UPPER LEON RIVER
MUNICIPAL WATER DISTRICT
REGIONAL WASTEWATER STUDY
VOLUME III
NON-POINT SOURCE CONTROLS EVALUATION

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REGIONAL WASTEWATER STUDY

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SECTION 1.0
EXECUTIVE SUMMARY

1.0 EXECUTIVE SUMMARY

This report presents the results of a Non-point Source (NPS) Controls Evaluation performed for the Upper Leon River Water District. The Evaluation was performed as one of three major components of the Upper Leon River Municipal Water District Regional Wastewater Study. The first component, the Water Quality Monitoring Program, provides an assessment of water quality in Lake Proctor and its tributaries and proposes a water quality monitoring program for the Lake Proctor watershed. The second component, this NPS Controls Evaluation, identifies existing land uses, projects future land uses, determines potential sources of non-point source pollution, and proposes best management practices to control NPS pollution and reduce negative impacts on the Lake Proctor Watershed. The third component is an evaluation of point-source controls which includes facilities planning recommendations for sewered and unsewered communities in the watershed.

This evaluation considers NPS pollution to be sediments, nutrients, and organic and toxic substances originating from land-use activities and carried to lakes and streams by runoff, in amounts such that the rate at which these materials entering the water exceeds natural levels.

The evaluation assessed the existing watershed as being predominantly rural in nature, with the amounts of cultivated land, pasture and rangeland having changed little since the 1960's. The watershed as a whole is comprised of 20 percent cultivated lands, roughly one percent each of residential areas and oil fields, and less than one percent being used for mining operations, localized industries and orchards. The remaining land which includes rangeland, pastureland and undeveloped land makes up approximately 77 percent of the watershed. Based on weighted averages of the amounts of ranchland and farmland in each county reported in the 1985 Texas Agricultural Statistics, approximately 45 percent of the total basin includes rangeland, 19 percent is pasture and the remaining 13 percent is undeveloped.

The future economy of the agricultural sector will likely be based on the original mixture of rangeland, cropland and pastureland because of limitations imposed by the soil capabilities, the climate, and present economic conditions. The estimated increases in the amount of land used for residential development and associated industrial activity between 1983 and 2022 in the study area are 17.3 percent and 57.3 percent respectively.

Non-point source (NPS) pollutants that can be controlled by best management practices are found primarily in areas of agricultural and urban development. When evaluated on a per-acre basis, the largest loadings of NPS nutrients are expected to originate from feedlots and residential areas, while croplands probably contribute somewhat less and pasture land and commercial areas contribute the least. When considering the watershed as a whole, cultivated land and pasture would likely contribute the most BOD, while cultivated land is predicted to contribute the most nitrogen and phosphorous. Major sources of urban runoff include accumulated contaminants washed from impervious surfaces, fertilizer and pesticide wash-off from lawns and parks, and septic tank filtrate.

Recommended actions for controlling NPS loadings generated from cultivated lands include installation of permanent ponds for control of nitrogen loadings associated with stormwater, addition of wind breaks for controlling erosion of sandy soils and funding for research of soil stabilization techniques for use on sandy soils including no-till farming practices. Those areas that would contribute the largest amounts of NPS loadings as identified from the monitoring program should be targeted for the addition of Best Management Practices (BMP).

Best management practices recommended for urban areas include the construction of retention/sedimentation pond systems in areas targeted as contributors of high NPS loadings, purchase of street cleaning equipment and promotion of public awareness programs conducted through the media.

Recommendations for controlling NPS generated from livestock wastes include the use of filter strips, random sampling of small dairies not permitted by the Texas Water Commission (TWC), and more research into alternative treatment/pretreatment methods for disposing of livestock wastes.

The potential for NPS loadings resulting from oil and gas field operations has not been thoroughly quantified in this report but is recognized as a potentially significant source based on field observations. Leaking storage tanks introduce petroleum wastes to the soil from which they can be washed off into surface waters during storm events. Review of information held by the Texas Railroad Commission indicates that these areas are far more extensive in the Lake Proctor watershed than information obtained from USGS maps and aerial photos would indicate.

Small unsewered lakeside developments along the north and south shores of Lake Proctor are potentially significant sources of NPS loadings because of their close proximity to the reservoir. Site visits revealed no obvious existing problems with sewage contamination though the potential exists for increased future development in these areas to result in the contribution of nutrients due to seepage into the lake.

Multiple sources were utilized to assess the number of acres of pecan orchards located within the Lake Proctor watershed. Analysis of 1983 aerial photographs indicated that commercial pecans occur on approximately 4,600 acres, or 0.5 percent of the study area though interviews with personnel with the Agricultural Extension Service revealed that a combined 19,500 acres of native and improved orchards are located in Comanche and Eastland counties.

Because of the intensive management associated with pecan orchard cultivation, NPS loadings contributed by them are expected to be insignificant. If monitoring detects excessive loadings of pesticides typically used for pecans from an area that includes orchards, analysis of soils and stormwater runoff in close proximity to suspected orchard sources should be conducted. Further inspection should be done to detect any misuse or mishandling of pesticides which may be the source of contamination. In the event that the over-application of fertilizers is found to be a source of NPS pollution, every effort should be made to help the orchard manager correct the problem.

SECTION 2.0
INTRODUCTION

2.0 INTRODUCTION

The Upper Leon River Municipal Water District Regional Wastewater Study has three major technical components. The first component, the Water Quality Monitoring Program includes an initial assessment of water quality, a coordinated water quality monitoring program for Lake Proctor and its tributaries, a surveying plan for developing model calibration data, and a quality assurance/control plan for the monitoring program. This report is the second major component of the effort to assist ULRMWD in controlling and enhancing water quality in the Lake Proctor watershed. It addresses the identification and control of non-point source pollution in the Watershed. The third major component, prepared as a separate report, is a point-source pollution control evaluation.

2.1 Purpose of Evaluation

In order to provide wastewater treatment services to its members and to insure that appropriate measures will be identified for water resources protection, ULRMWD has undertaken a regional wastewater facilities plan for the Lake Proctor Watershed. In order to ascertain the suitability of the water bodies in the watershed for effluent discharge and to determine effluent limitations for a regional facility, a water quality management plan is proposed to augment the facilities plan. Part of the water quality management plan is the identification and control of non-point source (NPS) pollution.

The purpose of this component of the NPS Controls Evaluation is to identify potential sources of NPS pollution, to develop a sampling plan to help quantify NPS pollution components, and to identify management practices which can be utilized to effectively control excessive pollution sources.

2.2 Scope of Evaluation

The NPS Source Controls Evaluation included the following major components:

- A land use analysis, which established the nature of existing land uses in the watershed and projected future conditions for the 30-year planning period;
- An evaluation of existing sources of NPS pollution, including agricultural uses, industrial uses, and residential uses;
- A description of subbasin watershed characteristics;
- The development of a NPS sampling plan; and
- The evaluation of best management practices which can be implemented to minimize the impacts of NPS pollution from the various identified sources.

The primary area of concern identified for the study was the Lake Proctor Watershed below Lake Leon. Although Lake Leon retains and to a large extent assimilates NPS pollution from the upper Lake Proctor Watershed, the Lake Leon watershed is viewed as a long-term potential contributor to Lake Proctor. Therefore, the NPS Controls Evaluation included an analysis of the Lake Leon Watershed.

2.3 Participants

Funding for the Non-Point Source Controls Evaluation was shared by the ULRMWD and the Texas Water Development Board. Other entities which were contributors in the development process or the review and comment process were:

Brazos River Authority
U.S. Geological Survey
Texas Water Commission
U.S. Corps of Engineers
Tarleton State University

2.4 Methodology

Non-point source pollution is defined as that "caused by sediment, nutrients, and organic and toxic substances originating from land-use activities and/or from the atmosphere, which are carried to lakes and streams by runoff. Non-point source pollution occurs when the rate at which these materials entering water bodies exceeds natural levels."[1] The task of evaluating (NPS) controls for a watershed includes the delineation of existing and future contributing land uses, identification of mechanisms by which specific groups of NPS pollutants enter surface waters, a qualitative and quantitative evaluation of the NPS characteristics for each of the subbasin watersheds, development of a plan for sampling non-point sources from representative land uses areas, and the appraisal of the applicability and effectiveness of various best management practices for controlling potential NPS pollution identified in the study area. Data obtained from the NPS monitoring program will be used both to identify the locations of major controllable sources and target areas for best management practices that would be most effective.

2.4.1 Land Use Delineation Methodology

Land uses were delineated using aerial photographs in conjunction with the most current 7.5 foot maps obtained from the U.S. Geological Survey (USGS). Aerial photographs produced in 1983 were obtained on 24-inch by 24-inch prints at a 1:24,000 scale from the U.S. Department of Agriculture Photography Field Office located in Salt Lake City, Utah. These photographs were overlain with transparencies onto which land use areas were traced. Land use designations were then verified to the extent possible by comparing corresponding areas to labeled land uses shown on equal scale USGS maps that had been updated since 1983. Acreage contained within each delineated land use area were then determined within the boundaries of each of thirty-three 7.5 foot maps which covered the Lake Proctor watershed.

Six land use categories were defined for the watershed analysis from the aerial photographs, including: cultivated lands, residential areas, localized industrial areas, orchards, quarries, and oil and gas fields. Of the remaining land areas, pasture, range and undeveloped lands were further segregated using information contained in U.S. Department of Agriculture (USDA) publications concerning agricultural statistics for the study area[2]. Those areas not classified otherwise were assigned acreage based on weighted averages for the Comanche, Eastland and Erath County areas using data obtained from agricultural statistics available for the area[3]. These data are presented in Section 2.2 "Existing Land Use" Tables 1 through 12.

TABLE 1

EXISTING CONDITIONS LAND USE DELINEATIONS IN ACRES

ARMSTRONG CREEK BASIN

USGS Map	Cultivated	Residential	Industrial	Orchards	Quarries	Oil & Gas	Range & Pasture	Woodlands
Bernie Lake								
Bunyan	75		9				597	1745
Carbon								
Cisco North								
Cisco South								
Comanche								
Comyn	3293						1995	5827
Cross Plains								
De Leon								
Desdemona								
Dublin	14		18				117	343
Duster								
Eastland								
Gorman								
Huckaby SW	581						4757	13899
Hunting Shirt Creek								
Kokomo								
La Casa								
Lingleville	2146	30	75	72			7658	22374
May								
Mercers Gap								
Pioneer								
Putnam North								
Putnam South								
Proctor								
Ranger								
Reddy Mountain								
Rising Star								
Rucker								
Sabanno								
Scranton								
Sidney								
Sipe Springs								
Star Mountain								
Turkey Creek								
Union Center								
Wayland								
Total Acres	6109	30	102	72	0	0	15124	44188

TABLE 2

EXISTING CONDITIONS LAND USE DELINEATIONS IN ACRES

DUNCAN CREEK BASIN

USGS Map	Cultivated	Residential	Industrial	Orchards	Quarries	Oil & Gas	Range & Pasture	Woodlands
Bear Mountain								
Bernie Lake								
Bunyan								
Carbon								
Cisco North								
Cisco South								
Comanche	4473			200			1882	5497
Comyn								
Cross Plains								
De Leon								
Desdemona								
Dublin								
Duster								
Eastland								
Gorman								
Huckaby SW								
Hunting Shirt Creek								
Kokomo								
La Casa								
Lingleville								
May								
Mercers Gap								
Pioneer								
Putnam North								
Putnam South								
Proctor								
Ranger								
Reddy Mountain								
Rising Star								
Rucker								
Sabanno								
Scranton								
Sidney	1639		12				713	2084
Sipe Springs								
Star Mountain								
Turkey Creek								
Union Center								
Wayland								
Total Acres	6112	0	12	200	0	0	2595	7581

TABLE 3

EXISTING CONDITIONS LAND USE DELINEATIONS IN ACRES

LOWER LEON RIVER BASIN

USGS Map	Cultivated	Residential	Industrial	Orchards	Quarries	Oil & Gas	Range & Pasture	Woodlands
Bear Mountain								
Bernie Lake								
Bunyan								
Carbon								
Cisco North								
Cisco South								
Comanche	1267	32					86	251
Comyn	3412	30	358			296	1482	4328
Cross Plains								
De Leon	3546			30			711	2078
Desdemona								
Dublin								
Duster								
Eastland								
Gorman								
Huckaby SW								
Hunting Shirt Creek								
Kokomo								
La Casa								
Lingleville								
May								
Mercers Gap								
Pioneer								
Putnam North								
Putnam South								
Proctor	92	100					313	915
Ranger								
Reddy Mountain								
Rising Star								
Rucker								
Sabanno								
Scranton								
Sidney								
Sipe Springs								
Star Mountain								
Turkey Creek								
Union Center								
Wayland								
Total Acres	8317	162	358	30	0	296	2592	7572

TABLE 4

EXISTING CONDITIONS LAND USE DELINEATIONS IN ACRES

RUSH CREEK BASIN

USGS Map	Cultivated	Residential	Industrial	Orchards	Quarries	Oil & Gas	Range & Pasture	Woodlands
Bear Mountain								
Bernie Lake								
Bunyan								
Carbon								
Cisco North								
Cisco South								
Comanche	700						401	1172
Comyn								
Cross Plains								
De Leon	1937			90			1239	3621
Desdemona								
Dublin								
Duster	7897	60	83	338			5346	15619
Eastland								
Gorman								
Huckaby SW								
Hunting Shirt Creek								
Kokomo								
La Casa								
Lingleville								
May							152	444
Mercers Gap								
Pioneer								
Putnam North								
Putnam South								
Proctor								
Ranger								
Reddy Mountain								
Rising Star	5573	505	26	155	160	1057	3147	9196
Rucker								
Sabanno								
Scranton								
Sidney	2131			167			626	1828
Sipe Springs	8195	120	56	30			7486	21871
Star Mountain	2727						2635	7699
Turkey Creek								
Union Center								
Wayland								
Total Acres	29160	685	165	780	160	1057	21032	61450

TABLE 5

EXISTING CONDITIONS LAND USE DELINEATIONS IN ACRES

SABANA RIVER BASIN

USGS Map	Cultivated	Residential	Industrial	Orchards	Quarries	Oil & Gas	Range & Pasture	Woodlands
Bear Mountain								
Bernie Lake								
Bunyan								
Carbon	224	253	50	74			797	2330
Cisco North								
Cisco South	1326		8				418	1221
Comanche								
Comyn								
Cross Plains	48					275	642	1876
De Leon	5811		50	72			3643	10642
Desdemona								
Dublin								
Duster	3367		30	96		143	1785	5216
Eastland								
Gorman	8851	626		611			6404	18709
Huckaby SW								
Hunting Shirt Creek	6139			24	45		8681	25361
Kokomo								
La Casa								
Lingleville								
May								
Mercers Gap								
Pioneer	626		11				186	543
Putnam North								
Putnam South								
Proctor								
Ranger								
Reddy Mountain								
Rising Star	1118			102			740	2161
Rucker	3084			167			813	2375
Sabanno	5573			10			6056	17693
Scranton								
Sidney								
Sipe Springs	584	7					458	1339
Star Mountain								
Turkey Creek								
Union Center	8502		90	730		323	7831	22877
Wayland								
Total Acres	45253	886	239	1886	45	741	38454	112343

TABLE 6

EXISTING CONDITIONS LAND USE DELINEATIONS IN ACRES

SOUTH FORK LEON RIVER BASIN

USGS Map	Cultivated	Residential	Industrial	Orchards	Quarries	Oil & Gas	Range & Pasture	Woodlands
Bear Mountain								
Bernie Lake		1	23				33	98
Bunyan								
Carbon	4515			285	55	747	5686	16613
Cisco North	671	1377	86	120		2543	3407	9955
Cisco South	3740	6	102	107	42		8513	24870
Comanche								
Comyn								
Cross Plains	343						281	822
De Leon								
Desdemona								
Dublin								
Duster								
Eastland	1818	1565	580	60	45	219	5601	16364
Gorman								
Huckaby SW								
Hunting Shirt Creek	37						17	49
Kokomo	49	310	86				2355	6881
La Casa								
Lingleville								
May								
Mercers Gap								
Pioneer								
Putnam North								
Putnam South	432						119	347
Proctor								
Ranger	100	80					942	2752
Reddy Mountain								
Rising Star								
Rucker								
Sabanno	775			15			735	2149
Scranton	6496	70	6	477		388	7142	20864
Sidney								
Sipe Springs								
Star Mountain								
Turkey Creek								
Union Center								
Wayland								
Total Acres	18976	3409	883	1064	142	3897	34831	101764

TABLE 7

EXISTING CONDITIONS LAND USE DELINEATIONS IN ACRES

SOUTH PROCTOR BASIN

USGS Map	Cultivated	Residential	Industrial	Orchards	Quarries	Oil & Gas	Range & Pasture	Woodlands
Bear Mountain								
Bernie Lake								
Bunyan								
Carbon								
Cisco North								
Cisco South								
Comanche	969	110					278	812
Comyn								
Cross Plains								
De Leon								
Desdemona								
Dublin								
Duster								
Eastland								
Gorman								
Huckaby SW								
Hunting Shirt Creek								
Kokomo								
La Casa								
Lingleville								
May								
Mercers Gap								
Pioneer								
Putnam North								
Putnam South								
Proctor	39	3	8				22	66
Ranger								
Reddy Mountain								
Rising Star								
Rucker								
Sabanno								
Scranton								
Sidney								
Sipe Springs								
Star Mountain								
Turkey Creek								
Union Center								
Wayland								
Total Acres	1008	113	8	0	0	0	300	878

TABLE 8

EXISTING CONDITIONS LAND USE DELINEATIONS IN ACRES

SOWELL'S CREEK BASIN

USGS Map	Cultivated	Residential	Industrial	Orchards	Quarries	Oil & Gas	Range & Pasture	Woodlands
Bear Mountain								
Bernie Lake								
Bunyan								
Carbon								
Cisco North								
Cisco South								
Comanche								
Comyn	2086						2388	6977
Cross Plains								
De Leon								
Desdemona								
Dublin	6						71	206
Duster								
Eastland								
Gorman								
Huckaby SW								
Hunting Shirt Creek								
Kokomo								
La Casa								
Lingleville								
May								
Mercers Gap								
Pioneer								
Putnam North								
Putnam South								
Proctor								
Ranger								
Reddy Mountain								
Rising Star								
Rucker								
Sabanno								
Scranton								
Sidney								
Sipe Springs								
Star Mountain								
Turkey Creek								
Union Center								
Wayland								
Total Acres	2092	0	0	0	0	0	2459	7183

TABLE 9

EXISTING CONDITIONS LAND USE DELINEATIONS IN ACRES

SWEETWATER CREEK BASIN

USGS Map	Cultivated	Residential	Industrial	Orchards	Quarries	Oil & Gas	Range & Pasture	Woodlands
Bear Mountain								
Bernie Lake								
Bunyan								
Carbon								
Cisco North								
Cisco South								
Comanche	164			95			352	1030
Comyn								
Cross Plains								
De Leon	104						151	441
Desdemona								
Dublin								
Duster	149			40			47	137
Eastland								
Gorman								
Huckaby SW								
Hunting Shirt Creek								
Kokomo								
La Casa								
Lingleville								
May								
Mercers Gap	7						125	364
Pioneer								
Putnam North								
Putnam South								
Proctor								
Ranger								
Reddy Mountain								
Rising Star								
Rucker								
Sabanno								
Scranton								
Sidney	8761	220		145	255		5510	16097
Sipe Springs								
Star Mountain	2488			32			4332	12656
Turkey Creek								
Union Center								
Wayland								
Total Acres	11673	220	0	312	255	0	10517	30725

TABLE 10

EXISTING CONDITIONS LAND USE DELINEATIONS IN ACRES

UPPER LEON RIVER BASIN

USGS Map	Cultivated	Residential	Industrial	Orchards	Quarries	Oil & Gas	Range & Pasture	Woodlands
Bear Mountain	149		6	5			416	1215
Bernie Lake								
Bunyan								
Carbon	1833	149		8	60	83	1681	4910
Cisco North								
Cisco South								
Comanche								
Comyn	164						236	688
Cross Plains								
De Leon	194	1119	86	14			702	2052
Desdemona	8314	89	60	117		554	5606	16377
Dublin								
Duster								
Eastland	253	127	26	15		606	2625	7671
Gorman	3070	166	28	5			744	2172
Huckaby SW	209						614	1794
Hunting Shirt Creek								
Kokomo	5230			20		230	6059	17703
La Casa	1221						634	1853
Lingleville	1594			5			1603	4684
May								
Mercers Gap								
Pioneer								
Putnam North								
Putnam South								
Proctor								
Ranger	1207	589	76		110	426	5549	16211
Reddy Mountain								
Rising Star								
Rucker	8597		103	69		46	6400	18699
Sabanno								
Scranton								
Sidney								
Sipe Springs								
Star Mountain								
Turkey Creek								
Union Center								
Wayland	983			6		390	800	2339
Total Acres	33018	2239	385	264	170	2335	33253	97153

TABLE 11

EXISTING CONDITIONS LAND USE DELINEATIONS IN ACRES

WEST PROCTOR BASIN

USGS Map	Cultivated	Residential	Industrial	Orchards	Quarries	Oil & Gas	Range & Pasture	Woodlands
Bear Mountain								
Bernie Lake								
Bunyan								
Carbon								
Cisco North								
Cisco South								
Comanche	417						143	416
Comyn								
Cross Plains								
De Leon								
Desdemona								
Dublin								
Duster								
Eastland								
Gorman								
Huckaby SW								
Hunting Shirt Creek								
Kokomo								
La Casa								
Lingleville								
May								
Mercers Gap								
Pioneer								
Putnam North								
Putnam South								
Proctor								
Ranger								
Reddy Mountain								
Rising Star								
Rucker								
Sabanno								
Scranton								
Sidney								
Sipe Springs								
Star Mountain								
Turkey Creek								
Union Center								
Wayland								
Total Acres	417	0	0	0	0	0	143	416

TABLE 12

EXISTING CONDITIONS LAND USE DELINEATIONS IN ACRES

SUMMARY TABLE

Subbasin	Cultivated	Residential	Industrial	Orchards	Quarries	Oil & Gas	Range & Pasture	Woodlands
Armstrong Basin	6109	30	102	72	0	0	15124	44188
Duncan Creek Basin	6112	0	12	200	0	0	2595	7581
Lower Leon River Basin	8317	162	358	30	0	296	2592	7572
Rush Creek Basin	29160	685	165	780	160	1057	21032	61450
Sabana River Basin	45253	886	239	1886	45	741	38454	112343
South Fork Leon River Basin	18976	3409	883	1064	142	3897	34831	101764
South Proctor Basin	1008	113	8	0	0	0	300	878
Sowell's Creek Basin	2092	0	0	0	0	0	2459	7183
Sweetwater Creek Basin	11673	220	0	312	255	0	0	0
Uper Leon River Basin	33018	2239	385	264	170	2335	33253	97153
West Proctor Basin	417	0	0	0	0	0	143	416
Total	162135	7744	2152	4608	772	8326	150783	440528

Those areas designated as cultivated land include agricultural lands developed for row crops, cover crops, grain crops and fallow. Croplands were identified from the aerial photographs using the following methodology[4]:

- No evidence of use by livestock;
- Bundles of straw or hay or harvesting marks discernible;
- Crowns of individual plants not clearly discernible;
- Cultivation pattern present;
- Field boundaries regularly shaped;
- Row crops visible; and,
- Fine textured appearance.

An estimation of the relative amounts of crop types grown was made using information obtained from the Texas Agricultural Statistics Service (TASS)[2][3] and the Soil Conservation Service[5][6][7] presented on a by county basis. The 1985 TASS data indicated the numbers of acres of each crop grown in Comanche, Eastland and Erath counties from which a percentage was determined using a weighted average and applied to the amounts of acres of croplands found in each subbasin using the 1983 aerial photographs. This information is presented in Table 13.

Orchards were defined separately from other cultivated areas by utilizing aerial photographs to identify characteristic cross patterns, broad spacing and the recognizability of individual plants associated with cultivated trees. Since many of the current USGS maps are less current than the aerial photographs, information collected from the photos were used in the final interpretation.

The relative amounts of range, pasture and wooded areas in each county were estimated using published statistical information obtained from the Texas Agricultural Statistics Service (TASS)[2][3] and the Soil Conservation Service (SCS)[5][6][7]. An estimation of the percentages of rangeland, pastureland and woodlands was developed for otherwise unclassified areas using agricultural statistics bulletins and soil surveys obtained from the TASS and SCS. Based on conversations with personnel at the Soil Conservation Service offices located within the study area, the relative amounts of land in each of these categories has changed little since the current soil surveys were

TABLE 13

RELATIVE AMOUNT OF LAND USED FOR VARIOUS CROPS

	Comanche County		Eastland County		Erath County	
Crop	***% Planted***	***% Harvested***	***% Planted***	***% Harvested***	***% Planted***	***% Harvested***
Corn	*	*	0	0	*	*
Oats	16	4	11	7	36	5
Peanuts	51	51	42	42	21	21
Rye	9	1	8	2	*	*
Sorghum	6	5	6	6	9	5
Wheat	18	7	33	12	34	8
Total	100	68	100	69	100	39

From: 1985 Texas County Statistics, Texas Agricultural Statistics Division.

