1 INTRODUCTION

1.1 Background

In recent years, the contribution that nonpoint sources make to pollution in the United States' surface waters has come under closer scrutiny. Nonpoint source, or diffuse, pollution can be defined as pollution that is not associated with a specific location, pipe effluent discharge, or "point". Duda (1993) lists nonpoint sources of pollution to include agricultural activities, urban and industrial runoff, combined sewer overflows and leaks, hazardous waste dumpsites, septic tank systems, mining and forest harvesting activities, spills, atmospheric deposition, and hydrologic modifications. Intermittent discharges from these sources travel over land in a diffuse manner before reaching surface waters (Rifai et al., 1993).

The relative significance of nonpoint sources in the overall spectrum of pollutants has also been reassessed in recent years. In a national assessment compiled by the U.S. Environmental Protection Agency (EPA) (1992), four times as many waters were found to be polluted by agricultural activities than by municipal point source discharges. Olem (1993) has identified nonpoint source pollution as the main reason that U.S. waters do not meet water quality standards and, in an analysis of nutrient water pollution, Puckett (1995) found that nonpoint sources were the dominant source of nitrogen and phosphorus in the majority of streams studied.

While the Clean Water Act (CWA) of 1972 provided the initial legislative means for restoring the quality of the nation's waters, it was not until section 319 was added in the Water Quality Act of 1987 (PL 100-4) that specific accounting for nonpoint sources of pollution was addressed. Through section 319, titled "Nonpoint Source Management Programs", the legislature required State governors to submit State Assessment Reports identifying significant nonpoint sources of pollution to the States' navigable waters. The Act also required the adoption and implementation of State management programs for controlling pollution added from nonpoint sources to navigable waters (U.S. Congress, 1987).

The Water Quality Act of 1987 also included, as section 320, a provision for the establishment of regional National Estuary Programs (NEP's) to oversee the development of comprehensive estuary management plans. These National Estuary

Programs are administered by the EPA and include representatives from State and local jurisdictional entities, interested Federal agencies, and affected industries and educational institutions. One of the main purposes of each National Estuary Program, in the construction of the management plan, is the development of a relationship between in situ loads and point and nonpoint loadings of pollutants to the estuarine zone (U.S. Congress, 1987). As a result of this focus, much emphasis has been placed on the characterization of water quality, including nonpoint source pollution estimates, in each of the National Estuary Program study areas.

In addition to sections 319 and 320 of the Clean Water Act, section 6217 of the Coastal Zone Act Reauthorization Amendments of 1990 requires States to establish coastal nonpoint programs, subject to approval by the EPA and the National Oceanic and Atmospheric Administration (NOAA). The main purpose of section 6217 is to reinforce the interface between Federal and State coastal zone management and water quality programs in order to strengthen regional efforts to manage land use activities that typically degrade coastal waters (USDC-NOAA and USEPA, 1993).

At the Texas State level, the Texas Clean Rivers Act (Senate Bill 818), enacted subsequent to section 319 of the Clean Water Act, requires that biennial water quality assessments be performed for each major basin in the State. The Texas Natural Resource Conservation Commission (TNRCC) is responsible for administering these assessments and relies on regional partner entities, such as river authorities, to organize the assessments for each river basin. For those locations/basins where no river authority exists (such as in coastal areas between river basins), the TNRCC is responsible for producing the assessment report (TNRCC, 1994).

Pursuant to Senate Bill 818, the Texas Clean Rivers Program was created by the TNRCC to be the administering entity for the regional assessments. One of the responsibilities of the Clean Rivers Program is the organization of the assessment report for the San Antonio-Nueces Coastal Basin, which does not fall within the jurisdiction of an existing river authority. The Corpus Christi Bay National Estuary Program (CCBNEP) is also currently being conducted in the region and there is considerable interest in the accurate characterization of pollutant loads to the bay network and estuarine system there.

In support of the TNRCC's water quality assessment of the San Antonio-Nueces basin, a study of pollutant sources is needed. As part of this study, a reliable method of assessing nonpoint source pollution in the basin is required. This report addresses the need for such a method and takes advantage of the technical opportunity to investigate alternatives for computing nonpoint source loadings on a spatially distributed basis.

1.2 Objectives

A simplified method of nonpoint source pollution assessment is developed using the Arc/Info geographic information system (GIS). This method uses a fine mesh of 1 hectare (ha) cells laid over the landscape, accounting for the pollutant loading and runoff derived from each cell. By tracing the flow of water from cell to cell, the movement of pollution over the landscape and through a stream network is simulated. This method allows for the calculation of average annual nonpoint source pollutant loadings to a regional hydrologic system. In addition, estimates of average expected pollutant concentrations resultant from nonpoint sources are determined.

