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Environmental Evaluation of Water Resources Development

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Texas A&M University

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ENVIRONMENTAL EVALUATION OF WATER RESOURCES DEVELOPMENT

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ABSTRACT

Methodology for the utilization of LANDSAT-1 imagery and aerial photography on the environmental evaluation of water resources development is presented. Environmental impact statements for water resource projects were collected and reviewed for the various regions of Texas. The environmental effects of channelization and surface impoundments are discussed for twelve physiographic regions of the state as delineated on black and white satellite (LANDSAT-1) mosaic of band 7. With the aid of LANDSAT-1 imagery, representative or typical transects were chosen within each region. Profiles of each site were constructed from topographic maps and environmental data were accumulated for each site and related to low altitude aerial photography and enlarged LANDSAT-1 false color composites.

Each diagrammatic transect, with accompanying data and photographs, provides significant information for input of environmental amenities on a local and regional scale into preliminary water resources development studies. The utilization of the transects provides a visual display of available information, aids in the identification and inventory of resources, assists in the identification of data gaps and provides a planning tool for additional data acquisition.

Remote sensing techniques are readily adapted to water resources planning. LANDSAT-1 imagery as well as conventional low altitude aerial photography provides the planner with a synoptic overview of the resource area. The delineation of physiographic regions by LANDSAT-1 imagery will be helpful in defining delicate border areas and delineating broad environmental areas.

Satellite imagery is applicable for transect siting in aerial river

basin studies or regional analysis. The diagrammatic transects along with satellite imagery can be used to grossly quantify habitat types and amounts.

The transects and accompanying data can be used in displays for public hearings and project monitoring. They lend themselves to constant update and can be included in resulting environmental impact statements.

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CHAPTER I

INTRODUCTION

The 1969 National Environmental Policy Act (NEPA) (PL91-190) requires that an environmental assessment be conducted for each major federal action that significantly affects the quality of the human environment. Initial guidelines were not explicit and many water resources projects were delayed because of inadequate environmental impact statements. It became evident, early in the procedural evolution, that an interdisciplinary approach was required. In order to achieve the necessary interaction between disciplines, the engineering, economic, and environmental studies will be conducted concurrently utilizing much common data and often conducted by many of the same personnel.

A water resources development will often be an environmental modification of substantial magnitude. With special and multi-use structures covering large areas and impacting on a much greater area, environmental inventory and analysis can be extremely costly and time consuming. Prediction of the ecological impact of a project is often the most critical part of the environmental assessment and has been most difficult to accomplish primarily because of the lack of established procedure. To aid in the orderly development of Texas' resources, this study has three objectives; (1) to identify ecological changes associated with specific water resource project facilities or activities, (2) to compile diagrammatic transects depicting the environmental amenities of selected sites based on available information, and (3) to demonstrate the application of these transects to preliminary alternative selection and environmental impact assessment.

CHAPTER II

ENVIRONMENTAL ASPECTS OF WATER RESOURCE DEVELOPMENT

Circuit Judge J. Shelly Wright, in a written deposition on the Calvert Cliffs case, provides this appropriate theme: "Congress did not establish environmental protection as an exclusive goal; rather, so that environmental costs and benefits will assume their proper place along with other considerations" (90).

In Texas, the orderly development of water resources is a necessary prelude to growth and productivity. Perhaps no other state in the union has the temporal and spatial water availability problems of Texas. To exploit this resource, the Texas Water Plan (79) proposes extensive channelization and impoundment of surface and imported waters. The obvious conflict arises between water resource development and environmental protection. In the vein of Judge Wrights comments, a systematic interdisciplinary appraisal of the environmental effects of each alternative is necessary to optimize the human environment.

Procedures for conducting the environmental assessment required by the National Environmental Policy Act of 1969 (PL91-190) have been promulgated by most federal and state agencies involved in water resource development. Moreover, the President's Council on Environmental Quality has published guidelines to which all federal agencies must adhere (65). These guidelines and procedures emphasize the necessity of integrating environmental considerations early in the engineering feasibility studies of project development. Specifically, paragraph 1500.2(b) "Initial assessments of the environmental impacts of proposed action should be undertaken concurrently with initial technical and economic studies..." describes the policy. However, because of subject diversity, they do not provide a detailed method of achieving this purpose. Several recent publications have summarized the literature and analyzed the proposed methods of assessment (8,2).

The latter Environmental Protection Agency publication is based on the lack of a standardized technical assessment method (2). It points out that following the enactment of NEPA (PL91-190), the back-log of "in the pipeline" projects requiring environmental statements developed a procedural process with little emphasis on content. This has evolved into lengthy complex statements of excessive, often unrelated, material the process of which varies with the lead agency. After reviewing numerous impact methodologies, the EPA publication concluded that no single approach to impact assessment is superior in all circumstances.

The answer may lie in what is recognized as the necessity of preliminary environmental studies. Fischer and Francis (41) state that environmental information requirements may become the time horizon within which engineering planning is done. Welland (88) proposes that ecological-environmental research be undertaken even before projects are conceived. This latter requirement is obviously independent of funding for such extensive data acquisition. Realistically, it may be considered a costly overkill. However, Welland does promote three sound ideas. First of all, involve the public in thinking, planning and deliberations; they are a vital, helpful, constructive ecosystem component. Secondly, develop a repertoire of potential alternatives (and their environmental impacts) and seek to augment these over time. Increase the data base with time.

Lastly, monitor existing projects to increase the ability to predict accurately in the future.

Public participation is already a legal component of federal water agency projects. Most of the time, this process is undertaken after project formulation in the form of public hearings. Martel and McLaughlin (56) point out that, in Massachusetts, public hearings did not fill the communications gap because testimony was unanswered. Similar to Texas, Massachusetts has intrabasin water diversion which has encountered stiff opposition from residents of donor areas. The assumption that demands must be met neglects the fact that when a valuable resource is transferred from one region to another without compensation, benefits accrue only to the recipient and costs (environmental and economic) primarily to the donor. This, of course, influences political opposition in the donor area. It has long been recognized that the public, gathered into public hearings, will provide identification of critical environmental areas in terms of what is important to them and "red-flag" potential project trouble spots (48). However, it has now been clearly established that reliance on the concerned public to achieve consensus on matters of relative significance or relative criticality was delusory (56). Perhaps the greatest drawback to public participation is inflated aesthetic values and land costs. Although these will always be difficult to control, it could be addressed through enabling legislation or local sponsor involvement. Nevertheless, the general public can provide valuable information in the preliminary, preformulation period. This information provides agency planners and decision makers with citizen values, interest, and attitudes prior to commitment of agency resources. This could not only provide "timely information" for the public and the agency alike, but could streamline any resulting EIS (Environmental Impact Statement) review. Therefore, public participation should not be limited to the review process (17).

After the draft environmental statement is released, the review process is extremely useful in evaluating the adequacy of the statement, frequently independent of public sentiment and speculation. In this regard, the public hearings may become the unanswered sounding boards of special interest groups.

Welland's second point dealt with a repertoire of alternatives, these are already in existence in most agencies (Table 1).

Lastly, monitoring similar existing projects is also already in practice. However, it is evident by reading many environmental statements, that these Operation and Maintenance (O and M) Environmental Impact Statements are not utilized in the assessment of new projects. The mostly glaring example is the problem of aquatic macrophyte encroachment in Texas reservoirs. These rooted and floating plants choke recreational areas, increase evapo-transpiration, offer resistance to flow, and occupy storage capacity. Partial control is achieved through large applications of chemical herbicides. Nowhere in the statements reviewed for this study were downstream or long range effects considered for the inevitable use of these chemicals in Texas waters.

Alternative evaluation is an integral part of the environmental impact statement; indeed, of the project formulation itself. Hufschmidt (49) found the inadequate treatment of alternatives was of major concern in Water Resource Planning in North Carolina. Further, he was unable to find proof that any project had been altered for environmental

TABLE 1. - Water Development Alternatives (12)

Development and Purpose (1)	Alternative(s) (2)
Flood Control FOR Urban Areas Agricultural Areas Utilities Transportation	Acquire Flood Plain Easements Acquire Flood Plain in Fee Channel Improvement Channelization Clearing, Selective Detention Reservoirs Diversion Drain Enlargement Evacuation, Permanent Flood Forecasting Evacuation, Temporary Flood Fighting Plans Flood Insurance Flood Plain Zoning Flood Proofing Flood Wall Flood Way Land Use Regulation Levee Snagging Urban Redevelopment Watershed Treatment Weather Modification Combination No Action
Water Supply FOR Municipal Industrial Irrigation Recreation	Desalination Diversion Interbasin Intrabasin Priority Use Evaporation Control Groundwater Development Recycle Reduce Use Needs Restrict Use Surface Water Development Weather Modification Combination No Action
Water Quality FOR Water Supply Aesthetics Fisheries Water Fowl	Dilution Diversion of Pollutants Low Flow Augmentation Removal of Pollutants Desalination Advanced Waste Treatment No Action

TABLE 1. - Continued

Development and Purpose (1)	Alternatives (2)
Water Navigation	Air Conveyor Pipeline Rail Truck Combination No Action
Recreation FOR Outdoor Activities Urban Park Water Oriented Land Oriented	Greenbelt Neighborhood Parks Recreation Lake Recreation Stream Combination No Action
Commercial and Sport Fisheries FOR Fish Production Fish Harvest Recreation*	Caged Fish Culture Decrease/Increase Fertility Fish Farming Increase Water Acreage Low Flow Augmentation Fisheries Water Level Fluctuation Combination No Action
Waterfowl and Upland Wildlife FOR Game Production Game Protection Game Harvest	Alternate Marsh Game Farm Greenbelt Lake Hatching Increase Habitat Intense Habitat Combination No Action
Erosion and Sediment Control FOR Bank and Shore Protection Preserve Lake Storage Preserve Channel Capacity	Gabions Groins Silty Reduce Erodable Flow Rip Rap Sediment Entrapment Watershed Treatment Combination No Action
Ground Water Recharge FOR	Natural Surface Open Reduce Consumption

TABLE 1. - Continued

Development and Purpose (1)	Alternatives (2)
Ground Water Recharge (con't.)	
Water Supply	Reduce Spring Flows
Stream Flow	Shafts
	Wells
	Combination
	*Water Spreading Pits
	*Recharge Pits
	No Action
*Not contained in original list.	

reasons but observed a gradual improvement in environmental assessment since the promulgation of the Council on Environmental Quality Guidelines (65). It should be emphasized that NEPA (PL 91-190) Section 1500.8 (1) (4) states: "A rigorous exploration and objective evaluation of the environmental impacts of all reasonable alternative actions... is essential. In each case the analysis should be sufficiently detailed to reveal the agency's comparative evaluation of the environmental benefits, costs, and risks of the proposed action and each reasonable alternatives." Leopold et al. (53), writing for the U.S. Geological Survey proposed that a report detailing the characteristics and conditions of the existing environment be prepared prior to the proposed action. As some of the first authors on the subject, they suggest that in some cases, this report may be incorporated as part of the engineering proposal. Recently, courts have required consideration of alternatives which may accomplish less than the proposed action. Also, an agency must discuss alternatives beyond the power of that agency to implement. The detail of alternative impact discussion should be sufficient to permit the reader to assess the environmental risks of each alternative in comparison to the project proposal (9). This indeed is the crux of this study, to demonstrate a technique which may serve as one tool to analyze the existing environment and incorporate these amenities into preliminary alternative selection and engineering proposals.

The two most common forms of water development in Texas are channelization and impoundment. Both are used for flood control but more importantly in Texas, impoundments are used for water storage. In order to provide background information, the environmental aspects of these actions will be discussed in the following sections.

Impoundments

Surface water storage has provided many benefits for mankind but recently concern has arisen over the subtle and oftentimes extensive environmental consequences which result. Large quantities of money, material and land have been involved in the creation of these impoundments. Common benefits include flood protection, water supply, and recreation which by law, have exceeded the costs. The ecological costs and benefits have not been so balanced. Since rainfall is unevenly distributed over the state, the environmental impact of impoundment is often remote to the project benefactors. This has caused development problems in the state and is an important concern in the implementation of the Texas Water Plan (79).

A considerable amount of research has been conducted on, in, and around surface water impoundments. A complete review is not warranted here because of the broad range of subject matter involved. Primary impacts are the subject of most of the research and are, therefore, well documented. Secondary impacts are oftentimes more subtle, take longer to manifest themselves, and are less well documented, but may be equally as important as primary effects.

Most federal agency checklists of potential impacts are predominately primary impacts. For example, the U.S. Army Corps of Engineers (46) provides the following list:

(1) Conversion of terrestrial habitat to aquatic
(2) Reduction of bottomland forest
(3) Downstream water quality effects

(4) Effects on community cohesion

Many other checklists are available but for the purposes of this report, the following specific topics will be addressed: (a) Remaining lotic habitat, (b) Newly created lentic habitat, (c) Surrounding terrestrial habitat, and (d) Water quality effects.

Remaining Lotic (Running Water) Habitat. Upstream and downstream of surface impoundments, the effects are inversely related to the distance. Velocity decreases nearer the impoundment upstream but may be increased downstream. Stream depth, on the other hand, is likely to be increased as the flow gradually blends into the reservoir but may be decreased or increased downstream of the dam. This depends on the riverine scheme before impoundment and the operating rules of the new lake. Tempertures are also less variable nearer the reservoir. Suspended sediments are settled from the incoming flows and therefore are considerably decreased immediately downstream. The reacquisition of the bed load may cause erosion problems in the receiving channel.

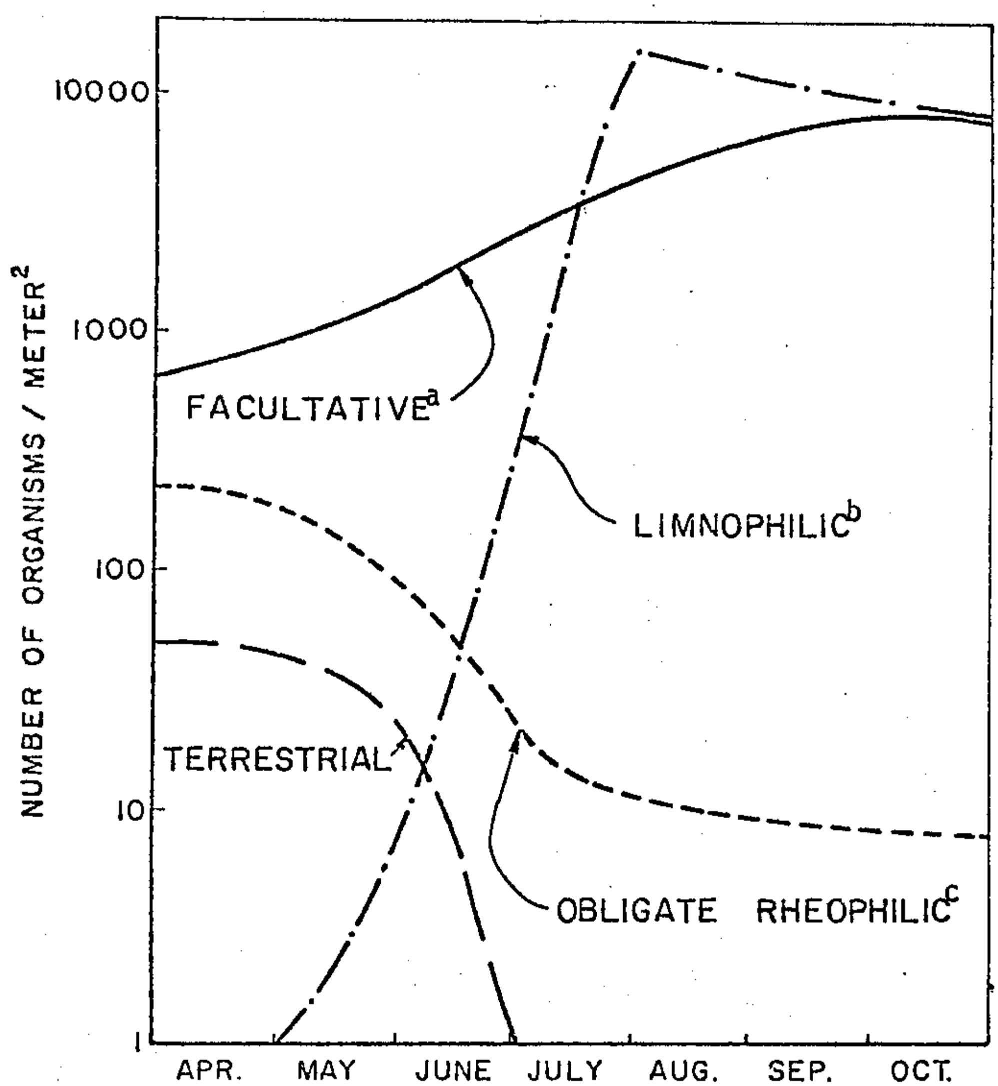
A decrease in benthic diversity is often encountered as a stream enters an impoundment as well as in the tail waters. This is caused by increased depth and sedimentation upstream and erosion downstream. In both instances, the natural riffle-pool sequence is eliminated.

Since most Texas impoundments include flood water storage capacities, the range of upstream impacts will vary with fluctuating water levels. Ideally, an ecotone or pulse stability will develop between the two communities. If waste discharge outfalls (industrial or municipal) are located in this zone, the effluent could conceivably move upstream during certain high water periods. Other pollutants could become adsorbed to sediments which fall out in this zone or their decay rates altered.

In intermittent west Texas streams where secondary channel impoundments predominate, the impact of these phenomena would be greatly reduced. However, if these streams, often dominated by municipal or irrigation return flows, are subjected to substantial volumes of water from interbasin transfer, the effects may be pronounced. With the use of reasonable planning and consideration, these impacts may be beneficial as well.

Recent trends in reservoir designs have emphasized the use of multi-level discharges for Texas reservoirs. The costs associated with these appurtenances may better be spent on other mitigation measures or on watershed management. Fruh (43) has reported massive algal blooms downstream of Lake Livingston when mixing of water levels was undertaken. Downstream channelization or rectification associated with reservoir construction is discussed in following sections.

Newly Created Lentic (Standing Water) Habitat. The creation of large bodies of standing water completely alters the life forms of the flooded stream. The new reservoir is usually rather sparsely populated at the beginning. Stocking of desirable game species during filling is often necessary to insure their establishment and productivity. These introduced species grow rapidly as the available foodstuffs, which have shorter life cycles, multiply virtually uninhibited. Biological diversity then tends to increase until an equilibrium is established (Fig. 1). This equilibrium may take 10-15 years to establish and result



[a]Adaptable to either environment

[b]Lake species

[c]River Species

FIG. 1.- Typical Pattern of Colonization in a New Reservoir (28).

in substantial amounts of standing crop. These desirable game fish are soon shadowed by numbers of rough fish species, but the total productivity remains high. This phenomenon is known to most sport fisherman who have seen a new lake's fishing success drop off in 7-10 years. This process can produce secondary effects on surrounding land use and biological and sociological aspects of the watershed. All of these factors affect the euthrophication, sedimentation and water quality of the new impoundment. Unfortunately, management is often applied after the fact rather than incorporated in the planning.