* Either limited production or unpublished to avoid disclosure of individual operations.

published. Conversations with Agricultural Extension Service agents indicate that there has been a slight trend in recent years for farmers to allow previously cultivated lands to revert to pasture in the Lake Proctor basin.

Non-agricultural developed areas were also identified using aerial photographs and verified to the extent possible using those available USGS maps that were at least as current as the photos. Residential areas delineated for this study include metropolitan areas, lakeside developments and cross-road communities. Localized industrial areas were defined to include those areas associated with industrial activity which did not involve oil and gas fields or quarry operations which were treated separately. Quarries include gravel and clay pits whose locations and extends were verified by comparing their position on the aerial photos with information contained on the USGS maps.

The land areas identified as associated with oil and gas operations were based on both aerial photographs and 7.5 foot USGS maps. Field observations in the study area suggested that the extent of land areas effected by the oil and gas industry are probably more extensive than information obtained from the photos and USGS maps would indicate. Data available through the Texas Railroad Commission were found to be a more comprehensive source of information on area oil wells, though due to the time required to compile a comprehensive listing, complete information on the extent and locations of oil fields was not obtained for this study. A more detailed study would be required to develop a comprehensive list of these non-point sources.

Based on the relative amounts of different soil associations found within each subbasin and information concerning crops normally grown on specific soil types as reported in soil surveys obtained from the SCS, estimates of the amounts of land suitable for cultivation were made. This information is included in Section 4.0.

Future land use acreage was estimated based on population projections obtained from the Texas Water Development Board (TWDB). Population projections from this source were designated for both major metropolitan areas and areas which pertain to the rural county. For these designations pertaining to urban and rural areas, a percent change was determined between the calculated 1983 population (which correlated with the time the aerial photos used to delineate existing land use areas were taken) and the projected population of 2022. This percentage was then used to adjust the existing acreage associated with residential and industrial lands to the exclusion of oil fields, cultivated areas and quarries (presented in tables 1 through 11) to reflect future conditions in the year 2022. Land uses other than those associated with residential and industrial activity were not adjusted similarly since the effect on their land area would be unpredictable based on a change in rural populations. Contacts with personnel at the local offices of the Soil Conservation Service who maintain records on amounts of land used for various agricultural activities indicated the watershed currently experiences a slow trend in alteration of land use patterns in rural areas.

2.4.2 Sources of Non-Point Source Pollution

The mechanisms by which NPS pollutants enter waterways, discussed in section 4.0 "Sources of Non-Point Source Pollution" were researched for those pollutants suspected of being associated with land uses characteristic of the Lake Proctor watershed. Pollutants enter the environment through various mechanisms as a function of their own physical and chemical properties as well as that of the soil or other media with which they come in contact. The mobility of NPS pollutants depends largely on their tendency to dissolve in water or attach to soil which then becomes the vehicle by which they enter waterways. Various information sources were utilized while researching the properties of various pollutants. Contacts with research organizations including the Agricultural Extension Service and published reference material were used to determine the vehicles by which NPS pollutants leave the area of application or containment and enter surface water sources based on handling and application practices.

2.4.3 Subbasin Watershed NPS Characteristics

The potential for various kinds of non-point source pollutants to originate from each of the subbasin watersheds, as evaluated in section 5.0, was based on the amount of acres associated with each land use and the pollutants normally associated with that land use. Loadings per acre of various pollutants associated with specific land uses were determined from published studies and developed into a spreadsheet into which was factored the amount of acres of each land use. The developed spreadsheet produced a rough estimate of annual loadings per acre of the various pollutants for each subbasin. Each subbasin was then ranked as to the amount of loadings predicted by the spreadsheet to be generated and the relative amounts of associated developed land. Developed lands considered to have the greatest potential for generating NPS pollution were classified as those associated with crop production, residential and industrial areas, and pasture land. Finally, soil characteristics concerning suitability for certain types of cultivated and natural vegetation, erosion potential and slopes were identified for individual subbasins based on the relative amount of each soil type (soil association) determined using soil surveys developed by the Soil Conservation Service.

2.4.4 Non-point Source Sampling Plan

A non-point source sampling plan was developed in section 6.0 by choosing single-land use watersheds that are representative of each land use category. These were identified using 1983 aerial photographs to determine land uses and USGS topographic maps to determine the associated drainage area. The primary criteria used in choosing these sites were representativeness of specific land uses and accessibility. Those drainage areas chosen include a high percentage of land used for a particular land use category in order to reduce the chance that NPS runoff might be masked by non-representative land use sources. All selected single-land use sites are located within a four mile radius to allow quick response during a storm sampling event. More than one of each single-land use watershed were selected in order to allow alternatives in the event that access problems are encountered.

2.4.5 Best Management Practices

Best management practices (BMP's) were evaluated for their applicability to the various land uses identified in the Lake Proctor watershed and their cost of implementation. A list of potential BMP's and their associated costs was compiled using various sources including the Soil Conservation Service, the Agricultural Extension Service, the Institute for Applied Research at Tarleton State University, published reference material and commercial distributors of products such as seeds and biological control organisms. BMP cost estimates are presented in table 26 in terms of the cost per acre treated. Text values for unit costs were adjusted to 1991 equivalent prices using an 8.75 percent interest rate as recommended by the Texas Water Development Board. Removal efficiencies associated with implementation of BMP's were reported for those for which values were found from reference material.

SECTION 3.0
LAND USE

3.0 LAND USE

The watershed above Lake Proctor is predominantly rural in nature and has changed very little since the early 1960's. Only a small percentage of the population is located within 20 miles of metropolitan areas of 5,000 or greater[5]. Population levels within the watershed peaked around 1920 due to an oil boom which attracted new people to the area. A succession of dry years in the 1950's forced many farms to be abandoned, while many acres of cropland were seeded to grass or remained idle. During this time the average size of farms increased as remaining landowners purchased additional land to make their operations more profitable[5].

The topography of the study area includes broken, hilly areas to the north and gently rolling hills to the south. Approximately 60 percent of the watershed includes deep, sandy loams that are suitable for crops and pasture. Peanuts and sorghum are common crops grown here. About 30 percent of the watershed includes shallow to deep loamy, clay soils best suited for rangeland because of its stony nature. The remaining 10 percent includes deep, clayey, loamy soils which are best suited for sorghum, small grains and rangeland.

The dominant harvested crop grown in the watershed is peanuts, while wheat, corn, oats, sorghum and rye are planted on fewer acres. Nearly 76,600 acres of peanuts were planted in the watershed in 1989 representing approximately 80 percent of the total crop harvested. A large part of the oats, wheat, and sorghum planted are grazed by livestock. Hay, other than sorghum, is grown on approximately 54 percent of the cultivated land[2]. The distribution of crops depend on local soil types, and potential profit. Under current market values, profits from peanuts is roughly $550 per acre; sorghum, alfalfa and rye hays bring between $100 and $120 per acre; and grain crops including wheat, oats and sorghum produce roughly $50 to $80 per acre[2][8][9][10][11].

The amounts of cultivated land, pasture and rangeland has changed little since the 1960's as agricultural trends are slow to develop in this area. The acreage of pastureland within the watershed tends to increase with time as marginal cropland or brush areas are established to improved grasses[5].

The Lake Proctor watershed has a subtropical climate with dry winters and humid summers. The mean annual precipitation ranges between 27 and 28 inches with summer thunderstorms occurring about 5 times per month. High intensity rains are common during May, June, and September. The average annual temperature here is 65 degrees fahrenheit with summer highs averaging 96 degrees. Prevailing winds here are southerly to southeasterly throughout most of the year. The growing season lasts 240 days and the average first freeze date is November 25.

3.1 General Land Use Patterns by County

The following information was obtained from soil surveys produced by the Soil Conservation Service for Comanche, Eastland and Erath counties. Though these surveys have not been updated since the 1970's, the information pertaining to dominant land uses are considered useful to this report because based on conversations with area county agents with the Soil Conservation Service, land uses have remained largely unchanged in the Lake Proctor watershed since the time these documents were published.

3.1.1 Comanche County

Approximately 317,600 acres (39 percent) of the study area is located within Comanche County in the southeast portion of the study area. The landscape here includes open prairies in the southern part of the county; sandy, wooded areas in the central and northern sections, and hilly and broken areas to the west.

The dominant land uses here include rangeland, pastureland, and cropland making up approximately 41 percent, 26 percent and 21 percent of the land use respectively. Residential and industrial areas make up less than 5 percent of the county. The main pasture grasses used in the study area include improved bermuda grass, love grass, and Klein grass[5]. The amount of pastureland found here increases with time as cropland is established to improved grasses. Beef cattle and dairy cattle are the main forms of livestock grown in this county, though hogs, sheep and goats make up a smaller percentage[3]. There are currently 59 dairy farms located throughout the county with an average herd size of 209 milk cows in 1990[12].

Approximately 71 percent of Comanche County contains soils that are suitable for crops of which peanuts, sorghum, wheat, oats, barley, watermelon and cantaloupes are the dominant varieties produced in cultivated areas[5]. Pecan orchards and peach orchards are maintained here to a lesser extent.

Soil associations found in the Comanche County portion of the watershed include approximately 80 percent deep sandy loams, 10 percent shallow to moderately deep loamy and clayey soils and 10 percent deep clayey and loamy soils. Deep, sandy and loamy soils that include the Chaney-Demona, Nimrod-Patilo, and Pedernales-Menard associations are used mainly for crops and pastureland. Crops grown on these soils include peanuts, sorghum, small grain, and pecan and fruit trees. Shallow to moderately deep loamy and clayey soils which include the Purves-Bolar, and Hensley Associations are used mainly as rangeland supporting mid to tall grasses. Deep, clayey and loamy soils that include the Krum-Lewisville-Abilene, and Truce-Thurber Associations are used predominantly for sorghum and small grains cultivation[5].

3.1.2 Eastland County

Approximately 426,800 acres (52 percent) of the Lake Proctor watershed is included within Eastland County located in the northwest half of the watershed. This area is characterized by gently rolling hills and sandy soils to the south, and hilly and broken-topography areas to the north and east.

Rangeland, pastureland and cropland in Eastland county comprise 51 percent, 18 percent and 15 percent of the area respectively[6]. Beef cattle are the main form of livestock raised here though some amount of mohair goats and diary cattle are produced. County ranches are generally operated as cow-calf operations with some areas established for crops and some for pasture. Only six dairy farms are currently in operation throughout the county[12]. Improved pasture consists mainly of Coastal bermuda grass, Klein grass and weeping love grass. Native grass cover ranges from short grasses on shallow clay to tall grasses on sandy soils[6]. Irrigated pastureland supplies supplemental forage including mainly Johnson grass, small grains, and sorghum. Clayey soils on native range that has been heavily grazed for many years are comprised mainly of buffalo grass and annual grasses. Tight sandy loams produce buffalo grass, Texas grama, and three-awn, while mesquite tends to encroach these areas to some extent. Sandy soils support dropseed, silver bluestem, three-awn, and shin oak. Roughly one third of the county as a whole is under cultivation. Croplands are primarily planted in peanuts, grain sorghum and forage crops for grazing[6].

Soil types found in that portion of the watershed occurring in Eastland County includes approximately 50 percent deep sandy and loamy soils, 35 percent very shallow to deep loamy and clayey soils, and 15 percent deep loamy and clayey soils. Deep sandy and loamy soils which include the Chaney, Pedernales-Cisco, and Patilo associations are used mainly for crops and pasture, with peanuts and grain sorghum being the primary crops. Native vegetation found on these soils is dominated by post oak savanna[6]. Very shallow to deep loamy and clayey soils that include the Exray-Bonti-Owens, Hensley-Lindy, and Brackett-Lamar associations are used mostly for rangeland due to their shallow, stony nature. Vegetation found on these soils is primarily grassland interspersed with post oak and live oak trees. Deep, loamy and clayey soils include the Truce-Thurber-Leeray associations and are used mainly as rangeland where a grassland-mesquite tree mixture exists.

3.1.3 Erath County

Approximately 75,499 acres (nine percent) of the Lake Proctor watershed occurs within Erath County. The county is divided into the Grand Prairie, West Cross Timbers and North Central Prairie physiographic regions.

Land uses in the county as a whole include rangeland (65 percent), pastureland (12 percent), and cropland (11 percent)[7]. Most of the county includes gently rolling hills used as rangeland. Cultivated lands here include some idle cropland while the major crops include oats, peanuts, and grain sorghum. Most of the oats produced here are grazed by cattle. Dairy and beef cattle are the main forms of livestock raised in the county while goats, sheep and chickens make up a small percentage. There is currently a trend in Erath County for cropland to be allowed to revert to grasslands, in part to support the livestock industry [SCS, Erath County]. Introduced grasses commonly planted for livestock include Coastal and common bermuda grass, johnson grass, weeping love grass, King Ranch bluestem, and blue panic grass. Native grasses found in pastures here include indian grass and switch grass[7]. Erath County has the highest density of dairy farms of the three county study area with 178 in operation supporting approximately 52,300 head of cattle in 1990[12].

Soil types in the portion of the watershed contained in Erath County include approximately 30 percent deep sandy loams, 20 percent deep sand, 15 percent deep loams and 35 percent shallow, stony or gravelly soils. Cropland soils are susceptible to both water and wind erosion. Deep sandy loams of the Windthorst-Duffau association include old fields of native grasses and cultivated fields planted mainly in sorghum, small grains, and peanuts. Some of these fields have been sodded in bermuda grass[7]. Deep sandy soils within Erath county include Nimrod-Seldon and Chaney-Demona associations. Nimrod-Seldon soils include croplands planted in peanuts, sorghum and watermelons, pasture sodded in bermuda grass, and wooded areas containing scrub post-oak and blackjack oak stands. The Chaney-Demona soils contain native post oak and blackjack oak woodlands, croplands planted in peanuts, small grains, and sorghum, and a few pasture areas sodded in bermuda grass. Deep loam soils include the Duffau-Bunyan association which contains mostly croplands planted in peanuts, sorghum, and small grains. A few areas are seeded to grass for pasture and some native pecan trees are located here as well. Shallow, stony or gravelly soils of the Maloterre-Purves-Dugout association series are predominantly open prairies with a few scattered live-oak motts with juniper and mesquite trees occurring in a few areas. Soils of this association, generally too shallow and stony for cultivation, are best suited for native rangeland that includes native grasses such as little bluestem, silver bluestem, side-oats grama, tall grama, and buffalo grass[7].

3.2 Existing Conditions

The watershed as a whole is comprised of 20 percent cultivated lands, roughly one percent each of residential areas and oil fields, and less than one percent of the land is used for mining operations, localized industries and orchards. The remaining land which includes rangeland, pastureland and undeveloped land makes up approximately 77 percent of the watershed. Based on weighted averages of the amounts of ranchland and farmland in each county reported in the 1985 Texas Agricultural Statistics, approximately 45 percent of the total basin includes rangeland, 19 percent is pasture and the remaining 13 percent is undeveloped. The watershed was divided into 11 subbasin watersheds as shown in Figure 1.

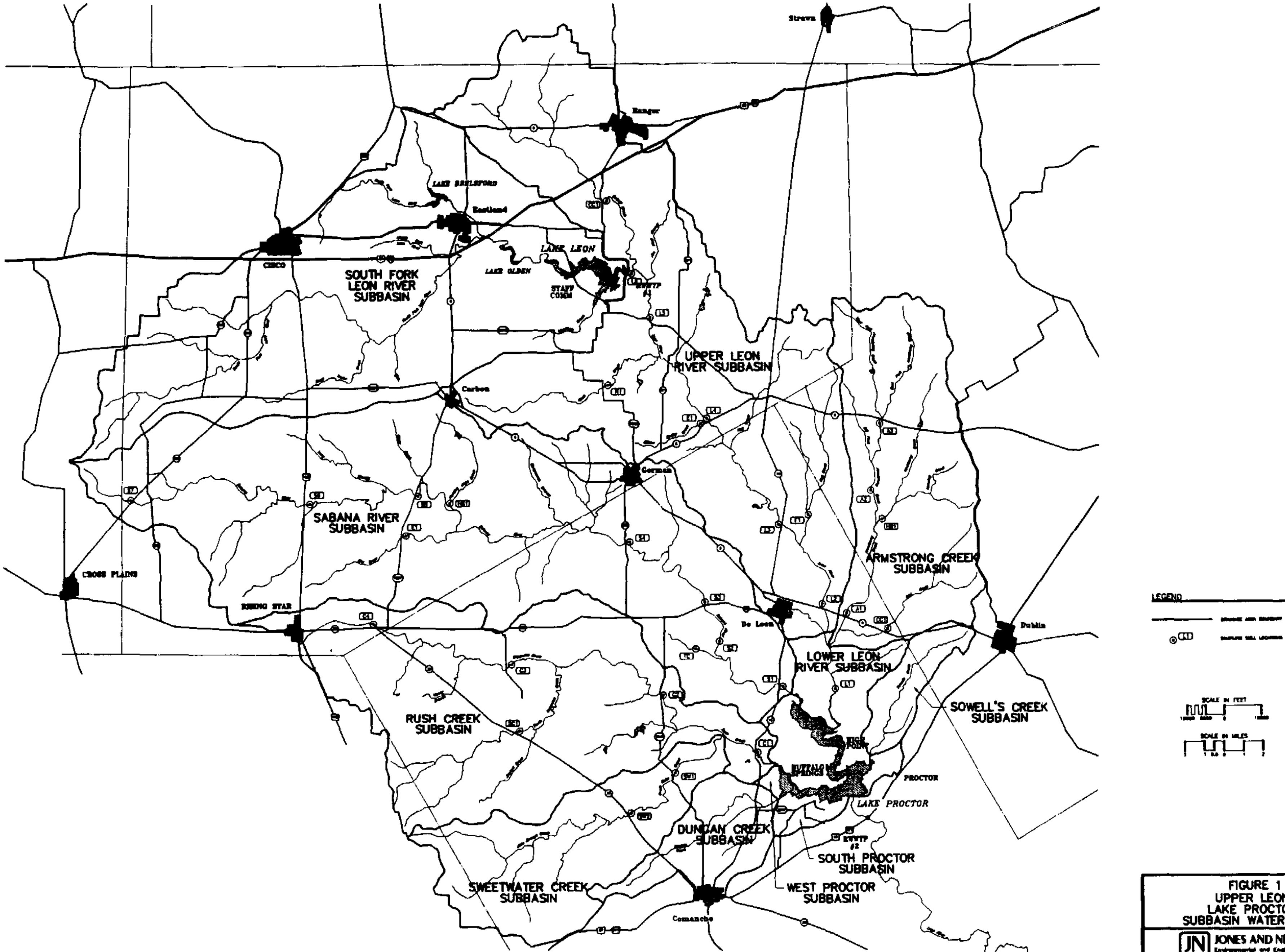
3.2.1 Armstrong Creek Subbasin

The Armstrong Creek subbasin drains approximately eight percent of the Lake Proctor watershed along the eastern boundary of the study area. This drainage includes relatively little cultivated land compared to the watershed as a whole and is dominated by pasture, range and wooded areas. Most of this drainage is located in Erath County which has a high number of dairy farming operations which dispose of the majority of the livestock wastes in close proximity to their confinement areas. Several large dairies are located here with herds in excess of 900 head in some cases. No communities of significant size are located in this subbasin as the population is essentially rural in nature. Land use areas here include cultivated land (nine percent) as well as small amounts of residential, industrial, and orchard developments (less than one percent combined). Approximately 23 percent of the drainage area is maintained as pasture, while the remaining 67 percent of the area includes rangeland and woodlands. Croplands here generally include peanuts, sorghum and small grains. Pastures are often planted in bermuda grass, while rangeland includes scattered live oak motts, juniper and mesquite trees. Rangeland grasses include little bluestem, silver bluestem, side-oats grama, tall grama, and buffalo grass.

Dominant soil types in this subbasin include loamy soils of the Duffau-Bunyan association in the lowlands (20 percent), shallow stony and gravely soils overlying limestone of the Maloterre-Purves-Dugout association in the uplands (60 percent), and deep sandy, loamy soils of the Nimrod-Seldon association (20 percent) along the western boundary[7].

3.2.2 Duncan Creek Subbasin

The Duncan Creek subbasin is located southwest of Lake Proctor and north of the Town of Comanche draining only two percent of the watershed. This basin is characterized by a relatively



7/11/91

FIGURE 1
UPPER LEON
LAKE PROCTOR
SUBBASIN WATERSHEDS

JN JONES AND NEUSE, INC.
Environmental and Engineering Services

large amount of cultivated land scattered among rangeland and pastureland. Land uses within this subbasin include 37 percent cultivated land, one percent orchards, 15 percent pasture and less than one percent localized industries while the remaining 47 percent is composed of rangeland and wooded areas.

Dominant soil types in this subbasin include deep, sandy upland soils of the Chaney-Demona (45 percent) and Nimrod-Patilo (five percent) soil associations; shallow to moderately deep, loamy and clayey soils of the Purves-Bolar association (30 percent); and deep clayey and loamy soils of the Krum-Lewisville-Abilene association (20 percent).

3.2.3 Lower Leon River Subbasin

The Lower Leon River subbasin is located to the north of Lake Proctor and drains roughly 2.5 percent of the watershed. This drainage is characterized by a relatively large amount of cultivated land area scattered among undeveloped, range and pasture lands. Land uses within this subbasin include 43 percent cultivated land, one percent residential areas, two percent localized industries, 1.5 percent oil and gas fields, 13 percent pasture and approximately 40 percent rangeland and wooded areas. The population is essentially rural with no communities of significant size located here.

The Lower Leon subbasin contains deep, sandy and loamy soils of the Chaney-Demona (60 percent) and Nimrod-Patilo (five percent) associations: very shallow to deep loamy and clayey soils of the Exray-Bonti-Owens (15 percent) and Hensley-Lindy (10 percent) soil associations: and deep loamy and clayey soils of the Truce-Thurber-Leeray soil associations (10 percent).

3.2.4 Rush Creek Subbasin

The Rush Creek subbasin, located to the west of Lake Proctor drains approximately 14 percent of the watershed. This area includes a relatively large amount of cultivated land compared to the watershed as a whole and contains representative land uses from each of the land use delineations evaluated for this study. A portion of the Town of Ranger is located in the upper reach of this subbasin contributing essentially all of the urban land. Land uses here include cultivated land (26 percent), pasture (18 percent), residential development (0.6 percent), localized industry (0.1 percent), orchards (0.7 percent), and quarries (0.1 percent), while the remaining 54 percent of the area includes rangeland and woodland.

Generally, soils within the Rush Creek drainage include deep, sandy and loamy soils of the Chaney-Demona (35 percent), Nimrod-Patilo (25 percent), and Pedernales-Menard (10 percent) associations: shallow to moderately deep, loamy and clayey soils of the Purves-Bolar (five percent) and Hensley (10 percent) associations; and deep, clayey and loamy soils of the Truce-Thurber soil associations (15 percent).

3.2.5 Sabana River Subbasin

The Sabana River subbasin is one of the larger within the watershed comprising 24 percent of the total area. This basin includes a moderate amount of cultivated land and otherwise contains representative land uses from each of the land use delineations evaluated for this study. Major residential areas within this subbasin include the Town of Gorman and a portion of the Town of Carbon. Land uses here include cultivated land (23 percent), pasture (19 percent), residential development (0.4 percent), localized industry (0.1 percent), orchards (one percent), quarries (less than 0.1 percent), and oil and gas fields (0.4 percent) while approximately 57 percent of the area includes rangeland and woodland.

Soils of the Sabana subbasin include deep, sandy and loamy soils of the Chaney-Demona (62 percent), Nimrod-Patilo (two percent), Patilo (six percent), and Pedernales-Cisco (nine percent) associations; shallow to moderately deep, loamy and clayey soils of the Hensley-Lindy (12 percent) association; and deep, loamy and clayey soils of the Truce-Thurber-Leeray (three percent), Truce-Thurber (six percent) associations.

3.2.6 South Fork Leon River Subbasin

The South Fork Leon River subbasin drains the watershed above Lake Leon in the northwest portion of the Lake Proctor watershed. This subbasin contains approximately 20 percent of the entire study area and includes the Town of Eastland and a significant portion of the Town of Cisco. This area includes roughly half of the oil and gas fields within the watershed including approximately 3900 acres. Land uses here include Pastureland (21 percent), cultivated land (12 percent), residential development (two percent), localized industry (0.5 percent), orchards (0.6 percent), quarries (less than 0.1 percent), and oil and gas fields (two percent) while approximately 62 percent of the area includes rangeland and woodland.