This research shows that the association of typical pollutant concentrations with land uses in a watershed can provide a reasonably accurate characterization of nonpoint source pollution in the watershed. This method can also be used to identify areas within a basin that may contribute more significantly to nonpoint source pollution. Accordingly, the method is well suited for the selective location of sampling stations in the establishment of local water quality sampling programs.

There are some limitations with the method discussed in this report. First, only average annual assessments are performed, so that runoff and pollutant loads are considered to be steady state parameters from year to year and within any year. Average monthly assessments could be just as easily performed using the same method, but temporal variations in runoff and pollutant loads throughout the basin would need to be correlated with gauged U.S. Geological Survey (USGS) streamflow values and are not considered in this study.

Secondly, pollutant concentration from local runoff is assumed to be directly related to land use in the region and is not considered to vary from event to event or within areas of similar land uses. In particular, a single average estimated pollutant concentration is assigned to all agricultural land uses instead of considering unique concentrations for different crops, soil types, or activities.

Throughout this study, pollutant transport in streams is considered to be conservative, i.e. no decay of pollutants is examined. This assumption is more legitimate for smaller watersheds, whose times of concentration (Chow et al., 1988) are shorter than the chemical reaction times of pollutant constituents.

Finally, point sources are not initially considered as part of the regional pollution assessment. A separate study, performed in the later stages of the research, investigates a method of estimating and simulating point loads along with the spatially distributed nonpoint loads. However, a preferred method of including point source loads would be through the access of publicly available point source permit documentation.

1.3 Study Area

For this study, the area of interest is the San Antonio-Nueces Coastal Basin, located in south Texas, just north of the city of Corpus Christi. The basin is approximately 7000 square kilometers in size and is bounded by the San Antonio River Basin to the north, the Nueces River Basin to the south and west, and the Texas Intracoastal Waterway, including San Antonio Bay, Aransas Bay, and Corpus Christi Bay, to the south and east. The basin includes two main rivers, the Mission and Aransas Rivers, which both flow to the southeast into Copano Bay and, ultimately, into Aransas Bay. Figure 1.1 shows the location of the San Antonio-Nueces Coastal Basin and Figure 1.2 identifies most of its major hydrologic features.

Topographically, the San Antonio-Nueces Coastal Basin is characterized by fairly distinct variations in elevation in the western part of the basin, away from the coast, and extremely flat terrain in the near-shore portions of the basin, to the south and east. Much of the southern part of the basin is used for agricultural purposes. Major crops and land uses receiving applications of nutrients and chemicals include cotton, corn, grain sorghum, melons, and improved pasture. Soils that support these land uses range from the dark, calcareous Victoria clays in the coastal portions of the basin to the fine sandy loams of the Papalote and Orelia series inland and in the

