4.0 LITERATURE REVIEW

4.1 Non-Point Source Processes

Several general characteristics describe non-point source pollution according to Novotny and Chesters (1981):

- Non-point source discharges enter surface waters in a diffuse manner and at intermittent intervals that are related mostly to the occurrence of meteorological events.

- Pollution arises over an extensive area of land and is in transit overland before it reaches surface waters.

- Non-point sources generally cannot be monitored at their point of origin, and their exact source is difficult or impossible to trace.

- Elimination or control of pollutants must be directed at specific sites.

- In general, the most effective and economical controls are land management techniques and conservation practices in rural zones and architectural control in urban zones.

- Compliance monitoring for non-point sources is carried out on land rather than in water.

- Non-point source pollutants cannot be measured in terms of effluent limitations.

- The extent of non-point source pollution is related, at least in part, to certain uncontrollable climatic events, as well as geographic and geologic conditions, and may differ greatly from place to place and year to year.

- Non-point sources are derived from operations on extensive units of land, as opposed to industrial activities that typically use repetitive operations on intensive (small) units of land.

4.1.1 Rural (Non-Urban) Non-Point Sources

In general, rural non-point sources are related to agricultural and silvicultural activities, such as fertilizer and pesticide application, tillage and logging. Since these operations do not occur continuously, non-point source loads from rural areas can fluctuate significantly from storm to storm. For many agricultural areas, high sediment, nutrient, and fertilizer loads are observed in the spring, when plowing and agricultural chemicals are added to

the soil. Much lower loads are observed after harvesting, when cultivated fields are converted to pasture or lie fallow.

For the Galveston Bay watershed, some local research indicates that rice production may result in significantly lower pollutant loads of sediment, nutrients, and pesticides than row crops (McCauley, 1991). During the growing season water is impounded behind small dikes, limiting the potential for any sheet or rill erosion. Published research on pollutant export from rice fields (USEPA, 1978) indicates that high concentrations of these pollutants are found in runoff at certain times during the year (for example, high nutrient concentrations were observed shortly after fertilizer application) but that very low concentrations were also observed during much of the growing season. The complicated hydrology of rice fields and the variable water quality over time make it very difficult to estimate an average NPS-related concentration in rice-field runoff.

Non-point source loads from forested watersheds change dramatically due to the effects of silvicultural activities. Forests usually exhibit very low sediment and nutrient yields; during logging operations, however, erosion rates can increase by several orders of magnitude.

4.1.2 Urban Non-Point Sources

Urbanization and related hydrologic modifications increase pollution loads to values that are significantly above the original or background levels. A variety of sources have been identified as NPS contributors: urban bird and pet populations, street litter accumulation, tire wear of vehicles, oil from car crankcases, fertilizer and pesticide application, eroded areas, abrasion of road surfaces by traffic, and construction activities. Water quality constituents of concern in urban runoff include sediments, nutrients, oxygen-demanding compounds, oil and grease, bacteria, heavy metals, and synthetic organic chemicals.

Of all the urban land uses, low-density residential zones and open areas yield the lowest NPS loads, while highest pollution loads are associated with high-density commercial areas, industrial centers and, above all, construction sites. During construction activities considerable areas are stripped of vegetative cover, exposing open soil. The NPS loadings from construction areas can be an order of magnitude higher than other land uses, and can dominate the total NPS loadings in some watersheds.

4.1.3 Important Water Quality Constituents in Runoff

Total Suspended Solids (TSS) refers to the concentration of suspended sediment in water. TSS is measured by weighing the undissolved material trapped on a 0.45 micrometer filter after filtration. The constituents that pass

through the filter are designated Total Dissolved Solids (TDS) and are comprised of ions such as iron, chloride, sodium, sulfate, etc. TSS is a measure of the amount of erosion occurring in a watershed.

Total Nitrogen (TN) consists of all the various forms of inorganic and organic nitrogen present in water. Nitrogen (N) usually occurs in water in the form of nitrate (NO_3), nitrite (NO_2), organic N, or ammonia (NH_4). Total Kjeldahl Nitrogen (TKN) refers to an analytical procedure that measures organic nitrogen and ammonia together. Nitrogen, particularly the nitrate form, is an indicator of fertilizer application.

Total Phosphorous (TP) occurs in natural waters in the form of orthophosphate and organic phosphorous. As with nitrogen, phosphorous is associated with fertilizer runoff and treatment plant effluent.