The South Fork of the Leon River drainage includes deep, sandy and loamy soils of the Chaney-Demona (62 percent) and Nimrod-Patilo (two percent), Pedernales-Cisco (nine percent), and Patilo (six percent) associations, very shallow to deep loamy and clayey soils of the Hensley-Lindy association (12 percent), and deep, clayey and loamy soils of the Truce-Thurber (6 percent) and Truce-Thurber-Leeray (six percent) associations.

3.2.7 South Proctor Lake Subbasin

The South Proctor Lake subbasin, drains the southern shore of Lake Proctor and is one of the smaller subbasins within the watershed with only 0.2 percent of the total area. This drainage is comprised of a large amount of cultivated land and undeveloped land. Land uses here include cultivated land (44 percent), pasture (13 percent), residential development (five percent), localized industry (LT 1 percent). Approximately 38 percent of the area includes rangeland and woodland.

The entire South Proctor Lake drainage contains soils of the Chaney-Demona association. These are deep, sandy soils having slopes ranging from zero to eight percent. These soils have a moderate potential for runoff.

3.2.8 Sowell's Creek Subbasin

The Sowell's Creek subbasin drains a small 1200 acre area to the northeast of Lake Proctor. Approximately 18 percent of this subbasin is under cultivation, 21 percent is pasture while the remaining 61 percent contains rangeland and wooded areas. This subbasin represents one of the smallest drainage in the study area comprising roughly 1.5 percent of the total watershed.

Soil types found within this subbasin include deep, sandy and loamy soils of the Chaney-Demona association (60 percent), shallow to moderately deep, loamy and clayey soils of the Purves-Bolar association (30 percent), moderately deep loamy, clayey soils of the Windthorst-Duffau association (five percent), and deep clayey soils of the Houston Black-Denton-Purves associations (five percent).

3.2.9 Sweetwater Creek Subbasin

The Sweetwater Creek subbasin drains approximately 54,000 acres along the southern portion of the Lake Proctor watershed representing approximately 7 percent of the study area. Land uses here include cultivated land (22 percent), pasture (20 percent), residential development (0.4 percent), orchards (0.6 percent), and quarries (0.5 percent), while approximately 57 percent of the area includes rangeland and woodland.

Soils found in this subbasin include deep, sandy soils of the Chaney-Demona association (30 percent), stony, shallow to moderately deep, loamy and clayey soils of the Purves-Bolar association (30 percent), and deep, clayey and loamy soils of the Krum-Lewisville-Abilene associations (40 percent).

3.2.10 Upper Leon River Subbasin

The Upper Leon River subbasin is one of the larger within the watershed making up 21 percent of the total area. This drainage includes a relatively large amount of cultivated land and residential areas as well as oil and gas fields compared to the study area as a whole. The Town of De Leon and a portion of the Town of Ranger are contained within this drainage. Land uses here include cultivated land (19 percent), pasture (20 percent), residential development (one percent), localized industry (0.2 percent), orchards (0.2 percent), quarries (0.1 percent), and oil and gas fields (1.4 percent) while approximately 58 percent of the area includes rangeland and woodland.

The Upper Leon subbasin contains deep, sandy and loamy soils of the Chaney (30 percent) and Patilo (five percent) associations; very shallow to deep loamy and clayey soils of the Exray-Bonti-Owens association (30 percent); and deep, loamy and clayey soils of the Truce-Thurber-Leeray associations (20 percent).

3.2.11 West Proctor Lake Subbasin

The West Proctor Lake subbasin is the smallest of the 11 within the study area and comprises approximately 0.1 percent of the total area. Land uses here include 43 percent cultivated land and 15 percent pasture while the remaining 42 percent includes range land and woodlands.

Only deep, sandy soils are found within the West Proctor Lake drainage, all in the Chaney-Demona association. Slopes range from 0 to 8 percent and the runoff potential is moderate.

3.2.12 Watershed Soil Association Descriptions

The Chaney association contains deep, sandy, acidic soils found on gently sloping lands. This association is mainly used for cropland interspersed with pastureland. Wind erosion is the main limitation for cropland here while wetness limits this soil's value for urban development. The surface layer pH ranges between 6.1 and 7.3. Slopes vary from one to five percent while the runoff potential is moderate[6][7].

Chaney-Demona soils are deep, sandy soils found on nearly level, to sloping lands. They are mainly used for cropland interspersed with pastureland. Wind erosion is the main limitation for cropland use while wetness tendencies limit its value for urban development. Surface layer pH ranges from 5.6 to 7.8. Slopes range from one to eight percent (one to four percent predominantly) on the Chaney soils while Demona soils slopes normally range from zero to five percent (one to two percent normally). The runoff potential is considered moderate[5].

Duffau-Bunyan soils have a loamy texture and are found on nearly level to gently sloping lands occurring in long bands along the floodplain. These soils contain mostly croplands planted in peanuts, sorghum, and small grains. Some areas of Bunyan soils are subject to occasional damaging overflow whiles sloping areas of Duffau series soils are susceptible to soil erosion and wind erosion. Surface layer pH ranges from 6.1 to 7.8. Slopes range between zero and five percent and the runoff potential is low[7].

The Exray-Bonti-Owens association contains very shallow to moderately deep loamy to clayey soils gently sloping to hilly areas found on sandstone ridges and along the slopes leading to major streams. This association is mainly used for rangeland or wildlife habitat. Few areas containing this soil are suitable for cultivation, and some of the steep stony areas are not accessible to cattle. The native vegetation is a cover of trees and an understory of tall, mid and short grasses. Many ranchers lease these areas for hunting. The surface layer pH ranges between 6.1 and 8.4. Exray and Bonti soils have slopes ranging from one to eight percent, and Owens soil slopes range from one to three percent. Runoff potential is considered moderate to high[6].

Hensley soils are used as rangeland for which the low water retention and shallow soil depth are the main limitations. These are stony, shallow, loamy soils occurring in gently sloping to sloping areas. This soil has a medium potential for native range plants, while the potential for crops and pasture grasses is low. The pH ranges from 6.1 to 7.8 in surface layers. Slopes of Hensley soils are zero to three percent and the runoff potential is considered high[5].

Hensley-Lindy soils are shallow to moderately deep loamy soils occurring on gently sloping lands along narrow ridgetops and broad uplands used primarily for rangeland. Only a few areas of Lindy soils are cultivated. Soil pH ranges from 6.1 to 7.3. Slopes range from one to five percent, and runoff potential is moderate to high[6].

Houston Black-Denton-Purves soils occupy valleys and gently sloping prairies. These are deep to shallow clayey soils found on nearly level to gently sloping lands. Most of these soils are under cultivation with small grains and sorghum. Water erosion is a problem in some areas. The surface layer pH ranges from 7.9 to 8.4. Slopes range from one to five percent and the runoff potential is high[7].

Krum-Lewisville-Abilene soils have a surface layer of calcareous silty clay or clay loam and are found in low lying areas usually adjacent to a stream or drainage. This unit is used primarily as cropland, though soil erosion in the more sloping areas limit this use without employment of soil stabilization techniques. The potential for cropland production is high, but to achieve this potential requires the construction of terraces or the use of crop residue to stabilize the surface. Range and pasture potential is also high. The surface pH ranges from 6.6 to 8.4. Runoff potential for Lewisville, Abilene and Krum soils is low, medium and high respectively. Slopes range from zero to five percent[5].

The Malotere-Purves-Dugout association includes stony, gravelly soils located on gently rolling prairies, steep limestone ridges, and slopes having a stair-step appearance. These soils are dominated by open prairies with scattered live-oak motts with juniper and mesquite trees occurring in patches. These areas are best suited to native range with common grasses including little bluestem, silver bluestem, side-oats grama, tall grama, and buffalo grass. The surface layer pH ranges from 7.9 to 8.4. Slopes range between one and five percent, while the runoff potential is considered moderate[7].

Nimrod-Patilo soils are used mainly for cropland, but many areas are interspersed with pastureland. Wind erosion is the main limitation on farming use of this soil, but because of the medium potential for crop growth, supplemental irrigation is occasionally used in the summer months. The potential for rangeland use and fertilized pasture grasses is also medium. The surface layer pH ranges from 5.6 to 7.3. Slopes on these soils range between zero and five percent while the runoff potential is considered moderate[5].

The Nimrod-Seldon association includes deep sandy soils found on nearly level to gently sloping lands. These soils contain many areas planted in peanuts, sorghum and watermelons. Some old fields have been sodded to bermuda grass pasture, and scattered woodlands contain scrub post-oak and blackjack oak stands. The surface layer pH ranges from 6.1 to 7.3. Slopes of the Nimrod and Seldon series range from zero and eight percent and one and five percent respectively, while the runoff potential is moderate[7].

Patilo soils are deep, sandy soils generally found in broad areas with nearly level to gently sloping topography and weakly defined drainage patterns. About 30 percent of the soil type is cultivated while peanuts are the main crop. The remainder supports native grasses, pasture or woodlands. Wind erosion is a hazard in cultivated areas because of this soil's coarse grained texture. A few fields are irrigated and many are established in improved pasture grass. The surface layer pH ranges from 5.6 to 7.3. Slopes range from zerp to three percent and the runoff potential is moderate[6].

Pedernales-Cisco soils are found mostly on broad, eroded floodplain. This association contains deep, loamy and sandy soils found on gently sloping to sloping lands. They are used mainly for crops, and to a lesser extent rangeland grown in native grasses including predominantly tall and mid grasses. The surface pH ranges from 6.1 to 7.8. Wind erosion is a hazard in cultivated areas because of the sand content while water-induced erosion is a problem in sloping areas. Slopes associated with these soils range from one to five percent and runoff potential is low to moderate[6].

Pedernales-Menard soils are found mostly on broad erosional uplands. This association contains gently sloping to sloping deep loamy soils that are used predominantly as cropland, while scattered pastureland occurs to a lesser extent. The low soil moisture characteristics common to these soils limits its value for farming, pastureland and rangeland. There is a medium potential for cultivated crops here, and a good cropping system is required for successful farming. The potential for production of native range plants and pasture grass is medium. The surface pH ranges from 6.1 to 7.8. Slopes on these soils range from one to eight percent and the runoff potential is low to moderate[5].

Purvis-Bolar soils found here are predominantly used as rangeland. This association includes gently sloping to sloping, stony, shallow to moderately deep, loamy soils. Purvis series soils are generally found on the upper parts of ridges while Bolar soils are found on the lower parts of slopes. This soil group's potential for use for crops or pasture is low because it has a stony surface and a shallow depth to bedrock. The surface layer pH ranges between 7.9 and 8.4. Slopes range from one to 40 percent on the Purves soils while Bolar soils range from one to eight percent (three to five percent usually). The runoff potential of these soils is moderate to high[5].

The Truce-Thurber association contains nearly level to gently sloping deep, loamy soils found along shallow valleys and sandstone ridges. They are used mainly as rangeland, though a few areas of Thurber soils are planted in small grains or forage sorghum. Surface crusting and a slow water uptake rate are the main limitations to using these areas for rangeland and farming. Terraces are used effectively in some areas to control soil erosion on Thurber soils for which the runoff potential is high. This soil has a greater potential for cool season crops than summer crops, whereby a cropping system is required that controls erosion, maximizes soil moisture availability, and maintains soil tilth. The productivity potential is medium for range plants and low for pasture grasses. The surface layer pH ranges from 5.6 to 7.8. Slopes range from zero to three percent for the Thurber soils and one to five percent for the Truce soils. The runoff potential for these soils is moderate to high[5].

The Truce-Thurber-Leeray association includes nearly level to gently sloping, deep, loamy and clayey soils found along ridges, and broad, shallow valleys. The shallow valleys generally receive extra water in the form of runoff from adjacent higher slopes. This association is predominantly used as rangeland, though several large areas of Leeray soils are used for crop production. Erosion has been found to be a problem in cultivated areas. The surface layer pH ranges from 5.6 to 8.4. Slopes of Thurber and Leeray soils range from zero to three percent while Truce soil slopes are between one and five percent. The runoff potential for this association ranges from moderate to high[6].

Windthorst-Duffau soils are moderately deep, gently sloping, sandy and loamy soils normally occurring on hills and ridges. Many fields previously put into crop production have been allowed to revert to native grasses while some fields have been sodded to bermuda grass. Cultivated areas are planted mainly in sorghum, small grains, and peanuts. The surface pH ranges from 6.1 to 7.8. Slopes range from one to five percent and runoff potential is low to moderate[7].

3.3 Future Conditions

The future land uses for the rural sections of the watershed are dictated by limitations imposed by the soil capabilities, the climate, and present economic conditions. These factors indicate that the future economy will likely be based on the original mixture of rangeland, cropland and pastureland[5].

Population projections for the year 2022, obtained from the Texas Water Development Board (TWDB) were used to estimate the increased acreage of residential and industrial lands associated with urban areas expected to develop between 1983 (when aerial photos used to estimate land use acreage for existing conditions were made) and the year 2022. The same estimated percentage of increases in population were applied to acreage under existing conditions in order to estimate the increase in land used for residential development and associated industrial land uses. Projected increases for the county as a whole were used to determine corresponding values for those similar land uses located outside the larger metropolitan areas of DeLeon, Cisco, Eastland, Gorman, Ranger and Rising Star. Other land uses delineated for this study, including cultivation, quarries, oil and gas, pasture and rangeland were not similarly adjusted due to the expectation that rural areas within the Lake Proctor watershed are as likely to experience decreases as well as increases in overall development during the next 30 years. The estimated increases in the amount of land used for residential development and associated industrial activity between 1983 and 2022 in the study area are 17.3 percent and 57.3 percent respectively.

3.3.1 Armstrong Creek Subbasin

The Armstrong Creek subbasin has a low expected future population increase compared to the watershed as a whole because of its lack of existing urban development. Though the existing population is expected to increase by 60 percent before the year 2022 based on figures for Erath county rural areas, the actual number will be low because of the basins small size and rural nature. This drainage is projected to experience a 60 percent increase in both residential land area from approximately 30 to 48 acres and associated industrial area from 102 to 164 acres between the years 1983 and 2022.

3.3.2 Duncan Creek Subbasin

The Duncan Creek subbasin, located within Comanche county is expected to experience negligible growth because of its sparsely populated character. No major urban areas are located within this basin for which major contributions to future non-point source loadings are expected to develop. This drainage is projected to experience almost no increase in residential land area or associated industrial area between the years 1983 and 2022.

3.3.3 Lower Leon River Subbasin

The Lower Leon River subbasin is expected to experience some of the largest increases in urban development in the study area during the next 30 years as a percentage of existing conditions. Though no major urban areas currently exist here, lakeside developments could double in size if expected trends for Comanche county outside major urban areas applies. Because of its relatively small size, this drainage area will contribute only a small amount of the total developed area within the watershed. This drainage is projected to experience a doubling in both residential land area from 162 to 367 acres and associated industrial area from 358 to 812 acres between the years 1983 and 2022.

3.3.4 Rush Creek Subbasin

The Rush Creek subbasin is expected to experience only a moderate amount of development potentially contributing to non-point source pollution though the town of Rising Star is contained within its boundaries. The projected population increase for this subbasin between 1983 and 2022 includes a net reduction expected for the town of Rising Star from 500 acres of occupied residential area to approximately 380 acres, a more than doubling of non-metropolitan residential areas from 180 to 410 acres, and an increase in land used for industry from approximately 165 acres to 335 acres.

3.3.5 Sabana River Subbasin

The Sabana River subbasin has one of the lower expected increases in population during the next 30 years despite its inclusion of the towns of Gorman and Carbon. This is due to the heavily rural character of the drainage and only an expected four percent population increase in the two metropolitan areas. The rural county population is projected to increase by 93 percent by the year 2022, but because of its sparse characteristics will result in a small actual gain. This drainage is projected to experience a five percent increase in residential land area from 885 acres to 928 acres and a 75 percent increase in associated industrial land area from 239 acres to 416 acres between the years 1983 and 2022.

3.3.6 South Fork Leon River Subbasin

The South Fork Leon River subbasin is projected to experience an above average increase in population during the next 30 years, though estimated population increases for the two major metropolitan areas, the towns of Cisco and Eastland are only -8.8 percent and 0.4 percent respectively. This is due to approximately 470 acres of residential area and 220 acres of associated industrial operations located outside major towns that are expected to experience a 76 percent population increase.

3.3.7 South Proctor Lake Subbasin

The South Proctor Lake subbasin is expected to experience a doubling in population by the year 2022 based on projections for Comanche county outside major metropolitan areas. No urban areas of significant size are located here though existing lakeside developments may experience expansion in the future. This drainage is projected to experience an approximately 125 percent increase in residential land area from 113 acres to 256 acres and a corresponding increase in associated industrial land area between the years 1983 and 2022.

3.3.8 Sowell's Creek Subbasin

The Sowell's Creek subbasin is expected to continue to be dominated by agricultural land uses resulting in a small, if not negligible population increase during the next 30 years. No urban communities occur here and negligible changes are expected during the next 30 years.

3.3.9 Sweetwater Creek Subbasin

The Sweetwater Creek subbasin is expected to experience only a small gain in population because of its rural nature and the lack of any significant urban development. This drainage is projected to experience an approximately 125 percent increase in residential land area from 220 acres to 500 acres between the years 1983 and 2022.

3.3.10 Upper Leon River Subbasin

The Upper Leon River subbasin is expected to have a modest increase in population potentially contributing to NPS loadings despite its inclusion of the towns of De Leon, Ranger and portions of the towns of Carbon and Gorman. This drainage is projected to experience a 14 percent increase in residential land area from 2240 acres to 2550 acres and a 48 percent increase in associated industrial area from 385 acres to approximately 570 acres between the years 1983 and 2022.

3.3.11 West Proctor Lake Subbasin

The West Proctor Lake subbasin is expected to experience negligible growth during the next 30 years due to its current rural nature. No significant communities exist within this small basin which is heavily used for cropland. No significant increase in residential or industrial land areas are expected between 1983 and 2022.

SECTION 4.0

SOURCES OF NON-POINT SOURCE POLLUTION

4.0 SOURCES OF NON-POINT SOURCE POLLUTION

Sources of non-point pollution (NPS) in the Lake Proctor drainage include both urban and rural areas. Land uses identified for the study area that potentially contribute to NPS pollutants include cultivated lands, urban residential land, industrial areas, land used for livestock production and undeveloped land. Based on information collected from empirical data indicating average loadings of NPS pollutants that are representative of various land use categories, feedlots contribute the highest amounts of loadings of those land uses found in the study area on a per acre basis as shown in table 14. Other representative land uses generate lesser amounts of loadings per acre but more for the watershed as a whole. Predicted annual loadings for the Lake Proctor watershed are shown in table 15.

Cultivated land becomes a source of NP pollutants through the application of fertilizers and pesticides. These compounds normally contribute to NPS loadings either as attached to soil particles or dissolved in water generated by storm events.

Agricultural lands associated with livestock production include pastures, rangeland and confined areas such as feedlots. Pollutants generated by these areas include nutrients that come primarily from waste material that washes off associated lands during rainfall. Dairy farms, most prevalent in the eastern portion of the Lake Proctor watershed, contribute pollutant loadings through runoff from confinement areas as well as from lands on which livestock wastes are applied for the purpose of waste treatment. Pasture and range lands have a lower potential for contributing pollutants on a per acre basis than do livestock confinement areas, but because of their larger associated land area potentially contribute greater amounts of loadings for the watershed as a whole.

Urban lands have one of the higher predicted NPS loading rates of any of the land use areas within the watershed. These sources include lawns applied with fertilizers and pesticides, seepage from septic tanks, construction areas and impervious surfaces on which debris accumulates. The primary vehicle by which pollutants from these sources enter waterways is stormwater.

TABLE 14

NPS LOADINGS LBS/ACRE/YEAR BASED ON EMPIRICAL DATA

Type	*TSS*	*BOD*	*Total P*	*Total N*
Cropland	27-4554	4-30	0.18-3.6	3.8-27.7
Residential	179-2054	27-45	1.0-5.3	6.2-8
Industrial	44.7-741	0	0.09-0.36	1.7-9.8
Pasture	89-447	5*	0.01-0.22	0.1-1.5
Feedlots	6520-24,100	20-5000	8.7-554	18-1100

From: [13] [14] [15] [16]

* No data available, 5 lb/ac assumed comparable to cropland.

TABLE 15

PREDICTED ANNUAL NPS LOADINGS (X 1,000,000 LBS)

FOR THE LAKE PROCTOR WATERSHED

EXISTING CONDITIONS

	TSS	*BOD*	*Total P*	*Total N*
Cropland	4.377-738.363	0.649-4.864	0.029-0.584	0.616-4.491
Residential	1.386-15.906	0.209-0.348	0.008-0.041	0.048-0.062
Industrial	0.096-1.595	0	0.0002-0.0007	0.004-0.021
Pasture	14.422-72.433	0.810	0.002-0.036	0.016-0.243

Industrial sources within the study area include gravel quarries, oil and gas fields and miscellaneous localized operations. The amounts of loadings generated by these sources are highly variable and dependant on the types of materials used at the particular facility which may come in contact with stormwater.

4.1 Cultivated Cropland Sources

Non-point pollution associated with storm water runoff from cultivated lands is transported either as attached to eroding sediment or dissolved in water. The degree to which these processes occur is a function of the chemical properties of the contaminant and the texture of the soil. The origin of non-point source runoff from cultivated lands primarily includes applied fertilizers and pesticides. The amount of runoff can be effected by farming practices whereby soil erosion prevention and conservation techniques can be employed to reduce runoff losses.

Sediment is a major fraction of non-point source runoff in cultivated areas, and is most pronounced in the Lake Proctor drainage in those areas involving cultivated land on steep slopes where fine textured soils such as clays and clay loams occur. Sandy soils, used predominantly for the cultivation of peanuts are most susceptible to wind erosion, while their course texture causes them to be less effected by flowing water. Most of the sediment loadings from agricultural sources occur during the spring, and especially when rains fall on still frozen soil[1] Soil materials include both cohesive and noncohesive sediments, whereby clays, organic materials and other fine particles tend to form bonds which cause flocculation and adsorption of pollutants.

Poor farming practices that may result in a large amount of non-point pollution from sources including the following:

- Farming on long slopes without terraces or runoff diversions;
- Row cropping up and down moderate or steep slopes;
- Bare soil following seeding of crops;
- Bare soil between harvest and establishment of new crop canopy;
- Intensive cultivation close to a stream;

- Poor crop stands;
- Gully formation; and,
- Long exposure of bare soil resulting from land use.

4.1.1 Fertilizers

Phosphorous

Phosphate ions are relatively immobile in soils due to their insolubility and do not tend to leach following storm events, but are strongly adsorbed by soils and tend to move with the sediment during storm induced soil erosion[1]. For those soils from which phosphorous is most likely to precipitate and consequently move out of the erosion zone and into groundwater sources (potentially creating problems in subsurface waters), the surface runoff of P is not necessarily reduced since more phosphorous may be added to replace that which is lost.

Most of the phosphate forms applied to croplands are removed by crop uptake or soil erosion since P is held as an anion by clays and organic matter. Because of these properties P is generally found in low concentrations dissolved in water. Almost all phosphorous originating from commercial fertilizers remains near the point of application, and after a normal growing season, fertilizer phosphorous applied in the spring tends to reside in the upper five cm of the soil layer where it is more susceptible to soil erosion. Exceptions to this include sandy or peat soils which show little tendency to react with phosphorus[1]; and alkaline, calcareous soils which form calcium complexes with phosphorous which are more likely to precipitate. In this way, calcareous soils control the solubility of P[17]. Calcareous soils within the Lake Proctor watershed include the Maloterre-Purves-Dugout soil associations of Erath County, the Pedernales-Cisco, Brackett-Lamar, and Truce-Thurber-Leeray associations of Eastland County and the Purves-Bolar, and Krum-Lewisville-Abilene soil associations of Comanche County. Phosphorous fixation in soil is most pronounced in acidic soils containing Al and Fe oxides, as well as by soils that have a high organic matter content. In acidic soils, which is characteristic of those having a high clay and organic matter content, phosphorous becomes less mobile as calcium is rapidly lost from soils with low pH values and phosphorous reacts with Fe and Al ions if present[17] forming a complex that is relatively immobile. NPS phosphate loadings from agricultural lands have been found to range between 0.09 and 3.6 lb/ac-yr[13] from one source and 0.03 and 2.1 lb/ac-yr, with an average value of 0.4 lb/ac-yr in another[18].

Loadings contributed by phosphorous applied as fertilizer are predicted to be low in the watershed because of the flatness of the terrain. Phosphorous applied as fertilizer becomes a non-point source primarily as attached to fine soil particles most susceptible to erosion on steep slopes. The predominant erosion problems within the study area result from wind blown sandy soils which are not as likely to complex with phosphorous as are silt and clay particles.