Eutrophication and sedimentation are prominent enemies of artificial lakes. The eutrophication potential should be analyzed prior to construction and included in the alternative selection process (68). The amount and type of remaining vegetation which is inundated by the new reservoir may also be important in this regard. Nutrients derived from these decaying plants provide metabolites for the new ecosystem, i.e. nutrients for algae growth. Therefore, the clearing plan should be carefully planned to minimize this potential problem but still provide quality habitat for desirable game fish species. These nutrient sources could create water quality problems which would detract from project uses. Likewise, aquatic plant infestation may become an important consideration. Often associated with eutrophic levels, the encroachment of aquatic vegetation may increase evapotranspiration rates, consume storage capacity and become detrimental to recreational benefits. Perhaps more importantly, the control of these plants usually requires large applications of chemical herbicides directly into raw water supplies (24). However, suspected water quality improvement in Lake Livingston by a large water hyacinth growth is somewhat substantiated by recent NASA research (42). Also of concern in anticipating eutrophication potential is return water from municipal, industrial, and agricultural uses. Increased demand and low supplies are necessitating water reuse notably in the Dallas and San Antonio areas with the proposed Tennessee Colony and Cibolo Reservoirs respectively. High sediment loads and sewage return flows occur in both of these cases. Water users will soon have to accept water recycling in increasing amounts.

Although modern reservoir construction allows for a sediment pool during project life, sediment accumulation may be drastically altered with land uses changes in the watershed. A recent study by AWWA Resources Division indicates that most user cities do not monitor remaining water supply capacities and therefore may have less water than planned (86). Sedimentation rates are also reflected in increased turbidity in the reservoir. Excessive rates may decrease productivity and produce unsuitable benthic conditions for microinvertebrates and fish spawning areas. Moreover sedimentation rates are related to climatic and vegetation areas as indicated in Fig. 2. Dredging of lake sediments is extremely expensive and serves to increase turbidity and recirculate toxic materials trapped in the sediments. Watershed land use control and management appears to be the answer to both eutrophication and sedimentation problems of impoundments.

Surrounding Terrestrial Habitat. The local and regional terrestrial habitat is affected both qualitatively and quantitatively by the creation of an impoundment. Animal and plant diversities as well as total numbers of individuals are reduced. This reduction is controlled

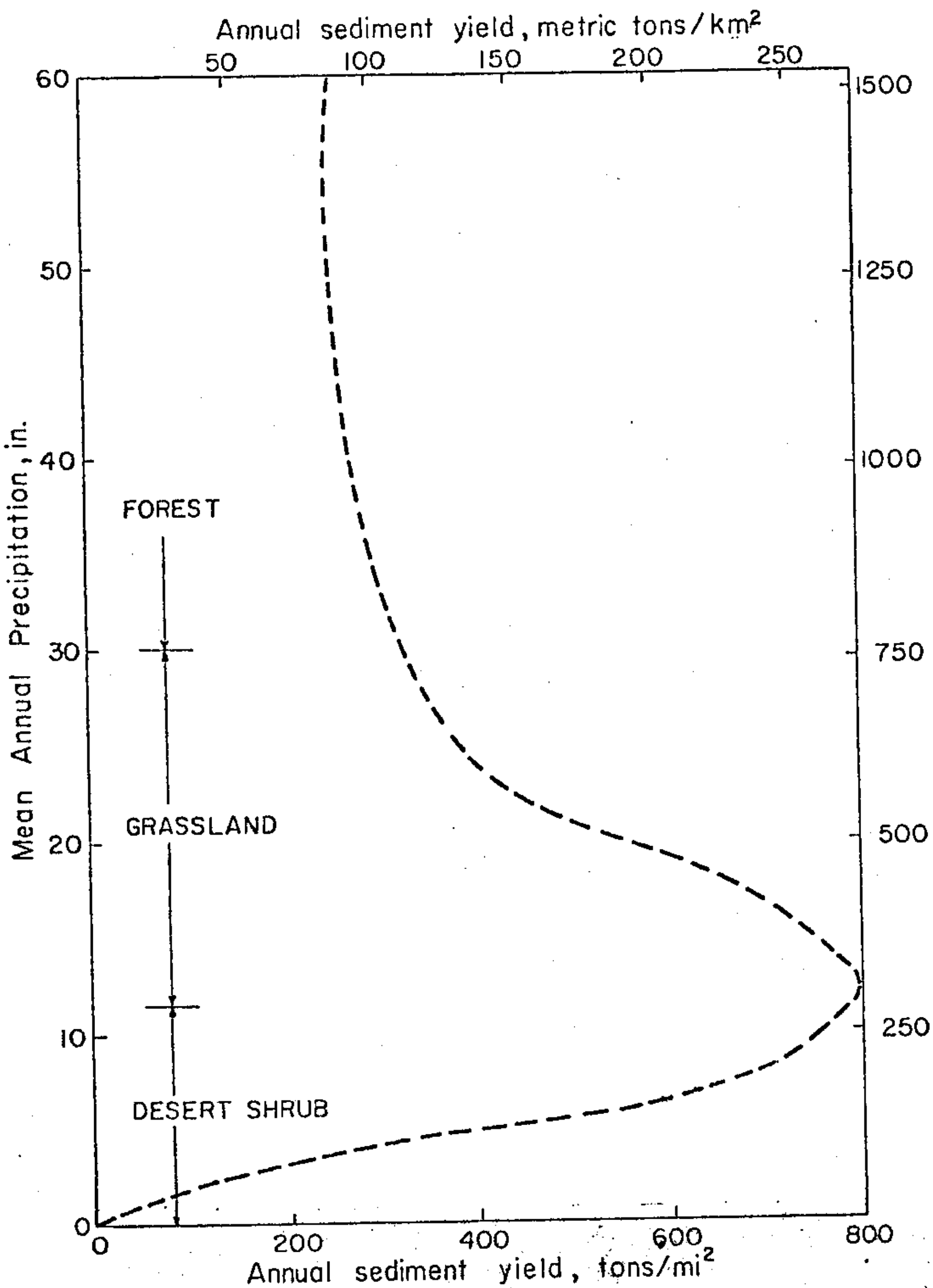


FIG. 2.- Relationship of Annual Sediment Yield to Mean Annual Rainfall (55).

by the regional carrying capacity but more tractably by the amount of similar habitat remaining and its proximity. The forest species occupying a given site are not necessarily those best adapted to compete and grow on that site, but merely the best of those that have access to that site at the time of its availability (72). The fauna are more dynamic as population cycles closely follow direct changes in the environmental conditions. Moreover, a disturbance, such as an impoundment, may favor the introduction of new plant and animal species. This is often evident around new impoundments as xeric species decline and more water tolerant ones invade the shorelines. Since reservoir rights-of-way are generally on the order of 100 feet (30.5 m) horizontally beyond the top of the flood pool, a peripheral, atypical environment is created. This new habitat may require game management and mitigation land acquisition which may be isolated from the direct effects of impoundment.

As game leases become more profitable in Texas, the isolation of wildlife population may subject the inhabitants to reduced gene flow, disease, and concentrated predation by man and animals. Detailed planning and land use management of adjacent tracts of land can enhance community cohesion and lessen the impact of reservoirs. Most environmental statements have addressed the habitat loss of impounded waters in terms of lost acreage or acreage converted to aquatic habitats. Detailed species lists are often included but not discussed in terms of wildlife communities or remaining available habitat. Indeed many small watershed projects which produce periodic impoundments may actually create additional wildlife habitat. This and other types of habitat improvements are probably the most successful game management techniques (61).

Water Quality Effects. Man-made impoundments have long been recognized as nutrient and sediment traps for upstream waters. Of course, the quality of water that is released below an impoundment is a function of the quality of water in the impoundment. No magical transformation is produced by flowing through the outlet works into the receiving stream. Consequently, multilevel outlets have been inplaced in many Texas reservoirs, at considerable extra expense, to mix the lake waters at the intake in order to minimize downstream effects. Fruh and Masch (43) observed that selective withdrawal, as a management tool (water quality), does not appear feasible from late spring through early fall in shallow Texas impoundments when the maximum depth is less than 40 feet (12.2 m) because of a relatively unstable density (thermal) stratification. Attempts to use this tool on Lake Livingston have not met with any particular success (76).

The impounded lake will normally have a greater assimilative capacity than the stream. The longer hydraulic residence time allows for degradation, sedimentation and accumulation of pollutants and allochthonous nutrients. Waters released from impoundments comprise the major, or sole, source of downstream flows. As such, they may be considered as point sources for all water quality parameters and subject to compliance with the anti-degradation policy of the Texas Water Quality Standards (80). It should be noted that in the Texas Water Quality Management Program, most stream segments below impoundemnts are effluent limited whereas most water quality limited segments occur upstream of reservoirs. This indicates that, in Texas, surface water impoundment most often improves the water quality. However, of the 1.9 million acres (7690 km^2) of surface waters in the state over 20 acres in size (0.08 km^2), 624,500 acres (2527 km^2) or nearly 33 percent of the state's surface waters have noticeable eutrophy or other problems (74). Water quality of impounded waters, however complex, is generally discussed in terms of the intended uses of that water. If the quality is such that it satisfies project purposes, it is seldom considered further.

Channelization

In Texas, channelization of natural water courses has been accomplished on over 1800 miles of streambed (73). The large scale Texas Water Plan (79) magnifies this total considerably but includes substantial "canalization" for intrabasin water transport. Other locally funded projects located notably in the Rio Grande and Coastal Plains are not reflected in these totals. Channel works, therefore, are of substantial environmental concern in Texas. A wide climitalogical variation in Texas produces equally as broad pre-project environmental settings. Projects also vary in location from strictly rural to urban fringe or completely urban. The latter case is often of little ecological consequence because of the existing artificial situation. The environmental impact of the first two cases can be substantial. The Corps of Engineers lists the following items to be addressed by planners involved in channelization projects (64): (1) Elimination of fish habitat and lower production of aquatic life (generally the streambed does not recover to its original condition), (2) Elimination of streamside habitat for small game, water fowl and fur bearing mammals, (3) Degradation of water quality by increased erosion and siltation during construction, (4) Increased flood peaks and damage downstream, (5) Lowering the water table of adjacent swamps and wetlands, and (6) Reduction of bottomland forest.

This typical list does not begin to tell the whole story of the consequences of channelization. Primarily, with regard to assessment procedures, what is meant by "channelization" for any specific project? Obviously clearing and snagging operations, i.e. removal from the channel of debris (boulders, trees, etc.) which retard the flow and/or accumulate more debris, are less destructive than a trapazoidal canal with 150 feet (46 m) of cleared area on either side. The exact procedure was rarely covered in detail in past EIS's. These serve to exemplify the reach of environmental coordination in engineering feasibility studies.

A recent study by Arthur D. Little Associates, submitted to the Council on Environmental Quality, addressed seven major categories dealing with channelization consequences (66). These include: (1) Wetland drainage, (2) Hardwood clearing (Bottomlands), (3) Cut-off meanders, (4) Groundwater and recharge, (5) Erosion and sedimentation, (6) Downstream effects and (7) Aesthetics. Of these, the first six are directly related to environmental amenities and warrant discussion for Texas waters.

Wetland Drainage. Five environmental statements from Texas concerned wetland drainage or conversion in the coastal plain. It is notable that some of these drainage projects, though not so labeled, are not eligible for federal funding if a primary purpose is to bring additional land into agricultural production. However, by increasing flood protection, further development is encouraged and agricultural or urban land use insues as a secondary effect. Examples in Texas include: Peyton Creek, Houston, Texas and Taylors Bayou, Beaumont, Texas.

An increasing amount of Texas projects are directly or indirectly related to estuarine waters. Channelization projects nearly always affect downstream flood peaks and depress local ground water levels. These, in turn change estuarine flow patterns and, in critical flow periods, may change salinity regimes in wetland areas. It is safe to say that all of the 1.3 million acres (5260 km^2) (1) of Texas Bays and associated wetlands have been affected by inland water resource development. Oftentimes these changes are subtle, but always additive. Still another important consideration, dilution water held by these wetlands, may be needed for waste load assimilation in the rivers and estuaries during low flow periods, and to buffer hurricane tidal and wave actions.

Bottomland Hardwood Clearing. One of the important diminishing habitats in Texas is "Bottomland Hardwoods." These areas support the richest, most diverse fauna in the state. The nomenclature is somewhat misleading in that hardwoods are not necessarily restricted to bottomlands, but rather remain there after extensive clearing elsewhere in the state.

As with wetland areas, almost every water resource development encountered to date had some adverse effect on bottomland hardwoods. Channelization is an exceptionally significant factor in this regard.

The process of channelization has many direct effects and many more subtle, indirect ones. For example, the lowered water table will not support intensive transpiration during critical months. In addition, if the channel is below an impoundment, the equalized flow raises the water table locally and denies the flooded root crowns oxygen during critical growth stages. Water projects are eliminating this valuable resource at an alarming rate. A typical example is served by the Big Pine Lake Project near Karrawha, Red River County, Texas which allows 1700 acres (6.9 km^2) for downstream flooding and 150 acres (0.6 km^2) of clearing and snagging easements. On 24 miles (38.6 km) of streambed, 17.8 miles (28.6 km) are committed to the reservoir and 4 miles (6.4 km) for downstream clearing, totaling 91 percent of the Big Pine Creek bottomland hardwood (11). Despite the obvious effects of terrestrial habitat removal, the canopy absence increases solar incidence in the stream, reduces bank stability, and removes nutrient sources from the aquatic habitat. Depending on other environmental factors, these effects become manifested in reduced aquatic and terrestrial productivity and diversity. Moreover, the terrestrial community is effectively divided along the water course in direct proportion to the degree of "canalization." The once unified community becomes two separate communities resulting in reduced populations of all species. In extreme cases, such as with the Texas Water Plan intrabasin flow scheme, genetic separation could be affected. Although it might be argued that the increase in forest-edge habitat will increase diversity (since this represents one of the more diverse transition habitats), the several hundred meters would contain sharp vegetative delineations instead of a gradual transition; in either case, it would differ from the natural riparian habitat (Fig. 3). Also, sediment loads are usually increased and as a result, runoff increases. Again, their effects reduce the waste assimilative capacity and cause pollutants to be transported further downstream before degradation.

One particular project along the Pecos River in New Mexico was designed to remove the bottomland vegetation (salt cedar) to reduce transpiration (water loss). Forty thousand acres (162 km^2) were cleared with substantial wildlife losses and no significant proof of water salvaged.

Cut-Off Meanders. Long histories of extensive water usage and the seasonal nature of flows lessen the importance of meanders in Texas; however, they are significant along the coastal region and major river main stems. An example, the Proposed Trinity River Navigation Canal will entail extensive realignment. Provisions for maintaining water in the natural channel are an integral part of the planning for this project. Planning has included extensive consideration of environmental factors but the effects will admittedly be devasting (75). As with wetland drainage and hardwood removal, the cut-off of meanders and oxbows reduces the channel capacities and increases downstream flood peaks. A straight, realigned channel will also have higher velocities resulting in erosion and undercutting problems. Maximum recommended velocities for canals and flumes are given in Table 2.

Water rights and therefore water and land usage are also altered around a blocked oxbow (50). These secondary effects may lead to further ecological changes. Oxbows provide lucrative slackwater areas and gravel deposits for fisheries production and habitat (Fig. 4).

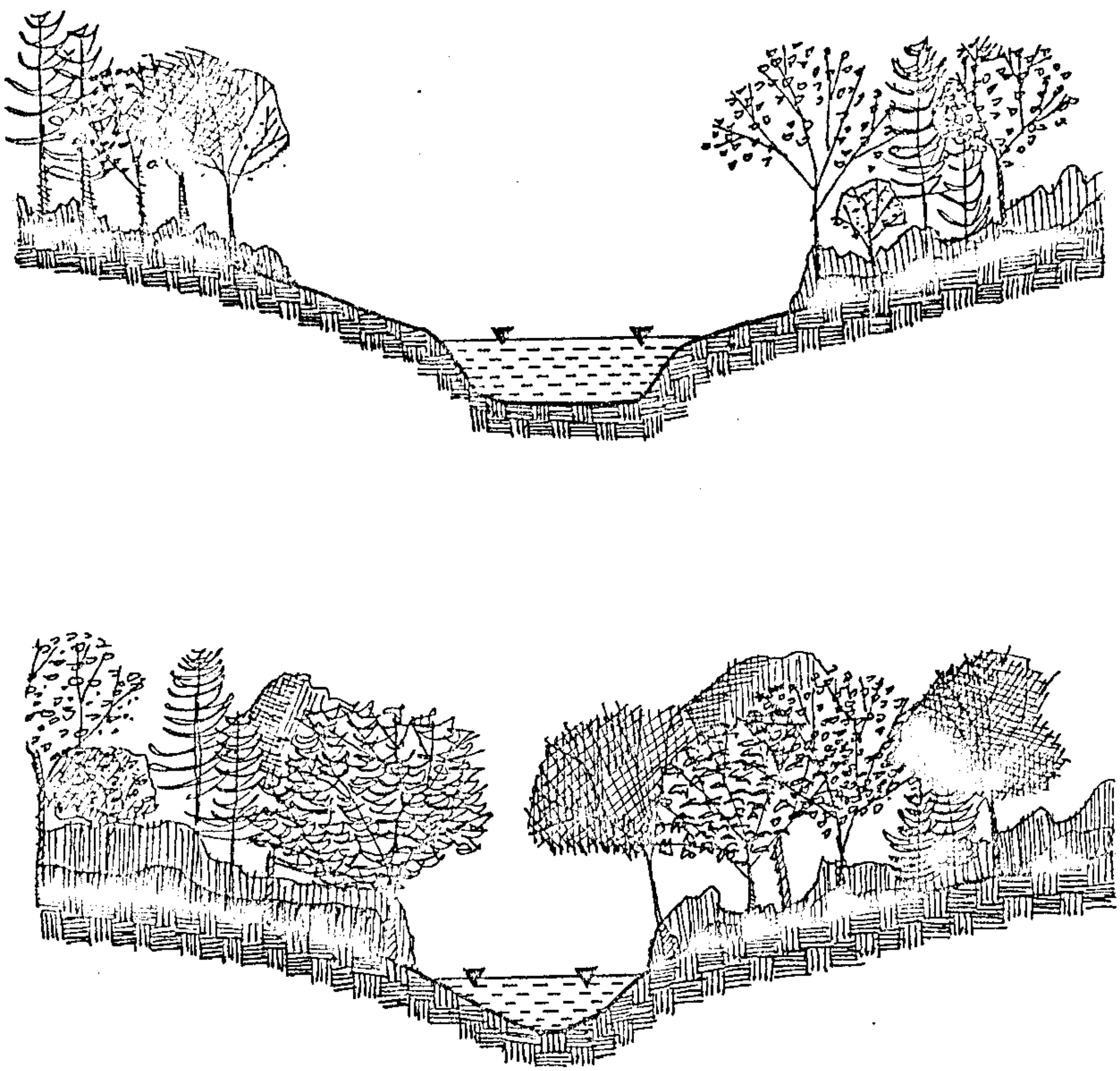


FIG. 3. - Creation of artificial forest-edge habitat (upper diagram) by channelization and clearing of natural streamside vegetation (lower diagram).