Biochemical Oxygen Demand (BOD or BOD_5) is an indirect measure of biodegradable organics in water, and is determined by measuring the dissolved oxygen decrease in a controlled water sample over a five-day period. During this five-day period, aerobic bacteria decompose organic matter in the sample and consume dissolved oxygen in proportion to the amount of organic material that is present. Stormwater runoff with a high Biochemical Oxygen Demand can have an adverse affect on water quality by depleting the oxygen in a receiving stream, lake, or bay.

Fecal Coliforms are bacteria that are present in the intestines or feces of warm blooded animals and are often used as indicators of bacteriological water quality. Concentration is expressed as number of colony forming units (CFU) per 100 milliliters of sample. Standards for contact recreation are 200 CFU per 100 milliliters of sample and 2,000 CFU per milliliter for non-contact recreation.

Heavy Metals occur naturally in soils and derive from a variety of human sources, including industry, automobiles, and agriculture. The primary constituents of interest in non-point source water quality include arsenic, cadmium, chromium, copper, lead, mercury, and zinc.

Oil and Grease is a measure of free-phase organic contamination. The primary source is motor vehicles.

Synthetic Organic Chemicals comprise a large class of compounds that includes pesticides, poly-chlorinated biphenyls, and other trace-level hydrocarbons. Chlorinated hydrocarbons, such as many pesticides, are of most concern.

4.2 National Non-Point Source Studies

In 1981-82 the EPA funded 30 applied research projects as part of an effort to complete a report to Congress on water quality impacts and control of urban runoff pollution. The resulting data collection effort, known as the Nationwide Urban Runoff Program (NURP) yielded the most extensive NPS database assembled in the country to date (USEPA, 1983).

Under NURP, field monitoring was conducted to characterize urban runoff flows and NPS pollutant concentrations. This was done for a variety of pollutants at 80 sites in 21 cities located throughout the country. The collected data represent a cross-section of regional climatology, land use types, slopes, and soil conditions and thereby provides a basis for identifying patterns of similarities or differences and testing their significance.

The collected data showed that urban runoff flows and concentrations of contaminants are quite variable. Experience shows that substantial variations occur within a particular event and from one event to the next at a particular site. The primary conclusions from the NURP study focused on the effects of urban runoff on natural stream systems:

WATER QUALITY EFFECTS (taken directly from USEPA, 1983).

Freshwater Aquatic Life

1. Heavy metals, in particular, are the urban runoff contaminants having the greatest potential for impacts on aquatic life. This conclusion is based on the fact that a number of heavy metals are consistently found in urban runoff in high concentrations relative to suggested toxic limits for aquatic life.

2. Despite the high concentrations of heavy metals in urban runoff, few significant problems traceable to urban runoff were found in the water column.

3. Several projects had identified possible problems in the sediments because of the build-up of priority pollutants contributed wholly or in part by urban runoff. However, the NURP studies in this area were few in number and limited in scope, and the findings must be considered only indicative of the need for further study, particularly as to long-term impacts.

4. The physical aspects of urban runoff, e.g., erosion, scour, etc., can be a significant cause of habitat disruption and can affect the type of fishery present. However, this area was studied only incidentally by several of the projects under the NURP program and more concentrated study is necessary.

5. Organic priority pollutants in urban runoff do not appear to pose a general threat to freshwater aquatic life.

6. Adverse effects of urban runoff in marine waters will be a highly specific local situation. It is not a beneficial use generally threatened by urban runoff, though specific instances where it is impaired or denied can be of significant local and even regional importance. Coliform bacteria present in urban runoff is the primary indicator of concern, causing direct impacts on shellfish harvesting.

Recreation

1. Coliform bacteria are present at high levels in urban runoff and affect all types of water bodies - streams, lakes, bays, estuaries, and oceans. However, only a portion of the coliform bacteria found in urban runoff is from sewage contamination, the sources of sewage contamination can be numerous, the most common being unrecorded connections. In areas without sanitary sewers, septic tank leaks may be substantial. In areas with sewers, house connections have been identified as a source of sewage contamination. In addition to sewage, domestic animal waste (i.e., pet waste) may contribute to high fecal coliform counts. However, natural sources appear to be the largest overall contributor to coliforms in urban runoff. Bacteria counts can be expected to exceed State criteria during and immediately after storm events in many surface waters used for body contact recreation.

2. Nutrients in urban runoff may accelerate eutrophication problems and severely limit recreational uses, especially in lakes. However, NURP's lake projects indicate that the degree of beneficial use impairment varies widely, as does the significance of the urban runoff component.