Nitrogen

Roughly half of the nitrogen applied as fertilizer either goes into soil organic matter or is lost to the environment through volatilization, de-nitrification, surface runoff or leaching. Because of their tendency to dissolve in water, nitrogen forms are relatively mobile, and easily enter surface and groundwater sources when over-applied. Nitrogen lost through leaching and surface runoff often reappears in the form of nitrate in surface and ground water which represents a major health concern in drinking water supplies[1]. Nitrate contamination of drinking water supplies contributes to the illness known as methemoglobinemia in infants and, though much more of a problem in groundwater sources can become a concern in surface drinking water supplies. Nitrogen exists in soils in four basic forms: ammonium, nitrate, organic phytonitrogen in plant residues, and protein nitrogen in microorganisms[1]. Most of the reactions of the nitrogen cycle in soils involve microbial activity and are thereby sensitive to temperature, moisture content, and aeration[19].

Nitrogen contribution to NPS runoff in the Lake Proctor Watershed is a significant problem only during occasional intense storm events which cause large amounts of applied N to be washed off of treated croplands. Research conducted by the Agricultural Extension Service by Dr. Dale Pennington at Texas A&M University indicate that overall for the area, more nitrogen is removed during harvest than is applied. Soil analyses conducted by county agents conclude that very low concentrations of nitrogen (1 to 2 lbs/acre) are found remaining following a growing season suggesting that over-application is not occurring[20].

Ammonia injection is a common method of applying nitrogen fertilizer to field crops in the study area. Split nitrogen fertilizer applications are common for fields planted in coastal bermuda grass[20]. These methods are explained in greater detail in section 7.1.1.

4.1.2 Pesticides

Pesticides become sources of non-point pollution by being transported in the atmosphere, groundwater or surface water. The degree to which these processes occur depend on atmospheric conditions, the mobility of the pesticide, and the characteristics of the soil.

Atmospheric transport includes drift occurring during application and by wind erosion involving pesticides adsorbed to wind blown soil particles. Drift is that portion of applied pesticides that do not reach the application target, but instead are carried from the site by wind due in part to improper application techniques. Common pesticide losses to drift range from 25 percent to 75 percent [19]. The most common form of wind erosion found in the Lake Proctor study area involves sandy soils on which peanuts are the primary crop. Though pesticides do not have a tendency to adsorb to sand particles, following a period with no rainfall those remaining in the surface layers of sandy soils are susceptible to loss in this way.

Leaching is the primary mechanism by which pesticides enter groundwater sources. Shallow groundwater flows can ultimately reach surface waters following storm events if induced by soil conditions to move laterally. Leaching is controlled by the soil type, pesticide composition, and climatic factors. Mobility of pesticides is generally a function of their solubility in water, which is inversely proportional to a pesticide's tendency to adsorb to soil particles and organic matter. Those compounds with high water solubility are more likely to leach than those having low solubility.

Pesticide adsorption depends more on organic matter content than clay content for nearly all pesticides. Non-ionic compounds such as organochlorine and organophosphorus insecticides absorb to organic material more readily than to clay particles. Pesticides are leached more readily from course than fine textured soils because of the reduced attraction these soils impart[1]. Water can facilitate desorption of pesticides from soil particles depending on the amount, intensity, and frequency of water infiltration[13].

The sorption of pesticides to soil particles varies with the composition of the particular pesticide. Acidic and basic compounds are effected primarily by soil pH which controls the compound's ionic charge which then controls their adsorptivity to clay and organic colloids. Weakly adsorbed, water soluble compounds are desorbed readily by water and have a greater tendency to leach. Organochlorine insecticides are the least mobile pesticides since they have limited solubility in water[21] while organophosphorus insecticides are slightly more mobile and the water soluble acidic herbicides are the most mobile. The effect that pH has on adsorption of organic chemicals depends on their composition. The adsorption characteristics of neutral compounds such as organochlorine pesticides is essentially independent of pH while polar compounds tend to be more influenced by the ionic content of the soil. The correlation between adsorption characteristics and pH does not always apply since the organic matter and clay particles have varying attractions for these compounds[21]. A list of pesticides commonly used for specific crops is presented in Table 16.

4.2 Orchard Sources

Multiple sources were utilized to assess the number of acres of pecan orchards located within the Lake Proctor watershed. Analysis of 1983 aerial photographs indicated that commercial pecan orchards occur on approximately 4600 acres, or 0.5 percent of the study area. Contact with the Agricultural Extension Service in Comanche county revealed that 16,500 acres of orchards including both improved and native pecans were harvested 1990 in Comanche county as reflected in the "Results of 1990 Agricultural Demonstration Statistics Handbook"[22]. An area pecan merchant reported that between 16,000 and 19,000 acres of orchards occur in Comanche county alone [23] while a source with the Town of Comanche Chamber of Commerce indicated that

TABLE 16

COMMONLY USED PESTICIDES CHARACTERISTICS

Crop	*Pesticide Trade Name*	*Use*	*Human Toxicity if Ingested**	*Mobility*
Peanuts	Benlate 50DF	Fungicide	Low	**
	Bravo 726E	Fungicide	Low	**
	Dual 8E	Herbicide	High	Moderate
	Kocide 606	Fungicide	High	**
	Manzate 200	Fungicide	Low	**
	Nemacure 15G	Nematicide	**	Moderate
	Poast	Herbicide	**	**
	Telone	Nematicide	**	**
	Temik 15G	Insecticide, Nematicide	High	High
	Terraclor	Fungicide	High	**
	Treflan	Herbicide	Low	Low
Wheat	Glean	Herbicide	Moderate	Moderate
	Lannate	Insecticide	**	High
	Malathion	Insecticide	High	**
	Methyl Parathion	Insecticide	**	**
	Sevin 8DS	Insecticide	High	**
Sorghum	Cygon	Insecticide	High	**
	Methyl Parathion	Insecticide	**	**
Pecans	Asana	Insecticide	High	**
	Benlate	Fungicide	Low	**
	Cymbush	Insecticide	High	**
	Du-Ter	Fungicide	**	**
	Guthion	Insecticide	High	Low

TABLE 16

COMMONLY-USED PESTICIDES CHARACTERISTICS

(Continued)

Crop	*Pesticide Trade Name*	*Use*	*Human Toxicity if Ingested**	*Mobility*
	Lorsban	Insecticide	High	**
	Malathion	Insecticide	High	**
	Sevin 8DS	Insecticide	High	**
	Super Tin	Fungicide	**	**
	Roundup	Herbicide	Moderate	Low
	Starfire	Herbicide	**	**

From : The Standard Pesticide User's Guide[25].

* Acute Oral LD50 for Rats mg/kg, low: 6,000 - >10,000 mg/kg, medium: 3,000 - 6,000 mg/kg, and high: 0 - 3,000 mg/kg.

** Information unavailable when this report was prepared.

12,000 acres of native pecans and 15,000 acres of improved pecans currently exist in Comanche county [24] based on data received by them from the County Agricultural Extension Service. Finally, the Agricultural Extension Service for Eastland county indicated that 3030 acres of orchards exist in that county[25]. Contact with the Soil Conservation Service in Comanche, Texas confirmed that nearly all the pecan orchards found in Comanche county are within the Lake Proctor watershed and few have been added since 1985[26]. Based on this information, the actual amount of land dedicated to pecan orchards within the watershed is probably between 16,000 and 19,000 acres.

Fertilizers and pesticides are potential pollutants originating from orchard areas, but because of the intensive management used here, and the expense associated with pesticide use, very little of the applied chemicals are allowed lost to the environment. Pesticides are normally applied directly to leaves using spray equipment resulting in a small likelihood of waste. Those pesticides reaching the soil tend to break down chemically. Fertilizer is normally applied to orchards through injection into underground irrigation systems and to a lessor extent through granular application at the ground layer[20]. The high uptake rate exhibited by pecan trees results in rapid absorption of fertilizers applied near the root. Contamination of groundwater here is unlikely since its depth is well over 100 feet.

4.2.1 Fertilizer

Generally, 100 lbs/acre of nitrogen fertilizer are applied to orchards during a single application, though the exact amount used is normally determined by a soil test. Because of the high uptake rate of pecan orchards resulting from a high leaf density which accelerates uptake of water through transpiration, most additives are quickly taken up by the plants so that very little is available to leach or runoff. Zinc is applied about five or six times a season, but because of the uptake rate rarely contribute to NPS pollution[20].

4.2.2 Pesticides

As is true for fertilizers, very little pesticide is wasted in a pecan orchard. Most applications are made using mist blowers which effectively apply pesticides to leaf areas with almost no loss to the atmosphere. Most pesticides used in orchards break down quickly if allowed to reach the soil, though virtually none leave the point of application. Orchard owners normally triple-rinse pesticide containers before discarding and reuse leftover spray to eliminate potential losses from handling areas. Common pesticides used include Lorsban, Asana, Benlate, Cymbush, Du-Ter, Guthion, Malathion, Sevin and Super-Tin[20].

4.3 Dairies

Sources of non-point pollution associated with dairy farms include feedlots and confining areas, lands irrigated with liquid wastes, and lands where manure is applied. Generally, dairy farming operations within the study area involve both collection of wastes from cattle confinement areas into lagoons and the scraping of solids from the ground in feedlots and other confinement areas.

Liquid wastes collected in lagoons are spray irrigated onto farmland while solids collected by scraping are land applied using spreading equipment. Land used for waste treatment does not include agricultural croplands used for human consumption crops.

The amount of available land in Erath County is considered sufficient to handle all the wastes generated by dairy and beef cattle operations now and in the foreseeable future if some amount of planning and cooperation with dairymen is attained. The specific areas available for application of dairy wastes are limited by numerous creek bottoms and also due to the need for obtaining permission from landowners required for land application. The majority of livestock wastes are applied on the farms at which they are generated, and in close proximity to the confining area. The trend to land-apply wastes off-site is increasing though the need still exists to design nutrient management plans for different land areas[27].

Most phosphorous in animal wastes is bound to or is a part of the structure of large, relatively insoluble compounds so are not readily lost to climatic conditions. Organic phosphorous forms contained in manure have a greater mobility in soils than inorganic forms, probably because soil microorganisms incorporate organic P during the breakdown of soil organic matter[17]. Dilution resulting from washing operations and rainfall will lower the concentrations of phosphorous in wastes but will not lower the quantity[29]. Little or no gaseous losses of phosphorous are known to occur from animal wastes because of it's chemical stability against volatilization.

Inorganic salts, including potassium, calcium, magnesium and sodium enter runoff and groundwater largely by dissolving in water. Calcium and magnesium have a greater tendency to form inorganic precipitates than either sodium or potassium and are less leachable when exposed to rainfall[29].

The TWC is currently trying to work with the dairy farmers in improving communication and cooperation. Programs may be instigated in the future to assist dairymen in implementing the most updated methods to manage their wastes. Problems sited by the TWC include lack of soil erosion prevention through non-implementation of diking and diversion structures, and losses occurring during off-site transport of solids. In the case of small dairy operations, the addition of soil erosion prevention techniques may ultimately make installation of lined lagoons necessary where they are not now required as for permitted dairies[30].

4.3.1 On-Site Sources

Livestock generated waste sources occur primarily in the form of runoff from lands applied with solid and liquid wastes, as wash-off from livestock confinement areas and from occasional spills from wastewater lagoons that are allowed to become overloaded. The amount of available land within the watershed is adequate to treat all livestock wastes produced in the next 30 years provided adequate planning is done concerning the distribution of land areas used for treatment and cooperation with dairymen is attained. The specific areas available for application of dairy wastes are limited by numerous creek bottoms and also due to the need to obtain prior permission from landowners for utilization of their lands. The majority of livestock wastes are applied on

The potential for NPS runoff from livestock waste application primarily results from poor application practices. If not properly applied, irrigated liquid waste can induce runoff before the soil allows infiltration. Though the land areas required to be available for waste disposal are stipulated in no-discharge permits required for those dairies with an excess of 250 head, the numerous small dairies found in the watershed are normally regulated only when the Texas Water Commission (TWC) determines there is a pollution problem following a citizen complaint downstream. Approximately 40 percent of the 179 dairies in Erath County are currently unpermitted[12].

There may be a tendency for small dairy operations to over-apply wastes because of the relative difficulty involved with transporting it off-site. The practice of discing in solids following application, intended to reduce the amount of nutrients lost to runoff, is unappealing to landowners partly because of the added cost, but also because discing operations performed during months other than february, march and april decreases a grass stands ability to recover. In addition, those application areas chosen because of ease of access may be located close to streams, floodplain, or on lands having steep slopes, all of which conditions that increase the potential for these pollutants to enter surface water sources. The measurable amount of total nitrogen in soils used for dairy waste treatment will generally not be increased with time unless large quantities are continuously applied[28].

Rain events can result in substantial leaching of soluble nitrogen compounds from solid wastes into the groundwater and in the form of runoff from concentrated stockpiles before application, if not properly covered. High concentrations of water soluble compounds including mainly nitrogen forms are found in these waste streams as well as inorganic salts such as potassium, calcium, magnesium and sodium. Soluble nitrogen makes up approximately 50 percent of the total nitrogen in steer manure. Due to rain exposure and washing operations, the volume of liquid wastes will be increased, and the concentration diluted while solid wastes become less manageable. Nitrogen loss by ammonia volatilization, primarily of the urine fraction during hot, dry weather conditions is most evident in open feedlots rather than total confinement systems[28].

the farms on which they are generated and in close proximity to the confining area. The trend to land-apply wastes off-site is increasing though the need still exists to design nutrient management plans for different land areas. Pastures and livestock handling areas such as confining areas are major sources of nitrogen and phosphorous resulting from improper management.

Potential sources of NPS pollution associated with dairies include illegal discharges from lagoons that are not pumped often enough and also from improper handling of solid waste on-site[31]. Only those dairies with an excess of 250 head of cattle are necessarily regulated by the TWC, while all smaller operations require a waste management plan, a permit is required only if a substantial potential for pollution of waterways is determined by TWC to exist.

Livestock wastes are generated at several areas within a dairy operation including the milking parlor from which flush water is generated during cleaning operations, feeding lanes which are often located down grade from the milking parlor in order to allow utilization of the same flush water, and manure storage areas. Some area dairy operations, typically the large ones, employ confinement techniques whereby all animals are maintained in a relatively densely populated area denuded of vegetation in order to ease the task of handling a large herd efficiently. Others may employ some combination of feedlots and pasture, or full utilization of pastures for cattle feeding. All dairy operations have some amount of confining area necessary for cattle inspection and vaccination operations. The potential is greatest for runoff from operations with large confining areas in which cattle are housed at high densities. Herd densities in confinement areas in the adjacent Bosque River basin vary between roughly two and eight cows per acre[32]. State law restricts herd densities to a minimum of 600 square feet per animal. Figures 2 and 3 show a typical dairy operation.

Waste disposal methods used at dairy operations within the watershed are fairly similar since there are few design alternatives available. Generally, liquids are caught in a lined lagoon from which waste is pumped and used to irrigate fields such as coastal bermuda or some other non-human consumption crops. Solids are scraped from the confining "stomped-in" areas and

Dairy Farming Operation

Runoff From Dairy Farm

stockpiled before being spread on agricultural land. Solids applied in this way are required to be disced within 48 hours of application in order to reduce the likelihood of runoff[30].

Discharges from on-site lagoons can occur as a result of inadequate irrigation pumping of wastes that continuously collect there from the confinement areas. Lagoons are used not only to collect and store wastes but also treat the waste by breaking down solids in an anaerobic environment. The number and configuration of lagoon systems that may be found within a particular dairy vary with the needs of the operation. Smaller lagoons are often used to capture the normal, smaller flows generated by flush water produced on a sustained basis within the milking parlor and otherwise captured from the confining area. Some drainage systems are designed to pass the same flush water over both the milking parlor and feeding lane areas in order to reduce the volume of water used. For dairies with large confining areas, larger lagoons are often designed to capture runoff from the 25 year 24 hour storm event and are utilized only during high flow situations. Regardless of the lagoon system configuration, it is required to be designed to capture this storm event[32].

4.3.2 <u>Irrigation Water</u>

Generally, irrigation wastes are applied only to those areas that can be reached by the piping system. Because of this, liquid wastes are typically applied in close proximity to the lagoon, potentially resulting in a heavier application rate than would be needed with more available land area[27].

The application of wastewater from lagoons by irrigation tends to decrease the soils' infiltration rate, probably due to the addition of monovalent cations (sodium, potassium and ammonium) which cause soil aggregates to disperse thereby reducing the paths of movement through the soil[29]. This would have the effect of increasing potential runoff since rainwater would be slower to enter the soil layer. Studies show that liquid dairy wastes applied at a rate of 53 cumulative wet tons/acre to frozen ground increase ammonium nitrogen and total coliform content in runoff, but does not increase the total nitrogen content over conditions where none is applied[29]. The use of liquid systems is becoming more prevalent, partly because liquids do not require storing, spreading and discing as do solids handling systems. But, since farmers prefer the use of concentrated forms of nutrients, it is unusual to find an adjacent landowner who is willing to accept liquid wastes for application on his property[27].

4.3.3 Solid Waste Application

Solid wastes are, as is true for liquid wastes typically applied to lands in close proximity to the confinement area in which they are generated. While transport of solids into neighboring counties occurs in a few cases, most is applied within 1/4 mile of the milking parlor. Some area dairies transport solid wastes to Cresson, Texas in northeast Somerville County where a composting facility exists, though approximately 95 percent of the total amount generated in the study area is applied to farm lands. Conversations with representatives of the Texas Agricultural Extension Service, indicated that excess nitrogen has been found to move vertically or laterally when solids are applied at two to six times the recommended application rate[27]. Increasing the rate of application at a site can increase the amount of nutrients lost in runoff.

4.3.4 Regulatory Requirements Effecting Dairies

The TWC does not allow any dairy farming operation, regardless of the size to discharge to surface waters. Those dairies having in excess of 250 head of cattle are required to have a no-discharge permit from the TWC. For waste disposal purposes, dairy farms are required by law to have an adequate amount of land area available to treat all wastewater generated by their operations, which may include owned or leased land. Permits may be required for smaller dairies if it is determined that they create a substantial hazard to water quality. Normally no treatment facilities are necessary for these smaller operations if it can be demonstrated that there is no discharge[30]. Those dairies that operate confining areas are required to install lined lagoons capable of retaining the 25 year 24 hour storm event falling within the drainage area associated with the total confining area.

4.4 Industrial Sources

The predominant rural non-agricultural industrial operations within the watershed include oil and gas (1.1 percent), and mining (0.1 percent) for gravel and clay. Other localized industries that are associated with urban areas make up less than 0.5 percent of the watershed.

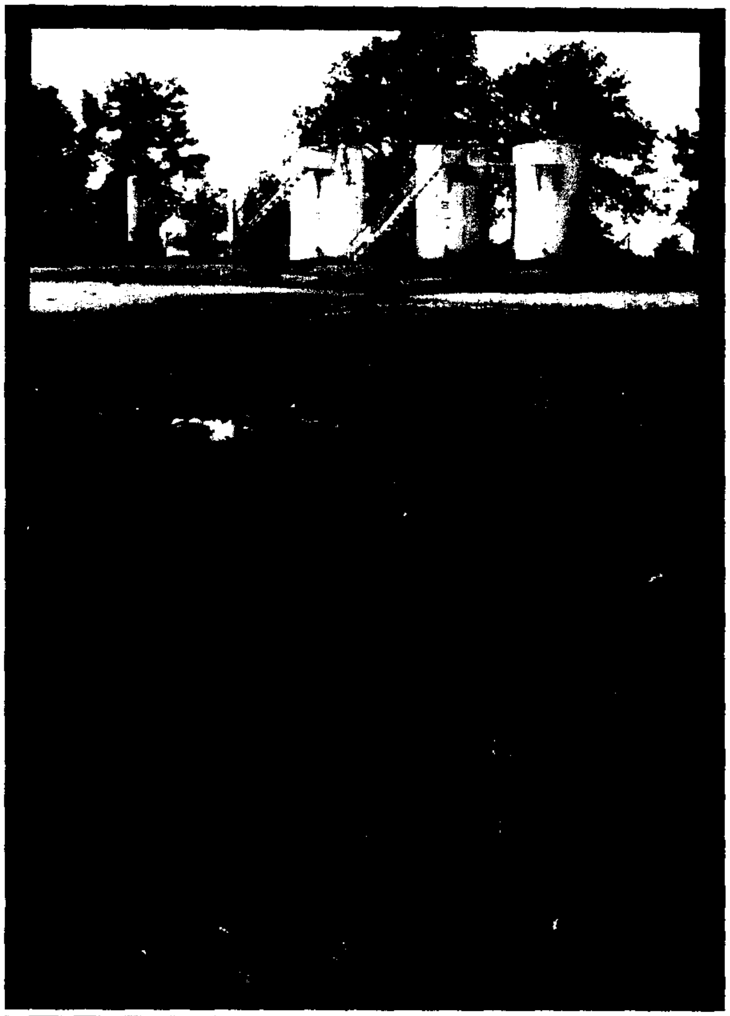
4.4.1 Quarries

Open pit surface gravel mining operations in the study area include isolated sites of roughly 10 to 15 acres in size. The largest number of acres of these operations occur within the Sweetwater Creek, West Proctor, South Fork Leon and Rush Creek subbasins, together comprising 94 percent of the total area associated with surface mines in the Lake Proctor drainage.

Gravel mining operations are potential non-point sources of erosional sediment and acid mine drainage. Because of the open pit nature of these operations, soil exposed by the removal of vegetative cover is susceptible to erosion. Exposed sediments in areas of acidic substrata will acidify the drainage water and increase the dissolution of metals exposed by excavation.

4.4.2 Oil and Gas Fields

Oil mining operations are potential sources of hydrocarbons contamination of runoff in that petroleum wastes exposed to storm water runoff tend to be carried downstream by floatation after extraction from saturated surface material such as leaf litter and soil. Oil leakage from well areas and associated oil storage tanks generally collect in the upper one inch of soil where susceptibility to wash-off is high[33]. Site visits to the study area revealed that leaking oil storage tanks are not uncommon in the Lake Proctor watershed. Figures 4 and 5 show a typical contamination site.



Runoff From Typical Oil/Gas Site

Local Contamination From Typical Oil/Gas Site

The potential for NPS loadings resulting from oil and gas field operations has not been thoroughly quantified in this report but is recognized as a potentially significant source based on field observations. Review of information held by the Texas Railroad Commission indicates that these areas are far more extensive than information obtained from USGS maps and aerial photos would indicate.

4.4.3 Localized Industries

Localized industries include commercial developments generally located within urban areas which store materials that could contribute to stormwater contamination. Non-point source pollution considerations associated with urban area industrial activity in general include storm water runoff contaminated with stored or stockpiled materials, dust formation from heavy equipment operation that can potentially be susceptible to erosional losses, and the impact on quantities of runoff from impervious surface areas associated with industrial activities. Non-point source pollutants associated with localized industries is highly variable but generally includes suspended solids, low concentrations of nutrients and metals.

4.5 Residential Areas

Major sources of urban runoff include accumulated contaminants on impervious surfaces, fertilizer and pesticide wash-off from lawns and parks, and septic tank filtrate. When a rain event occurs, the energy of raindrops striking impervious surfaces such as rooftops and pavement dislodge accumulated debris, water soluble fertilizers and pesticides become suspended in solution, and pollutants attached to particulates and debris are flushed from lawns, streets and pavement areas before being discharged to receiving waters via storm sewers and gutters. Fluids dissipating from septic tanks enter surface waters after inter-flowing through the near-surface groundwater paths. The amounts of non-point source pollutants generated from urban areas are strongly effected by population density, degree of impervious surface area, street litter accumulation rates, and traffic density[1]. The amount of these materials accumulated is a function of time, as the longer the period between storm events generating runoff, the greater the amount of non-point source pollutants that are washed into the receiving water-bodies.

4.5.1 Lawn Fertilizers

Compared to agricultural applications of fertilizers, the cost of over-applying chemicals to a lawn are less restricting to the residential applicator. As a result, in an effort to develop a lush lawn, a homeowner may tend to over apply heavily. Heavy watering applied for the same reason increases the potential loss of water soluble nitrogen forms of fertilizer.

Phosphate does not tend to contribute to non-point source pollution generated by lawns since P ions are relatively immobile in soils. Due to their strong tendency to attach to soil particles and organic materials and low water solubility, their contribution to storm water runoff would come primarily from lawn areas that had been heavily fertilized prior to a storm event. Most of the phosphate forms applied to lawns are taken up by grasses. There is a greater likelihood for over fertilization to occur on lawns than on agricultural fields because the economic cost of wasting is comparatively negligible. Almost all phosphorous originating from commercial fertilizers remains near the point of application. The exception to this would be lawns having sandy soils which have little tendency to react with phosphorus[34].

A large amount of nitrogen applied as fertilizer to urban lawns is either complexed with the soil's organic matter or is lost to the environment through volatilization, de-nitrification, surface runoff or leaching[1]. Because of its tendency to dissolve in water, nitrogen is relatively mobile, and easily enters storm-water runoff when over-applied. Most of the reactions of the nitrogen cycle in soils involve microbial activity and are thereby most active under conditions of adequate amounts of warmth, moisture, and oxygen[19].