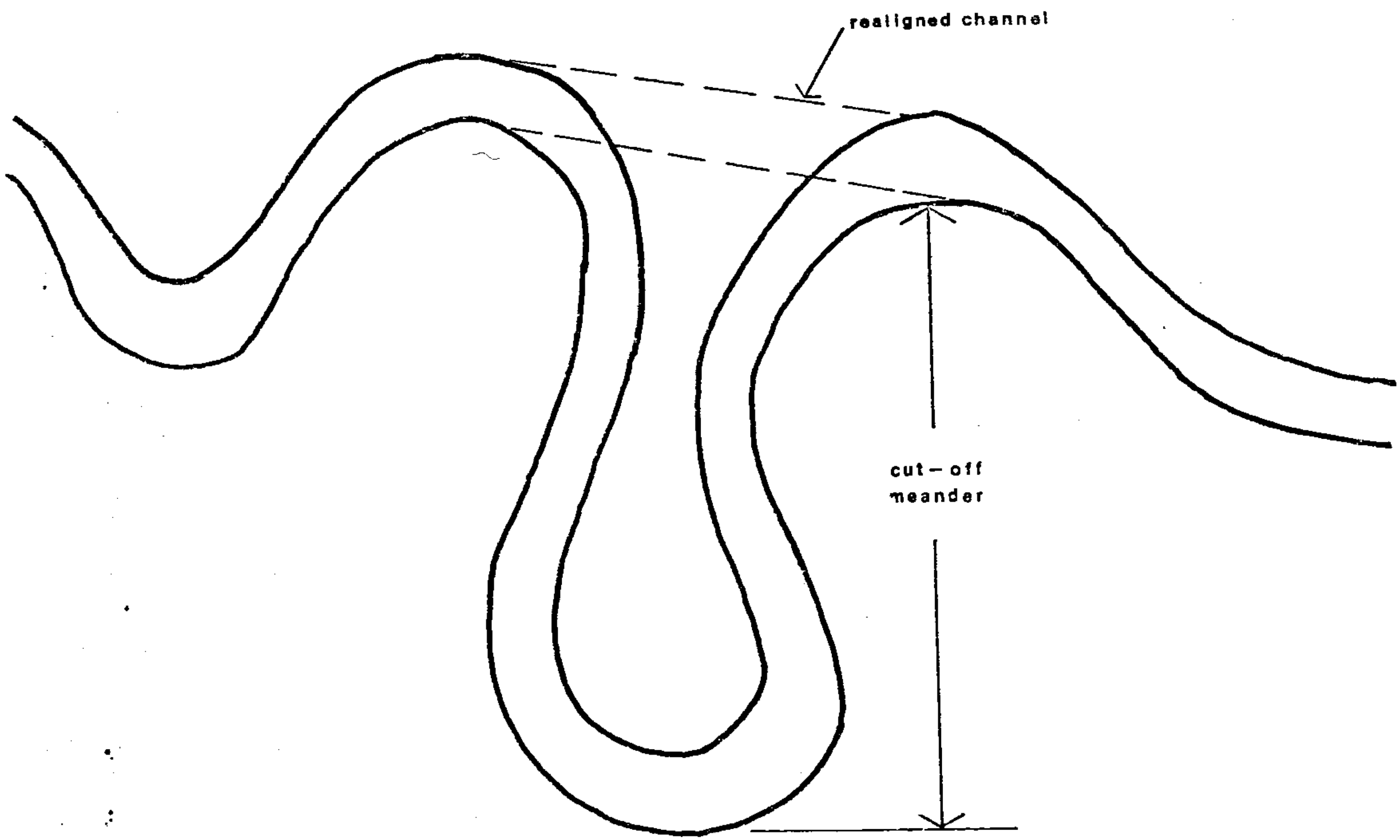


FIG. 4.- Meander cut-off and oxbow formation: (a) reduce channel capacity (b) increase velocity (c) loss of productivity in oxbow.

Meander and oxbows contain rich soils which, if drained, make ideal agricultural land. This and the false sense of security along the channel will intensify agricultural practices, leading to additional bottomland hardwood clearing and/or wetland drainage. These agricultural practices will include pesticide and fertilizer applications which will eventually enter the stream. Again, these pollutants will be transported downstream faster and less degraded.

TABLE 2. - Maximum Permissible Velocities in Canals and Flumes (ft/sec)

Channel Material (1)	Clear * Water (2)	Water with * Abrasive Sediment (3)	Natural Water ** (4)
Fine sand	1.5	1.5	0.75-1.00
Silt loam	2.0	2.0	1.00-1.50
Fine gravel	5.5	3.5	-
Stiff clay	4.0	3.0	4.00-5.00
Coarse gravel	4.0	6.0	4.00-5.00
Shale, hardpan	6.0	5.0	-
Steel	+	8.0	-
Timber	20.0	10.0	-
Concrete	40.0	12.0	-

* Source (54)
** Source (45)
\+ Limited only by possible cavitation

Ground Water and Recharge. Texas has long been dependent on groundwater supplies and consequently has been involved in its development and protection. A classical example is the recharge and protection efforts surrounding the Edwards Aquifer supplying San Antonio, Texas. This aquifer provides most of the water for the San Antonio River and the city's famous "River Walk."

One of the major concerns in channel conveyance of water resources is seepage lost or conveyance loss (Table 3). An intricate relationship exists between the stream channel and the groundwater. A stream may be classified as "gaining" or "losing." A gaining stream is drawing water from the ground water. This condition is often associated with rectified channels because the increased velocity provides less runoff detention time, less infiltration time and less recharge.

TABLE 3. - Seepage Rates from Unlined Canals (54)

Material (1)	Seepage Rate, cu ft/sq ft/day (2)
Clay loam	0.25-0.75
Sandy loam	1.0 -1.5
Loose sandy soils	1.5 -2.0
Gravelly soil	3.0 -6.0

This results in water flowing from the higher water table to the lower stream bed. As the water table is drawn down, riparian vegetation, which is dependent on a given water table level for nourishment, is adversely affected. A losing stream, on the other hand, carries water from an upstream source resulting in a net outflow along the pressure gradient to the groundwater. This occurs in artificially equalized river flow regimes such as below an impoundment. The higher groundwater may flood root crowns and prevent adjacent land drainage (Fig. 5).

Canal lining may be used to prevent the above problems. A lined canal is essentially a biological dessert. Attachment sites, riffle-pool sequences, and cover are all eliminated. Also, unless overwalks

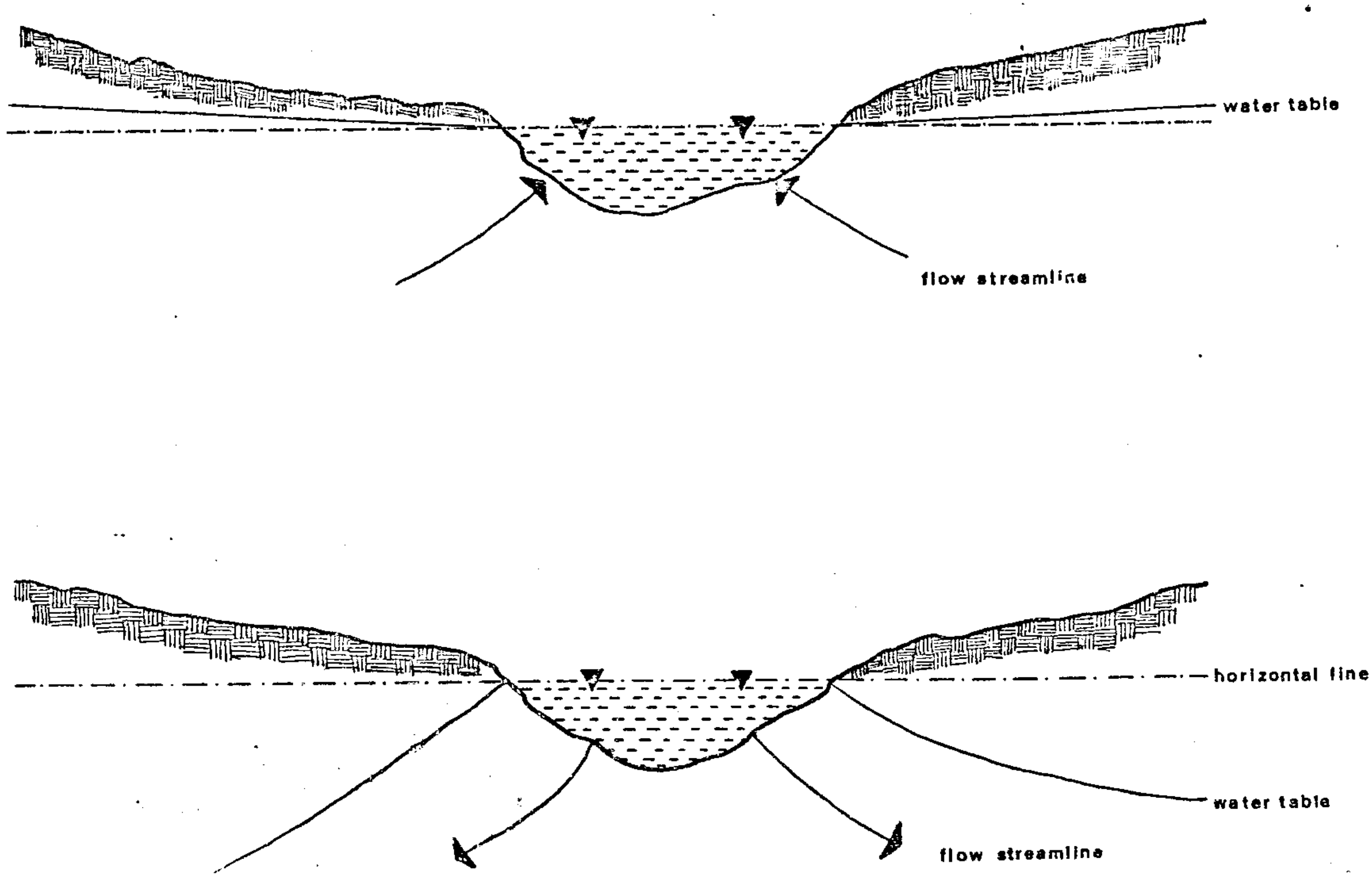


FIG. 5.- Diagram of losing stream (lower) and gaining stream (upper).

are provided, terrestrial species are further separated and populations reduced.

Erosion and Sedimentation. Any natural stream or other flowing water tends to move sediments along with it. The natural process to form a peneplain is often interrupted by man-made channel works or watershed changes. The Soil Conservation Service performs extensive work in the prevention of erosion on agricultural lands through land treatment measures as well as in-channel structures.

Land treatment measures may encompass upwards of two dozen specific applications for the conservation and upgrading of soil conditions, for the prevention of flooding, and for the improvement to vegetation for a number of purposes. Among these are conservation crop rotation, the planting of cover crops, the seeding of pasture, contour farming, crop residue utilization, field terracing, sub-soiling, drainage works by open field ditches or subsurface tile draining, gully stabilization structures, drop inlets, land grading and leveling, grassed waterways, farm ponds, diversion structures, fence row plantings, forestry improvement, wildlife area improvement and development, soil surveys, field strip cropping, field windbreaks, wildlife food planting, stubble mulch and hedge row plantings and spoil bank seedings. Wherever erosion is occurring, the scoured sediments moving with the bedload create an abrasive condition detrimental to benthic organisms and downstream productivity. Sedimentation, on the other hand, may cover reproduction sites, block off side channels, fill in pools, and destroy rooted vegetation. Bank stability is an important consideration to avoid excessive erosion. Linsley and Franzini (54) provide the following criteria for maximum bank side slopes in canals (Table 4).

TABLE 4. - Typical Side Slopes for Unlined Canals (54).

Bank Material (1)	Slopes (horizontal:vertical) (2)
Cut in firm rock	¼:1
Cut in fissured rock	½:1
Cut in firm soil	1:1
Cut or fill in gravelly loam	1½:1
Cut or fill in sandy soil	2½:1

To avoid erosion in channelization works, every attempt should be made to preserve or enhance the vegetation cover of stream beds, especially grasses, ridges and woody shrubs with dense fibrous root systems. In poorly vegetated areas along fairly straight stretches of steep stream bank it is necessary to flatten the slopes (generally 3:1 or 4:1, depending on bank height) and establish a good vegetative stand. Vegetative stability, as a rule of thumb, is achieved at a maximum of 50 percent slopes (2:1). Optimum vegetation occurs on slopes of 25 percent (4:1) or less. For droughty soils, or highly erodible soils, maximum slopes should be considerably less (45). Clearing and snagging operations, though oftentimes the most environmentally compatible, will increase the flow and intensify erosion at critical areas further downstream.

An increase in sediment content in the water column may create adsorptive surfaces for many pollutants and concentrate them in deposition areas. Also light penetration may be affected thereby reducing productivity and biological degradation of the pollutants.

Downstream Effects. Largely, this section serves as a recapitulation of effects mentioned in the previous discussion. The biological effects downstream of channelization projects are difficult to quantify and, therefore, briefly covered in the literature. These changes, however, do represent important regional impacts.

Wetland drainage upstream will decrease critical flows and increase velocities in the stream channel. The lack of low flow waters may cause the stream to become completely dried out in summer periods which will also change the aquatic and terrestrial communities. Oftentimes, upstream wetland drainage is associated with land use changes which will alter the water quality downstream.

Bottomland hardwood clearing may cause less nutrients to be introduced downstream. In addition, increased amounts of sediment may enter downstream reaches further reducing productivity. Perhaps more importantly, the total reduction of habitat type may exceed the carrying capacity of adjacent sites resulting in reduced populations.

The cutoff of meanders and oxbows will decrease the channel capacity upstream and increase flows downstream. The removal of these biologically productive areas will also alter the aquatic and associated terrestrial species diversity. Critical hardwood reproduction cycles may be affected by changes in flooding routine.

Groundwater will be depressed upstream and assuming contiguous aquifer formation, may affect downstream levels as well. The increased channel velocities will allow less time for recharge by causing the flood hydrograph to peak higher and sooner; this may change a gaining reach into a losing one.

The erosion and sedimentation scheme will also be altered which may affect the riffle-pool sequence and biological productivity. Stream bank stability may become important with increased velocities and a more varied flow regime.

CHAPTER III

COMPILATION OF DIAGRAMMATIC TRANSECTS

The environmental effects of water resources development, discussed in the previous chapter, provide a basis for acquiring the types of data that will be useful in the preliminary assessment of specific projects.

Although the amount of necessary information varies among projects and regions, several basic concepts are applicable to all preliminary studies. These data include: (1) A synoptic overview which provides a local-regional perspective, (2) an understanding of the types of ecological communities or associations present in the project area, (3) identification of any unique or sensitive areas in the project proximity, (4) a knowledge of the types of impacts and methodologies used in previous EIS's from the same region or about the same type of project, (5) a system of displaying pertinent information on physical and biological relationships which provides a ready means for update and reference, and (6) a means of project monitoring which combines pre-project analysis with post-project events.

Physiographic Regions

To accomplish these tasks, diagrammatic transects and accompanying data have been developed. The state of Texas was delineated into twelve physiographic regions from a band 7 (infrared) black and white satellite (LANDSAT-1) summer mosaic of the state (Fig. 6). These regions combine several of the land resource areas proposed by the Soil Conservation Service using band 5 (red) summer imagery (82).

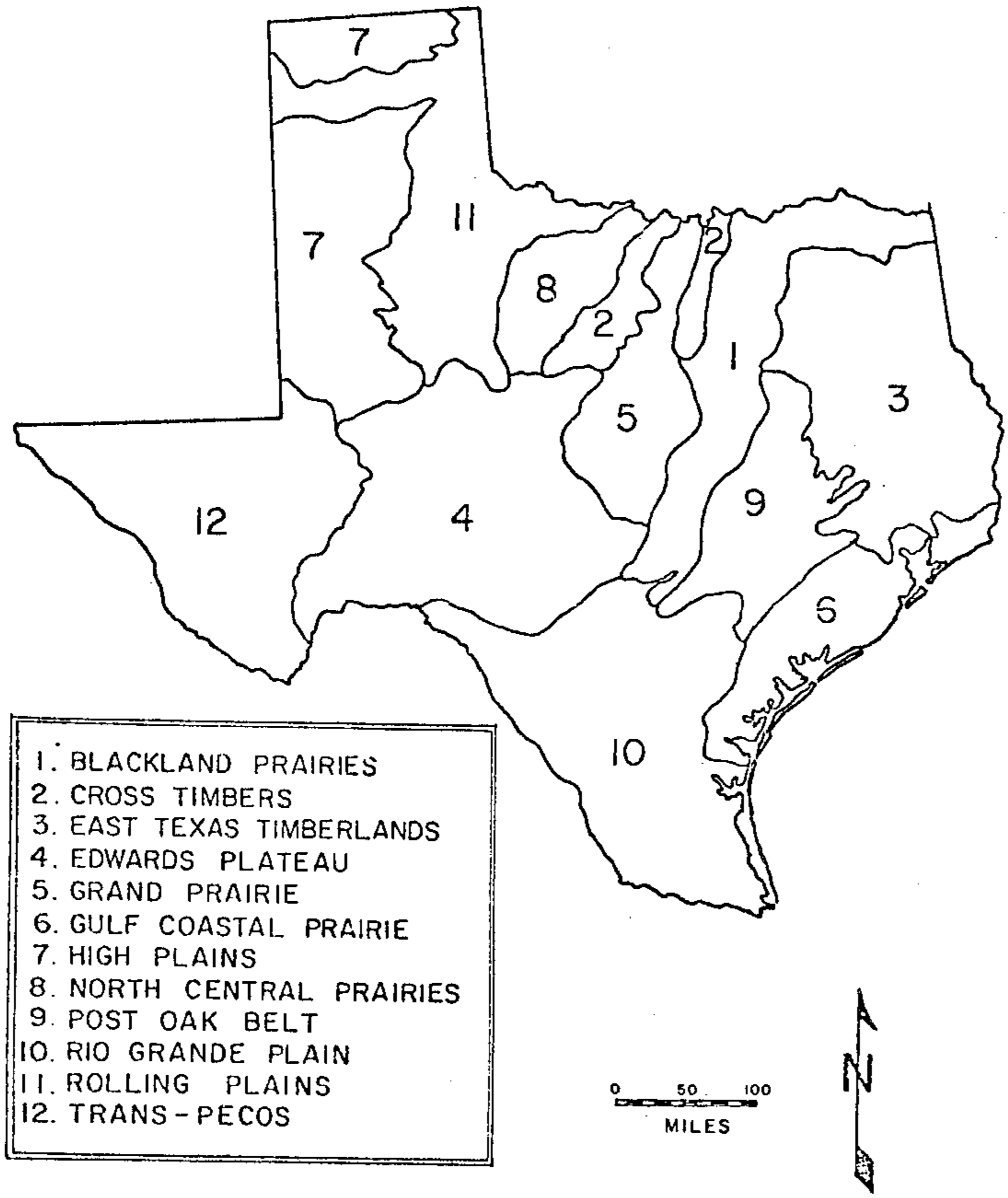


FIG. 6.- Physiographic Regions of Texas as Delineated by a Band 7 LANDSAT-1 Black and White Summer Mosaic.

Within each region, several sites were selected and low altitude aerial photographs, soils maps, topographic maps, county game surveys, and regional resource plans were obtained when available. In addition, thirty-five environmental impact statements for water resource developments throughout the state were procured and reviewed on a regional basis. These previous statements also provide valuable environmental information which supplements the other sources mentioned above.