4.3 State and Local Non-Point Source Studies

In 1988, the Texas Water Commission prepared a non-point source assessment of the State of Texas as part of the requirements of the Water Quality Act (Section 319(a). To gather non-point source data in the Houston area, the Houston-Galveston Area Council (HGAC) conducted a survey of 245 local governments and local, state, and federal agencies involved with water quality in the 13-county HGAC area (which includes almost all of this project's study area). Respondents were asked to identify the waterbodies/watersheds with non-point source problems, categories of non-point sources, the means of assessing whether a problem exists, specific pollutants of concern, and types of non-point source controls in each jurisdiction.

A total of 49 responses from the survey were received, and they indicated that 105 different waterbodies/watersheds were impacted to some degree by non-point source pollution. While the City of Houston Public Works Department and the Galveston County Health District reported that actual monitoring data had been collected in local watersheds, the rest of the respondents relied on visual inspection, word of mouth, records of complaints, personal opinion

or data more than 5 years old to assess current non-point source problems. The survey indicated that the most common problems were oxygen reducing materials, toxic chemicals/heavy metals, bacteria, sediment, and trash. Detention ponds, septic tank ordinances, litter/trash removal programs, and street sweep were identified as the most common best management practices for managing non-point source pollution.

The report recommended the following watersheds for inclusion into the state assessment report:

- Lake Houston Watershed: East Fork San Jacinto River (Segment 1003), Cypress Creek (Segment 1009), and Luce Bayou;

- Houston Ship Channel Watershed: Houston Ship Channel (Segment 1005, 1006, 1007), Buffalo Bayou Tidal (Segment 1013), and Buffalo Bayou Above Tidal (Segment 1014);

- Clear Creek/Clear Lake Watershed: Clear Creek Tidal (Segment 1101), Clear Creek Above Tidal (Segment 1102), and Clear Lake (Segment 2425).

The HGAC conducted several other projects related to local NPS pollution problems. The Areawide Waste Treatment Management Plan for the Greater Houston Area included an assessment of local non-point sources related to urban runoff, septic tanks, agricultural runoff, construction sites, dredging, and benthic oxygen demand (HGAC, 1977). In addition, NPS control strategies, costs, and impacts were also presented. The assessment of NPS loads were developed using the Stormwater Management Model (SWMM) with existing NPS monitoring data; no additional sampling was performed. An HGAC management study was conducted on the Clear Lake watershed (HGAC, 1983) to delineate land use, define activities associated with non-point source pollution, and to identify control measures. A similar management study was conducted on Lake Houston by HGAC (HGAC, 1984), with the exception that monitoring data from Rice University studies (discussed below) were also incorporated into the report.

The Texas Water Quality Inventory provides a summary of water quality in the state in accordance with Section 305(b) of the Clean Water Act (Texas Water Commission, 1990). The inventory includes water quality assessments of each of the designated water quality segments in Texas, and contains a discussion of the state's water pollution control program and non-point source control strategy.

The Texas Water Commission (TWC) established a 27-member Nonpoint Source Advisory Committee to plan NPS control activities for the state over a 20-year planning horizon. In September 1990 the committee issued fourteen recommendations that comprise a comprehensive program for NPS control

in Texas (Nonpoint Source Advisory Committee, 1990). Three main areas are represented in the recommendations: education, best management practices, and NPS monitoring.

The Texas State Soil and Water Conservation Board is also addressing NPS problems in the state. A detailed assessment of watershed impacts on water quality, published in January, 1991, provides estimated NPS sediment loads for 23 river and coastal basins from two sources: gross sheet and rill erosion, and gross gully and streambank erosion (Texas State Soil and Water Conservation Board, 1991). In addition, information on range and forestry issues, impacts of water quality, and the method used to estimate sediment loads is included.

Several local studies have focused on the actual measurement of non-point source loads and correlations to local land use patterns in the Houston area. The following sections summarize these sources of local NPS data and identify the primary references.