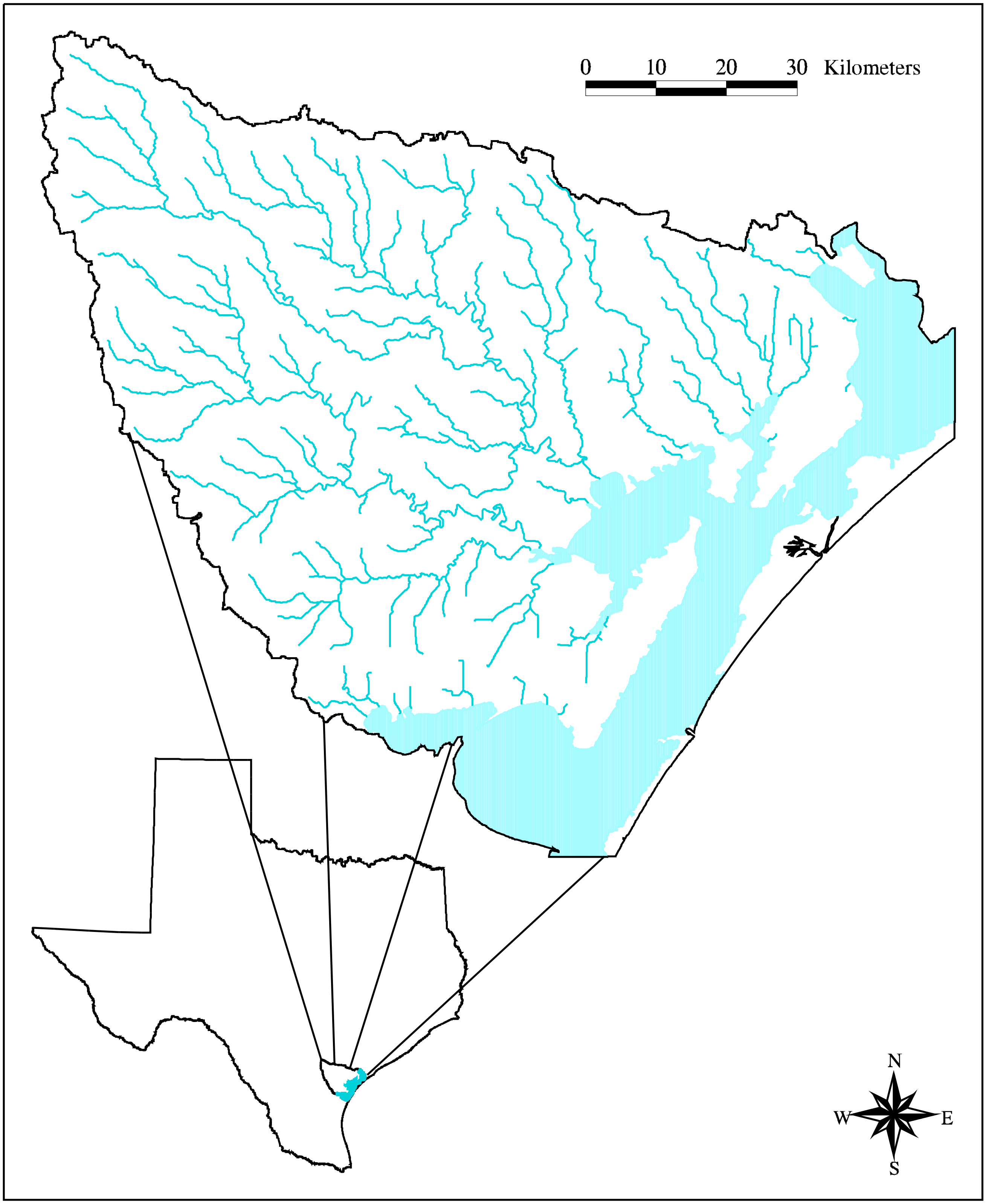

Figure 1.1 : San Antonio - Nueces Coastal Basin

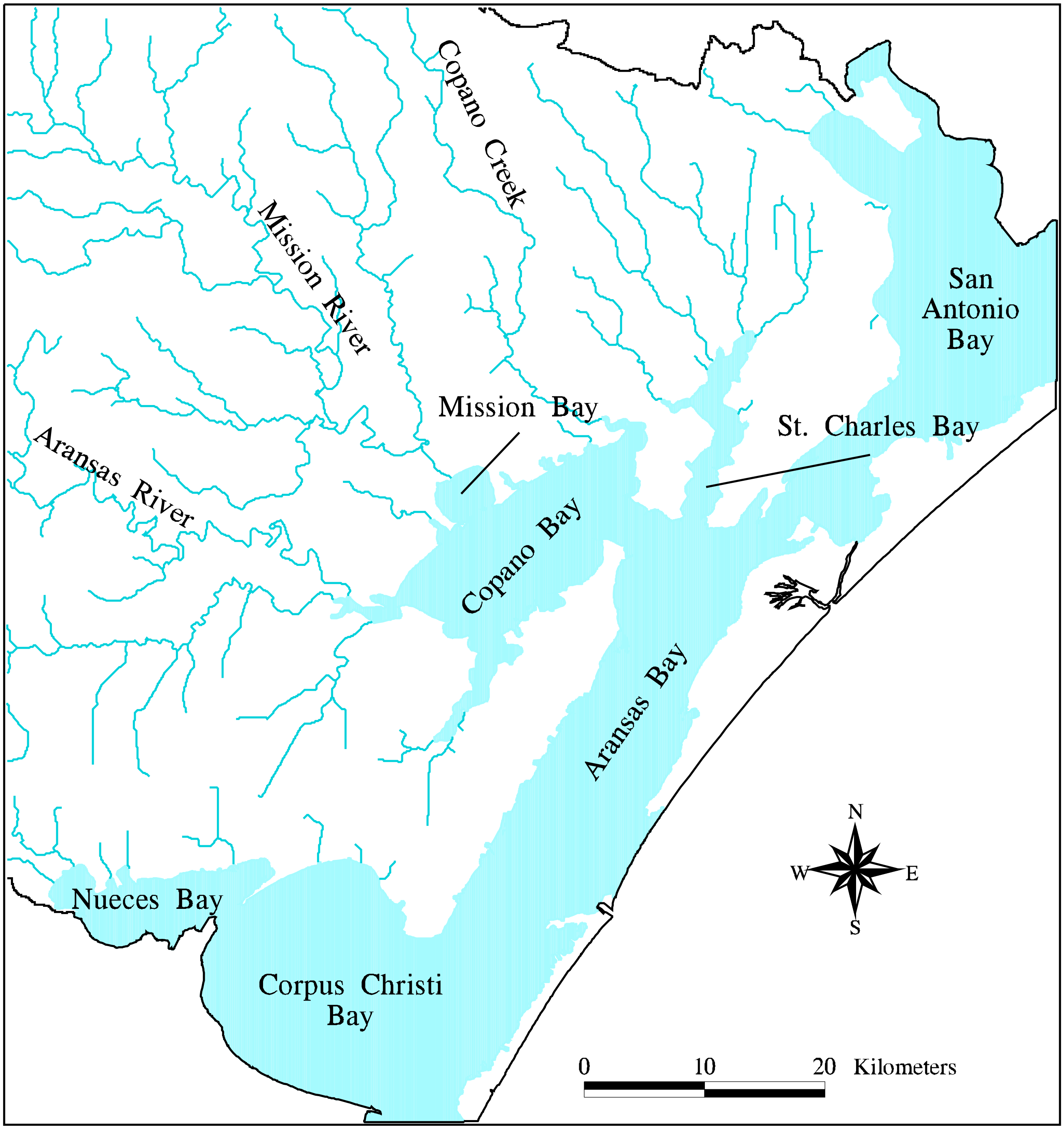

Figure 1.2 : Major Hydrologic Features of the San Antonio-Nueces Coastal Basin

southern basin. The shallow, gravelly loams of the Olmos series characterize the western upland portions of the watershed (Baird et al., 1996).

The San Antonio-Nueces Coastal Basin is largely rural, having only a few small cities with populations exceeding 5000. Table 1.1 shows the populations of the larger cities within the watershed.

1.4 Research Approach

This study makes use of Arc/Info version 7.0 with the GRID module installed. Additionally, some steps are performed in the accompanying ArcView 2.0 software. A FORTRAN 77 compiler is also required for the reformat of data acquired over the Internet. The methodology for this study is partitioned into 8 tasks:

(1) A digital database for the study area is established through the assembly of various publicly available physiographic data sets.

(2) The hydrography of the basin is then modeled using Arc/Info GRID manipulations of a digital elevation model. Digital elevation models (DEMs) discretely represent the surface elevations of a region with a fine mesh of equal area (1 hectare) grid cells. The flow of water over this digital elevation surface can be simulated from cell to cell by following the path of steepest descent. As a result, this step produces a digital replica of the basin stream network.

City or Town	County	Population
Beeville	Bee	13,547
Portland	San Patricio	12,224
Aransas Pass	San Patricio	7,180
Ingleside	San Patricio	5,696
Sinton	San Patricio	5,549
Rockport	Aransas	4,753
Refugio	Refugio	3,158

Table 1.1 : Populations of Major Cities within the San Antonio-Nueces Coastal Basin (Baird et al., 1996)