On the basis of available bands 4 through 7 (green, red, near infrared and infrared) false color composite satellite imagery, one site was chosen from each region. From the topographic maps, profiles were constructed for five-mile (eight km) cross sections. Data available from secondary sources, low altitude photography and satellite imagery were then combined and displayed on the diagrammatic transects and accompanying data.

A description of each region, display of available environmental amenities, correlation of remote sensing imagery, and discussion of previous environmental impact statements is presented in the appendix. In addition, a discussion of the two most common water development projects in Texas is included in order to compare and contrast the relative environmental effects of each in various regions of the state in the text of the general effects discussed in Chapter II. As an example, the Crosstimbers regional discussion and display is included in the following section.

Transects and accompanying data are intended to depict only that data available from the sources listed. The primary purpose is to explain and demonstrate a technique or tool useful in preliminary environmental assessment throughout the state. Although the information depicted thereon is considered accurate, no attempt has been made to evaluate or rate the data sources.

Crosstimbers

General Description

This region is a combination of the Eastern Crosstimbers and Western Crosstimbers. It covers an area of approximately 3 million acres (12,000 km^2). These north-south narrow bands are gently rolling, moderately dissected scrub oak broadlands which originated from the cretaceous period and are separated by the northern extent of the Grand Prairie (44,4) (Fig. 6, p. 36).

Annual average rainfall varies from 28 inches (71 cm) in the west to 35 inches (89 cm) in the east. Evaporation increased from 30 to 40 inches annually (76-102 cm) westward. Likewise, elevation increases westward from 500 to 1500 feet (157-457 m) (44).

Surface soils are mainly of sandy texture with sub soils ranging from friable sandy clay loam to firm sandy clay or clayey sand. These are light-colored acid soils low in organic matter and of moderate productivity. The best adapted crops are cotton, sorghums, vetch for seed, peanuts, truck crops and fruits. Oats and wheat are additional crops on the finer textured soils and prairie areas.

Native vegetation consists mainly of post oak and blackjack oak trees and a few other hardwoods. The trees are scrubby, of small size and unsuited for most uses other than firewood or fence posts. In places grasses, including little bluestem, grama and threeawn, and scattered mesquite trees form a thick ground cover where the oak growth is thin.

Alfalfa can be grown for hay in floodplains that are flooded for only short periods and bermuda grass grows well on bottomlands (59).

Over 257 species of birds occur in the hill country. Mammals include squirrels, opossum, bats, rabbits, beaver, rodents, foxes, deer and coyote. However, intensive agricultural use of the land has severely disrupted natural habitats (21). Westward, bobcats and deer are more common (30).

Environmental Impact Reviews

Because of the narrow north-south nature of the Crosstimbers, most water development projects involve transition areas or are positioned on more than one physiographic region. Certainly, these border areas, depicted in an idealized transect of the Blackland Prairie and Crosstimbers (Fig. 7), are ecologically significant because of their uniqueness. However, the extensive agricultural use of the land has already removed or disrupted most natural vegetation associations.

Reservoirs. All three impact statements reviewed for this region were concerned with reservoir construction (21,25) or modification of existing reservoirs (30). The latter, modification, or more specifically, enlargement, will probably become more common in the future as large scale projects become more costly and utilize vast areas of land.

The Lake Brownwood modification is designed to replace the existing dam which is structurally questionable. Also the maximum flood of record is calculated to overtop the existing structure because of inadequate spillway capacity. The watershed of the 40-year old lake has undergone some changes and new runoff data are available from stream gaging stations. Assessment procedures key on the consequences of dam failure. In reality, the new dam will require the use of only 83 acres (0.33 km^2) of land downstream from the existing structure (30).

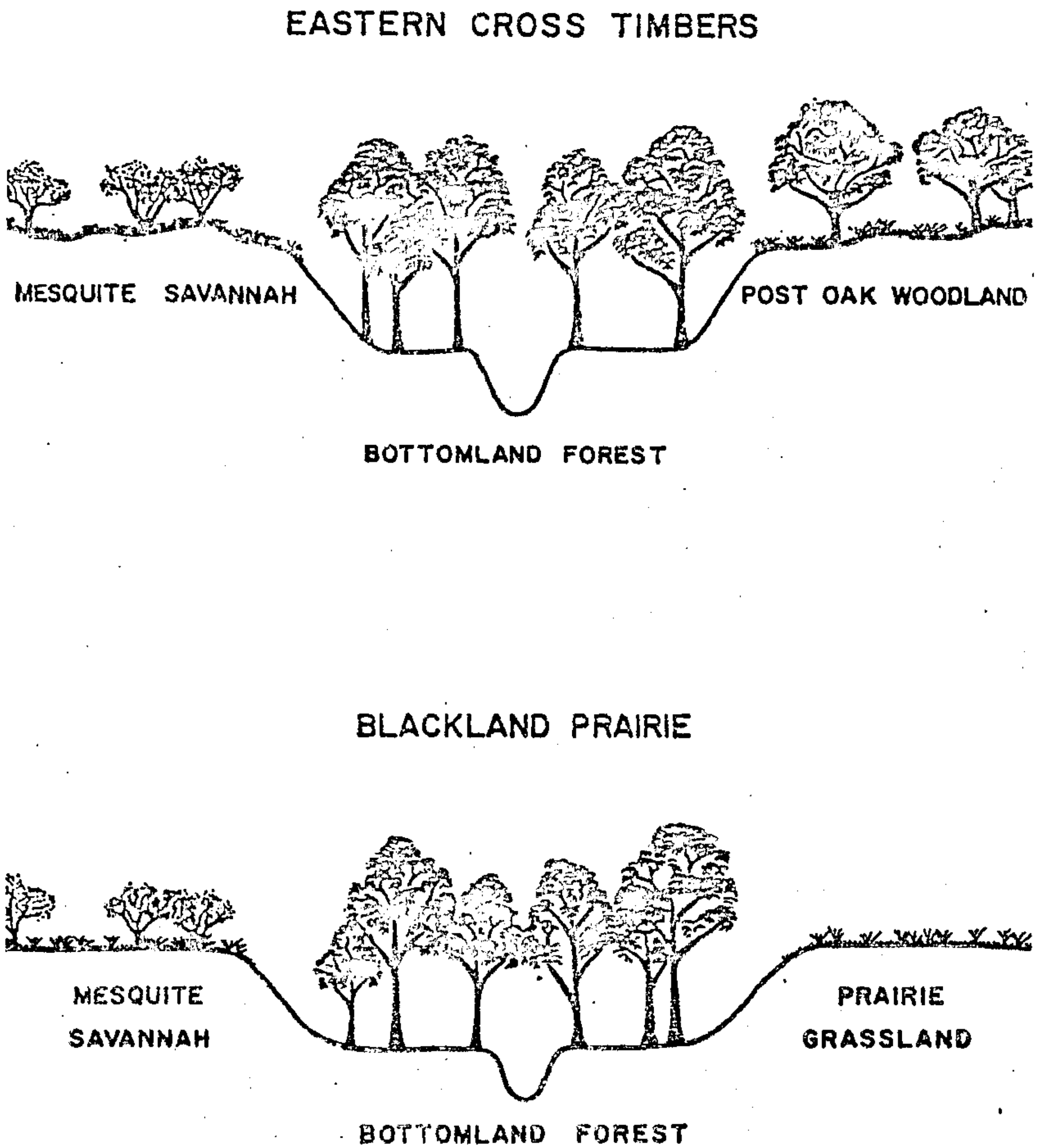


FIG. 7 .- Idealized Transect of Crosstimbers and Blackland Prairie (21).

The Aubrey Lake Project will require 43,560 acres (176.3 km^2) and 48 miles (77.2 km) of natural stream channel. Flood control is not a project purpose. Although only 25,000 acres (101.8 km^2) will be inundated, the remaining 18,560 acres (75.1 km^2) will be subject to intensive recreational pressures (in excess of 6 million visitor days/year) (25). In addition, downstream Lewisville Lake will have reduced sediment flows and the possibility of increased nutrient flows from the multilevel outlet works of Aubrey Lake. This potential adverse downstream effect was not addressed in the environmental statement.

The Battelle Environmental Evaluation System was used for impact assessment of Aubrey Lake. This system is a complex analytical matrix which arrived at a +1.75 environmental impact. Specifically, the aquatic habitat would be enhanced and the terrestrial habitat would be adversely affected. This unique product of the system, the statement that natural aquatic vegetation would be enhanced (25), made no mention of the herbicide applications which must eventually be used to control their encroachment.

Estuarine effects of Aubrey Lake were discussed in terms of the complexity of phenomena but included a quote which stated that the penetration of estuaries by marine and freshwater organisms is dependent more on the rate and magnitude of tidal changes than on the actual salinity gradient (47). Although this may be the physical method of transportation into the estuaries, it is commonly believed that salinity or temperature gradients are the stimuli for inland migration of oceanic larvae. A decrease in flow to the estuaries will change the salinity and temperature gradients and could have adverse effects on commercial marine fisheries.

The Aquilla Creek Project involves the transition area between the Crosstimbers, Blackland Prairie and Grand Prairies. Considerable environmental variations occur within short distances (21). A micro-environmental profile was included in the physical description portion of the statement (Fig. 10). The section on the relationship between short term uses and long term productivity includes the following statement for assessment (21):

> ...In the light of the fact that man's actions in many areas vital to ecosystem survival have irreversibly changed nature's balance, it would be disastrous to revert to a "naturalist" approach with regard to water supply, flood control or overall biological productivity. There appears no choice but to depend on advanced technology in all areas of endeavor to maximize the quality of life during the next 100 years while man's population growth and industrialization has time to develop...

This statement recommends a secondary main stem dam site which showed the least environmental affects in the matrix analysis. It is about 3 miles (4.8 km) upstream from the authorized site and it was within the Chief of Engineers discretionary authority to be designated the project site. This project, even though it ranks first in environmental matrix analysis, still involves substantial environmental impact, both local and regional as well as aquatic and terrestrial. It would appear that rejection of the authorized site could have taken place much earlier in the project formulation. This can probably be attributed to the interjection of NEPA requirements late in the planning process.

Channelization. Although none of the environmental statements reviewed from this region dealt with channelization works, the Lake Brownwood modification included the following statement in reference to downstream erosion protection (30): "...downstream of the weir, concrete curtain walls will be constructed to protect the exposed alternate layers

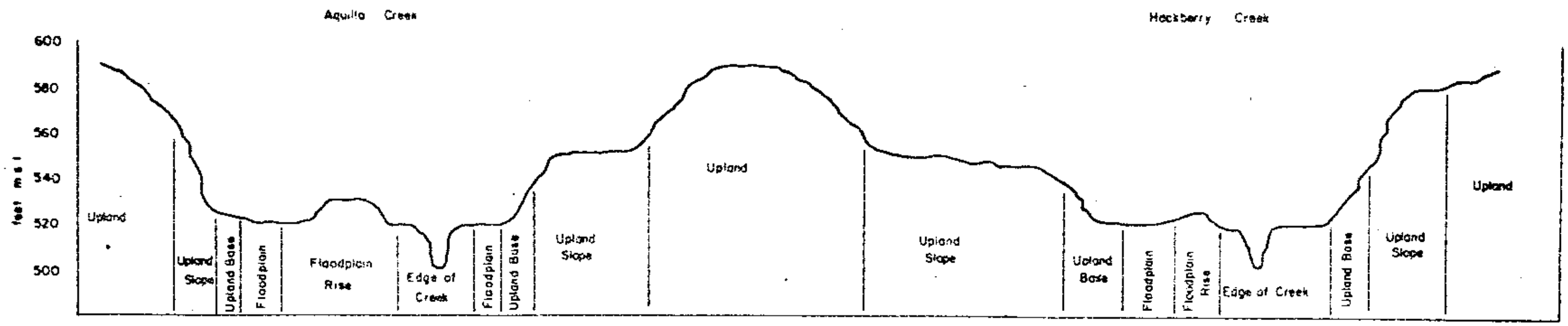


FIG. 8 .- Microenvironmental Profile, Aquilla Lake Project (21).

of shale and limestone and prevent erosion in the channel. Stream bed erosion is a problem where high velocities are encountered. The existing substrate could not support a suitable benthic community with the physical action of the shifting substrate. Likewise, throughout the Crosstimbers, the bedded limestone and shale will require soil cover for channelization works of even low velocities. This would mean careful consideration should be given to meander cut-off and rectification (clearing the floodplain), all of which increase stream velocities.

Environmental Assessment Procedures. (1) Supplemental biological inventory information was obtained from academic survey teams for both Aquilla Creek and Aubrey Lake Projects.
(2) The Battelle-Columbus Environmental Evaluation System was utilized in the Aubrey Lake Statement. A similar matrix analysis was also applied in the Aquilla Creek assessment. It appears that the latter is less complicated and adequately describes the probable impact.
(3) The late rejection of the authorized Aquilla Lake Project for environmental considerations was considered defeative to the assessment procedure.

Summary of Environmental Impact Reviews. (1) Matrix analysis is applicable to environmental assessment but in both cases required supplemental environmental inventory work.
(2) Alternative elimination should not be a subject of the environmental statement, rather a step in its development. The 3 miles (4.8 km) main stem shift in the dam location on Aquilla Creek should have been done much earlier in the project to arrive at the multipurpose dam alternative. This could then be compared with other viable alternatives equally

as well developed.

(3) A positive enhancement for aquatic vegetation derived from the Battelle System is shortsighted in that it omits the obvious problems of rooted aquatics in the state.

Diagrammatic Transects and Accompanying Data

Remote Sensing plates and accompanying data are displayed in Fig. 9 and Table 5 respectively and the transect is presented as Fig. 10. Fig. 9 includes low altitude photography (right), regional LANDSAT-1 imagery (lower left) and enlarged LANDSAT-1 imagery (upper left).

Low Altitude Photography. One set of photographs was viewed for each of the eastern and western sections of the Crosstimbers area. The bedded limestone and shale is subtly expressed in smoothly dissected uplands and flat relatively narrow floodplains. Upland tributaries are short and drainage is rapid. Bottomlands have several poorly drained areas around stream confluences and meanders (Fig. 9).

The short upland gullies are smooth, becoming deeper and V-shaped toward bottomlands. Contour planting is used on upland slopes. The western area is less humid and the bedding is evident on the gully slopes. Bottomland areas are darker gray with slightly more mottled areas eastward.

Numerous stock ponds and off channel retarding structures are present throughout the region. Roadways have little pattern except eastward in the more cultivated uplands. Gravel mining operations occur throughout the floodplain area.

Satellite Imagery. The north-south nature of the Crosstimbers are discernable from summer satellite imagery. The more arid nature of the western section reveals unvegetated light areas presumably on the gully slopes (Fig. 9). The Dallas-Fort Worth area straddles the eastern section and forms a north-south barrier extending to the narrow portion of the Grand Prairie as well. Surface water is present in numerous large reservoirs. The enlargement provides further insight into land use practices in the uplands and the extent of the floodplains (Fig. 9).

FIG. 9. - Crosstimbers, North Bosque River, Erath County, Texas. This figure includes low altitude photography at a scale 1:20,000 taken February 17, 1966 (stereopair on right), regional LANDSAT-1 imagery at a scale of 1:1,000,000 (lower left) and enlarged LANDSAT-1 imagery at a scale of 1:350,000 (upper left). LANDSAT-1 black and white reproductions were made of a false color composited bands 4, 5 and 7 taken December 12, 1973. The crop lands, pasture and forested areas are distinguishable in the LANDSAT imagery. The banded appearance of the upland area in the low altitude photography is typical of horizontal sedimentary rocks (limestone and shale).

	Uplands	Floodplain	Uplands
LANDFORMS	Uplands	Floodplain	Uplands
LANDUSE	Rangeland	Agricultural Cropland	Rangeland
PLANTS	Scrub Oak-Mesquite Association	Bottomland Hardwoods inc. Oaks Hickory Elm Understory Also inc. Short Grasses	Scrub Oak-Mesquite Association
ANIMALS	Predators Upland Game Birds White tailed Deer Southern Bald Eagle (E) Peregrine Falcon (E)	Furbearers White tailed Deer Quail Foxes Waterfowl Fresh water Fisheries	Predators Upland Game Birds White tailed Deer Southern Bald Eagle (E) Peregrine Falcon (E)

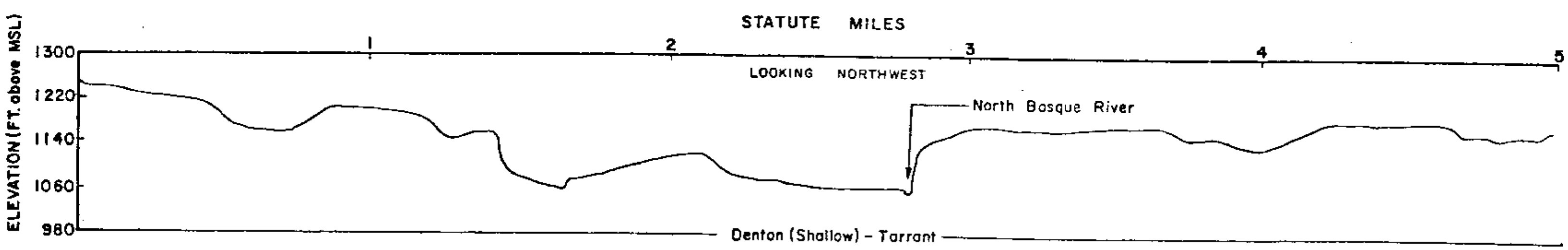


FIG. 10 .- Crosstimbers Transect, North Bosque River, Erath County, Texas.

Table 5.- Crosstimbers, North Bosque River, Erath County, Texas.

Landform (1)	Airphoto Pattern Elements (2)	LANDSAT-1 Elements (3)
Floodplain	Well defined moderately incised floodplain. Well drained in most areas with some slack-water areas around confluence with minor streams. Minor streams may parallel main stem in floodplain. Channel is well defined with little erosion on flat, cultivated areas. Hardwoods adjacent to streams and dense in slackwater areas. Mottled dark to gray soils.	Parallel drainage somewhat evident. Bottomlands are light colored where cultivation is most intense. Easily detectable increased cultivation to the west of the transect. Surface water body to the southwest. Vegetation adjacent to stream appears dark in enlargement.
Uplands	Moderately dissected rolling bedded limestone and shale. Well drained with stock ponds located in some gully headwaters. Exposed limestone and shale is smooth and almost void of woody vegetation. Some scrubby hardwoods are present. Light tones where cultivated. Banded slopes of limestone and shale.	Mottled gray areas in regional view. A transition is evident from right to left (east to west). Light colored slopes are evident adjacent to stream in enlargement. (Limestone bedding).