4.5.2 Pesticides

Urban sources of pesticides include lawns, parks, and dust accumulation on impervious surfaces. The degree to which pesticides enter storm water runoff in urban areas depend on atmospheric conditions, the mobility of the pesticide, and the characteristics of the soil.

Leaching is the primary mechanism by which pesticides enter storm-water runoff. The mobility of a pesticide is generally a function of its solubility in water, which is inversely proportional to the tendency it has to adsorb to soil particles and organic matter. Those compounds with high water solubility are more likely to leach due to storm water than those having low solubility.

Pesticide adsorption onto soil particles and organic matter depends more on organic matter content than clay content for nearly all pesticides. Non-ionic compounds such as organochlorine and organophosphorus insecticides absorb to organic material more readily than to clay particles. Pesticides are leached more readily from course than fine textured soils because of the reduced attraction these soils have. Storm water can facilitate desorption of pesticides from soil particles if produced in large quantities[1].

The sorption of pesticides to soil particles varies with the composition of the particular pesticide. Acidic and basic compounds are effected primarily by soil pH[21] which controls the compound's ionic charge which controls their adsorptivity to clay and organic colloids. Weakly adsorbed, water soluble compounds are desorbed readily by water and have a greater tendency to leach. Organochlorine insecticides are the least mobile pesticides since they have limited solubility in water[1] while organophosphorus insecticides are slightly more mobile and the water soluble acidic herbicides are the most mobile. The effect that pH has on adsorption of organic chemicals depends on their composition. The adsorption characteristics of neutral compounds such as organochlorine pesticides is essentially independent of pH while polar compounds tend to be more influenced by the ionic content of the soil. The correlation between adsorption characteristics and pH does not always apply since the organic matter and clay particles have varying attractions for these compounds[21].

4.5.3 Septic Tank Infiltration

Unsewered residential areas located along the shore of Proctor Lake and Lake Leon can potentially introduce large amounts of organics, nutrients and bacteria into the lake. Unsewered areas are known to result in higher nitrogen concentrations in downstream areas. Nitrogen waste emitted from septic tanks does not tend to be taken up by plants since it is discharged below the root zone. Soils conducive to septic tanks typically have high permeability rates and low organic matter contents which results in very little immobilization of nitrogen[1]. Because of their close proximity to the lake, these systems represent a potentially significant source of NPS pollution affecting Lake Proctor.

4.5.4 Impervious Surfaces

Impervious surfaces include streets, pavement and parking lots that are interconnected with storm water conveyance structures. Rooftops are not included in this category since they normally drain to lawns and do not contribute significantly to urban runoff except during heavy rain events. Common contaminants that accumulate on impervious surfaces include oil from vehicular traffic, accumulated dust and debris from leaves and litter, heavy metals, and organics and fecal material from birds and mammals. Petroleum products deposited on roadways tends to volatilize to some extent while a small part of the remaining fraction will detach from the pavement and float on the runoff water generated by storm events.

4.5.5 Construction Areas

Land areas located on exposed, high slopes are important sources of sediment erosion in urban areas such as those found at housing construction sites and lot clearings associated with residential development[1]. If proper erosion and sediment controls are not implemented during a developments' construction phase, sediment loadings and associated pollutants resulting from bare ground disturbance by storm water exposure will find their way into downstream surface water sources.

4.6 Range Land

Rangeland includes approximately 46 percent or 377,200 acres of the study area. Compared to other land uses, unit loadings from rangelands of NPS pollutants have been found to be an order of magnitude less than that of croplands for TSS and nutrients. While compared to improved pasture, TSS loadings were an order of magnitude higher for rangeland. Similarly, total phosphorous was comparable and total nitrogen was lower for rangeland than that of pastureland. Range land and woodlands had comparable values for TSS, total phosphorous and total nitrogen[13]. Nitrogen and phosphorous loadings contributed annually by rainfall has been found to be greater than that resulting from native prairies such that these rangelands are actually nutrient sinks[1].

4.7 Undeveloped Land

Undeveloped lands, comprising approximately 11 percent of the study area include mainly wooded areas. Woodlands are some of the best protection of lands from pollutant and sediment loss and are used as determinants of background pollution levels against which other land uses are judged. The high amount of surface water storage produced by leaves, mulch and terrain roughness decrease the amount of runoff generated within a watershed. Forest soils often have improved permeability allowing the absorption of large quantities of rainwater. Tree canopy, ground cover and the high organic matter content of forest soils can significantly reduce erosion losses. Streams draining lowland forested areas may contain elevated levels of organic and nutrient levels caused by leaching from soils by inter-flow and base flow[1].

SECTION 5.0

SUBBASIN WATERSHED NPS CHARACTERISTICS

5.0 SUBBASIN WATERSHED NPS CHARACTERISTICS

5.1 Existing Conditions

Generally, each of the subbasins within the study area contains a mixture of cultivated land, urban and industrial development, and range and pasture land for which loadings of NPS pollution can be predicted. The dominant source of NPS pollution in the Lake Proctor watershed is due to land disturbing activities on the relatively large amount of cropland. These activities can cause extensive erosion of soil with attached pollutants (including predominantly phosphorous and pesticides), as well as the transport of water-soluble pollutants dissolved in storm-water, including nitrogenous compounds and certain mobile pesticides.

A certain percentage of crops, including sorghum, oats, wheat and corn are grown for feeding livestock and as such are generally not treated with pesticides. A list of pesticides commonly used for specific crops is presented in Table 15 of Section 4.1.2. Pasture lands can contribute contaminated runoff in the form of nitrogenous and phosphorous compounds, the amount of which is a function of livestock density, climatic conditions and soil type. Residential areas are predominantly sources of fertilizer-derived nutrients and pesticides originating on lawns and park lands, while other contaminants from urban areas include oil from streets, sediment and debris contributing to suspended solids, heavy metals and fecal coliforms generated from the accumulation of wastes. Area mining operations include gravel quarries and clay pits from which bare ground is a potential source of sediment erosion while exposure of acidic substrate can result in acid mine drainage which in turn can cause metals in the sediment to go into solution and be spread by runoff. Oil fields are sources of oil saturated soil resulting from leaking storage tanks and pumps from which oil particles attached to sediment will tend to float and wash-off along with storm water passing through the area.

A comparison was made for each of the subbasins as to the percentage of acres that potentially contribute the most NPS loadings within each subbasin (Table 17) and also the Lake Proctor watershed as a whole (Table 18). These areas include acreage developed in cropland, orchards, pasture, residential areas, mining operations, oil and gas fields and localized industry.

TABLE 17

COMPARISON OF DEVELOPED LAND WITHIN EACH SUBBASIN

EXISTING CONDITIONS

Location	*Rank*	* *Acres With High Potential For NPS Contribution*	** *Acres With Low Potential For NPS Contribution*	*% of Land With High Potential For NPS Contribution*
South Proctor Basin	1	1,430	877	62%
Lower Leon River	2	11,790	7,537	61%
West Proctor Basin	3	560	416	57%
Duncan Creek	4	8,910	7,590	54%
Rush Creek	5	53,810	60,679	47%
Sabana River	6	87,930	111,917	44%
Sweetwater Creek	7	23,090	30,612	43%
Upper Leon River	8	71,600	98,848	42%
Sowell's Creek	9	4,580	7,154	39%
South Fork Leon River	10	62,690	102,276	38%
Armstrong Creek	11	21,660	43,965	33%

* **Cultivated, urban, industrial, and pasture land**

** **Rangeland and undeveloped land**

TABLE 18

COMPARISON OF DEVELOPED LAND WITHIN LAKE PROCTOR WATERSHED

EXISTING CONDITIONS

Location	*Rank*	* *Total Acres Of Land With High NPS Contribution Potential*	*Total Acres within Subbasin*	*% Of Land With High Potential For NPS Contribution*
Sabana River	1	87,930	199,847	10.7%
Upper Leon River	2	71,600	170,448	8.7%
South Fork Leon River	3	62,690	164,966	7.7%
Rush Creek	4	53,810	114,489	6.6%
Sweetwater Creek	5	23,090	53,702	2.8%
Armstrong Creek	6	21,660	65,625	2.6%
Lower Leon River	7	11,790	19,327	1.4%
Duncan Creek	8	8,910	16,500	1.1%
Sowell's Creek	9	4,580	11,734	0.6%
South Proctor Lake	10	1,430	2,307	0.2%
West Proctor Lake	11	560	976	0.1%

* **Cultivated, urban, industrial, and pasture land**

Rangelands and undeveloped areas were excluded from this category because they are subject to less intensive management and are less of a source of NPS pollution. Both of these comparisons, for the individual subbasins and the watershed as a whole were performed for each of the eleven subbasin areas, each of which were assigned a rank. Under this ranking system a value of one denotes the subbasin with the highest percentage of developed lands (having a relatively high expected NPS runoff potential) while a rank of 11 indicates the subbasin with the lowest percentage of developed areas. Estimated NPS loadings from cultivated, urban, and pastureland determined for individual subbasins and the watershed as a whole are presented in Table 19.

Analysis of soil samples by the Agricultural Extension Service indicate that only small amounts of nitrogen (one to two pounds per acre) remain in the soil following growing seasons. Studies conducted by Dr. Dale Pennington of the Agricultural Extension Service at Texas A&M University in College Station indicate that more nitrogen is being removed from year to year in the Lake Proctor watershed than is being applied[20].

The primary NPS loadings originating from agricultural lands include nitrogen wash-off during intense storm events from fertilizer and manure applications and wind erosion of sandy soils on cultivated lands. Current farming practices used that are intended to reduce these losses include leaving crop residue on fields until immediately prior to planting, cover cropping in the winter, ammonia injection and split nitrogen application of fertilizers, and the establishment of windbreaks in sandy areas prone to wind damage[20]. These methods are explained in section 7.1.1.

5.1.1 Armstrong Creek Subbasin

The Armstrong Creek drainage contains pasture (23 percent), cropland (nine percent), and less than one percent each for localized industry and orchards. There are little or no mining operations or oil and gas fields found here. The primary pollutants expected from non-point sources in the subbasin include TSS, BOD, nitrogen and phosphorous originating from pasture and cropland. The combined developed area within this subbasin is 33 percent, or 21,600 acres.

TABLE 19
ESTIMATED ANNUAL NPS LOADINGS
FROM CULTIVATED, URBAN AND PASTURELANDS
(X 1000 LB)

EXISTING CONDITIONS

Subbasin	*Total Suspended Solids (TSS)*	*BioChemical Oxygen Demand (BOD)*	*Total Phosphorous*	*Total Nitrogen*
Armstrong Creek	1,524-34,730	100-260	1-26	25-193
Duncan Creek	396-29,005	37-196	1-23	23-173
Lower Leon River	501-39,635	51-270	2-32	33-239
Rush Creek	2,793 - 144,000	241-1,011	6-113	117-846
Sabana River	4,820-225,000	398-1,590	9-176	182-1,321
South Fork Leon River	4,268-111,111	342-897	7-94	98-614
South Proctor Lake	75-4,963	8-37	0.3-4	5-29
Sowell's Creek	276-10,628	21-75	0.4-8	8-62
Sweetwater Creek	1,292-58,321	105-413	2-46	47-341
Upper Leon River	4,312-170,000	361-1,260	9-138	143-987
West Proctor Lake	24-1,963	2-13	0.08-2	2-12

Approximately 25 percent of the soils found here are suited for peanuts, sorghum and small grains while the remainder is best suited for native range. Soils used for cropland are susceptible to both soil erosion and wind erosion with occasional damaging overflows occurring in flood prone areas. The runoff potential for these soils is considered to be moderate[7].

This subbasin has the lowest percentage of developed land in the watershed, but because of its average size ranked sixth in terms of the amount of developed land it contributed to the entire watershed.

In terms of loadings per acre of TSS, BOD, total phosphorous and total nitrogen resulting from pastures and cropland, the Armstrong Creek subbasin ranked eleventh out of the eleven subbasins because of its low level of development, but because of its large size ranked seventh for total loadings contributed to the entire Lake Proctor watershed. The small amount of orchards found here would not be expected to contribute appreciably to the NPS pollution in the subbasin.

5.1.2 Duncan Creek Subbasin

The Duncan Creek drainage contains cropland (37 percent), pasture (15 percent), orchards (one percent), localized industry (one percent), and essentially no residential land use, mining operations, or oil and gas fields. The primary pollutants expected from non-point sources here include BOD, nitrogen and phosphorous from croplands and pastureland. Some amount of pesticides might be expected due to the relatively large amount of land under cultivation. The combined developed area within this subbasin is 54 percent, or 8910 acres.

Seventy percent of the soil types here are suited for cropland though because of the sandy texture of most areas, wind erosion is a limiting factor for crop production while soil erosion is an important factor on approximately 20 percent of the land where slopes are steep. The runoff potential for this drainage is considered moderate.

This subbasin was ranked fourth of the eleven in percentage of developed land within its own subbasin, but because of its small size was ranked 8th in terms of the amount of developed land it contributed to the entire watershed.

In terms of loadings per acre of TSS, BOD, total phosphorous and total nitrogen resulting from cropland and pastures, the Duncan Creek subbasin ranked 4th out of the eleven subbasins because of its high level of development. This drainage ranked 7th for total loadings contributed to the entire Lake Proctor watershed. The small amount of orchards found here would not be expected to contribute appreciably to the NPS pollution in the subbasin.

5.1.3 Lower Leon River Subbasin

The Lower Leon River drainage contains cropland (43 percent), pasture (13 percent), localized industry (two percent), oil and gas fields (two percent), and orchards (0.16 percent). There are little or no mining operations found here. The primary non-point pollutants likely to be derived from this subbasin include BOD, nitrogen, phosphorus and pesticides derived from crop application in this heavily cultivated area. Some amount of grease and hydrocarbons may result from areas of concentrated oil fields. The combined developed area within this subbasin represents 60 percent, or 11,790 acres.

Approximately 65 percent of this drainage is suitable for crop production that because of the sandy texture of the soils are effected by wind erosion. The remaining soils are best suited for rangeland and wildlife habitat. The runoff potential for the cultivatable areas in this drainage is considered moderate.

This subbasin was ranked second of the eleven in percentage of developed land within its own subbasin, but because of its smaller size was ranked seventh in terms of the amount of developed land it contributed to the entire watershed.

In terms of loadings per acre of TSS, BOD, total phosphorous and total nitrogen resulting from developed areas, the Lower Leon River subbasin ranked second of the eleven subbasins because of its high level of development. This drainage ranked only sixth for total loadings contributed to the entire Lake Proctor watershed because of its relatively small size. The small amount of orchards and oil fields found here would not be expected to contribute appreciably to the NPS pollution in this subbasin.

5.1.4 Rush Creek Subbasin

The Rush Creek subbasin contains cropland (26 percent), pasture (18 percent), oil and gas fields (one percent), orchards (one percent), residential areas (one percent), and less than one percent each of mining operations and localized industry. There are little or no mining operations or oil and gas fields found here. The main source of non-point source pollution in this drainage are cropland and pasture potentially contributing BOD, nitrogen, phosphorous and pesticide derivatives from applications to agricultural lands. The combined developed area within this subbasin represents 47 percent, or 53,810 acres.

Roughly 70 percent of the soils in the Rush Creek drainage are suitable for cultivation or pasture though wind erosion and low soil moisture are limitations to crop production. The runoff potential for agricultural lands here is moderate.

This subbasin was ranked fifth out of the eleven in percentage of developed land within its own subbasin, and because of its relatively large size was ranked fourth in terms of the amount of developed land it contributed to the entire watershed.

In terms of potential loadings per acre of TSS, BOD, total phosphorous and total nitrogen resulting from developed areas, the Rush Creek subbasin ranked fifth because of its moderate level of development, but because of its large size ranked third for total loadings contributed to the entire watershed. This drainage contains small amounts of mining operations and oil fields from which acid drainage and hydrocarbons may originate.

5.1.5 Sabana River Subbasin

The Sabana River subbasin contains cropland (23 percent), pasture (19 percent), orchards (one percent), and less than one percent each of residential area, oil and gas fields, localized industry, and mining operations. The primary NPS pollutants potentially originating from this subbasin include BOD, nitrogen, phosphorous and pesticides from agricultural lands. The combined developed area within this subbasin represents 44 percent, or 87,930 acres.

Over 60 percent of the soils in this drainage are suitable for crops with wind erosion of soils and low water retention being the main problems associated with cultivation. The remainder is best used for rangeland and pastureland. The runoff potential for developed areas of the subbasin are moderate to high.

This subbasin was ranked sixth of the eleven in the percentage of developed land within its own subbasin, but because it is the largest drainage within the watershed contributed the largest amount of acreage to the watershed as a whole.

The Sabana River ranked sixth in terms of potential loadings per acre of TSS, BOD, total phosphorous and total nitrogen resulting from developed areas, but because of its large size ranked first for total loadings contributing to the entire watershed. This drainage contains small amounts of mining operations and oil fields from which acid drainage and hydrocarbon pollutants may originate.

5.1.6 South Fork Leon River Subbasin

The South Fork Leon River subbasin contains pasture (21 percent), cropland (12 percent), oil and gas fields (two percent), residential area (two percent), and less than one percent each of orchards, localized industry, and mining operations. The main pollutants derived from non-point sources likely to occur in this area includes BOD, nitrogen, phosphorous and pesticide compounds resulting from fertilizer and pesticide application to cropland, and fertilizer to pastureland. The combined developed area within the subbasin represents 38 percent or 62,690 acres.

Nearly 70 percent of the soils in this subbasin are suitable for crops or pasture. Wind erosion is the main problem for farming applications due to the sandy texture of the soil. The potential for runoff is low to moderate.

This subbasin ranks 10 in terms of percentage of developed land within its own subbasin, but because it is one of the larger drainage areas within the watershed ranks third overall in terms of the amount of developed land within the Lake Proctor watershed.

The South Fork Leon River subbasin ranked next to lowest for potential loadings per acre of TSS, BOD, total phosphorous and total nitrogen resulting from developed areas, but because of its large size ranked fourth for total loadings contributing to the entire watershed. The towns of Cisco and Eastland give this drainage the highest amount of urban land area with 3409 acres, potentially contributing metals, and fecal coliforms to the storm water runoff. This drainage contains small amounts of mining operations and oil fields from which acid drainage and hydrocarbon pollutants may originate.

5.1.7 South Proctor Lake Subbasin

The South Proctor Lake subbasin contains croplands (44 percent), pasture (13 percent), residential area (five percent), and less than one percent localized industry. There are virtually no orchards, mining operations, or oil and gas operations. The primary contaminants from non-point sources expected from this watershed include derived compounds from cropland applications including BOD, nitrogen, phosphorous and pesticides. The combined developed area within this subbasin represents 62 percent or 1430 acres.

Essentially all the soils found in this drainage are suitable for crops, but because of the sandy texture is susceptible to wind erosion. The runoff potential for these soils is moderate.

This subbasin ranks highest in terms of the amount of developed land within its boundary, but because it is one of the two smallest subbasins within the watershed, ranks 10th in terms of its contribution of developed land to the entire watershed.

The South Proctor Lake subbasin ranked highest in terms of potential loadings per acre of TSS, BOD, total phosphorous and total nitrogen resulting from developed areas, but because of its small size ranked next to lowest in total loadings contributed to the entire watershed. Residential areas bordering Lake Proctor give this drainage area the highest concentration of urban land area in the study area (five percent), potentially contributing metals, and fecal coliforms to the storm water runoff.

5.1.8 Sowell's Creek Subbasin

Sowell's Creek subbasin contains pasture (21 percent) and cultivated land and (18 percent). There are virtually no residential areas, localized industry, orchards, mining operations, or oil and gas operations. The remaining 7160 acres includes range and woodlands. The main sources of NPS pollutants in this drainage are pastureland from which BOD, nitrogen and phosphorous would be expected and to a lesser extent, croplands potentially contributing BOD, nitrogen, phosphorous and pesticides. The combined developed area within this subbasin represents 39 percent or 4,580 acres.

Approximately 2/3 of the soils in this subbasin are suitable for cropland that is limited by wind erosion. The remaining soils are usable only for rangeland because of its stony nature. The runoff potential for cultivatable lands here is moderate.

This subbasin ranks ninth in terms of the amount of developed land within its boundary. It also ranks ninth in terms of its contribution of developed land to the entire watershed.

The Sowell's Creek subbasin ranked ninth of 11 in terms of potential loadings per acre of TSS, BOD, total phosphorous and total nitrogen produced from developed areas, and ninth in total loadings contributed to the entire watershed.

5.1.9 Sweetwater Creek Subbasin

The Sweetwater Creek subbasin contains croplands (22 percent), pasture (20 percent), and less than one percent each of residential areas, orchards, and mining operations. There are virtually no localized industry or oil and gas operations in this drainage. The primary sources of NPS pollutants are croplands and pastureland potentially contributing nutrients from fertilizer application on pasture and crop areas, as well as pesticides from croplands. The combined developed area within this subbasin represents 43 percent or 23,090 acres.

Approximately 70 percent of the land in the drainage is suitable for crops, but limited by wind erosion on the sandy fractions and by water erosion on the loamy fractions. The runoff potential here is moderate to high.

This subbasin ranks seventh in terms of the amount of developed land within its boundary, but because of its moderate size, ranks fifth in terms of its contribution of developed land to the entire watershed.

The Sweetwater Creek subbasin ranked seventh out of the 11 subbasins in terms of potential loadings per acre of TSS, BOD, total phosphorous and total nitrogen produced from developed areas, but because of its relatively large size ranked fifth in total loadings contributed to the entire watershed. This drainage contains small amounts of mining operations from which acid drainage may originate.

5.1.10 Upper Leon River Subbasin

The Upper Leon River subbasin contains pasture (20 percent), cultivated land (19 percent), oil and gas fields (one percent), residential area (one percent), and less than one percent each of localized industry, orchards, and mining operations. Primary sources of NPS pollutants here are croplands and pastureland potentially contributing nutrients from fertilizer application on pasture and crop areas, as well as pesticides from croplands. The combined developed area within this subbasin represents 42 percent or 71,600 acres.

Only about 40 percent of the soils of this drainage area are suitable for cultivation. Those that are have wind erosion as a limitation, and water erosion to a lesser extent. The runoff potential in this subbasin is considered moderate.

This subbasin ranks 8th in terms of the amount of developed land within its boundary, but because of its large size ranks 2nd in terms of its contribution of developed land to the entire watershed.

The Upper Leon River subbasin ranked eighth out of the 11 subbasins in terms of potential loadings per acre of TSS, BOD, total phosphorous and total nitrogen produced from developed areas, but because of its relatively large size ranked second in total loadings contributed to the entire watershed. This drainage contains small amounts of mining operations and oil fields from which acid drainage and hydrocarbon runoff may originate.

5.1.11 West Proctor Lake Subbasin

The West Proctor Lake drainage contains cropland (43 percent) and pasture (15 percent) and essentially no urban land, orchards, localized industry, mining operations, or oil and gas fields. The primary source of NPS pollutants here are croplands potentially contributing nutrients from fertilizers and pesticides application on cultivated areas. The combined developed area within this subbasin is 57 percent, or 556 acres.

Only deep, sandy soils are found within the West Proctor Lake drainage, all suitable for crop production limited by the potential for wind erosion. The runoff potential for these soils is considered moderate.

This subbasin was ranked third of the eleven in percentage of developed land within its own subbasin, but because it is the smallest basin in the watershed ranks 11th in terms of the amount of developed land it contributes to the entire watershed.

The West Proctor subbasin ranked third overall in terms of potential loadings per acre of TSS, BOD, total phosphorous and total nitrogen produced from developed areas, but because it is the smallest subbasin ranked lowest in total loadings contributed to the entire watershed.

5.2 Future Conditions

Projected population increases for metropolitan areas and other areas within each of the subbasins were used to estimate the resulting increase in expected NPS loadings using the same lbs/acre values shown in table 14. Corresponding NPS loadings projected for each of the subbasins within the Lake Proctor watershed under future conditions are shown in table 20. Associated increases in NPS loadings resulting from new development as a percentage of existing conditions are presented in table 21. A comparison of high NPS potential verses low NPS potential lands for each subbasin under future (2022) conditions are shown in table 22, while those for the entire Lake Proctor watershed are ranked in table 23. Predicted total loadings under future conditions are given in table 24.

5.2.1 Armstrong Creek Subbasin

The Armstrong Creek subbasin has one of the lower expected future increases in NPS loadings of any of the drainage within the watershed because of its lack of urban development, though it is projected to experience a 60 percent increase in population by the year 2022. Compared to the watershed as a whole, the Armstrong Creek subbasin ranks 7th in overall loadings from non-point sources in the year 2022.