(3) A mathematical relationship between rainfall and runoff in the basin is established by performing a regression analysis of the 30-year average rainfall distribution in the basin and the adjusted 30-year average runoff measured at USGS gauging stations.

(4) Expected Mean Concentration (EMC) values for a number of pollutants are linked with the various land uses in the basin. The values used in this study are published by the U.S. Department of Agriculture Natural Resource Conservation Service (USDA-NRCS).

(5) Annual pollutant loadings throughout the basin and at sub-basin outlet points are estimated by accumulating runoff downstream through the digital stream network.

(6) Estimates of the aerial concentration distribution are calculated for each pollutant constituent by dividing the total annual cumulative load grid by the total annual cumulative runoff grid. These values are compared with average sampled pollutant concentrations at various locations within the basin.

(7) Point loads in the basin are estimated for locations where the average sampled concentration is significantly larger than the calculated concentration.

(8) Finally, in an effort to adjust the literature-based Expected Mean Concentration values, an optimization routine is used to establish values of Expected Mean Concentration from the mass balance equations at a number of constituent sampling locations in the basin.

The process developed here, while specific to the San Antonio-Nueces Coastal Basin, could also be employed for similar nonpoint source pollution assessments in other geographic regions. For this study, only average annual loads and annually averaged concentrations have been considered and estimated. However, average seasonal or average monthly loads and concentrations could also be established by further analysis of the same data sets.