4.3.1 Rice University

Characklis et al. (1978), Bedient et al. (1978a & b), Bedient and Quevedo (1979), and Bedient et al. (1980a) performed some of the first detailed NPS research in the Houston area. Monitoring programs were conducted in The Woodlands and Westbury areas and in the Brays Bayou and Hunting Bayou watersheds. Sediment and nutrients were the primary parameters of concern. The data were used to construct load-runoff curves relating total storm load in lb/acre (kg/ha) to total storm runoff (in or cm). More recently, a number of studies were performed on the inflows and pollutant loads to Lake Houston (Baca et al., 1982; Bedient et al., 1980b & c; Bedient and Anderson, 1983; Newell, 1981), the major surface water supply for the City of Houston. Results from the Rice University studies were used to develop the NPS database for this project as discussed in Section 5.0.

4.3.2 USGS Studies

The USGS sampled urban runoff in Houston between 1968 and 1984 as part of the Houston Urban Runoff Program (HURP), and collected over 1500 samples for analysis. The database covers a variety of watersheds of varying land use and has been invaluable in assessing the impact of urbanization on water quality in Houston. Most of the resulting data were published in a series of reports by Ferguson, Ranzau, Fisher and King, Hutchison, and Liscum et al., (USGS, annual reports from 1968-1984). Although significant research has been conducted on rainfall/runoff processes, relatively little interpretation of the extensive water quality database has been reported to date. This project made extensive use of the USGS database as discussed in Section 5.0.

An important water quality study was performed by the USGS in the Barker-Addicks Reservoirs (Liscum et al, 1987) and also provided data for this project.

4.3.3 Houston Ship Channel Non-Point Source Study

Winslow and Associates (1986) completed a large study on NPS loads to the Houston Ship Channel which included over 500 samples of storm data at 7 main tributary sites and six small homogeneous land use sites. A detailed analysis of the USGS historical data was combined with actual sampling results to compute NPS loads to the Houston Ship Channel. The Winslow study concluded that NPS loads accounted for 99% of the TSS load, 43% of ammonia N, and 63% of TKN for the data analyzed by tributary sampling (Table 4.1). The data also suggested that construction may have a major impact on NPS loads, as TSS loads from the single land use were approximately half of what was observed in the main tributaries.

Finally, a significant amount of the resources from the 1986 project were devoted to quantifying the effect of sanitary sewer overflows and bypasses. Based on this data, the authors concluded that these sources contributed approximately 11% of the annual BOD load, 7% of the annual TSS load, and 7% of the annual ammonia load to the Ship Channel.

4.3.4 Other Sources of NPS Information

During this project, several water quality and environmental planning groups were contacted as part of the NPS data collection and literature review effort. Three companion GBNEP projects being conducted concurrently with this project were contacted: a wetlands survey being conducted by the U.S. Fish and Wildlife Service, a tributary loading assessment being conducted by the University of Texas, and a point/non-point source assessment now being performed by a private contractor. Other agencies and governmental organizations that were contacted and the type of information obtained included the Houston-Galveston Area Council (land use and population data), the Texas Water Commission (state NPS reports and planning documents), the U.S. Environmental Protection Agency (background NPS information), the City of Houston (water quality data related to collection systems), Texas A&M University (rice cultivation information), the U.S. Soil Conservation Service (soil maps and agricultural information), NOAA (current NPS estimates), and private contractors who performed earlier NPS studies in the Houston area.

Table 4.1 - Summary of Annual Load Estimates
Non-Point Source Characterization Project
Galveston Bay National Estuary Program

Source	$CBOD_5$	TSS	NH_3 - H	TKN
Tributary Sampling Method				
Wet weather tributary load	16.18	692.0	1.78	5.53
WWTP load, no-rain days	1.79	3.2	2.04	2.74
Industry load	1.99	5.6	0.29	0.52
TOTAL	19.96	701.0	4.01	8.79
Individual Component Evaluation				
Urban runoff	20.19	282.0	0.99	5.84
Overflows	2.73	20.5	0.28	0.56
Bypasses	0.40	0.7	0.03	0.07
Wet weather WWTP	1.15	2.3	1.08	1.45
WWTP load, no-rain days	1.79	3.2	2.04	2.74
Industry	1.99	5.6	0.29	0.52
TOTAL	28.25	314.0	4.71	11.18
Tributary Sampling Evaluation				
Individual Component Evaluation	0.70	2.23	0.83	0.78

NOTES:
1. From Winslow & Associates (1986).
2. All loads are in millions of lbs/yr.
3. WWTP = Wastewater Treatment Plant.
4. $CBOD_5$ = Cabonaceous Biochemical Oxygen Demand
   NH_3 - H = Ammonia Nitrogen
   TSS = Total Suspended Solids
   TKN = Total Kjeldahl Nitrogen as Nitrogen