5.2.2 Duncan Creek Subbasin

The Duncan Creek subbasin has one of the lowest expected future increases in NPS loadings in the watershed because of its lack of urban development, though projections for non-urban areas in Comanche county indicate existing development is likely to more than double. Existing land uses here include little or no non-agricultural industry or residential development from which

TABLE 20

ESTIMATED ANNUAL NPS LOADINGS

(X 1000 LB)

FUTURE CONDITIONS (2022)

Subbasin	*Total Suspended Solids (TSS)*	*BioChemical Oxygen Demand (BOD)*	*Total Phosphorous*	*Total Nitrogen*
Armstrong Creek	1,530-34,815	102-261	1-26	25-194
Duncan Creek	398-29,016	37-196	1-23	24-173
Lower Leon River	558-40,392	56-279	2-33	36-245
Rush Creek	2,819 -144,000	243-1,016	6-114	118-849
Sabana River	4,836-226,000	399-1,592	9-176	183-1,323
South Fork Leon River	4,318-110,000	349-908	8-96	100-617
South Proctor Lake	101-5,264	12-43	0.4-5	5-31
Sowell's Creek	276-10,628	21-75	0.4-8	8-62
Sweetwater Creek	1,342-58,894	113-425	3-47	49-343
Upper Leon River	4,376-171,000	370-1,274	9-140	146-991
West Proctor Lake	24-1,963	2-13	0.08-2	2-12

TABLE 21
ESTIMATED ANNUAL NPS LOADINGS
(X 1000 LB)

BY THE YEAR 2022

Subbasin	*Total Suspended Solids (TSS)*	*BioChemical Oxygen Demand (BOD)*	*Total Phosphorous*	*Total Nitrogen*
Armstrong Creek	0.24-0.39	0.38-2.0	0	0-0.52
Duncan Creek	0.04-0.51	0	0	0-4.35
Lower Leon River	1.91-11.38	3.33-9.80	0-3.13	2.51-9.09
Rush Creek	0-0.93	0.49-0.83	0-0.88	0.35-0.85
Sabana River	0.33-0.44	0.13-0.25	0	0.15-0.55
South Fork Leon River	1.01-1.17	1.23-2.05	2.13-14.29	0.49-2.04
South Proctor Lake	6.06-34.67	16.22-50	25-33.33	0-6.90
Sowell's Creek	0	0	0	0
Sweetwater Creek	0.98-3.87	2.91-7.62	2.17-50	0.59-4.26
Upper Leon River	0.59-1.48	1.11-2.49	0-1.45	0.41-2.10
West Proctor Lake	0	0	0	0

TABLE 22
COMPARISON OF DEVELOPED LAND WITHIN EACH SUBBASIN

FUTURE CONDITIONS (2022)

Location	*Rank*	* *Acres With High Potential For NPS Contribution*	** *Acres With Low Potential For NPS Contribution*	*% of Land With High Potential For NPS Contribution*
South Proctor Basin	1	1,583	724	69%
Lower Leon River	2	12,449	6,878	64%
West Proctor Basin	3	560	416	57%
Duncan Creek	4	8,916	7,584	54%
Rush Creek	5	54,082	60,407	47%
Sabana River	6	88,149	111,698	44%
Sweetwater Creek	7	23,369	30,333	43%
Upper Leon River	8	72,094	98,354	42%
Sowell's Creek	9	4,580	7,154	39%
South Fork Leon River	10	63,088	101,878	38%
Armstrong Creek	11	21,740	43,885	33%

* **Cultivated, urban, industrial, and pasture land**

** **Rangeland and undeveloped land**

TABLE 23

COMPARISON OF DEVELOPED LAND WITHIN LAKE PROCTOR WATERSHED

FUTURE CONDITIONS (2022)

Location	*Rank*	* *Total Acres Of Land With High NPS Contribution Potential*	*Total Acres within Subbasin*	*% Of Land With High Potential For NPS Contribution*
Sabana River	1	88,149	199,847	10.8%
Upper Leon River	2	72,094	170,448	8.8%
South Fork Leon River	3	63,088	164,966	7.7%
Rush Creek	4	54,082	114,489	6.6%
Sweetwater Creek	5	23,369	53,702	2.9%
Armstrong Creek	6	21,740	65,625	2.7%
Lower Leon River	7	12,449	19,327	1.5%
Duncan Creek	8	8,916	16,500	1.1%
Sowell's Creek	9	4,580	11,734	0.6%
South Proctor Lake	10	1,583	2,307	0.2%
West Proctor Lake	11	560	976	0.1%

* **Cultivated, urban, industrial, and pasture land**

TABLE 24

PREDICTED ANNUAL NPS LOADINGS (X 1,000,000 LBS) FOR THE LAKE PROCTOR WATERSHED

FUTURE CONDITIONS

	TSS	*BOD*	*Total P*	*Total N*
Cropland	4.377-738.363	0.649-4.864	0.029-0.584	0.616-4.491
Residential	1.625-18.650	0.245-0.409	0.009-0.048	0.056-0.073
Industrial	0.151-2.508	0	0.0003-0.0012	0.006-0.033
Pasture	14.422-72.433	0.810	0.002-0.036	0.016-0.243

population increases are expected. Because of its relatively small size, the Duncan Creek subbasin ranks eighth in overall non-point source loadings for the year 2022.

5.2.3 Lower Leon River Subbasin

The Lower Leon River subbasin is expected to experience some of the largest increases in potential non-point pollution sources in the study area during the next 30 years as a percentage of existing conditions. Because of its relatively small size this drainage area will contribute only an average total amount of NPS pollution compared to the watershed as a whole.

5.2.4 Rush Creek Subbasin

The Rush Creek subbasin is expected to experience a moderate amount of development contributing to non-point source pollution though the town of Rising Star is contained within its boundaries. The projected population increase for this subbasin is approximately 32 percent with a net reduction expected for the Town of Rising Star and a doubling of the rural county. Because of its large size, this subbasin is ranked third in terms of the amount of NPS loadings it will contribute to the watershed compared to other subbasins.

5.2.5 Sabana River Subbasin

The Sabana River subbasin has one of the lower expected increases in NPS loadings projected for the next 30 years despite its inclusion of the towns of Gorman and Carbon. This is due to it's heavily rural character and an expected four percent population increase in the two metropolitan areas. Other county areas have a projected 127 percent population increase predicted by the year 2022. Despite the modest increases in expected non-point source loadings in this drainage, the Sabana River subbasin ranks 1st in overall future loadings from non-point sources mainly because it includes the largest amount of drainage area.

5.2.6 South Fork Leon River Subbasin

The South Fork Leon River subbasin is projected to experience an above average increase in NPS pollutant loadings during the next 30 years, though estimated population increases for the two major metropolitan areas, the towns of Cisco and Eastland are only -8.8 percent and 0.4 percent respectively. This is due to approximately 470 acres of residential area and 220 acres of associated industrial operations located outside major towns that are expected to experience a 76 percent population increase.

5.2.7 South Proctor Lake Subbasin

The South Proctor Lake subbasin is expected to experience the highest percentage increase in loadings contributed by non-point sources of any of the subbasins in the Lake Proctor watershed but because of its small size will contribute relatively small amounts. In terms of percentages of total loadings for the study area, this drainage ranks next to lowest. Because of its close proximity to Lake Proctor, any NPS pollution from this area would probably have a greater effect on the eutrophication of the reservoir.

5.2.8 Sowell's Creek Subbasin

The Sowell's Creek subbasin is expected to experience small, if not negligible increases in NPS loadings during the next 30 years as it is dominated by agricultural land uses with no significant metropolitan areas. Overall, this drainage ranks ninth in terms of total future loadings contributed to the watershed.

5.2.9 Sweetwater Creek Subbasin

The Sweetwater Creek subbasin is expected to have one of the highest percentage increases in non-point source loadings by the year 2022 within the study area. No large metropolitan areas are located within this basin though because of its average size is ranked sixth in terms of future loadings from NPS pollutants.

5.2.10 Upper Leon River Subbasin

The Upper Leon River subbasin is expected to have a modest increase in population potentially contributing to NPS loadings despite its inclusion of the towns of De Leon, Ranger and portions of the towns of Carbon and Gorman. In terms of total future contributions of non-point source pollutant loadings, this drainage ranks second overall because of the relatively large amount of urban development and subbasin size.

5.2.11 West Proctor Lake Subbasin

The West Proctor Lake subbasin is expected to experience small, if not negligible increases in NPS loadings during the next 30 years as it is dominated by agricultural land uses and no significant metropolitan areas. Overall, this drainage ranks lowest in terms of total future loadings contributed to the watershed.

SECTION 6.0
NON-POINT SOURCE SAMPLING PLAN

6.0 NON-POINT SOURCE SAMPLING PLAN

6.1 Single Land Use Watersheds

From aerial photography, several small watersheds were selected which are representative of single land-use types. Primary land use categories include residential subdivisions, residential homes on septic systems, orchards, dairies, oil and gas fields, and cultivated lands. For each of the land use categories, several alternative representative watersheds were chosen to allow for possible access problems that might be encountered. All representative watersheds were selected within a four mile radius for ease of access.

6.1.1 Residential (Subdivisions)

A 99 acre drainage (designated U1) located in the western section of the Town of De Leon was the primary choice to represent urban runoff conditions because it is composed almost entirely of medium density residential development. Two additional sites were chosen in the event that access to the chosen watershed is unavailable. The second alternative (U2) includes a 63 acre drainage located in the southeast part of the town and includes medium density residential areas occurring over approximately 90 percent of its drainage. The third choice (U3) contains a 400 acre drainage area which includes the drainage of the two smaller watersheds previously mentioned. Each of the three watersheds drains into an unnamed tributary that enters the Leon River near its intersection with the Texas Central railroad.

6.1.2 Residential (Septic Tanks)

Two small lakeside development drainage areas were chosen along the perimeter of Proctor Lake to represent potential non-point sources of pollutants originating from urban areas employing septic systems. The first watershed (SE1) is a 29 acre area located on the east shore 1.8 miles southwest of the Town of Roch in Comanche county. The second choice (SE2) includes a 69 acre area roughly 0.5 miles southeast of SE1 and 1.9 miles southwest of the Town of Roch and along the north shore of Lake Proctor. Both drainage areas enter Proctor Lake.

6.1.3 Orchards

Three watersheds in close proximity to each other were chosen to represent pecan orchard drainage conditions. Each are located approximately 2.8 miles northwest of the Town of De Leon in Comanche county. The first watershed (O1) includes a 105 acre area to the north of and adjacent to the Texas Central railroad. The second alternative watershed (O2) drains 78 acres to the south and adjacent to the Texas Central railroad. The third alternative site includes 122 acres along the south side of the Texas Central railroad and northwest of watershed O2. Both watersheds O1 and O2 drain into an unnamed tributary that enters the Leon River approximately 3.8 miles above State Highway 6. Watershed O3 enters an unnamed tributary which enters the Sabana River approximately 0.5 miles upstream of State Highway 587.

6.1.4 Dairies

An 84 acre drainage area (D1) located roughly 2000 feet west of the dairy farm owned by Billy C. Christian was chosen as the primary watershed representing pasture treated with cattle waste. The site is located within the Armstrong Creek subbasin roughly 6.5 miles southwest of the Town of Lingleville in Erath County. This dairy is permitted to contain 600 head of cattle and to irrigate 455 acres with liquid livestock waste. This watershed flows into an unnamed tributary of Armstrong Creek approximately 0.4 miles upstream of State Highway 2156.

The second watershed chosen (D2) drains 46 acres located approximately 3.6 miles northeast of the Town of De Leon. This watershed enters an unnamed tributary which enters the Leon River approximately 2.1 miles upstream of State Highway 6.

The third alternative watershed (D3) is a 56 acre area located 6.5 miles southwest of the Town of Lingleville and east of State Highway 2156. This area drains into Armstrong Creek approximately 1.1 miles upstream of the State Highway 2156 intersection.

6.1.5 Oil and Gas Fields

Two watersheds were selected to represent oil and gas field drainage basins. The first site (OG1) is a 25 acre drainage area located 5.7 miles north of the Town of De Leon to the west of State Highway 16. This basin enters the Leon River approximately 0.6 miles above State Highway 6. The second alternative watershed (OG2) includes a 183 acre drainage area to the east and adjacent to the Town of Comyn in Comanche county. This area enters Walker Creek approximately 1.9 miles above its confluence with the Leon River.

6.1.6 Cultivated Land

Three alternative watersheds were selected to represent non-point source runoff from cultivated lands. The first site (CU1) is a 315 acre area located 1.1 miles south southeast of the Town of Roch in Comanche county. This drainage enters an unnamed tributary that enters Sowell's Creek 0.5 miles upstream of its intersection with State Highway 1476. The second alternative site (CU2) is a 232 acre area located 0.6 miles southeast of the Town of Victor in Erath county. CU2 enters a ditch that enters an unnamed tributary entering the Leon River 2.1 miles upstream of State Highway 6. The third watershed (CU3) includes a 343 acre area located 4.2 miles south southeast of the Town of De Leon. The CU3 drains into an unnamed tributary of the Leon River at a point 1.3 miles upstream of the Leon River's intersection with Proctor Lake.

6.2 Sampling Protocol

In order to characterize the storm water discharge, samples will be collected from a hydraulic control point during runoff events for each of the single use watersheds. The laboratory analysis for these samples should include the same parameters as those proposed for the lake monitoring program, with the exception of chlorophyll-a which will not be included with the non-point source sampling analysis. These are shown in Table 25. Total coliform and fecal coliform analyses should be performed on grab samples only.

TABLE 25

LABORATORY PARAMETER TABLE

No.	Measurement Parameter	40 CFR 136 EPA Ref.	WPCF/AWWA[37] Std. Meth.	Units	Method	Lower Detection Limit	Holding Time
1	Biochemical Oxygen Demand	[35] 405.1	507	mg/L	Oxygen Electrode Dissolved O_2 Uptake	0.1 mg/L	48 hours
2	Soluble BOD	[35]405.1	507	mg/L	Oxygen Electrode Dissolved O_2 Uptake	0.1 mg/L	48 hours
3	Chemical Oxygen Demand	[35]410.1-.2	508A	mg/L	Reflux Method Titrimetric	5 mg/L	28 days
4	Total Suspended Solids	[35]160.2	209C	mg/L	103°-105°C Gravimetric	0.5 mg/L	7 days
5	Total Phosphorous	[35]365.2	424C(III) 424D	mg/L	Persulfate Digestion Vandomolybdophosphoric Acid-Spectrophotometric	10 ug/L	28 days
6	Soluble Phosphorous	[35]365.2-.3	424C(III) 424F	mg/L	Persulfate Digestion Vandomolybdophosphoric Acid-Spectrophotometric	10 ug/L	28 days
7	Total Ortho-phosphate	[35]365.2-.3	424F	mg/L	Ascorbic Acid Spectrophotometric	10 ug/L	48 hours
8	Soluble Ortho-phosphate	[35]365.2	424F	mg/L	Ascorbic Acid Spectrophotometric	10 ug/L	48 hours
9	Ammonia Nitrogen	[35]350.2	417D	mg/L	Titrimetric Distillation	20 ug/L	28 days
10	Nitrate Nitrogen	[35]352.1	NA	mg/L	Spectrophotometric	20 ug/L	28 days
11	Nitrite Nitrogen	[35]354.1	419	mg/L	Spectrophotometric	20 ug/L	48 hours
12	Total Kjeldahl Nitrogen	[35]351.3	417B	mg/L	Distillation-Titrimetric	5 ug/L	28 days
13	Bicarbonate Alkalinity	[35]310.1	403	mg/L	Titrimetric	5 mg/L	14 days
14	Carbonate Alkalinity	[35]310.1	403	mg/L	Titrimetric	5 mg/L	14 days
15	Fecal Coliform	[36]p 132	909C	#/100 ml	Membrane Filter Multiple Tube MPN	NA	24 hours
16	Total Coliform	[36]p 114	909A	#/100 ml	Membrane Filter Multiple Tube MPN	NA	24 hours
17	Plankton primary Productivity	NA	1002I	gc/m^2 /day	Light Bottle/ Dark Bottle	NA	24 hours
18	Turbidity		214A	NTU	Nephelometric	1.NTU	48 hours

(35) "Methods for Chemical Analysis of Water and Wastes", U.S. Environmental Protection Agency, Office of Research and Development, Environmental Monitoring and Support Laboratory, Cincinnati, Ohio. 1979

(36) "Microbial Methods for Monitoring the Environment, Water and Wastes", U.S. Environmental Protection Agency EPA-600/8-78-017, Office of Research and Development, Environmental Monitoring and Support Laboratory.

(37) "Standard Methods for the Examination of Water and Wastewater", 16th Edition, APHA, AQQA, WPCF, Washington, D.C. 1985

Based on data generated from the single use watersheds, loadings of pollutants associated with each land use category can be correlated with stream flow hydrographs developed from flow data collected concurrently in order to predict and identify land uses above sampling points located spatially across the watershed. From these data, the planning for non-point source controls that would most efficiently reduce non-point source runoff to Lake Proctor can be accomplished.

6.2.1 First Flush/Sequential Samples

Normally, the higher concentrations of pollutants from non-point sources are found in the storm water generated early in the runoff phase of a rain event. This is due to the initial release of easily detached debris and associated pollutants that have collected on the surface since the preceding storm event. It is during this stage that pollutants attached to easily transported particles such as fine sediment, organic material and debris, as well as petroleum products that accumulate on impervious surfaces are detached and transported in surface flow. During the first thirty minutes of storm water runoff, grab samples will be collected using the automatic sampler described below, in order to obtain an accurate representation of those pollutants carried in the first flush storm phase. Automatic samplers can be programmed to begin sampling at the initiation of precipitation either at a user selected liquid level or as triggered by an attached rain gage. First flush samples can be collected during the first thirty minutes and stored in a refrigerated container.

6.2.2 Event Mean Samplers

A dedicated composite sampler should be used to obtain event composite samples. American Sigma in Medina, New York manufactures the "Streamline" Model 800SL automatic sampler monitoring system which is activated by a high resolution depth sensor. The system includes a multiple bottle sampler with an integral flowmeter which measures flow induced by a peristaltic pump, an integral liquid level actuator, and rain gauge. The sampler can be programmed to begin sampling at the initiation of precipitation either at a user selected liquid level or as triggered by the attached rain gage. First flush samples are collected during the first thirty minutes and stored in a refrigerated container. Data collected by the sampler which characterizes the hydrograph for the watershed can be retrieved either by recording readings by hand from a display window or by downloading the collected data to a PC computer using an RS-232 serial interface. For remote sampling locations as will be utilized for the non-point source samplings, power can be supplied by a 12 VDC battery.

6.2.3 Field Data

Data pertaining to parameters not available through analysis of composite samples should be recorded at the hydraulic control point and recorded in an appropriate field book that correspond to the times grab samples are collected during the first 30 minutes of storm water runoff if possible. These parameters include temperature, dissolved oxygen, pH, conductivity, and depth.

6.2.4 Recording Stream Gauges and Hydrographs

In addition to the water quality samples taken during the storm water sampling, continuous flow measurements should be recorded during the runoff events. This will be accomplished though the installation of a fiberglass flume at a hydraulic control point in each single land use watershed. A recording level meter will be positioned in the flume to measure depth of flow for conversion to a volumetric flow rate. If the response of the meter is determined to be accurate, the records will be used to represent a hydrograph of storm water runoff from the watershed.

6.3 Parameters Measured

Laboratory analysis of grab samples and composite samples will include parameters and methodologies shown in Table 25.

SECTION 7.0
BEST MANAGEMENT PRACTICES

7.0 BEST MANAGEMENT PRACTICES

Best Management Practice (BMP) means a "practice or combination of practices that are determined by state (or designated area-wide planning agency) after problem assessment, examination of alternative practices, and appropriate public participation to be the most effective practicable (including technological, economic, and institutional considerations) means of preventing or reducing the amount of pollution generated by non-point sources to a level compatible with water quality goals"[1].

Non-point source pollutants result from both natural and man-induced causes. Natural sources include weathered minerals and residues of natural vegetation eroding from undeveloped lands creating a background level from which additional pollution caused by human activity can be measured and controlled to some extent using BMP's. In terms of practicality, the removal of NPS pollutants is most effective in those areas exhibiting high loading rates per acre for which BMP's are known to be effective for the area of concern.

The most effective program for controlling non-point source pollution within the Lake Proctor watershed is one that targets those areas having the highest concentration of land uses that are amenable to control methods. Though large amounts of NPS runoff are generated from lands that are not highly developed such as woodlands and rangeland, these areas are not best suited for NPS controls since the origins of pollutant loadings are more diffuse than land use areas that are subjected to intensive management. Cultivated lands, urban residential and industrial areas have the greatest potential for effect by control practices because they are regularly managed, altered and under controls implemented by man. These areas are also less diverse in vegetation types and terrain than are less developed areas allowing more effective implementation of control practices due to the more predictable and constant nature of the resulting NPS runoff. The primary targets that have the greatest potential for controls within the Lake Proctor watershed include cultivated lands, residential lands, industrial areas and lands used for treatment of livestock waste.

7.1 Croplands

Sources of non-point runoff from agricultural croplands include applied fertilizers and pesticides attached to eroding soil particles or dissolved in water. Though any applications of these chemicals can potentially result in NPS pollution, reductions in the amounts can be achieved through the employment of proper application rates, timing, and soil stabilization techniques. Many methods are available that are designed primarily to decrease losses of topsoil and to optimize the effectiveness of chemical additives to croplands that, at the same time result in a reduction in non-point source pollution entering storm water runoff. In addition to having the effect of reducing NPS pollution effecting waterways, farmers have an added incentive to employ BMP's because of the associated cost savings involved with using techniques developed to decrease the amount of fertilizer and pesticide applications required to maximize crop productivity.

Because of the historical heavy agricultural influence on the land uses here, and the occasional need for implementation of intensive conservation practices necessary to stabilize the soils during past years of adverse climatic conditions, farmers in the area have developed a heightened awareness for the need to reduce losses of topsoil and crop additives. Farmers have an economic incentive to utilize the most cost effective methods for reducing runoff and loss of fertilizers and pesticides applied to crops and are normally receptive to any programs that would make their operations more cost effective including soil stabilization techniques, and fertilizer and pesticide application methods that minimize the amount of chemicals required. Most area farmers are full time land managers who devote considerable time to keeping abreast of and using techniques shown to be effective in reducing soil erosion[20].

A substantial amount of non-point source pollution generated from cropland originates as attached to the sediment load resulting from erosion following storm events. Soil erosion is primarily a concern within the study area in cultivated areas where clayey and loamy soils occur having slopes greater than one percent[5]. Conversely, soils that have a sandy surface texture are more susceptible to erosion caused by wind erosion than from storm water runoff. Approximately 60 percent of the soil associations found within the drainage basin are deep sandy or loamy soils, 22 percent are shallow to deep loamy and clayey soils, 12 percent are deep clayey and loamy soils and six percent of the area is made up of shallow stony or gravelly soils. Sediment produced at the source normally varies qualitatively from that found in the receiving waterbody as soils are influenced by vegetative buffers, detention in low lying areas, and microbial activity[1]. Common farming practices used within the Lake Proctor watershed that are intended to reduce soil loss through erosion include application of cover crops and the practice of leaving a crop residue on the surface that is not tilled-in until immediately prior to planting.

Practices recommended by the Soil Conservation Service (SCS) for reducing the potential for erosion from cropland in the Lake Proctor watershed include a cropping system that keeps vegetative cover on the soil for extended periods, minimization of tillage, leaving a crop residue on the surface, construction of terraces, and contour farming. Erosion due to wind erosion can be reduced by cover cropping, wind strip cropping, creation of wind breaks, and by returning plant residues to the soil surface[5].

Non-point source runoff is best managed by controlling the path by which it enters groundwater and surface water sources. Compounds applied to croplands become NPS pollutants in various ways requiring control of that vehicle in which they leave the application area. Nitrogen forms generally contribute to NPS pollution through leaching when they are in a water soluble form. Phosphorous contributes to nonpoint source pollution generally by attaching to eroding sediment. Pesticides become part of the NPS load by either attachment to soil particles or dissolved in water depending on its chemical composition. Recommended nitrogen fertilizer application techniques are intended to optimize the uptake by crops before climatic conditions cause it to be removed from the area primarily through leaching. Nitrogen application techniques intended to reduce the amount wasted include the use of nitrification inhibitors, split nitrogen application, incorporation and injection. Common fertilizer application techniques currently used in the study area to reduce the amount wasted include fertilizer banding, split nitrogen application and ammonia injection. Banding and injection methods are intended to place the nutrients near the root zone where the uptake rate is optimized. Split nitrogen application reduces the amount applied for any single application thereby reducing the potential for wash-off during rain events.

Phosphorous fertilizer conservation is best achieved by using soil stabilization techniques since it tends to attach to soil particles and organic matter by which it is most susceptible to loss through soil erosion. Management of pesticides is best accomplished by optimizing the amount used, paying attention to the climatic and soil conditions under which it is applied, and by using only those chemicals that specifically target the pest of concern. There is an inherent interest on the part of farmers who apply fertilizers and pesticides on croplands to use effective application techniques because of the high cost of using more than is needed. Unit costs for implementing best management practices on a yearly per acre treated basis are presented in Table 26.

