core chronology could be established for an additional six locations in the bay. These six cores had sediment accumulation rates ranging from 0.16 to 0.79 cm/yr.

Regarding the remainder of the geochemical results, there were two statistically significant trends: 1) there was a high correlation of the metals, including Al, Cr, Cu, Fe, Mg, Na, and V, to percent silt and clay, and 2) there were high inter-correlations between metals, with especially high correlations to Al and Fe. The

Pearson's correlation coefficient exceeded 0.70 for each of the metal-to-particle-size comparisons. Correlation coefficients between metal pairs often exceeded 0.80. Barium was poorly correlated to percent silt and clay and to the above list of metals. Thus, adsorption onto silt and clay particles and co-precipitation of metals with iron and aluminum hydrous oxides are apparently two of the dominant processes controlling the fate of metals in Galveston Bay.

The dominant foraminifera found in Galveston Bay were *Miliammina fusca*, *Ammotium salsum*, *Ammonia parkinsoniana*, and *Elphidium* spp. The species composition of individual subsamples generally fit into one of two biofacies described for Gulf of Mexico estuaries: 1) the *Miliammina-Ammotium* biofacies, which is generally confined to the portion of the estuary that is below a salinity of ten parts per thousand (ppt), and 2) the *Ammonia-Elphidium* biofacies, which is dominant in the middle and lower estuaries where salinity is above 15 ppt. Examination of the cores for which the chronology of the subsamples was calculated revealed a recurring temporal pattern of species composition shift from the *Miliammina-Ammotium* biofacies to the *Ammonia-Elphidium* biofacies. Generally, these species shifts occurred in the late 1800s in lower and middle Galveston Bay and as recently as the 1970s in one portion of Trinity Bay. This step-wise progression of a higher salinity biofacies further into the estuary is consistent with the timing of major dredging events along the Houston Ship Channel, events which commenced in the early 1900s. With the exception of one location in Trinity Bay, this species shift occurs prior to the development of oil and gas fields in Trinity and Galveston Bays (1930s to 1940s) and prior to major impoundment of the Trinity River (beginning in 1952). Foraminiferal species shift in Galveston Bay is empirical evidence of increasing salinity in the bay during this century. The pattern and timing of the species shift is consistent with the hypothesis that dredging of the Houston Ship Channel has been a major contributing factor to salinity intrusion in Galveston Bay.

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Rehkemper, L. J. 1969. Sedimentology of Holocene estuarine deposits, Galveston Bay, Texas. Ph.D. Thesis. Rice University.

Shephard, F. P. 1953. Sedimentation rates in Texas estuaries and lagoons. Am. Assoc. Petro. Geol. Bull. 37:1919-1934.