The literature search revealed that much of the research conducted has been in reference to navigation effects and bank protection. Research containing actual relationships between navigation processes, or any processes for that matter, and bank erosion were rare and often unverified in the field. Only two articles were identified which presented a shoreline retreat model related to wave energy. One, Grigor'eva (1987), was unverified and showed a conceptual method for bank reworking due to wind waves only. The second, Nanson et al. (1993), was a study conducted on the Gordon River in Australia. The authors measured erosion rates while recreation boats passed a site. A good correlation was found between wave power or wave height and erosion. Based on their observations, they developed a set of maximum wave height thresholds for various soil types and recommended appropriate vessel speed restrictions.

The lack of applicable models and need for further research was expressed in many articles. This nature is best described in an article by Pilarczyk et al. (1989): "*The mechanisms of bank erosion and the stability of protection structures subject to hydraulic loading are complex problems. The understanding of erosion processes and failure mechanisms of structures is still in a rudimentary stage, and it is not yet possible to describe many important phenomena and their interactions by theory*."

At the present time, no computational method exists for linking a commercial vessel with chosen hull shape, traveling at a chosen speed in a channel of chosen depth and chosen cross-sectional area and shape with banks of a chosen height and materials, to a predicted occurrence of erosion. Therefore, there is no existing modeling technique, nor does this paper purport to develop one, that can predict or quantify bench erosion based on physical forces associated with commercial navigation. The model developed by this study is an effort to relate observed erosion, which may or may not be related to navigation, to various parameters associated with navigation through the use of contingency[1] analysis.

II. ASSESSMENT OF DATA

A. Available Data. During the 1995 field survey, data on detailed bank and channel conditions were collected at forty-three erosion sites along the UMR. In addition,

[1] A statistical method of testing the independence of two variables; both of which must be categorical (e.g., minor, moderate, and severe) as opposed to continuous numeric values.

comparable but less intensive data collections were made at thirty-six observation sites. Along the IWW, detailed data were obtained from twenty-nine erosion sites. The principal information obtained during the field survey are listed in Table 1. During the present investigation, a database for each of the three data groups (UMR, IWW, and UMR observation sites) was developed.

B. Preliminary Assessment of Data. A statistical modeling effort was undertaken to relate the risk of bank erosion to a number of site specific physical parameters. The project was originally envisioned as producing a mathematical model of the severity of bank erosion based upon a number of significant physical parameters taken from the large list of parameters available in the field data sets. This model, based on a limited number of the erosion sites and later validated against the remaining sites, could then be applied to the entire river system. Therefore, the two main phases of the modeling effort undertaken were: (1) significant parameter identification, and (2) model construction based on correlation/regression of these significant parameters related to the perceived bank erosion severity and causative mechanisms. Ideally the resulting model would be based upon a limited number of parameters such that it could be easily applied to the entire UMR and IWW system.

C. Data Assessment Approach. Initial plans called for an exploratory analysis of the field data sets to investigate trends, clustering, and distributions of the data. Outliers and inconsistent data were identified and remedied, and an attempt to verify the analytical approach was made by visualizing the data in scatter plots, histograms, and three-dimensional cluster graphs. Numerical correlation testing was used to identify the numeric site-specific parameters related to bank erosion severity and to use a rank analysis for identifying the significant descriptive parameters. Exploratory scatter plots, cluster analysis, and frequency analysis were made of all parameters, each one considered against the remaining ones. However, no significant results were obtained.

These detailed analyses revealed a bias in the sampling method used during the field survey that made them unfit for use with the standard statistical techniques proposed. This bias resulted in a violation of the normal distribution assumption, which underlies most statistical methods. The selected erosion sites visited during the field survey did not represent a randomly selected set of observations of bank erosion severity as would be required for the proposed modeling effort. The data set represents sites that were exclusively eroded. Therefore, there is no way to produce a numerical model based on these sites capable of predicting the occurrence vs. non-occurrence of bank erosion.

Table 1. Principal Information Obtained During the 1995 Field Study

1	Site Number
2	Date
3	Time
4	River
5	River Mile @ Midpoint
6	UTM X
7	UTM Y
8	Bank Profile Type
9	RDB/LDB (Right Descending Bank/Left Descending Bank)
10	Pool Name
11	Geomorphic Characteristics
12	Bank Type
13	Wing Dams (Present or Not)
14	Archeological Site (Y/N)
15	Surrounding Structures
16	Commercial Traffic Level (Barges per Year)
17	Recreational Traffic Level (Trip-Miles per Year)
18	Estimated Distance to Sailing Line (ft)
19	Land Use on Bank Crest
20	Type of Vegetation on Top of Bank
21	Type of Vegetation at Scarp Face
22	Type of Vegetation at Bench
23	Extent of Tree Root Exposure on Bank Face
24	Overland Drainage
25	Bank Erosion Type (Causitive Mechanisms)
26	Scarp Height (ft)
27	Scarp Slope (V:H)
28	Scarp Soil Type (USCS)
29	Berm Height (ft)
30	Berm Width (ft)
31	Berm Soil Type (USCS)
32	Subaqueous Bench Slope (V:H)
33	Bench Sediment Type
34	Subaqueous Bench Description
35	Channel Top-Width (ft) at Low Flow
36	Degree of Bend Curvature
37	Radius of Bend Curvature (ft)
38	Bench Width (ft)

Note: Parameters No. 35 through No. 37 were determined during the development of the GIS database.