Soils & Origin (1)	Description and Location (2)
Denton*-Tarrant (Alluvial)	Friable to crumbly granular or blocky subangular calcareous silty clay loam to clay, 4-8 in.,over crumbly plastic strongly calcareous clay and limestone fragments, strongly cemented calciche, or limestone bed rock at less than 12 in. below the surface with many limestone fragments or outcrops on the surface. *(Denton-shallow phase)

Table 5. - Continued

Community Location (1)	Ecological Factors (2)
Bottomlands	Mesophytic oaks, hickory and winged elm are the predominant hardwoods. Hackberry and cedar elm increase eastward. Light understory present in slackwater areas. Grasses are also plentiful including bluestems, dropseed, and wintergrass. Forage crops, cotton and peanuts are cultivated. Game species include white tailed deer, bobwhite quail, and furbearers. Others are gray fox, red fox, bobcat, coyote, and few water fowl. Squirrels are present in moderate numbers. A fair warm water fisheries exist.
Uplands	Some hardwoods are present, overgrazing of native grasses has caused bushy encroachment in many areas. Predators and mourning dove are moderately abundant. The area is within the range of the endangered Peregrine Falcon, and Southern Bald Eagle. It is on the western edge of the migration route of the Whooping Crane. Mesquite is the major invader on range lands. Over 90% is rangeland.

Data Source (1)		Acquisition Source (2)
Low-Altitude Photographs	AXA-2GG-130, 133, 113	Western Aerial Photography Laboratory Program Performance Branch ASCS-USDA 2505 Parley's Way Salt Lake City, Utah 84019 Tel: AC 801, 524-5326 Price: $2.00 each

Table 5.- Continued

Data Source (1)		Acquisition Source (2)
LANDSAT-1 6-24-74	81705162805G200 False Color Composite	EROS Data Center Data Management Center Sioux Falls, South Dakota 57198 Tel: AC 605, 594-6511 FST: AC 605, 594-6151 Price: $7.00 per color composite
Topographic Map 1961	Alexander and Clairette Quadrangle 1:24000	Texas Water Development Board Topographic Mapping Section P. O. Box 13087 Austin, Texas 78711 Tel: AC 512, 475-3191 Price: Free to State Agencies or Contractees
Soils Map 1963	Erath County 1:152000	Texas Agricultural Experiment Station Texas A&M University Reed-McDonald Building College Station, Texas 78743 Tel: AC 713, 845-2413 Price: Free, limited to twelve per customer
Biological Inventories	Kickapoo Creek Watershed Project EIS Dec 1974	United States Department of Agriculture Soil Conservation Service P. O. Box 648 Temple, Texas 76501 Tel: AC 817, 773-1711 Price: Free

Table 5.- Continued

Data Source (1)		Acquisition Source (2)
Biological Inventories	Big Pine Lake EIS June 1974	U. S. Army Engineer District, Tulsa P. O. Box 61 Tulsa, Oklahoma 74102 Price: Free

CHAPTER IV

APPLICATION OF TECHNIQUES

From conception, the process of project formulation varies among agencies and is geared to their staff and organizational responsibilities. New projects may be general in nature, such as a river basin survey report, or specific such as flood control on a certain reach of stream. In either case, the first step is to analyze the site(s) and obtain information on the existing environment.

Suboptimum alternatives should also be considered as well as those alternatives beyond the lead agency's authorization to construct (required by NEPA Section 102 (2) (D) and discussed in CEQ Guidelines, 1500.8 (a) (4)). In short, technologically feasible, economically justifiable, and environmentally acceptable alternatives should be equally developed. In describing project formulations, Linsley and Franzini (54) discuss the use of unit sites for each alternative. For example, for a damsite designated as site 1, three alternative dams of different heights might be 1A, 1B, and 1C. To optimize environmental considerations, however, an alternative designated as 1, 2, or 3 etc. may have several locations and sizes that, like the dam height alternative, bracket the range of possibilities, but for preliminary planning, the alternative should be the use of the dam not the site.

A decision must be made on the adequacy of the existing data base for both engineering and environmental considerations; as each alternative involves different engineering techniques it also involves different environmental impacts. For example, a hypothetical municipal water supply is not adequate for future needs. An advanced waste treatment and water reuse alternative will reduce return flows and affect the receiving stream in one way. Increasing the available raw water supply, as another alternative, may eventually increase the return flows and affect the receiving stream in another manner. The question reduces to whether or not sufficient information is available to analyze each of the alternatives equally. Is the advanced waste treatment/water reuse alternative technically feasible at estimated costs? Likewise, how does the increased raw water supply and return flow alternative affect the local or regional ecosystem? If sufficient information exists to make these judgements, the alternative selection process is continued. If not, plans are made to obtain the necessary data.

When a sufficient data base has been established, the alternatives may be assigned to different persons or groups of persons (depending on staffing) for analysis and development. With this techniques, each feasible alternative can be developed as independently as possible at equal levels of emphasis, cost estimation, benefits, environmental effects, etc.

Preliminary Methodology

To obtain the recommended data for preliminary environmental assessment, diagrammatic transects and accompanying data can be used. The compilation of these data is accomplished using secondary sources as depicted and demonstrated in Chapter III.

Using the Crosstimbers Region (p. 38) as an example, the remote sensing plate provides a synoptic overview of the local-regional relationship (Fig. 9, p. 49). A west to east regional transition is evident. In addition, several surface water impoundments are noticeable as is the extensive floodplain cultivation. Unique areas, such as the sparse dark-toned riparian vegetation on the LANDSAT-1 enlargement can also be identified.

From the data accumulation and display on the diagrammatic transect (Fig. 10, p. 51), an understanding of the regional characteristic ecological communities can be obtained. At the same time, the physical and biological relationships are displayed in such a manner that facilitates rapid updating and reference. The bottomland hardwoods abruptly terminate on the upland slopes (Fig. 9, p. 49 and Fig. 10, p. 51 indicating a narrow band of fair quality habitat along the streams and a scrub oak-mesquite association on the uplands. Although the upland habitat provides areas for endangered species and game birds, it may be more significant as a west-east transition area.

A review of previous environmental statements from the Crosstimbers Region may prevent duplication of data collection efforts and avoid several shortcomings. For example, a 3 mile (4.8 km) shift in the dam site for the Aubrey Lake Project may involve significant loss of regionally and locally important bottomlands. A similar 3 mile (4.8 km) southeastern shift of the transect site (Fig. 9 , p. 49) would be about 0.375 inch (9.52 mm) on the regional LANDSAT-1 image, 1.5 inches (38.1 mm) on the LANDSAT-1 enlargement, and 4.75 inches (120.6 mm) on the low altitude photograph. This shift would involve the regionally scarce dark-toned vegetation immediately southeast of the transect site on the LANDSAT-1 images and the major east-west highway on the low altitute photography. The relocation of this highway would cause additional environmental impact.

Biological inventories already conducted for several impact statements in the region may be sufficient for preliminary studies of nearby areas. Moreover, the matrix analysis of event/impact may also be applicable to other projects.

Lastly, the comparison of future satellite imagery, low altitude photography, and physical-biological relationships with pre-project data will provide a means of project monitoring that can be planned and included in preliminary environmental assessments. Not only will project monitoring provide useful input into future environmental assessment but may be recommended by commenting agencies. CEQ Guidelines Section 1500.9 (3) (e) in dealing with commenting entities of the draft environmental statement states:

> Agencies and members of the public should indicate in their comments the nature of any monitoring of the environmental effects of the proposed project that appears particularly appropriate. Such monitoring may be necessary during the construction, startup, or operational phases of the project. Agencies with special expertise with respect to the environmental impacts involved are encouraged to assist the sponsoring agency in the establishment and operation of appropriate environmental monitoring (65).

Retention of transect material as correlated to remote sensing information will allow detailed comparison of project effects. The extension of monitoring land use changes regionally may add credence to rejection of the no action alternative, reveal extensive or subtle secondary ecological changes, and aid in impact assessment of adjacent projects. These factors should prove invaluable in future environmental assessments of similar projects and/or projects within the same region. This type of input was noticeably lacking in past environmental impact statements.

Other Data Applications

Additional Preliminary Uses. Based upon regional satellite imagery characteristics, transects can be located to optimize coverage and minimize the cost involved in additional data needs. Since all available information is displayed or included in the transects and their accompanying tables and photographs, data gaps are easily distinguished, especially in transition or unique areas or at potential site locations. Utilizing forestry sampling techniques laid out along the existing transects, a full scale or limited biological survey can be conducted if necessary. The use of the point centered quarter method along transect lines has been used to catalog the flora and fauna along the Trinity River in conjunction with environmental studies (75). The logical extension of this data base appears to be as estimation of the relative amounts of habitat type which are available within and surrounding the project area. From the vegetation information collected along the transects, species distribution, composition, and dominance can be displayed on the diagrammatic transects and applied to low altitude aerial photography to obtain the acreages of various habitat types. Ball et al. (5) applied this technique to vegetation mapping of Palmetto Bend Reservoir in an attempt to quantify nutrient leaching from inundated vegetation. The leached nutrients effect the eutrophication rate of the new reservoir as discussed in Chapter II. Daniel (10) used low altitude photography to estimate habitat quality and quantity. This was applied to a numerical matrix to preserve in kind, through mitigation, habitat lost to water resource development in Missouri. Similar to Missouri, Texas studies will probably require updated low altitude photography as discussed in a latter section.

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APPENDIX

Blackland Prairie

General Description

This rich agricultural area is generally located east and south of central Texas. It is bordered on the west by the Balcones Escarpment, on the east by the East Texas Timberlands, and on the south by the Oakville Escarpment. It extends north of 29^{o} latitude to the Red River on the Oklahoma border and between 96^{o} and 99^{o} longitude (Fig. 6).

Annual rainfall varies over the area from 30 to 45 inches (76-114 cm) increasing to the northeast. Evaporation equals rainfall in the southern extent but is less than one-half in the northern areas. Topographic elevation ranges from 250 to 700 feet (76-213 m), generally higher on the western border (44,4).

This important prairie land has developed on the upper cretaceous (Gulf Series) formation. Physiographically the Eagle Ford Prairie and Taylor Prairie are in close proximity. The latter developed over the Taylor marl which overlies the Austin Chalk. The surface is mildly rolling while some interstream surfaces are broad flats. South of Austin it extends in less typical development to San Antonio. The heavy clay therein, yields no water to shallow wells but is underlain by sandy strata bearing artesian water (19,20).

Upland soils are dark, calcareous, clayey soils typified by the Houston-Black. Bottomland soils are reddish brown to dark gray alluvial soils. Potential vegetation in the bottomlands consists of many species of oak, elm, cottonwood, pecan, and sycamore. Upland vegetation is tall prairie bunch grasses including silver bluestem, needlegrass, buffalo grass, various gramas, sneezeweed and other weeds. Upland areas

As discussed in previous sections, a regional overview can be obtained with satellite imagery. The selection of transect sites and identification of unique, transition, or sensitive areas may also be accomplished with the remote sensing data. These characteristics, coupled with diagrammatic transects, lend themselves to serial analysis of large watersheds for preliminary survey purposes. For example, Figs. 12 (p. 91), 26 (p. 183), 28 (p. 197), and 32 (p. 227) are all of the Brazos River Watershed. Analysis of these figures, their transects and accompanying data provide insight into the nature of the environmental variations. Studying the LANDSAT-1 imagery one sees an apparent difference between the ill-defined stream of the North Central Prairie (Fig. 26, p. 183) and the heavily silted Double Mountain Fork of the Brazos River (Fig. 32, p. 227). After their confluence, and further downstream in the Blackland Prairie (Fig. 12, p. 91) a peripheral floodplain becomes evident. This floodplain and attendant ecosystem become well developed in the Post Oak Belt (Fig. 28, p. 197).

From this exercise, the use of satellite imagery clearly serves as an aid in the location of transect sites by identification of ecotones and unique areas. The first point is exemplified by the confluence of the heavily silted Double Mountain Fork of the Brazos River and the main stem of the Brazos River. Certainly transect sites would be located to bracket the environmental changes which may be of regional importance. Likewise, in the latter instance, the slackwater areas of the Post Oak Belt reach would require coverage by transect siting to determine local significance.

Updating Low Altitude Photography. The temporal disparity between the recent LANDSAT-1 imagery and the low altitude photography may limit the complimenting affect of the two data sources (see Data Source in Tables 7-17 for dates of available low altitude photographs in Texas). If updating the low altitude photography becomes necessary, the satellite imagery would be helpful in flight planning. Exact location of flight lines along the transects and selection of the film type and filters would optimize flight time, reduce costs and insure useful spectral coverage. Particular things of interest such as floodplain slackwater habitat, transition areas, vegetation mapping, habitat mapping, or possible land use changes could be emphasized.

Further Uses of Satellite Imagery. For broad regional or basin studies, seasonal variations in LANDSAT-1 imagery can enhance specific studies. Vegetation mapping, for example, may be facilitated by spring imagery. Soil mapping may require fall imagery (81). Krumpe conducted extensive studies on the uses of LANDSAT-1 photography in vegetation/terrain resources of the Feather River Basin in northern California. Applicable data (extracted for Texas) are presented in Table 6. It should be noted that all of Krumpe's imagery was from the summer. Like this study, he found MSS Band 4, 5, and 7 false color composites helpful in the display of regional ecological characteristics (51).

Also utilizing satellite imagery, the Texas Parks and Wildlife Department is currently installing remote terminals for vegetation/habitat mapping of the entire state. Programmed for installation in June 1976, this project will provide an invaluable source of secondary data for environmental assessment. Tentatively six frames of south

TABLE 6. Preliminary Indicators of the Feasibility of Wildland Landscape Features Detection and Identification Within the Feather River for LANDSAT-1 Imagery (adapted for Texas from Krumpe, 1973).

Imagery Parameters[a]	MSS Band 4		MSS Band 5		MSS Band 7		MSS Bands 4,5,7	
Sensor System	MSS Band 4		MSS Band 5		MSS Band 7		MSS Bands 4,5,7	
Date	7-25-72		7-25-72		7-25-72		7-25-72	
Image Type	B & W		B & W		B & W		Color Enhanced	
Interpretation Results	D[b]	I[c]	D	I	D	I	D	I
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Coniferous Forest	M	M[d]	M	M	M	0	E	M
Hardwood Forest	M	0	M	M	0	0	M	0
Grassland-Meadow-Marshland	M	0	M	0	0	0	E	M
Mesic Cultivated Cropland	M	0	E	E	E	E	E	E
Mesic Rangeland	M	M	E	E	0	0	E	E
Xeric Grassland-Shrub	E	M	E	E	0	0	E	M
Forest Plantation	E	M	E	M	0	0	E	M
Urban	M	0	E	0	0	0	M	M

TABLE 6 .-continued

Imagery Parameters[a] Sensor System / Date / Image Type	MSS Band 4 7-25-72 B & W		MSS Band 5 7-25-72 B & W		MSS Band 7 7-25-72 B & W		MSS Bands 4,5,7 7-25-72 Color Enhanced	
Interpretation Results (1)	D[b] (2)	I[c] (3)	D (4)	I (5)	D (6)	I (7)	D (8)	I (9)
Standing Water	M	M[d]	E	E	E	E	E	E
Running Water	O	O	M	M	O	O	M	M

[a]This study was conducted with satellite images commercially enlarged to 16 X 20 inches.

[b]D - Detection - Ability to discriminate from surrounding tone matrix.

[c]I - Identification - Ability to classify and assign a name to an image determined by its unique color, tone, shape, pattern, size, association, or other quality.

[d]Key: Easy (E) Marginal (M) Unable (O)

Texas will be mapped by September 1976 and twenty frames of East Texas are scheduled for FY 77 (57). This information could also be displayed on the diagrammatic transects.

Public Hearings. The display of physical-biological relationships provided by the diagrammatic transects and their correlation to remote sensing imagery could provide an effective media for public hearings. Discussion of this type of display will help establish two way communications between the planners and the public. It could lead to additional public input. Also, a better understanding of local-regional relationships could be gained by both parties.

Expanded Transects. Additional uses of the diagrammatic transects at the present scale may be limited. However, detailed ecological information could be transposed onto transects of a larger scale to delineate transition areas or community boundaries. These would require more data but would be applicable to both smaller projects or critical areas of large projects. This display provides planners and decision makers with specific information about spatial ecosystem relationships. For example, as reservoir sites become less plentiful, enlargements of existing impoundments will be needed. The peripheral ecosystem which has developed will be subject to inundation. A detailed transect of the existing community will provide some insight into elevation limits which should be considered. Since recreation homes and other land use changes outside the project right of way (ROW) often isolate the riparian ecosystem, futher inundation may not provide an adjacent habitat for disrupted species (Fig. 11). Severe population reductions could occur. Radiating corridors may provide relief in some areas.

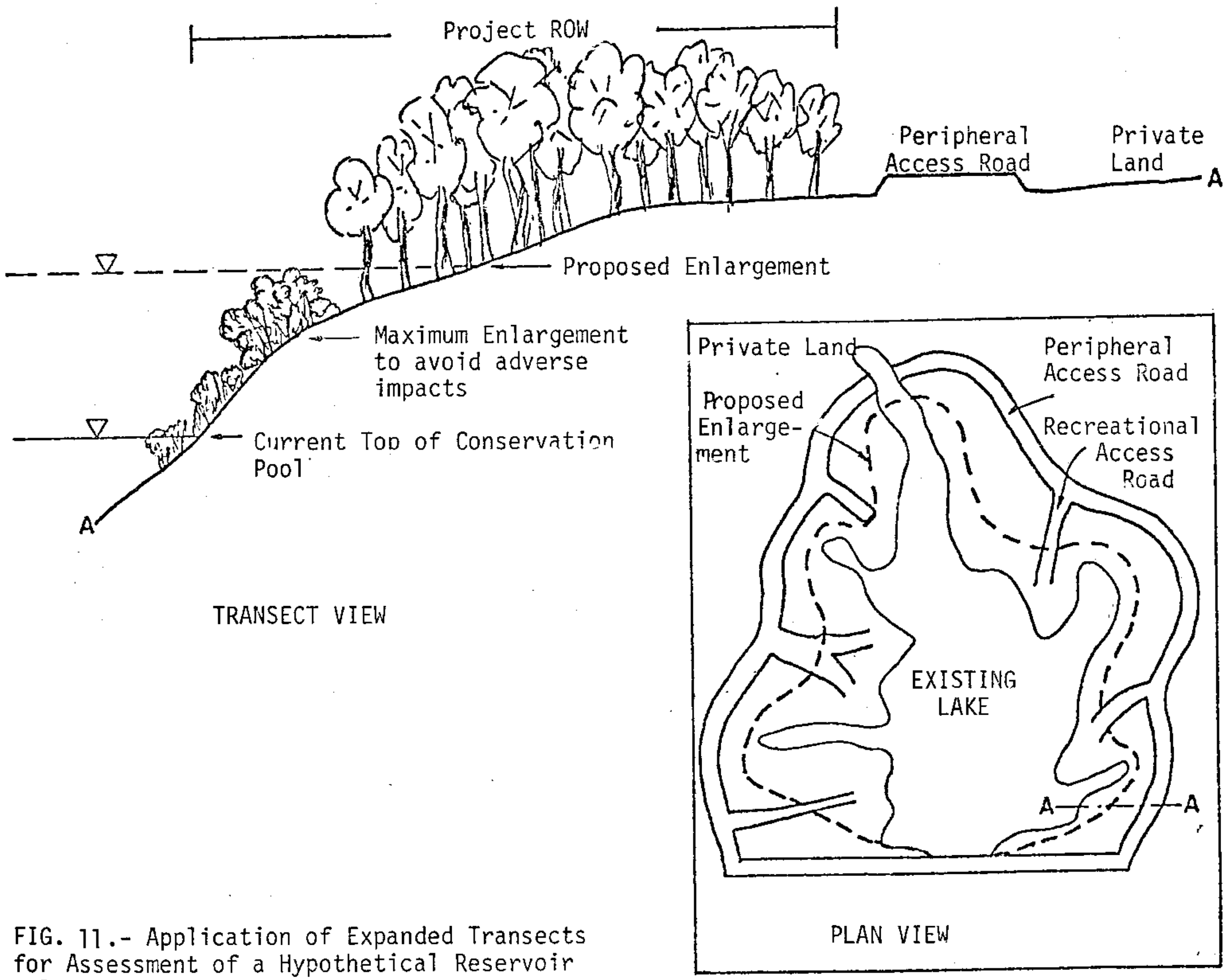

FIG. 11.- Application of Expanded Transects for Assessment of a Hypothetical Reservoir Enlargement.