7.1.1 Nitrogen Fertilizer Application Techniques

Because of the tendency for most nitrogen forms to leach when exposed to flowing water, losses are best controlled by optimizing nitrogen fertilizer availability to plants at those times when factors that contribute to leaching are at a minimum. Avoidance of over application, placement near the root zone and the use of immobile forms when applied in wet soil conditions are common methods for minimizing losses of nitrogen fertilizer. Proper planning of fertilizer applications by which the quantities and composition of fertilizers are matched to crop needs and soil fertility can reduce the amount of nutrients lost by increasing uptake by plants and by increasing crop density thereby reducing the surface runoff and erosion potential. Increased root density from proper application may improve soil permeability and decrease runoff[11].

Nitrification inhibitors are used to delay the conversion of ammonia nitrogen fertilizer to the less stable nitrate form when less than optimal conditions exist. Its function is to slow the conversion of the more stable ammonium form to the highly leachable nitrate form. The use of ammonium forms of fertilizer creates more of a potential for non-point source runoff from sediment erosion since it has less of a tendency to leach, especially in clay soils. This method is most effective on soils that are not prone to soil erosion.

Decreased total nitrogen fertilizer application rates can be attained through the use of **split nitrogen applications**. The split-nitrogen technique involves applying an adequate amount of nitrogen fertilizer at the beginning of the growing season and adding small amounts of fertilizer

TABLE 26

UNIT COSTS FOR IMPLEMENTING BEST MANAGEMENT PRACTICES

Land Use	Best Management Practice	Cost/Acre-Treated/Year
Croplands	**Fertilizer Application**	
	Nitrification Inhibitors	+
	Split Nitrogen Application	$7 [38]
	Nitrogen Injection	$7-$8 [38]
	Proper Timing	$0
	Aquaculture Ponds	$31 ****
	Soil Stabilization	
	Conservation Tillage	$0 [39]
	No-Till Planting	$0 [54]
	Wind Strip Cropping	$57 [1] ++
	Cover Cropping	$8 [38] *
	Contour Farming	$0 [39]
	Terrace Construction	$160-300 ** [38]
	Windbreak Establishment	++
	Pesticide Control	
	Proper Timing	$0
	Proper Disposal of Wastes	$0
	Product Substitution	$0
	Waste Recycling	$0
	Crop Rotation (Peanuts/Sorghum)	$500 *** [3][9][10][11][53]
	Continuous Pest Monitoring	$5 [51]
	Biological Control (Wheat,Peanuts)	$3-6 [48] ***
	Altering Planting Times	$0
	Soil Fumigation	$1800 [41]
	Biological Control (Pecans)	$6.50 [48]
Residential Areas	Regulations and Ordinances	$0

TABLE 26

UNIT COSTS FOR IMPLEMENTING BEST MANAGEMENT PRACTICES

(Continued)

Land Use	Best Management Practice	Cost/Acre-Treated/Year
	Community Cleanup Programs	$0
	Increased Infiltration	$0
	Sedimentation/Filtration Ponds	$13 **
	Erosion Prevention (Chemlawn Treatment)	$230 [52]
	Street Cleaning	$43 [43] +
Quarries	Diversion Structures	$20 [38] **
	Removal of Collected Water	$118 **
	Revegetation	$8 [38] *
Oil and Gas Fields	Diversion Dikes	$20 [38] **
	Filtration Ponds	$13 **
Dairy Farms	Buffer Strips	$10 [38][39] **
	Filter Strips	$1 [38] **
	Double Cropping	$8 [38] *
	Incorporation	$8.50 [38]

* Cost primarily associated with equipement operation.
** Based on information obtained from referenced sources and/or best judgement.
*** Based on seed cost, expected yield, and current market price and does not account for increased productivity resulting from crop rotation.
\+ Not used in Lake Proctor Climate Zone.
\+ + Costs highly variable.
\+ + + Obtained from reference and adjusted to 1991 prices.

following each additional harvest period thereby allowing less excess nitrogen build-up to occur at any given time thereby reducing the runoff potential. The additional cost of applying fertilizer several times during the year is offset by the reduction in the amount fertilizer used.

Build-up in the surface residue from which erosional losses may occur can be reduced by **nitrogen injection** under most forms of conservation tillage thereby reducing the potential for nitrogen contamination in runoff. This method allows application without significant disturbance of the cover crop or soil surface.

The **proper timing of nitrogen application** can maximize the efficiency of crop uptake and reduce the amount of nitrogen that attaches to sediment and organic material on the soil surface. This includes avoiding the fall application of nitrogen, especially in wet climates as is found in the Lake Proctor watershed where the potential for loss through runoff is high. If fall application is necessary, the Texas Agricultural Extension Service recommends that this be done while the soil temperature at the four inch depth is below 50 degrees (F). An exception to the avoidance policy for fall fertilizer application includes fall application to wheat and oats which grow and take up nutrients in the cooler months. Nitrogen fertilizers should not be applied to sandy soils in the fall, especially in wet climates, since much of it will be leached during rain events and require reapplication.

7.1.2 Soil Stabilization Practices

Common soil stabilization techniques currently used on cultivated lands in the Lake Proctor watershed include the establishment of wind breaks and the leaving of crop residue cover on fields until immediately prior to plowing to reduce stormwater-induced soil erosion. A small amount of wind strip cropping is done to control wind erosion from sandy soils. The currently available technology for stabilizing sandy soils used for peanut cultivation lags behind the need for new research in this area. Better methods are needed for farmers to reduce the amount of soil lost from farming practices[20].

No-till planting is considered an effective erosion control practice used on agricultural lands though is rarely used in the study area. Seeds are placed in the soil without tillage thereby retaining previous plant residues. Chemical herbicides are often used to kill the previous planting and control weeds. Plant and root residues that remain provide the necessary surface stabilization. No-till planting can reduce soil loss to less than five percent when compared to conventional planting and plowing practices[40]. It is most effectively used in dormant grasses or small grains. This practice minimizes spring sediment surges and provides year round control of soil erosion. Labor, machine hours, and fuel requirements are reduced by using this method, though more pesticides and nitrogen applications are required[1]. A small additional amount of nitrogen fertilizer is required added to facilitate the decomposition of organic matter in the form of left over plant residue. Little or no additional equipment would be required in the study area for employing no-till farming methods since the soils used for peanut production here primarily consist of sandy loams which are easily penetrated. The Agricultural Extension Service in Comanche county is currently researching future applications for no-till farming but are limited by funding[20].

Residues left on the ground for long periods of time harbor diseases that effect crops. Southern blight is a problem associated with crop residue which acts be releasing plant-killing toxins[20].

Conservation tillage is a technique recommended by the Department of Agriculture to reduce soil erosion by cultivating a cover crop between row crops in order to stabilize the soil surface. This practice replaces conventional plowing with some form of tillage that retains some of the residue mulch on the surface. Plowing is done either in strips plowed across slopes or in row zones in which inter-row zones are left untilled. In areas where water availability is not a major problem, water loss through uptake by the additional plant mass is offset by the reduced loss in topsoil, and the subsequent reduction in non-point source pollution generated. This practice is employed to a limited extent primarily on sandy soils used for peanut production in the study area. Because of the inversion type plows often used for this method, less fuel is used in operating farm machinery.[39] Conservation tillage is more widely adaptable but less effective than no-till planting. The advantages and disadvantages are generally the same as for no-till farming but to a lessor degree[1].

Wind strip cropping is a conservation technique intended to reduce wind-caused erosion on cultivated sandy soils. The method involves planting bands or strips of approximately 50 feet in width with some type of vegetative cover that grows tall enough to act as temporary wind breaks on otherwise bare soils exposed between crop harvests. Within the Lake Proctor drainage, peanuts are the primary crop grown on sandy soil but, because many of the chemicals used for peanuts inhibit the growth of strip crops this practice is not common here. For wind stripping to be effective in this area, larger tracts of land would be required to allow buffers between the chemicals used for peanut production and the areas used for stripping[42]. Because of the need to rotate croplands used for peanuts, wind strips would be required to be re-established with every new planting[20]. This technique is rarely used in the study area.

Cover cropping is a soil stabilization technique practiced between growing seasons whereby a cover crop is established during winter months. In addition, tilling operations are normally postponed until immediately prior to the planting of the summer crop thereby leaving a protective cover of crop residue on the surface as long as possible. Cover crops are disadvantageous on fields where manure is applied because vegetation tends to prevent the solid wastes from reaching the soil layer thereby increasing the potential for mechanical removal by storm water. Livestock wastes are often applied to an area and disced in before a cover crop is introduced to improve the seed bed condition of the soil[39]. Bermuda grass is commonly used as a cover crop in the study area on sandy soils which are planted in peanuts[42].

Contour farming involves conducting field operations such as plowing, planting, cultivating and harvesting across slope. This is best suited to soils having smooth, uniform slopes and has been found to reduce soil loss by 50 percent on moderate slopes, but less so on steep slopes. If used on long slopes, contours can be supported by terraces. One disadvantage to contouring is that structural instability occurs on less stable soils where large machinery is used. Contouring can reduce average soil loss by 50 percent on moderate slopes, but less on steep slopes. Effectiveness is also lost if rows are allowed to break over. These must be supported by terraces on long slopes. Fertilizer and pesticide applications are apparently not effected by this practice[1]. Contouring is not commonly used in the study area because of the shallow slope characteristics found there.

Construction of terraces, utilized more during the 1950's and 1960's than today, is a method of reducing soil erosion by reducing slope gradients that would otherwise create high velocities in runoff water. This practice has the effect of reducing soil erosion and conserving soil moisture[1]. The Soil Conservation Service (SCS) is involved in a cost share program utilized for the building of new terraces for which the SCS is responsible for design and land management requirements. Many of the terraced areas in the watershed have been allowed to revert to pasture though some are still maintained as cropland.

Wind erosion from sandy soils can be reduced through the establishment of **windbreaks** strategically located where they would have the greatest effect. Much work has been done in the past and is continuing to be done to establish tree lines, brush lines and fence lines intended to act as barriers from wind but the identification of these areas may be enhanced through information gained from NPS monitoring.

7.1.3 Pesticide Application Techniques

Best management practices associated with pesticide application include use of the proper timing; proper disposal of pesticide containers which could otherwise leak into the environment; proper use of a pesticide for a particular soil condition; waste minimization and implementation of Integrated Pest Management (IPM) methods developed to reduce the amount of chemicals needed to optimize pest control. Waste minimization includes product substitution, waste exchange and waste recycling. Characteristics of pesticides that should be considered when determining the best method of application in order to maximize its effectiveness and reduce the potential for losses include the compound's mobility and degradation characteristics. A pesticides mobility is a function of its tendency to either dissolve in water or attach to soil particles. The mobility will determine which of these vehicles for transport should be controlled or avoided. The degradation of a pesticide following application is an important consideration when attempting to reduce the potential for its entering groundwater or surface water sources, because application methods can be used that result in rapid breakdown of the pesticides structure when it leaves the application zone.

The proper pesticide for the particular soil condition should be considered to reduce its movement. In areas with high water tables, only those pesticides having very low mobility should be used and only at times when no rainfall is likely to occur in order to avoid its entering the groundwater. In areas of high soil permeability, low mobility pesticides should be used because they are less likely to become a source of NPS pollution by moving through the soil carried by water. Pesticides designed for incorporation should not be applied to the surface since they generally have low mobilities and tend to remain where they are applied. The mobility characteristics of a particular pesticide formulation is indicated on the container label and should be considered before application.

Proper timing of an application includes avoiding its use during those times when it would likely be lost or be ineffective. By avoiding the application of pesticides when rainfall is likely waste from wash-off of expensive pesticides can be reduced which consequently reduces the amount of contaminated runoff entering the environment. Timing can also be effective on the target pest when the applicator is aware of those times during the life cycle of the target organism that it is most susceptible to the particular pesticide formulation used. Improved pesticide application can be achieved by paying attention to proper pressure, timing and agitation as well as proper maintenance of application equipment.

Proper waste disposal is an important consideration when reducing the potential for off-site contamination. Hazardous pesticide containers should be disposed of properly, as outlined on the label in a manner suggested for the particular chemical formulation.

Pesticides are classified as either hazardous, acutely hazardous, or Texas regulated wastes. The disposal of these requires completion of a Uniform Hazardous Waste Manifest when shipped off-site for treatment, storage or disposal. Typical wastes generated from an agricultural application include rinsate from empty containers and the containers themselves. Empty pesticide drums or containers may be disposed of in a sanitary landfill without completion of a Uniform Hazardous Waste Manifest only if they have been triple rinsed and rendered unusable by removing both ends, puncturing or crushing the container. Pesticide rinsate or residue can be reused or retained for future use so long as it is used for the purpose for which it was intended[44]. The disposing of pesticide wastes by other means should be avoided in order to be in compliance with state laws designed to protect the environment. The Texas Water Commission (TWC) has established a waste exchange program "RENEW" (Resource Exchange Network for Eliminating Waste) through which farmers can increase their knowledge concerning the reuse and reclamation of waste pesticides. Information for the program can be obtained by contacting the TWC[44].

Product substitution involves evaluation of the use of non-hazardous products in the place of more hazardous products. Coordination between an agricultural manager and his chemical supplier can result in his finding of substitute products that would have the same effect on crop pests as the more hazardous chemicals for his particular situation.

Waste recycling involves reusing rinsate from empty containers and excess pesticides left over after an application is complete. This practice reduces the amount of waste generated and reduces the potential for its entering the environment as a NPS pollutant[44].

Integrated Pest Management (IPM) employs alternative methods of pest control designed to avoid an applicators responding to a pest problem by adding excessive amounts of pesticides. The intent of IPM is to reduce the amount of pesticides used in order to reduce the non-point source pollution potential of pesticides from agricultural lands by using alternative methods. IPM techniques, including continuous monitoring of pest populations, evaluation of the most effective pesticides to apply and the timing of applications are practiced commonly on peanuts and pecan crops[20]. Because of the current acceptance of these practices area farmers may be receptive to other IPM practices such as biological control which is not currently used in this area.

These methods include the following[45]:

Crop rotation can reduce the number of pest species by cheating those that have been able to prosper due to the presence of a specific crop. The tendency for a pest population to increase as a result of growing the same crop through several crop cycles, along with the decline of pest species that utilize some alternate crop can work to the advantage of a farm manager if he plants a crop which the pest species does not parasitize.

Continuous monitoring of pest populations enables the land manager to apply the optimum amount of control measures as a function of the numbers of a certain pest species that must be controlled. The Texas Agricultural Extension Service employs "scouts" who, for a fee will make periodic visits to cropland areas in order to assess pest thresholds and numbers for which he can recommend the best time to apply treatment, the kind of treatment and the amount of application[45].

Resistant crop species which are developed through agricultural research programs are available to farmers that when available can be used to protect against specific pests. Disadvantages may include higher seed costs and lower yields.

Pheromone application is used to confuse certain organisms during their breeding period by attracting potential mates to pheromone application areas. The predominate application for this technique is as a bait for traps used to monitor the population of insect pests. These compounds, produced synthetically, mimic the scent of certain pest species used to attract breeding pairs to each other.

By **altering planting times** in order to avoid those times when pest populations are reaching a peak, a farm manager can allow a crop to become established during a time when pest numbers are reduced. By monitoring pest populations and having a knowledge of their life cycles the best time to plant a crop in order to avoid its availability to pest species can be determined.

7.1.4 Aquaculture Ponds

Water hyacinth (*Eichornia crassipes*) ponds have been recommended as a possible alternative for treating NPS runoff[46]. This method involves the collection of stormwater in a catchment basin which contains some form of vegetation specifically chosen to remove and incorporate contaminants. Water hyacinth systems are capable of removing large amounts of BOD, TSS, metals, and nitrogen as well as significant levels of trace organics. Nitrogen removal rates for runoff having N concentrations in the range typical for runoff from agricultural lands (9 mg/l)[16] can approach 50 percent using an aquaculture system[47]. Floating plants are preferable to submerged forms since they tend to block out sunlight thereby inhibiting algal growth. If allowed to become established, algae would carry pollutants incorporated into algal cells downstream with water drained from the pond whereas the larger plants would be containable. Other floating plants that have been used and/or tested for aquaculture systems include duckweed Lemna sp., Spirodela sp., and Wolffia sp., and pennywort Hydrocotyle umbellata[46].

Because of low tolerance for cold water temperatures, water hyacinth systems would be effective only about 6 months out of the year in the Lake Proctor area. This time frame corresponds both to the higher fertilizer application rates of the spring and summer and to that period of the year that experiences the more intense storm events. Maintenance of these ponds would require annual draining and removal of plant material. Restocking of hyacinths would be required each spring when water temperatures reach 50 degrees fahrenheit. This would involve either maintenance of seed stocks in protective environments during the winter months or shipping plants from the south each spring. Hyacinths ship well and are easy to collect and add to pond systems. It has been estimated that a single hyacinth plant can produce 45,000 more during a six month growing season. Roughly 600,000 plants will completely cover a one acre pond[46].

The design of the pond should take into account factors which would maximize the nutrient removal efficiency of the plants. Since the roots extend only inches below the water surface, the relative amount of water coming into contact with the roots increases as the pond depth decreases. Three to five foot depths have been used in experimental treatment systems. The suggested maximum single basin area (for secondary treatment systems) is one acre and the recommended basin shape has a 3:1 length to width ratio[46]. The small recommended size is intended to facilitate clean-outs. Since no information was found concerning design of aquaculture systems for stormwater applications, further research may be needed to determine the optimum design for treating the lower concentrations associated with nonpoint source pollution.

The application of **aquaculture ponds** would be limited to those areas identified as contributing excessive NPS loadings. Because these impoundments would be intended for capturing stormwater runoff, a large pond-volume-to-treated-land area ratio would be needed in order to have the available storage capacity to contain the volume of water generated from a cultivated area during a large storm event. A one acre pond with a three foot depth above a normal pool elevation of two feet could capture 1/2 inch of runoff from approximately 72 acres of drainage area, or 18 acres for two inches of runoff. These ponds should be established at the hydrologic control points of drainage areas determined by NPS monitoring to contribute high concentrations of NPS loadings. Ponds would include outlet structures designed to slowly release excess volumes contributed by stormwater over a 24 hour period until the water level in the pond reached its normal pool elevation. More detailed soils analysis is required to determine whether these ponds would require liners for water retention. The amount of expected water loss from evapotranspiration in hyacinth ponds between rain events should be analyzed to insure that an adequate storage capacity is available to avoid their drying out. Other considerations for an aquaculture systems include mosquito control, water loss through evapotranspiration, vegetation management, sludge removal, and pond liner requirements.

Mosquito control can best be accomplished through the introduction of mosquito fish gambusia affinis. Other organisms that control mosquitos include frogs and grass shrimp palemonetes kadiakensis.

Water loss through evapotranspiration (ET) is accelerated by water hyacinths by up to three times the normal pan evaporation rate for an area. ET losses calculated for hyacinth basins in Kissimmee, Florida were found to range from 0.5 to 0.8 gallons per day per square foot[47] which equals two to three feet of draw-down per month caused by evapotranspiration alone. The actual draw-down due to water loss would be much less than this amount since input from rainfall and runoff also contribute to the net loss.

Since the local climate will not allow year round growth of the hyacinths, annual removal of plants and plant debris will be necessary during the winter months. Because the plants are roughly 95 percent water, an intermediate drying step is recommended prior to disposal or utilization. The most common drying method involves simply spreading the plants in an open area adjacent to the pond. The simplest method for beneficial reuse of the plant material is to compost it and then use that material as a soil conditioner/ fertilizer. Processing of the plants for animal feed has been shown to be technically feasible but marginally cost effective[46].

7.2 Orchards

Orchards are intensively managed areas on which little wastage of pesticide applications is likely since control chemicals used are normally sprayed directly on the leaves at close range, and most pesticide formulations used break down quickly if allowed to reach the soil. Common pests that effect pecan trees in Texas include the pecan nut casebearer, walnut caterpillar, fall webworm, yellow aphid, hickory shuckworm, spider mite, black pecan aphid, stink bug, leaf footed bugs, pecan weevils and phylloxera.

Biological control involves the cultivation of specific pests in large quantities for agricultural applications to control pests that they naturally prey on. This practice includes the use of parasites and diseases to control insects and weeds. Bio-Fac, Inc. located in Mathis, Texas cultivates and sells quantities of green lacewing flies which have proven to be effective in controlling soft-bodied insects such as aphids and green bugs which parasitize pecans and wheat. Application is made using tubes containing approximately 500 pre-fed adult lacewings each which, upon release lay up to 400 eggs over a three to four week period that hatch in approximately three days and begin feeding. The cost of application has been reported to be less than that for pesticides usage while the effectiveness is said to be comparable[48]. This method has been used to some extent in parts of south and central Texas but has had little or no application in the Lake Proctor area.

Soil fumigation is an alternative control technique taken to exterminate soil borne pesticides such as nematodes and give a crop the best chance of developing into a healthy stand. Research indicates that for pecan orchards in the study area, little or no increase in productivity is gained through this method[20].

7.3 Dairy Farms

NPS runoff generated on lands on which livestock waste is applied is mainly a function of the presence of vegetative cover, degree of incorporation, and the amount of manure applied. Best management practices utilized to reduce the potential for waste losses from soil include pretreatment, variable cropping practices, timing of applications, buffer strips, filter strips and incorporation. Runoff volumes can be decreased through the addition of manure to soils to some extent because the addition of organic matter increases the soils infiltration rate[29].

Part of the criteria used to choose alternative methods of waste disposal and design considerations may include environmental concerns that are not related to non-point source runoff. The major public relations problems that may ultimately shape future policies by the regulating agencies concerning feedlot operations include odor and the accumulation of flies. Because of currently depressed milk prices, innovative new waste handling technologies are generally not being implemented at dairy operations in the Lake Proctor watershed[32].

The quantity of inorganic salts and heavy metals fed to livestock will effect the concentrations of these compounds found in the waste. Animals (swine) fed rations high in copper will produce wastes that contain high quantities of copper. Inorganic salt fed to cattle will result in higher salinity wastes produced. At least one study found no benefit in daily gain and feed efficiency by providing additional salt in a cow's diet. Animals fed a roughage ration of vegetative feed excrete more potassium than those fed a high concentrate ration of grains, since grains have a lower potassium content[29]. Nitrogen control by rationing is probably unnecessary since this is one of the most expensive components of animal feeds, and so normally contain the minimal amounts that will give optimal performance. No research was found that deals with the effects of rationing on nitrogen, phosphorous or BOD content of livestock wastes.

7.3.1 Pretreatment Alternatives

Several alternatives for livestock waste management are currently being studied at the Institute for Applied Research at Tarleton State University located in Stephenville. Potential alternative methods include composting, the rock-reed filter method, bio-remediation, solids separation units, double cropping cultivation techniques, and evaporation ponds[32].

The nitrogen content of animal wastes can be reduced before application using certain management techniques. The application of livestock wastes on agricultural land within the Lake Proctor watershed is intended primarily as a waste treatment process rather than a source of fertilizer so any reduction in nitrogen content before application would be beneficial.

Utilization of **rock-reed filters**, also known as the "wetlands" method involves passing a wastewater stream through a wetlands type environment where biological processes associated with inherent plant forms and microbes break down organic compounds into simpler forms. This method has been used successfully at small municipalities for treatment of municipal wastes having constant flows, but there is a concern that dairy wastes, having a higher solids content might tend to clog a rock-reed filter system. If utilized for livestock wastes, the filter system would probably follow lagoon treatment in order to remove solids[32]. Use of this method would require a delicate balance of wastewater inflow to avoid either flooding the system or allowing it to dry out. An actual pilot study using the higher solids content waste associated with livestock would be necessary to determine the feasibility of this method for use at area dairy operations.

Bio-remediation involves the introduction of specific microorganism strains for the purpose of breaking down solids in waste lagoons to reduce odors and organics concentrations. This technique is currently being used at some area dairy farms with some success[32].

The BOD content of animal wastes can be reduced through the **digestion process**, though the effect on land application properties of the waste have not been established[29].

Evaporation ponds are shallow catchment areas constructed to maximize evaporation for an applied wastewater thereby creating a more solid material that can be spread on agricultural lands for treatment purposes. There is a concern that this may not be an effective treatment method within the Lake Proctor watershed because of the generous amount of precipitation received here. Based on computer simulation conducted at the Institute of Applied Research at Tarleton State

University in Stephenville, evaporation ponds would be feasible within the study area provided a large amount of land were available. One problem with these systems is the build-up of salts that reduce the evaporation rate of the pond[32].