Chapter V

SUMMARY AND CONCLUSIONS

Summary

The delineation of twelve physiographic regions of Texas was accomplished with a band 7 (infra-red) black and white summer mosaic of the state. These regions often correspond to existing regional boundaries, soil types, climatic factors, and potential vegetation. Extreme variations in the existing environment were noted throughout the state. Mean annual rainfall varies from 56 inches (142 cm) to 8 inches (20 cm) from east to west while mean annual net lake evaporation ranges from 10 inches (25.4 cm) to 90 inches (229 cm), respectively. Likewise, the vegetation ranges from lush mixed hardwood and pine forest of the East Texas Timberlands to the brush infested Trans-Pecos region. Habitat quality and available water supply show similar trends.

The ecological changes associated with specific water resource project facilities were identified for surface water impoundment and channelization projects. For impoundments, these changes were effects on or in (1) the remaining lotic (running water habitat), (2) the newly created lentic (standing water) habitat, (3) the surrounding terrestrial habitat, and (4) the water quality. For channelization works, these impacts included (1) the drainage of wetland areas, (2) the clearing of bottomland hardwoods, (3) the cutting off of stream meanders, (4) the effects on groundwater recharge, (5) the change in erosion and sedimentation patterns, and (6) the downstream effects.

With the assessment of these impacts in mind, data were collected on selected sites within each physiographic region. These secondary sources included previous environmental impact statements, county game surveys, academic biological inventories, open-space plans of regional councils of government, topographic maps, soils maps, LANDSAT-1 (satellite) imagery and low altitude aerial photography. Then, for one site in each region, a diagrammatic transect was constructed to display the available information. Accompanying tables and photographs were combined with these selected transects to provide a unique tool for the preliminary assessment of environmental impacts of the two main types of water resource development in Texas.

The application of this tool will significantly narrow the communications gap among engineers, biologists, and planners involved in alternative selection processes. In addition, this procedure will facilitate the assumption of environmental factors into "their proper place along with other considerations" (90).

The use of these transects and accompanying data will certainly find other application including further use of the satellite imagery, expanded transects and project monitoring.

The review of previous environmental impact statements on a regional basis, in the text of impoundment and channelization effects, provided the following notes:

(1) Differences in assessment methodologies and, therefore, thoroughness are evident among the various orginating agencies.

(2) Local ecological evaluations rarely encompass regional effects or address ecosystem integrity.

(3) Engineering alternatives do not develop environmental impacts in sufficient detail to base a decision on the relative merits of each alternative.

(4) Critical ecological factors are repeatedly mitigated by only economic benefits.

(5) Long term productivity versus short range benefits sections do not include lessons learned from existing projects or future secondary effects resulting from economic growth, recreation, or other project uses. For impoundments, aquatic macrophyte encroachment is a prime example.

Conclusions

During the conduct of this study and following the assimilation and application of data, the following conclusions were drawn:

(1) Satellite imagery is useful in the delineation of large physiographic regions.

(2) Secondary data from previous environmental impact statements, regional councils of government, county game surveys, county soils maps, and academic studies provide good statewide coverage (in most cases) of environmental amenities for preliminary studies.

(3) The display of secondary physical, photographic, and ecological data on diagrammatic transects provides a useful working tool for environmental assessment of preliminary water resource development and lends itself to rapid, low cost update for more detailed planning.

(4) The inclusion of satellite and low altitude imagery into preliminary environmental studies provides a synoptic overview of regional ecosystem relationships, direct correlation

with gross critical ecological factors, and a basis for project monitoring of environmental effects.

(5) The application of diagrammatic transects and accompanying data to preliminary environmental assessment of water resource development alternatives provides a tool which significantly narrows the communications gap among planners and facilitates the early incorporation of environmental factors along with other project considerations.

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are nearly ninety percent cultivated. Remaining areas are used for grazing and have moderate mesquite encroachment (60).

Wildlife populations are limited by narrow habitat bands and intensive land use. Deer and other mammal populations are depressed or non-existent. Upland game birds, quail and mourning dove are moderate to abundant. Aquatic species are likewise depressed because of pesticide application and the intermittent nature of smaller streams. Some large catfish survive in deeper pools. Artificial impoundments on the other hand support large numbers of game fish and provide local-wildlife habitat (40).

Environmental Impact Reviews

Development of the region's water resources parallels the use of this valuable crop and pasture land; however, the thirteen largest impoundments yield some 1.2 million acre-feet (1480 million m^3) and inundate some 230,000 acres (931 km^2) along the Brazos and Trinity Rivers. The continual clearing of bottomland hardwood species is of increasing concern (48). These bottomland areas are especially important in the grasslands area because they afford most of the available cover and habitat for wildlife species. The north-south linear nature of the region with northwest to southeast drainage provides many ecologically sensitive border areas (Fig. 6, p. 36). These areas may be quite unique ecologically.

Reservoirs. Since most of the Blackland Prairie is cropland, erosion control is an important concern in land use. Impoundments acting as nutrient traps, accumulate agricultural chemicals and eroded soils in their sediments. Secondary aspects of recreation, increased flood protection, and increased water availability provide environmental enhancement for the floodplain (31). This may encourage further land clearing in ecologically significant bottomlands. With on-stream impoundments, downstream flows are equalized which may affect drainage in adjacent cropland as well as damage water intolerant vegetation in the floodplain. In the lower region, water demands for estuarine management become of critical importance and may encourage water reuse. In northern areas, recreational demands from Dallas-Fort Worth could cause considerable alterations of surrounding terrestrial areas. Relatively large terrestrial ecosystems have developed around Whitney and Lavon Reservoirs which in the former case will be damaged by raising the water level as proposed (40).

Generally, throughout the region, reservoirs of forty feet (12.2 m) depth or less will not stratify thermally long enough to create reducing conditions in the hypolimnion (43). However, the natural stream habitat is lost as is the natural flooding scheme so important to maintenance of downstream areas.

Channelization. Primarily, effects include water table lowering in the local area because of increased velocities and the loss of the lotic-lentic stream and adjacent habitats. Since Blackland Prairie soils are vulnerable to erosion (40), extensive floodplain clearing would be detrimental. In addition, channel side slopes would be important and may need stabilization especially downstream from impoundments. A notable example is the Lavon Dam and Reservoir Modification and East Fork Channel Improvement (31). This project consisted of widening, deepening, realigning and straightening 31.8 miles (51.2 km) of river and raising the reservoir conservation pool. Levees were included to prevent erosion and provide increased channel capacity below Rockwall-Forney Dam. This statement omitted the environmental consequences but discussed the increase in upland game habitat resulting from flood-protection. No regional considerations were included nor the fact that ponding may occur behind the levees on valuable agricultural land. The creation of a large channel will significantly divide terrestrial communities resulting in further reduced numbers and diversities. In other reviews involving channelization, little discussion was afforded alternatives and in no cases were alternatives given equal consideration.

Environmental Assessment Procedures. (1) Academic institutions were used for large scale biological inventories.
(2) Surveys were conducted to assess the human impact in local and regional areas.
(3) Localized impacts of southern prairie projects may require estuarine management while northern ones may not be as complex.
(4) Impact assessments are readily mitigated with enhancement measures, i.e., green-belt corridors and prevention of additional land clearing for agricultural expansion (the no-action alternative).
(5) Consideration of no action alternative is important because present land use will reduce the remaining bottomland acreage for agricultural production.

Summary of Environmental Impact Reviews. All statements reviewed for the Blackland Prairies were written soon after the passage of NEPA and several projects were already under construction. (1) A failure to address the regional environmental consequences in either the Lavon Reservoir or Whitney Lake Projects was noted.

(2) A failure to present alternatives in sufficient detail to properly assess their impacts was also evident.

(3) The loss of agricultural potential in flooded lands was mitigated by protection and enhancement of remaining lands.

(4) Failure to discuss water quality conditions including pesticide and sediment concentrations was noted.

Diagrammatic Transects and Accompanying Data

Remote sensing plates and accompanying data are displayed in Fig. 12 and Table 7 respectively; the Blackland Prairie transect is presented as Fig. 13. Fig. 12 includes low altitude photography (right), regional LANDSAT-1 imagery (lower left) and enlarged LANDSAT-1 imagery (upper left).

Low Altitude Photography. Floodplains vary in width from 2 to 5 miles (3.2-8.1 km) and are usually well defined. Upland elevation increases northward. The entire area slopes southeastward and drainage is parallel in most places.

Floodplains are poorly to moderately well drained. Large streams meander considerably with old oxbows and slack water areas maintaining vegetated areas (Fig. 12). Drainage is rapid and slightly incised in the northern areas becoming less in the lower relief of the south.

Hardwoods appear on some north and east facing slopes. Extensive agricultural production limits most large stands to the bottomlands. A moderate understory is present in some areas around stream channels.

Crop production practices include erosion control measures such as contour planting (Fig. 12).

Upland areas are gray to light where uncultivated. Bottomland soils are generally darker or mottled in many areas.

Roadways follow parallel east-west ridges in the north and south and section lines in the central area. Agricultural communities are located on ridges and terraces.

Satellite Imagery. In the northern region the proximity of numerous large impoundments is evident. Vegetation, both natural and agricultural, is evident along streams. Most larger tributaries enter NW-SE streamflow from the northern side. A regional transition is evident. The central region reveals unique tonal variation during winter months (Fig. 12). Light colored winter crop production in this area is clearly delineated from surrounding vicinity. Streamflow is more southerly. Lighter color hue also noted to west and north in adjacent regions. Southern area is near Balcones Escarpment but reveals little other regional significance.

FIG. 12. - Blackland Prairie, Brazos River, Falls County, Texas. Figure includes low altitude aerial photography (right) at a scale of 1:20,000 taken December 8, 1968, and regional LANDSAT-1 imagery at scales of 1:1,000,000 (lower left) and 1:350,000 (upper left). The five-mile transect is shown on the LANDSAT imagery which was taken October 18, 1973. The black and white reproductions of the LANDSAT-1 imagery in the figure were taken from a color composite of bands 4, 5 and 7.

LANDFORMS	Floodplain	Terrace	Uplands
LANDUSE	Agricultural Cropland (Except where poorly drained)	Agricultural Cropland	
PLANTS	Bottomland Hardwoods inc. Cottonwood, Post Oak, Red Oak, White Ash, American Elm	Mesquite-Grasslands inc. Mesquite, Cedar Elm, Hackberry, Post Oak, Blackjack Oak, Winged Elm, Bluestem Grasses, Indian Grass, Grama Grasses, Switch Grass, Buffalo Grass, Legumes	
ANIMALS	Furbearers, Cottontail Rabbit, Fox Squirrel	Upland Game Birds, Gray Fox, Peregrine Falcon (E), White tailed Deer	

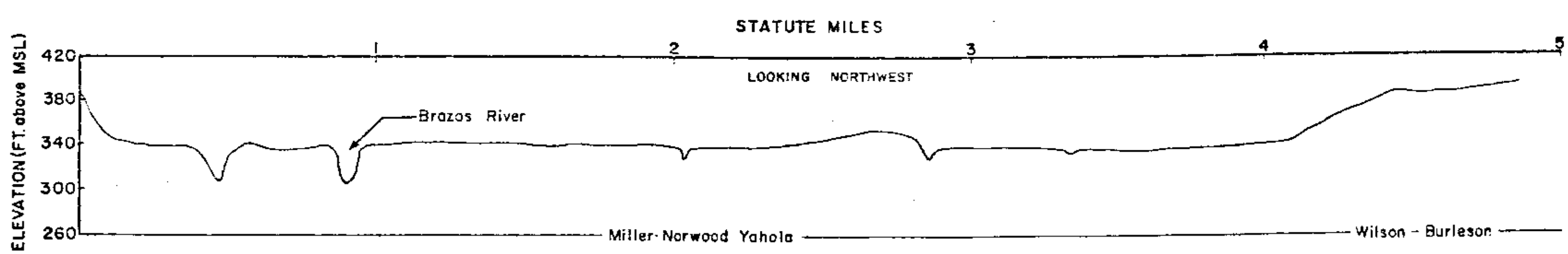


FIG. 13. - Blackland Prairie Transect, Brazos River, Falls County, Texas.

Table 7. - Blackland Prairie, Brazos River, Falls County, Texas.

Landform (1)	Airphoto Pattern Elements (2)	LANDSAT-1 Elements (3)
Flood Plain	Flattened, broad bottomlands with incised streambeds. Extensive agricultural row crop production. Artificial, dendritic and internal drainage. Erosion in streams. Hardwoods limited to stream banks and fence rows. Mottled to dark soils.	Areas around stream meanders are dark colored in slack water areas and light colored where agricultural cropland. Large area of light coloration around sample site is unique on regional basis.
Terraces	Varying in development. Contain gravel deposits. Also cropland with more well drained soils. Some grasses and mesquite on rangeland areas. Lighter soils.	Distinquishable on enlargements as such areas parallel to river in some spots. Otherwise difficult to separate from uplands.
Uplands	Gently rolling, moderately dissected. Dendritic drainage. Livestock tanks on slopes. Hardwoods and mesquite grass associations. Tones lighter.	Tones more grayish to reticulated. Clear transition from bottomlands especially on enlargement.

Soil & Origin (1)	Description and Location (2)
Miller-Norwood-Yahola (Fluvial)	Friable to crumbly calcareous very fine sandy or silt loam, silty clay loam or clay, 6-30 in., over crumbly subangular blocky calcareous, very friable granular silt or silty clay loam, or stratified fine sand loam. (Streambed to Elev. 350 ft)
Wilson-Burleson (transition and uplands)	Acid to neutral very firm clay or sandy and clay loam, 4-12 in.,clays 30-40 in., over firm to blocky massive clay, calcareous or neutral to calcareous with depth. (Above Elev. 350 ft., East Bank)

Table 7.- Continued

Community Location (1)	Ecological Factors (2)
Bottomlands	Limited habitats except in some slackwater areas. Cottonwood, oaks, and native pecans are present. Furbearing mammals are limited by habitat availability. Fox squirrel populations are low to absent.
Terraces, transition and uplands	Grading into some hardwoods stands in abandoned fields or east facing slopes. Mostly agriculture with upland game birds abundant. Some predators are present, but populations are generally low. Few white-tailed deer are present due to lack of habitat. Historical range of the endangered Peregrine Falcon.

Data Source (1)		Acquisition Source (2)
Low-Altitude Photographs 2-12-72	CKR-255-16, 17, IJJ-226, 227 250, 251	Western Aerial Photography Laboratory Performance Division ASCS-USDA 2505 Parley's Way Salt Lake City, Utah 84109 Tel: AC 801, 524-5826 Price - $2.00 each
LANDSAT-1 12-12-72	81146163044G200-C False Color Composite	EROS Data Center Data Management Center Sioux Falls, South Dakota, 57198 Tel: AC 605, [illegible]-6511 FTS: AC 605, [illegible]-6151 Price - $7.00

Table 7.- Continued

Data Source (1)		Acquisition Source (2)
Topographic Map 1957	Marlin Quadrangle 1:24000	Texas Water Development Board Topographic Mapping Section P.O. Box 13087 Austin, Texas 78711 Tel: AC 512, 475-3191 Price: Free to State agencies or Contractees
Soils Map 1961	Falls County 1:139000	Texas Agricultural Experiment Station Texas A&M University Reed McDonald Bldg. College Station, Texas 77843 Tel: AC 713, 845-2413 Price: Free, limited to twelve per customer
Biological Inventories undated	Falls County Resource Inventory	Texas Parks and Wildlife John H. Reagen Bldg Austin, Texas 78701 Tel: AC 512, 822-4631
	EIS Whitney Lake Feb., 1971 Trinity River Status of Environmental Studies July, 1975	U.S. Army Engineer District, Fort Worth P. O. Box 17300 ATTN: Public Affairs Officer Fort Worth, Texas 76102 Tel: AC 817, 334-2212 Price: Free

Crosstimbers

See Chapter III, page 38 for discussion of the Crosstimbers.

East Texas Timberlands

General Description

Situated in the eastern-most area of the state, this area extends from 30^0 latitude to the Sulphur River and from the Texas-Louisiana border to east of the Trinity River (Fig. 6, p. 36).

Rainfall ranges from 44 inches (112 cm) in the north to 56 inches (142 cm) in the southeast. Evaporation is generally less than 10 inches (25 cm). The elevation varies from 200 to 700 feet (61-213 m) increasing westward. Locally, hilly conditions produce variable drainage.

Generally, the East Texas Timberlands are of Eocene origin, soils are light colored, acid, sandy loams and sands with some red soils in the uplands. In the bottomlands, soils are light brown to gray, acid to calcareous, loamy to clayey alluvial, some are poorly drained.

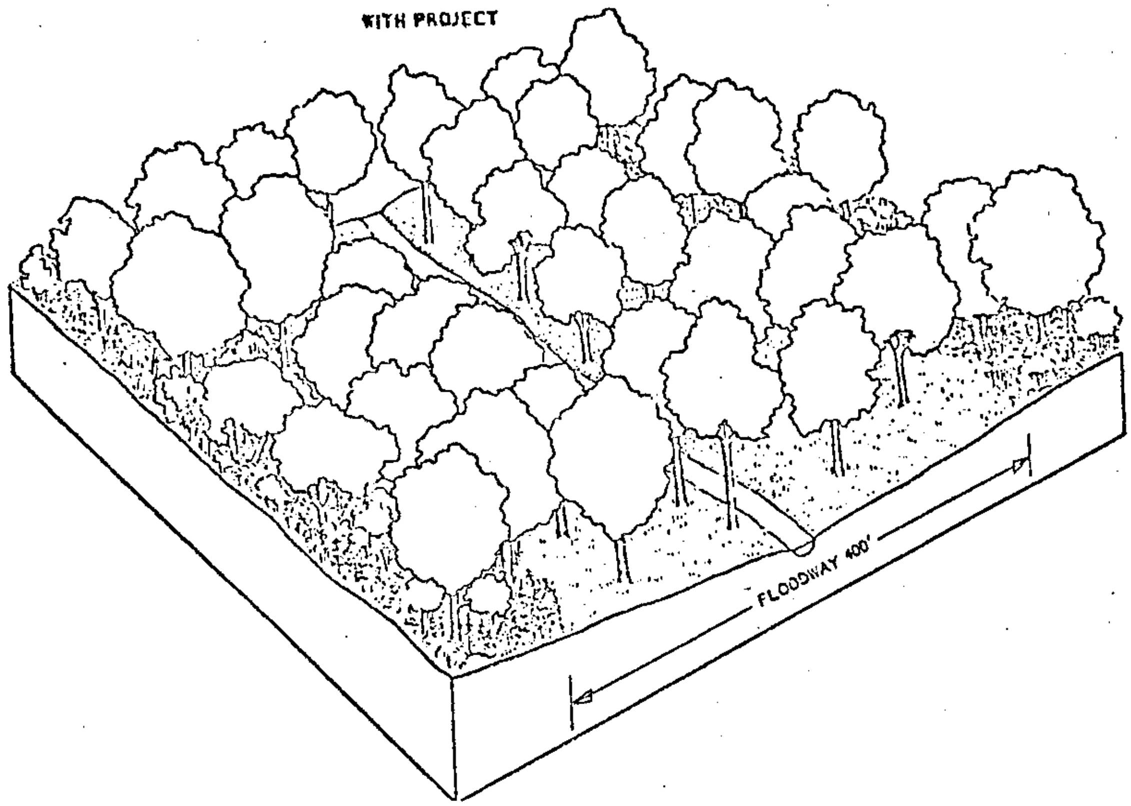
Vegetation consists of loblolly, shortleaf and longleaf pine with associated hardwood species, mainly oak in the uplands. In the bottomlands hardwood species of oak and sweetgum are dominant with some pine and cypress (44). These associations are more aptly defined as Oak-Hickory-Pine Forest.

The timbered bottomlands and swamps provide habitat for numerous wildlife species including otter, mink, raccoon, opossum, fox, muskrat, skunk, squirrel, birds of prey and song birds. The open fields and clearings in the woodlands along the river provide nesting and feeding areas for quail, dove, water-fowl and wading birds such as wood duck, mallard, egret, ibris, and heron which nest and feed in the swamps and sloughs. Many rare and endangered wildlife species require the southern swamps and timberlands as habitat. Among these are the American alligator, American bald eagle, ivory-billed woodpecker, northern red-cockaded woodpecker, and the red wolf (33).

Environmental Impact Reviews

The East Texas Timberlands is the most forested area of the state. It therefore possesses a diverse biota and habitat as well as many aesthetically scenic areas. Unfortunately, only two environmental statements were available for review from this area. The Sabine River and Tributaries, Texas and Louisiana EIS (38) is one of the first published under NEPA and as such is extremely brief. For example, the project proposed flooding 62,000 acres (251 km^2) of land and 90 miles (145 km) of stream with 3 major reservoirs and gives the following statement under paragraph C, Identify Alternatives to the Proposed Action: "Any alternative system of projects which would provide the needed water supply, flood damage reduction and recreational opportunities would be more expensive than the recommended multiple-purpose reservoir system and the environmental effects of such alternatives would be essentially similar to that of the recommended projects."

By contrast, the other statement, Sandy Creek Watershed (14) is relatively thorough. The latter proposed four off-channel floodwater retarding structures and the creation of 2.9 miles (4.7 km) of floodway. The floodway will be cleared of water intolerant species and underbrush (Fig. 14). However, the statement goes on to point out that if all watershed projects now appearing feasible are constructed, there will be 113 floodwater retarding structures, 82 miles (132 km) of channel work, and 3 miles (3.8 km) of floodway. At the same time, this statement includes little discussion of regional effects and no development of



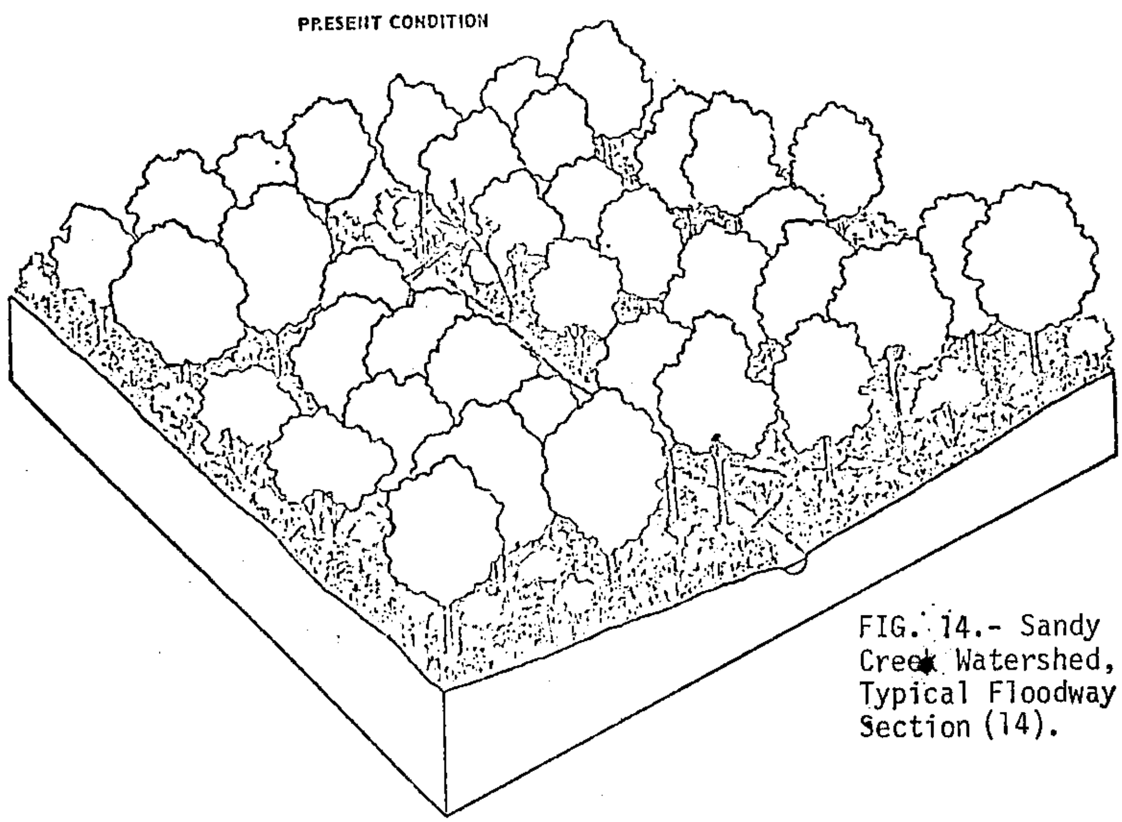


FIG. 14.- Sandy Creek Watershed, Typical Floodway Section (14).

alternatives.

Reservoirs. Because of the dissected topography, construction of large reservoirs in this region would inundate or affect vast bottomland areas and possess many miles of shoreline. Any such shoreline would largely consist of wooded slopes. As the reservoir would cause the water table to rise on peripheral slopes, a change in dominant overstory may occur. Thus, in the riparian area adjacent to the reservoir the dominant pine forest would be gradually overcome by water tolerant hardwoods.

Likewise, the inundation of the region's wide floodplains would replace many miles of warm water stream fisheries with impoundments. The region has less than ten cities over 10,000 population (4) and the major land uses are dryland farming and forest production. Therefore, the necessity of rural flood control, large water supplies, or recreational areas is not pressing. Off-channel, smaller watershed projects are not usually sufficient to prevent urban flooding on main streams. The Sandy Creek Watershed Project (14) includes channelization work with upstream off-channel impoundments to provide sufficient flood protection. However, these projects only affect local terrestrial habitats and usually disturb small intermittent streams.

Channelization. In light of the population densities, land use, and local recreation demand, extensive floodplain clearing should be unnecessary in this area. Clearing and snagging operations or short channel rectification measures may be applicable to tributary streams, but the capacity of these broad floodplains to flatten flood peaks could be diminished by too much clearing. The Sandy Creek Watershed Project Selective Clearing Plan (Fig. 14) is designed to lower the "n" values

(Manning's coefficient of roughness) to significantly improve the hydraulic characteristics of the floodplain. This technique will reduce the elevation of the 100-year flood event but will alter the downstream flooding sequence by transposing (in time, duration and magnitude) the flood hydrograph peak (14).

Environmental Assessment Procedure. (1) The early 1970 statements of the Corps of Engineers relied on mutual understanding of the planners as to the effects of large impoundments.
(2) The Soil Conservation Service EIS (14) included extensive preauthorization coordination among local interest and the sponsoring agency. This allowed for local input into pre-planning assessment of the regional environment.
(3) The reliance on secondary data for environmental inventory or coordination with other federal and state agencies was evident in the Sandy Creek Project. However, larger projects may require more data as input into the alternative selection process.

Summary of Environmental Impact Reviews. (1) An overall failure to assess the regional impacts such as downstream water quality, alteration of flooding sequence and possible land use changes was noticed.
(2) Alternatives were not developed to sufficient extent to allow an analysis of their environmental merits.
(3) A failure to deal with water development within the region in local perspectives was noted. In other words, this area cannot use the water stored in numerous surface impoundments. For the Neches River alone projected in-basin requirements for 2020 is 1.03 million acre-feet (1271 million m^3) annually (79) whereas 4.68 million acre-feet (5773 million m^3)

are annually present and less than 1.18 million acre-feet (1456 million m^3) are needed for out-of-basin requirements. The balance, 2.5 million acre-feet (3084 million m^3), is excess. (These figures are based on maximum storage area of existing reservoirs).

Diagrammatic Transects and Accompanying Data

Remote sensing plates and accompanying data are displayed in Fig. 15 and Table 8, respectively; and the East Texas Timberlands transect is presented as Fig. 16. Fig. 15 includes low altitude photography (right), regional LANDSAT-1 imagery (lower left) and enlarged LANDSAT-1 imagery (upper left).

Low Altitude Photography. Land forms are relatively constant throughout the region. Uplands are moderately dissected to sharply rolling. Floodplains vary in width, increasing in the southern areas. Streams are meandering with marshy areas and many tributaries in the floodplain (Fig. 15). Northern tributaries tend to be longer and more dendritic than southern ones.

Drainage features include the dendritic tributaries and numerous low water collection areas in the upland gullies. In the southern extent, floodplain tributaries form a deranged pattern. Many slack-water areas exist in all floodplains.

Gullies are V-shaped in the north flattening to low profiles in the south. Erosion is active in all main stems on the outside of turns; likewise, deposition occurs on insides. Upland areas show some erosion especially in northern cleared areas on steep slopes. Contour plowing is used in all areas especially in east central dryland farming areas.

Hardwoods are predominant in the bottomlands throughout the area with some mixed pine. Old meander scars are covered with heavy underbrush and the entire floodplain has a distinct two story flora (Fig. 15). In the uplands, mixed hardwood and pine forests are abundant. Some row crop farming occurs throughout the regional uplands. In the north, heavy vegetation occurs on north facing slopes. In central areas, these slopes appeared to be more often cleared for agriculture. In the south, most north facing slopes have more hardwoods.

Photographic tones do not vary greatly throughout the area. Little bottomland clearing makes soil tones difficult to assess; however, in cut areas around major streams they appear light to moderate. Light tones occur in stream deposition areas. In the uplands, soils are light to mottled in marshy areas and mostly light colored elsewhere. Vegetated north facing slopes are usually darker. Defoliated hardwoods are easily distinguished from conifers in winter photographs (Fig. 15).

Most man-made structures are located along upland road networks which curve along ridgelines wherever possible. Contour plowing is used on upland slopes throughout the area. Small cities are relatively few in number. In upland cleared areas, the feeder streams often have grassed floodways. Pipelines are numerous in the east central area, often cutting through wooded stands in uplands.

Satellite Imagery. LANDSAT-1 imagery provides a good view of the relative amounts of forest and cropland in the region (Fig. 15). It can be seen that the cropland is more abundant in the western portion where the relief is greater and streams are smaller. Most drainage follows a northwest to south-southeastern tract, turning south in the eastern extent. The eastern portion of the region is almost entirely covered by woodland. Several large main stem impoundments are evident in this region while smaller off-channel lakes are in the agricultural areas.

FIG. 15. - East Texas Timberlands, Sabine River, Panola and Harrison Counties, Texas. This figure includes low altitude aerial photography at a scale of 1:20,000 taken December 8, 1968 (stereopair on right). The regional LANDSAT-1 imagery taken December 10, 1973 (left) was reproduced at a scale of 1:1,000,000 (lower left) and 1:350,000 (upper left). The five-mile transect is shown on the LANDSAT-1 imagery. The high contrast between the timber areas and open areas can be observed in the LANDSAT-1 imagery. Light photo tones in the uplands indicate sandy, well-drained soils. Meander scars can be seen along the Sabine River in the stereopair. While the reader may not be a skilled photo interpreter, he can see enough difference in the patterns to delineate boundaries of similar vegetation within the forested areas on the stereopair.

	Floodplain	Uplands
LANDFORMS	Floodplain	Uplands
LANDUSE	Forest Production	Forest and Crop Production
PLANTS	Bottomland Hardwoods inc. Lush understory: Oaks, Hickory, Elm, Ash	Mixed Pine Hardwood Forest inc. Loblolly Pine, Shortleaf Pine, Oaks, Sycamore
ANIMALS	Freshwater Fisheries, White tailed Deer, Squirrels, Quail, Waterfowl, Turkey	Predators, White tailed Deer, Mourning Dove, Gray Fox, Rich Avifauna

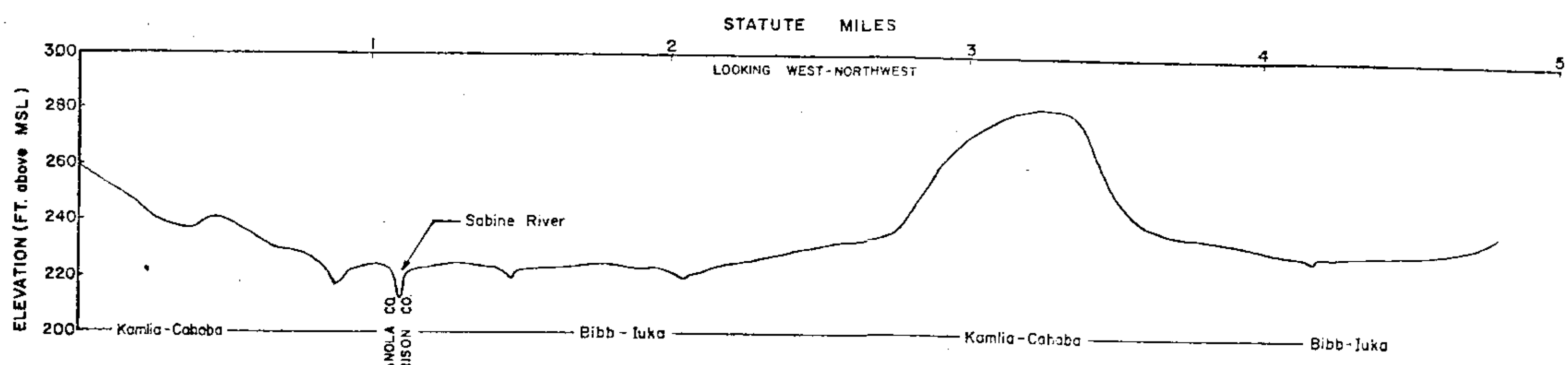


FIG. 16.- East Texas Timberlands Transect, Sabine River, Panola and Harrison Counties, Texas.

Table 8. - East Texas Timberlands Transect, Sabine River, Panola and Harrison Counties, Texas.

Landform (1)	Airphoto Pattern Elements (2)	LANDSAT-1 Elements (3)
Floodplain	Broad flat floodplain with poor drainage. Marshy low lying areas contain meanders and oxbow lakes. Gullies are well developed with erosion on steep banks. Dense underbrush in predominantly hardwood stands. Coarsely textured with light to mottled soils.	Regional drainage patterns are easily distinguishable. The longer northern tributaries indicate a slope to the south as well. Width of floodplain is greater than five miles in many areas and easily delineated from light upland areas. Slackwater areas are noticeable as vegetation extends upstream of tributary confluences.
Upland	Finely dissected, well defined uplands with extensive clearing. Marshy areas in some upland gullies. Drainage is dendritic. Numerous water retention structures are evident. Contour plowing is practiced on cultivated slopes and erosion is evident on denuded areas. North facing slopes are often cleared leaving mixed pine and hardwoods on other slopes. Uplands are light to mottled in marshy areas where cleared and dark in vegetated areas. Terraces are poorly developed in most areas.	Highly reticulated regional view is indicative of extensive clearing expecially on ridge tops. Slopes toward drainage areas are largely vegetated. Enlargement shows light colored cleared areas and importance of corridor type floodplain ecosystem. Proximity to the Red River is also evident.

Table 8. - Continued.

Soils & Origin (1)	Description and Location (2)
Bibb-Iuka (Alluvial)	Acid fine sandy loam to clay loam, 4-20 in., over friable acid sandy to sandy clay loam or massive strongly acid clay loam (streambeds to Elev. 240 ft)
Kalmia-Cahaba (Residual)	Acid sandy loam to loamy sand, 8-20 in., over friable porous acid sandy clay loam (above Elev. 240 ft.)

Community Location (1)	Ecological Factors (2)
Bottomlands	Rich hardwood habitat with dense understory. Occasional pines are also present. Dominant vegetation includes water oak, willow oak, overcup oak, American sweetgum, hickory, elm, ash, and black tupelo. Understory species include hawthorns, button bush, planer trees, wax myrtle, Ohio buckeye, Alabama supplejack, grape, holly, and yaupon. The fauna includes abundant bird species, white tailed deer, fox squirrels, some quail, foxes, wolves, water fowl, and a moderately abundant freshwater fisheries.
Uplands	A mixed pine hardwood upland, interspersed with improved pastureland or dry cropland. Overstory consists mainly of short leaf pine, loblolly pine, oaks, hickory, sweetgum, and sycamore. Persimmon is found as an invader on idled cropland. White tailed deer also frequent the uplands. Predators, rodents, dove, and quail also occur in the uplands. A high population of gray fox is present as well.

Table 8. - Continued.

Data Source (1)	Acquisition Source (2)
Low-Altitude Photographs Dec 1968 CGC-2KK-275-278-222	Western Aerial Photography Laboratory Program Performance Branch ASCS-USDA 2505 Parley's Way Salt Lake City, Utah 84019 Tel: AC 801, 524-5826 Price: $2.00 each
LANDSAT-1 12-10-73 81505162145N200-C False Color Composite	EROS Data Center Data Management Center Sioux City, South Dakota 57198 Tel: AC 605, 594-6511 FST: AC 605, 594-6151 Price: $7.00 per color composite
Topographic Map Panola and Harrison County Soils Maps 1:155000 1:192000	Texas Water Development Board Topographic Mapping Section P. O. Box 13087 Austin, Texas 78711 Tel: AC 512, 475-3191 Price: Free to State Agencies or Contractees
Biologial Inventories Northeast Texas Game Management Survey Harrison County 1962 Panola County 1966	Texas Parks and Wildlife Department John H. Reagen Building Austin, Texas 78701 Tel: AC 512, 822-4631 Price: Free

Table 8. - Continued.

Data Source (1)		Acquisition Source (2)
Biological Inventories	Lake Texarakana O & M EIS Oct 1973	U. S. Army Engineer District, New Orleans P. O. Box 60267 New Orleans, Louisiana 70160

Edwards Plateau

General Description

The Edwards Plateau covers the south central portion of Texas. It is bordered on the south and east by the Balcones Escarpment, on the west by the Pecos River, and on the north by the High Plains, Rolling Plains and Prairies regions. It extends approximately from 98^{0} to 104^{0} longitude and $29^{0}15'$ to $31^{0}30'$ latitude (Fig. 6, p. 36).