Composting is a method predicted to reduce nutrient levels in livestock wastes to 1 mg/l for nitrogen, phosphorous and potassium. This method is attractive since nitrates entering soils within the watershed is a major concern and phosphorous is a limiting nutrient within the watershed. Problems associated with this alternative include odor, the additional permitting that would be required through the Air Control Board in addition to the TWC requirements, and the need to transport the wastes to a central location. This option would involve transporting livestock wastes to an area where the composing process can be monitored to insure the proper composition of nutrients is attained before the solids are land applied for final disposal. Composting for too long a period results in a high percentage of nitrates which has a higher pollution potential than other forms of nitrogen.

Solids separators are used at some dairies primarily to treat flush water from milking parlors prior to it's treatment in a lagoon. Funding for these additional systems makes their installation cost prohibitive for smaller dairy farms[32].

7.3.2 Application Techniques

Double cropping is an agricultural technique involving crop rotation whereby the result is that more waste is assimilated because live plants are taking up nutrients throughout the year. One example of this technique now in practice within the study area is the planting of winter wheat followed by coastal bermuda grass in the summer[32]. Double cropping improves the soil structure and enhances its ability to assimilate wastes.

The quality of runoff is largely dependant on the **timing of the application**. Applications of manure in the spring has been shown to result in little or no runoff, while winter applications are extremely variable ranging up to 24 lb/ac in one study. Addition of manures to frozen soils results in high quantities of nitrogen, potassium, and phosphorous in runoff though less so for phosphorous since it is more soluble in manure [29].

Incorporation of animal wastes after soil application results in lower losses of nutrients through runoff. Incorporation of nitrogen forms such as urea and manure helps reduce losses from surface runoff and soil erosion, though the use of tillage for this purpose would increase the erosion hazard by breaking up the soil surface layer. This practice is required by the TWC to be performed within 48 hours of the application of livestock solid wastes. Some of the smaller, unpermitted dairies might apply solid wastes to their own lands without proper incorporation because of the damaging effect this practice has on a fields ability to recover. Normally manure is applied to croplands prior to planting of a cover crop in order to prepare the seed bed for the next crop.

Buffer strips can be established within croplands to allow filtration and partial treatment of runoff from areas on which manure is applied. Normally a 15 foot strip of bermuda grass is planted between 100 to 130 foot strips of crops resulting in an approximately 13 percent reduction in the amount of land available for crops.

Filter strips are similar to buffer strips but are established along the downstream perimeter of a cultivated area resulting in a substantial reduction in the land needed for the strip. This results in a potentially large cost savings both in grass sprigging and land available for cultivation. The Conservation Reserve Program (CRP), available through the Agricultural Stabilization and Conservation Service (ASCS) is a program by which farmers with land dedicated to filter strips can be reimbursed for loss of production. To enroll a section of land used as a filter strip, a farmer must apply by stating the amount of annual payment per acre he would accept for converting cropland. If this bid is accepted, a 10-year contract can be signed with the USDA during which a landowner is paid for lands utilized as filter strips. The extent to which filter strips are already used was not determined for this study but their utilization provides a relatively inexpensive method for reducing nutrient loadings from land used for manure treatment.

The Agricultural Extension Service at Texas A&M University in College Station is currently conducting a study in the Bosque River basin, located to the east and adjacent to the Lake Proctor watershed, involving NPS source runoff contributed by lands used to treat livestock wastes. NPS loadings resulting from various manure application rates are the primary focus of this study for which results are expected to be available by the middle of 1992[27].

7.4 Industrial Areas

7.4.1 Quarries

Controls for NPS pollution resulting from mining operations must include erosion control practices limiting loss of particulates from stripped lands and control of acid mine drainage water. Recommended control measures include: diversion of surface runoff around exposed mine areas, minimization of contact time with acid forming minerals whereby collected water is removed following rains, equalizing the flow of water pumped from the mine over a 24 hour period rather than removing slugs of potentially high concentration material, employing re-vegetation efforts following mine closures, avoidance of stockpiling of mined material in exposed areas, treating acid mine drainage with neutralizing chemicals such as lime, and dilution of acid mine discharge into streams by low flow augmentation[1].

7.4.2 Oil and Gas Fields

Best management practices designed to reduce the amount of oil saturated soil in and around oil wells include bio-remediation, physical removal of saturated soil, and storm water detention. Bio-remediation involves the application through spraying apparatus of oil digesting microbes whereby the waste product is broken down into smaller carbon chains that can be metabolized by naturally occurring organisms. Since spilt oil tends to collect in the upper one inch layer of soil, unless pushed down over a period of time by additional oil, it will be recoverable by hand equipment or heavy machinery such as front end loaders. Oil that is physically recovered will require proper disposal in a proper waste handling facility designed to handle petroleum products. Large areas for which other means are impractical could include storm water diversion structures that drain into a filtration pond in which oil particles are removed by filtering though a sand layer which must be periodically replaced.

7.4.3 Localized Industries

Industrial areas comprise less than one percent of the Lake Proctor watershed but are potential sources of heavy loadings of NPS pollutants associated with sediment. Industrial sites include large amounts of impervious surface area associated with parking lots and rooftops from which increased volumes of stormwater may be generated carrying pollutants removed from materials stored on-site that are associated with industrial activity. The Environmental Protection Agency's (EPA) new stormwater permitting process will regulate industrial operations in urban areas and will add a new level of NPS pollution control.

7.5 Residential Areas

Residential areas make up less than one percent of the total watershed area but are normally major sources of nutrients and pesticides on a per acre basis. Because of the highly managed character of urban sources of non-point pollution, these areas have a high potential for NPS control. Lawns and impervious surfaces are the main sources from which pollutants from non-point sources originate in residential areas.

Non-point source loadings resulting from stormwater runoff from urban areas can be controlled through implementation of existing removal technology such as stormwater retention ponds and by utilization of equipment designed to actively remove accumulated debris from impervious surfaces. Increased public awareness concerning environmentally sound practices used within citizen's property boundaries can reduce the amount of fertilizers and pesticides added to lawns that are potentially washed off during storm events. Promotion of community cleanup programs has been effective in some areas in reducing the amount of litter and trash that builds up in recreational areas that are often in close proximity to waterways.

Effective and enforceable **regulations and ordinances** relating to street cleanliness can be effective if adequate placement of litter containers is attained and public awareness is maximized. Newspaper, radio and television media can be used to educate the public on the ramifications of street litter, including its effect on water pollution. Specific regulations should be directed to common sources of urban litter including open trucks, refuse dumping operations, building construction and demolition, vacant lots, drive-in restaurants, trailer courts, stadiums, distribution of handbills and direct discharges into storm sewers. Regulations should be established that limit the use of chemicals commonly used for weed and pest control as well as fertilizer application. Since municipalities are usually responsible for a large amount of these applications, regulations should be relatively easy to enforce[49].

Well publicized **community cleanup programs** involving weekend projects have been effective in some cities at recreational and scenic areas for which the public has a heightened interest in the aesthetic quality of nearby outdoor areas. Those public officials responsible for maintaining clean streets should establish anti-litter ordinances and be given adequate legal authority to enforce those ordinances.

Increased infiltration reduces the amount of storm water runoff in urban areas that would otherwise carry with it non-point source pollutants. This can be attained by reducing the amount of impervious surface created during construction development together with the development of surface structures that allow water to seep below ground[1].

Sedimentation/filtration ponds are treatment options designed to remove particles and associated pollutants through a gravity settling process followed by passage through a sand filtration media in a separate basin. When used in series, these systems have been shown to result in removal efficiencies of 70 percent or greater for TSS, BOD and fecal coliforms, approximately 50 percent for iron, lead and zinc, and between 0 and 50 percent removal efficiencies for nutrients. A common control strategy for stormwater treatment is to capture the first 1/2 inch of runoff representing the first flush from the contributing drainage area which is likely to contain the highest concentrations of pollutants. A 24 hour draw-down time is recommended for the sedimentation component of this system to achieve desired removal of solids. Because of travel times and mixing effects, the maximum drainage area treated by each pond should not exceed 50 acres. The land area required for two of these basins has been found to be no more than that for single basin designs.[50]

Erosion prevention can be attained through employment of practices that target denuded areas such as construction sites for the placement of protective cover. Most municipalities now require the use of erosion and sediment control techniques during the development phase to reduce sediment loss. These may include silt fence barriers, sediment traps, diversion dikes and sedimentation ponds. Following completion and grading of developed areas, some form of soil stabilization is often needed until a vegetative cover can be established such as matting or hydromulching.

Street cleaning involves either street sweeping, flushing, or a combination of both for the removal of sediment and debris that collects on roadways between storm events. Sweeping alone is effective only for the removal of coarse particles, while street flushing targets the finer particles which tend to be associated with the bulk of the pollutants. As is true for soils, pollutants tend to adsorb to the finer fractions of sediment. Modern street cleaning equipment uses both sweeping and flushing techniques while collecting the flush water from the street for ultimate disposal at a treatment facility. Street flushing alone is effective as a non-point source control only for municipalities having a combined sewer system since it allows treatment of street flush water added to the treatment system at a time when the system can handle the flow. Flushing equipment allows water to drain into storm sewers while sweeping involves collection of solids prior to ultimate disposal. If street debris is allowed to build up until a storm event occurs, the pollutants may enter surface waters through overflows from a system that is overloaded by storm water. Areas with separate storm sewers would not benefit greatly from flushing operations alone because all the wastes washed from the street go directly into the waterways. Many small influxes of runoff generated by frequent flushing would have a less severe impact than that caused by large, infrequent storm events. Typical amounts of solids accumulation on urban streets ranges from 10 to over 100 grams/curb mile/day and includes nutrients, heavy metals, pesticides and coliforms. Removal efficiencies for vacuum street cleaners have been found to range from 26 to 45 percent for TKN, eight to 14 percent for phosphates, and 33 to 59 percent for pesticides within a range of one to three passes[1].

7.6 Undeveloped Lands

7.6.1 Pastures

Soil stability in a pasture can be improved through proper management which allows healthy grass stands to exist thereby reducing the potential for erosion. Proper pasture management includes fertilization, rotation grazing, proper stocking rates, growing supplemental forage, seeding with improved grass varieties and weed control.

Rotation grazing involves alternating periods when livestock are allowed to pasture the same area. This allows the vegetation to recover between grazing periods thereby reducing soil losses. Stocking rates can be reduced in order to allow recovery of pastureland previously overgrazed.

Planting of **improved pasture grasses** include coastal bermuda grass, Klein grass, and weeping love grass. Improved yield can be attained through supplemental fertilization of grasses used for grazing.

Supplemental forage grown for additional food sources for grazing can be developed in those pastures that are accessible to irrigation water. Plant types grown for this purpose include Johnson grass, small grains, and sorghum[15].

7.6.2 Rangeland

Range management requires an evaluation of the present condition of the range vegetation in relation to its potential. Range condition is a function of how closely the present plant community resembles the potential community or "climax vegetation". The objective in range management is to control grazing so that plants growing on a site are comparable in kind and amount as would be found in an area with no grazing. Proper range management involves the maximum production of vegetation, conservation of water, and control of erosion. Because of long term overgrazing in the Lake Proctor watershed, low quality vegetation now dominates much of the area rangeland including annuals, buffalo grass, three-awns, shin oak, and mesquite. To improve the range condition, grazing intensity must be managed to allow re-establishment and growth of the natural plant community. This can be done by keeping the number of livestock in balance with the various forage yields. Other conservation practices recommended for this by the SCS include brush management and seeding with improved grasses, which is a common method of improving range condition in the study area[5].

SECTION 8.0
CONCLUSIONS AND RECOMMENDATIONS

8.0 CONCLUSIONS AND RECOMMENDATIONS

Conclusions:

- The most effective program for controlling non-point source pollution within the Lake Proctor watershed is one that targets those areas having the highest concentration of land uses that are amenable to control. In general, these are areas already subjected to intensive management. The targets that have the greatest potential for controls within the Lake Proctor watershed include cultivated lands, residential lands, industrial areas, and lands used for livestock operations and livestock waste disposal.

- Croplands in the watershed make up approximately 20 percent of the total land area and include some of the highest potentials for NPS loadings of nutrients and pesticides in the study area on a per acre basis. However, nitrogen contribution appears to be significant only during intense storm events. Current studies indicate nitrogen accumulation in agricultural soils is not occurring. Loadings contributed by phosphorus applied as a fertilizer are predicted to be low although some phosphorous applied as fertilizer becomes a non-point source as a result of erosion on steep slopes.

- Soil stabilization techniques being used on croplands in the watershed can be improved to reduce erosion and subsequent contributions of nutrients and sediments.

- Fertilizer application techniques on croplands appear to be adequate in preventing over-application and accumulation of nutrients.

- Some integrated pest management (IPM) techniques are being utilized, but other methods are available and should be considered.

- Most area farmers are full time land managers who devote considerable time to keeping abreast of and using techniques shown to be effective in reducing fertilizer and chemical applications.

- The analysis of urban areas indicated that residential and industrial areas together make up less than two percent of the total watershed area, but are potentially major sources of nutrients, pesticides and other contaminants, on a per acre basis.

- Best Management Practices (BMP's) for control of nutrients, pesticides and debris in urban areas typically include public awareness programs, routine cleaning of streets and other impervious surfaces, and stormwater retention ponds. No unique aspects of the urban areas in this watershed were identified that would indicate a need for BMP's other than those normally used in urban areas.

- The Environmental Protection Agency's (EPA) new stormwater permitting process will regulate industrial operations in the urban areas and will add a new level of control of NPS pollution from industrial sites.

- The Lake Proctor watershed contains numerous dairies, pastures, and livestock handling areas which are potential sources of NPS pollution in the form of nitrogen, phosphorous, and organic loadings. Although the Texas Water Commission (TWC) regulates the larger dairies under permits and requires the smaller dairies to develop waste management plans, these regulatory requirements do not necessarily guarantee that water quality will be protected from improper management from improper management of solid and liquid waste contaminants and disposal systems. Additional sampling of surface waters and soils would help detect NPS trends. Continued research into alternative treatment and disposal systems for livestock wastes could provide more effective alternatives for controlling NPS pollution in areas where negative water quality impacts are detected.

- The potential for NPS loadings from oil and gas field operations could not be completely quantified within the scope of this study. However, field observations would indicate such sites may be potentially significant sources. Contamination of soils and tributaries appears to be occurring, at least on a local basis, from leakage and spills around storage tanks.

- Several unsewered lakeside developments showed the potential to become problematic with respect to improper treatment of sewage. Site inspection revealed undersized drain fields and direct discharges to drainage channels. Current development densities are such that these conditions can probably be resolved only by construction of centralized sewage collection and treatment systems.

- The evaluation of pecan orchards concluded that NPS loadings are likely to be insignificant. Pesticide and fertilizer application methods being utilized appear adequate to contain these chemicals within the application area.

Recommendations:

- Additional windbreaks should be established in cultivated areas that are prone to wind erosion based on the knowledge of locations of sandy textured soils and through the identification through NPS monitoring of drainage areas that contribute large amounts of sediment loads.

- Where existing BMP's appear to be inadequate to prevent nutrient runoff from cultivated lands, aquaculture ponds should be considered established for those drainage areas determined through monitoring to contribute excessive NPS loadings.

- Further research in soil stabilization techniques on croplands should be continued in order to assess the applicability and potential effectiveness of various alternative farming practices such as no-till farming.

- New integrated pest management practices currently being studied should be considered as a way to reduce the quantities of pesticides applied to cultivated lands.

- Area communities should consider ways to improve upon current methods used for cleaning streets and other impervious surfaces in urban areas. The capacity of existing wastewater treatment facilities to treat wastes collected from impervious surfaces should be evaluated.

- Public awareness and community clean-up programs should be established for urban areas.

  Sedimentation and filtration ponds should be established for those drainages in urban areas identified through NPS monitoring as contributing excessive loadings despite the implementation of improved street cleaning practices and public awareness programs.

- Random sampling should be conducted on soils used for livestock confinement areas and lands on which livestock wastes are applied to identify those areas for which additional controls should be implemented.

- Filter strips should be established along the downstream perimeters of lands treated with livestock wastes for those areas found in close proximity to waterways and those identified through NPS monitoring as contributing excessive loadings.

- Innovations and practices intended to improve methods for treating livestock wastes, currently being studied at research institutions should be considered for implementation as they are developed in the future.

- A more detailed analysis of the amount of land included in oil and gas field operations in the Lake Proctor watershed is recommended to be used in conjunction with monitoring data to assess the need for nonpoint source controls. For those areas determined to be significant sources, a combination of sedimentation/filtration basins and of repair options for leaking oil field equipment are recommended. Small contaminated areas can be cleaned through localized labor using hand tools and earth moving equipment.

- Wastes generated by small unsewered lakeside communities using septic systems should be put on-line with centralized wastewater collection and treatment facilities.

- Though the potential for NPS loadings contributed by orchards was found in this study to be small, stream monitoring should be conducted to identify problem areas resulting from poor management practices.

SECTION 9.0
REFERENCES

9.0 REFERENCES

[1] Novotny, Vladimir and Gordon Chesters, 1981, Handbook of Non-point Sources and Management, Van Nostrand Reinhold Environmental Engineering Series.

[2] U.S.D.A., 1989 Texas Agricultural Statistics, Texas Agricultural Statistics Service, Texas Department of Agriculture, Austin, Texas.

[3] U.S.D.A., 1985 Texas County Statistics, Texas Agricultural Statistics Service, Texas Department of Agriculture.

[4] Lillesand, Thomas M. and Ralph W. Kiefer, Remote Sensing and Image Interpretation, John Wiley and Sons.

[5] U.S. Soil Conservation Service, 1977, Soil Survey of Comanche County, Texas, USDA, Soil Conservation Service.

[6] U.S. Soil Conservation Service, 1977, Soil Survey of Eastland County, Texas, USDA, Soil Conservation Service.

[7] U.S. Soil Conservation Service, 1973, Soil Survey of Erath County, Texas, USDA, Soil Conservation Service.

[8] Archie Olson, Texas Department of Agriculture, Agricultural Statistics Services, Personal communication 5/31/91.

[9] Anon, Golden Peanut Seed Store, Comanche, Texas, personal communication 5/29/91.

[10] Russel Daggle, Callahans General Store, Austin, Texas, Personal communication 5/29/91.

[11] Brad Pierce, Texas Department of Agricultural, Austin, Texas, Personal communication 5/31/91.

[12] Texas Department of Health, Brucellosis Recording and Reporting System Database, March 1990.

[13] Chesters, G. et al, 1978, Pilot Watershed Studies, Summary Report, International Joint Commission, Windsor, Ontario.

[14] Schenk, J.E., and Sherger, D.A., 1974, The Effect of Residential and Commercial-industrial Land Usage on Water Quality, PLUARG Task A1, International Joint Commission, Windsor, Ontario.

[15] Timmons, D.R., and R.F. Holt, 1977, Nutrient Losses in Surface Runoff from Native Prairie, J. Env. Quality, **6**:369-373.

[16] Loehr, R.C., 1974, Characteristics and Comparative Magnitude of Non-point Sources, J. WPCF, **46**:1849-1872.

[17] Hsu, P.H., 1965, Fixation of Phosphate by Aluminum and Iron in Acidic Soils, Soil Science,99:398-400.

[18] Uttormark, P.D., Chapin, J.D., and Green, K.M., 1974, Estimating Nutrient Loadings of Lakes from Non-Point Sources, U.S. EPA/600/3-74-020, Washington, D.C.

[19] Steward, B.A., et al, 1975, Control of Pollution from Cropland, U.S.EPA Report No. 600/2-75-026 or USDA Report No. ARS-H-5-1, Washington, D.C.

[20] Bob Whitney, Agricultural Extension Service, Comanche, Texas, personal communication 6/13/91.

[21] Goring, G.A., and Hamaker, J.W., 1972, Organic Chemicals in the Soil Environment, Marcel Dekker, Inc., New York.

[22] USDA, 1990, Results of 1990 Agricultural Demonstration Statistics Handbook, Agricultural Extension Service, Comanche, Texas.

[23] Odie Dalin, Durham Pecan Company, Comanche, Texas, personal communication 6/12/91.

[24] Darlene Colsby, Town of Comanche Chamber of Commerce, Comanche Texas, personal communication of information obtained from the Agricultural Extension Service. Personal communication 6/12/91.

[25] David Tunmire, Agricultural Extension Service, Eastland, Texas, Personal communication 6/14/91.

[26] Lynn Creswell, Soil Conservation Service, Comanche, Texas, personal communication 6/12/91.

[27] Dr. John Sweeten, Texas Agricultural Extension Service, personal communication 5/10/91.

[28] Adriano, D.C., P.F. Pratt, and S.E. Bishop, 1971, Fate of Organic Forms of N and Salt From Land Exposed Manures from Dairies, Livestock Waste Management and Pollution Abatement, Proc. Int. Symposium on Livestock Wastes. P. 243-246. American Society of Agricultural Engineers, St. Joseph, Michigan, 1971

[29] U.S.E.P.A., 1975, Research Status on Effects of Land Application of Animal Wastes, Environmental Protection Technology Series, EPA-660/2-75-010

[30] Joy Watson, Texas Water Commission, Waco, Texas, Personal communication 5/3/91.

[31] Bead Northcutt, State Soil and Water Conservation Board, Personal communication 5/7/91.

[32] Nancy Easterling, Institute for Applied Technology, Tarleton State University, Stephenville, Texas, Personal communication 5/7/91.

[33] U.S.E.P.A., 1972, Runoff of Oils from Rural Roads Treated to Suppress Dust, Environmental Protection Technical Series, EPA-R2-72-054.

[34] Porcella, D.B., Bishop, A.B., Anderson J.C., Asplund, O.W., Crawford, A.B., Greenery, W.J., Jenkins, D.I., Jurinek, J.J., Lewis, W.D., Middlebrooks, E.J., and Walkingshaw, R.W., 1973, Comprehensive Management of Phosphorous Water Pollution, U.S.EPA/600/5-74/010, Washington, D.C.

[35] U.S.E.P.A., 1979, Methods for Chemical Analysis of Water and Wastes, U.S. Environmental Protection Agency, Office of Research and Development, Environmental Monitoring and Support Laboratory, Cincinnati, Ohio.

[36] U.S.E.P.A., 1978, Microbial Methods for Monitoring the Environment, Water and Wastes, U.S. Environmental Protection Agency EPA-600/8-78-017, Office of Research and Development, Environmental Monitoring and Support Laboratory.

[37] 1985, A.P.H.A., Standard Methods for the Examination of Water and Wastewater, 16th Edition, APHA, AQQA, WPCF, Washington, D.C.[38]Soil Conservation Service, 1990, Erath County Acreage Cost Handbook, unpublished, Erath County Soil Conservation Service, Stephenville, Texas.

[38] Soil Conservation Service, 1990, Erath County Acreage Cost Handbook, unpublished, Erath County Soil Conservation Service, Stephenville, Texas.

[39] Don Moore, State Soil Conservation Board, Stephenville, Texas, personal communication 6/13/91.

[40] Forster, D.L. and Becker, G.S., 1977, Economic and land management analysis in Honey Creek watershed, Ohio Agri. Res. and Development Center, Ohio State University, Columbus.

[41] Anon, Safeway Farm Products, Austin, Texas, personal communication 6/13/91.

[42] Guy Clinton, Soil Conservation Service, Personal communication 5/6/91.

[43] Pitt, R., 1979, Demonstration of nonpoint pollution abatement through improved street cleaning practices, EPA-600/2-79-161, U.S. EPA, Cincinnati, Ohio.

[44] T.W.C., 1989, Hazardous Waste Regulations - A Handbook for Pesticide Applicators, Texas Water Commission, Austin, Texas.

[45] Bohmont, Bert L., 1990, The Standard Pesticide User's Guide Revised and Enlarged, Prentice Hall Publishers, Englewood Cliffs, New Jersey.

[46] Dinges, Ray, 1976, Water Hyacinth for Wastewater Treatment, Texas Department of Health Resources, Division of Wastewater Technology and Surveillance, Austin, Texas.

[47] Reed, Sherwood C., 1988, Natural Systems for Waste Management and Treatment, McGraw-Hill, New York, N.Y.

[48] Tom Kelly, Bio-Fac, Inc., Mathis, Texas, personal communication 6/12/91.

[49] U.S.E.P.A., 1974, Water Quality Management Planning for Urban Runoff, EPA 440/9-75-004.

[50] City of Austin, 1987, Design Guidelines for Water Quality Control Basins, Draft, Department of Environmental Protection, Water Quality Division, Austin, Texas.

[51] Harris, B. L., Agricultural Extension Service, College Station, Texas, Personal communication 5/21/91.

[52] Anon, Chemlawn of Austin, personal communication 5/28/91.

[53] Anon, Texas Department of Agriculture, Agricultural Statistics Services, Personal communication 5/31/91.

[54] Forster, D.L., 1978, Economic impact of changing tillage practices in the Lake Erie basin, Tech. Rpt., Department of Agricultural Economics and Rural Sociology, Ohio State University, Columbus, Ohio.