This plateau rises westward from 1200 to 3000 feet (365 to 914 m) above sea level. It is predominately cretaceous in origin with dark, calcareous stony clay loams on the uplands. Bottomlands have minor areas of dark calcareous clayey alluvial soils (44).

Annual rainfall decreases from east to west from 32 to 13 inches (81 to 31 cm) and evaporation increases from 40 to 70 inches (102 to 177 cm).

About 98 percent of the area is in rangeland. Production of small grain, grain sorghum, forage and hay is limited. The major agricultural product is wool and mohair production (44). Small amounts of oil and gas production take place.

Vegetation consists of oaks and mesquite or juniper-short grass associations. Some bottomlands contain oak, pecan, black walnut, and other hardwoods. Deer, turkey, quail, javeline, rabbits and reptiles are present in varying numbers throughout the region.

Environmental Impact Reviews

This vast area of rangeland contains limited surface water resources. International Amistad Reservoir, Lake Travis, Lake Buchanan and Twin

Buttes Reservoir account for 86 percent (5.7 million acre-feet) (7000 million m^3) of the regional surface water supply (18). All of these are located near or on regional boundaries. The Texas Water Plan calls for intrabasin transfer into the region and continued development of groundwater supplies (79).

Three impact statements dealt with impacts on boundary areas of the Edwards Plateau; none was totally within the region. Since the area is mostly over-grazed semi-arid pastureland, wildlife habitats have a low carrying capacity. One unique statement deals with the development of recreation facilities around Amistad Reservoir. Although this project deals with secondary effects of reservoir construction, it provides insight into ecological pressures which result from multi-purpose reservoirs. The proposed development is part of an overall plan which includes nine sites chosen on the following factors: harbor quality, access from existing transportation routes, terrain, land ownership, distance from population centers, and probable need (36). No mention of ecological amenities was included in the priorities list. The statement does point out, however, that public construction will reduce uncontrolled use and misuse of the surrounding terrestrial habitat.

Reservoirs. Construction of large multi-purpose reservoirs on limestone soils could create seepage problems and at best would be difficult to site. Soil compaction may produce a suitable impervious seal in some areas (87). For example, the Amistad project included lining of sewage lagoons to prevent groundwater contamination (36). Also, a floodwater retarding structure on San Felipe Creek in the southwestern extreme of the region provided for loss of impounded floodwater through high seepage rates (87).

Perhaps the most significant ecological impact of reservoir construction in this area is aptly described as follows (36):

> Changes in the existing environment of the region are on an unalterable course. These changes began the day the gates of Amistad Dam were closed and water began to back up behind the dam. In a region devoid of large bodies of water and recreational opportunities, the creation of Amistad Reservoir was the beginning of a new way of life. The impact of the reservoir has produced deep and lasting social and economic changes. In an area where the economy has largely been agricultural, almost overnight an economy based on motels, water recreational supplies and services, restaurants, and new and enlarged business and rural subdivisions had developed.

These attendant secondary events would clearly have an effect on the newly formed terrestrial and aquatic habitat as well as the surrounding ecology.

Channelization. The hardwood-mesquite vegetation in the bottomlands is essential for soil stabilization of the region. The residual soils are finely textured and a vegetation cover is necessary along gullies where channelized drainage begins (87).

Locally, urban floodplains may be cleared by special interest. The ecological aspects of these projects are largely insignificant. However, the afforded flood protection may cause increased silt and pollution to be delivered further downstream faster.

Environmental Assessment Procedures. (1) The sparse wildlife in this region does not require detailed environmental assessment. The overriding need for enhancement of the human environment is paramount.
(2) Flood protection in urban areas can be readily justified by (1) above and estimated dollar damages to urban vs. rural lands. For example, a 1964 flood in Del Rio caused an estimated $276,200 damage, of which $272,000 was to urban properties (13).

(3) Public development of water resources will prevent misuse of related resources and implementation of special, local interest projects. This will allow for orderly regional development.

Summary of Environmental Impact Reviews. (1) Perhaps because of the regional magnitude of habitat, this aspect was not addressed in detail.

(2) Alternatives were not discussed or developed in sufficient detail to provide a decision base.

(3) Human and wildlife habitat enhancement can easily result from water development in this region. Discussion of the no-action alternative and long term vs. short term impacts are important to develop the agricultural potential of the region.

Diagrammatic Transects and Accompanying Data

Remote sensing plates and accompanying data are displayed as Fig. 17 and Table 9 respectively, and the Edwards Plateau transect is presented as Fig. 18. Fig. 17 includes low altitude photography (right) regional LANDSAT-1 imagery (lower left) and enlarged LANDSAT-1 imagery (upper left).

Low Altitude Photography. The Edwards Plateau varies in landform as its limestone base is exposed to different climatic features. In the east, rivers form relatively wide floodplains with gently rolling uplands (Fig. 17). On the other hand, the western portion of the region is characterized by deeply incised narrow streams with rugged, steeply sloping uplands. North to south variations are not as great, but the northern area is less dissected.

Regional drainage is by several large river systems; the Guadalupe, Colorado, Llano and Pecos Rivers are important. The eastern region has well drained uplands with dendritic feeder streams. Westward the feeder streams are much shorter with greater slopes and appear to leave radially dissected uplands.

The climatic effects demonstrate pronounced erosional patterns. The eastern area, with more rainfall is more rounded and gently sloping. To the south and west, the slopes are great and the erosion only takes place around the solution of the bedrock by water (i.e. streams and rivers). Gullies are generally flattened in the east and V-shaped in the arid west.

Regionally, the Edwards Plateau does not support heavy stands of hardwood. Mesquite and other brush species have invaded most of the rangeland. Some hardwoods, like oak, appear in the eastern one-third and around streams throughout the region. Generally vegetated gullies and stream bottoms are clearly discernable. Cultivated crops are concentrated in the floodplains in the north and the east (Fig. 17). Generally, the region has light colored tones with clearly banded slopes. Bottomlands are darker grey with vegetation or cultivation. The amount of brush vegetation will give varying textures to the landscape.

Ranching operations are located along waterways as are major road networks. Low water bridges are numerous. Cultivated crops are only in floodplain regions whereas livestock ranges are both in the uplands and in floodplains. Stock tanks are located at the bases of the upland slopes or in floodplains.

Satellite Imagery. Regionally, the Balcones Escarpment is the most striking feature. Photographic colors change from north to south. Northern colors are more subtle and change less suddenly than in the south. Agriculture concentration is evident along most stream channels (Fig. 17). In the west, a marked regional color change appears with less vegetative reflectance obvious. The transition belt of vegetative and non-vegetative colors is distinct. A central basin of uniform color hue is also evident in the eastern portion. Numerous small water bodies can be seen downslope of the Escarpment in adjacent regions.

FIG. 17. - Edwards Plateau, Guadalupe River, Kerr County, Texas. This figure includes low altitude photography (right), regional LANDSAT-1 imagery (lower left) and enlarged LANDSAT-1 imagery (upper left). Aerial photography taken October 1, 1969 at a scale of 1:20,000 is included in the figure as the stereopair on the right. The LANDSAT imagery (right) was taken July 21, 1973 and was reproduced from a color composite of bands 4, 5 and 7. The five-mile transect was drawn on the LANDSAT imagery 1:1,000,000 (lower left) and 1:300,000 (upper left). The summer LANDSAT imagery shows little contrast. The typical banded appearance of the Edwards Plateau can be observed in both the upper and lower part of the stereopair. The river terrace can be delineated from the upland using a stereoscope with the low altitude photography.

LANDFORMS	Uplands	Floodplain	Uplands
LANDUSE	Rangeland	Agricultural Cropland	Rangeland
PLANTS	Scrubby Hardwoods-Brush Grasses inc. Oaks inc. Bluestem Elm Dropseed Gramas	Oak-Cedar Association inc. Live Oak Shin Oak Post Oak Spanish Oak Lacey Oak Cedar	Scrubby Hardwoods-Brush Grasses inc. Oaks inc. Bluestem Elm Dropseed Gramas
ANIMALS	Avifauna inc. Hawks Dove Kingbirds Chickacee Wrens Warblers	Mammals inc. Bat Prairie Dog Gray Fox Coyote Rabbits Deer Rodents Avifauna inc. Sandpipers Owls Swallows Blackbirds Night Hawk Teal	Avifauna inc. Hawks Dove Kingbirds Chickadee Wrens Warblers

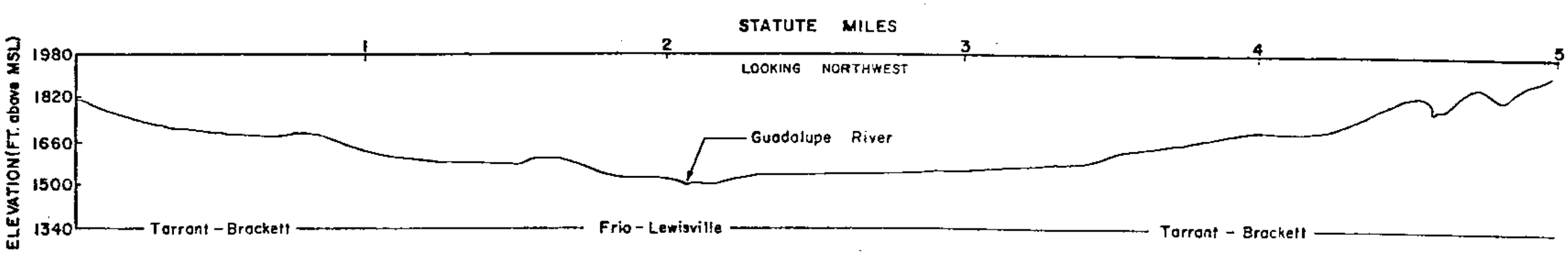


FIG. 18.- Edwards Plateau Transect, Guadalupe River, Kerr County, Texas.

Table 9. - Edwards Plateau, Guadalupe River, Kerr County, Texas.

Landform (1)	Airphoto Pattern Elements (2)	LANDSAT-1 Elements (3)
Floodplain	Well defined floodplain with moderately incised stream channels that confine most flows. Main stream channels may be a series of pools in low flow periods. Heavy siltation in main stream. Hardwoods present adjacent to stream channels. Extensive cultivation in floodplain. Tones vary from light to mottled gray where cultivated.	Distinguishable as light area on photograph. Areas of cultivation also appear light colored especially northwest of transect site. Enlargement reveals little more than intensity of cultivation (light areas).
Uplands	Dissected upland area of limestone. Hills are flat or slightly rounded giving nodular appearance. Drainage is angulate in some areas and larger tributaries parallel short feeders. Heavy siltation in upland gullies oftentimes without well defined streambed. Banded soil types on upland slopes are light colored. Other areas gray with shrub vegetation darker.	Lighter colored area northeast of transect site is more resistant limestone not influence by major river drainage. Transition areas are clear on regional photograph between drainage areas and uplands. Little surface water is present except directly upchannel from the transect site in a long thin line.

Soils & Origin (1)	Description and Location (2)
Frio-Lewisville (Alluvial)	Friable calcareous clay loam or clay, 6-30 in., over friable granular or subangular blocky calcareous clay loam, silty clay, or clay, with some strongly calcareous friable silty clay or clay loam below 30-60 in. (Streambed to Elev. 1600 ft)

Table 9. - Continued.

Soils & Origin (1)	Description and Location (2)
Tarrant-Brackett (Parent rock)	Friable calcareous clay or clay loam, 4-8 in., over friable granular calcareous clay and limestone fragments over chalky marl with interbedded limestone at 8-15 in. depth, or limestone bedrock within 12 in. of the surface. (Above Elev. 1600 ft)

Community Location (1)	Ecological Factors (2)
Bottomland	Oak-cedar assocation includes live oak, shin oak, post oak, and blackjack oak in combination with Spanish oak, Lacey oak and cedar. Numerous bird species include sandpipers, owls, swallows, jays, blackbird, flycatcher, night hawk, teal and other water birds. Mammals include bats, skunks, prairie dog, gray fox, coyote, cotton-tail rabbit, white tailed deer and many rodents. Numerous turtles, lizards, snakes and amphibians are also documented.
Uplands	Most of the same species of oak with more brush species and elm. Grasses include bluestem, dropseed, gramas, and others. Avifauna includes hawks, dove, owls, woodpeckers, king birds, chickadee, nuthatch, wrens, warblers, godlfinches, oriole, and viress. Mammals include the bats, prairie dogs, ground squirrel, rodents, jack-rabbit and others. Again, many species of turtles, lizards, and snakes are also present.

Table 9. - Continued.

Data Source (1)		Acquisition Source (2)
Low-Altitude Photographs Oct 1969	DDH-3JJ-62, 95, 96, 97, 142, 143	Western Aerial Photography Laboratory Program Performance Branch ASCS-USDA 2505 Parley's Way Salt Lake City, Utah 84019 Tel: AC 801, 524-5826 Price: $2.00 each
LANDSAT-1 5-29-73	81310164245G200-C (False Color Composite)	EROS Data Center Data Management Center Sioux Falls, South Dakota 57198 Tel: AC 605, 594-6511 FST: AC 605, 594-6151 Price: $7.00 for color composite
Topographic Map 1964	Center Point Quadrangle 1:24000	Texas Water Development Board Topographic Mapping Section P. O. Box 13087 Austin, Texas 78711 Tel: AC 512, 475-3191 Price: Free to State Agencies or Contractees
Soils Map 1963	Kerr County Soils Map 1:160000	Texas Agricultural Experiment Station Texas A&M University Reed-McDonald Building College Station, Texas 78743 Tel: AC 713, 845-4213 Price: Free, limited to twelve per customer

Table 9. - Continued.

Data Source (1)		Acquisition Source (2)
Biological Inventories	Kerrville State Park Improvement Program Undated	Open Space Program Manager Alamo Area Council of Governments Three Americas Building San Antonio, Texas 78205 Tel: AC 512, 225-5201 Price: Free
	Game Species Inventory Kerr County 1955	Texas Parks and Wildlife Department John H. Reagen Building Austin, Texas 78701 Tel: AC 512, 822-4631 Price: Free

Grand Prairie

General Description

The Grand Prairie lies west of the Blackland Prairies and borders the Edwards Plateau on the southwest. As it extends northward, the Grand Prairie narrows between the Eastern and Western Crosstimbers. Its northern boundary is the Red River. Cartiographically it lies between 30°30' and 34° latitude and 97° and 98°30' longitude (Fig. 6, p. 36).

Average annual precipitation varies from 30 to 35 inches (76-89 cm). Evaporation averages about 40 inches (102 cm) annually. The Grand Prairie elevations range from 600 to 1100 feet (182-335 m) in the north and from 1500 to 1800 feet (457-549 m) in the southern extent (Lampasas Cut Plain) (44,19).

Virtually the entire region is from the Cretaceous period. Strong limestone is present in the southern hills of the Lampasas Cut Plain. Soils have developed from limestone or marl with interbedded limestone. They are mostly calcareous crumbly granular clay soils that range from very shallow to deep. On the steeper slopes, the soils usually are dark grayish brown to brown and are underlain at a depth of a few inches by limestone bedrock on a deep bed of limestone fragments over bedrock.

The soils of the Grand Prairie, where not too shallow for cultivation, are suited for growing oats, wheat, cotton, grain sorghum, corn and other feed crops. Adapted grasses for meadow or pasture are big and little bluestem, King Ranch bluestem, Indian-grass and switch grass in the deeper soils and sideoats, grama and buffalo grass on the shallow soils. Other native vegetation includes small oak and juniper trees on rocky slopes of shallow soils and scattered mesquite trees throughout.

Wildlife species include white-tailed deer, turkey, quail, raccoons, ringtails, opossums, skunks, gray and red foxes, bobcats, coyotes, squirrels, and dove (52). Habitat availability is varied since about three-fourths of the area is in range (44).

Environmental Impact Reviews

Two environmental impact statements were reviewed from this region (28, 84). Both projects were located in the Paluxy River Watershed, which is a tributary of the Brazos River in Somervell County. It is useful to combine the water losses of these two projects to demonstrate the lack of regional impact assessment. For example, the Paluxy River Watershed Project will cause a 4.3 percent decrease in flows of the Paluxy River or 2277 acre-feet/yr (2.8 million m^3/yr). The loss in flows from Squaw Creek Reservoir (the cooling lake for Comanche Creek Station) will be 7176 acre-feet/yr (8.8 million m^3/yr). In addition, two additional gas and coal fired generation stations located within a 50 mile (80.5 km) radius will consume approximately 2024 acre-feet/yr (2.5 million m^3/yr). Also the Comanche Creek Station will have a net diversion from Lake Granbury (on the main stem of the Brazos River) of 24,000 acre-feet/yr (29.6 million m^3/yr). The total loss becomes 35,500 acre-feet/yr(43.8 million m^3/yr) or 3.3 percent of the average annual flow of the Brazos River near Glen Rose, Texas (84). Another salient point, the 3 generation stations, will cause an additional evaporation to the regional atmosphere of 26,000 acre ft/yr (32.1 million m^3/yr). This could affect local weather patterns or the surrounding micro-climate.

Reservoirs. The Comanche Peak Statement involved an extensive environmental inventory and assessment. The project involves diversion and return of water from Granbury Lake via pipeline to serve as a blowdown and make up for the cooling reservoir, Squaw Creek Reservoir. It included among other things, a realistic assessment on the amount of terrestrial riparian habitat loss from a regional standpoint. Specifically,

> the inundation of the Squaw Creek riparian communities is the most significant negative impact on the terrestrial ecosystems of the site. The applicant has estimated that construction of Squaw Creek Reservoir will eliminate approximately 5 percent of the riparian communities similar to Squaw Creek within Hood and Somervell counties. Riparian vegetation can occur in this part of Texas only along usually flowing streams where sufficient moisture is available to support tree growth. In areas such as Hood and Somervell counties, where rainfall is sparse and drainage patterns are not extensive, riparian vegetation is quite limited. Because of the scarcity of this vegetation, consumer species displaced from the Squaw Creek riparian will cause increased competition in other riparian areas, probably exceeding the carrying capacities of those areas.

However, the same statement proposed that suspension of cattle grazing on inundated and adjacent lands was a positive impact. This was based on the premise that the present overgrazing practices would be halted and riparian areas would be allowed to recover, a unique assessment.

Basically, the region contains many potential reservoir sites but the low rainfall and high evaporation preclude feasible use. For example, the Squaw Creek Reservoir will require diversion and make up from Lake Granbury for filling and maintenance (28).

Downstream effects of off-channel impoundments include alteration of the flooding sequence and intensified flood plain agriculture. The establishment of temporary or permanent pools from non-saline sources will reduce the dilution factor and increase salinity in the Brazos River (84).

Channelization. Grand Prairie soils are relatively shallow and overlay limestone or calcareous clays. However, the limestone of the Glenn Rose Formation has slight amounts of argillaceous impurities and is resistant to solution effects. Channel construction would, therefore, not require impervious layers to avoid undercutting. Also, losses to groundwater would be minimal because of these impervious characteristics (28).

Streams of the region often support diverse faunas. For example, Squaw Creek contains a continuous flow most years (28). The riparian terrestrial habitat is also important regionally as pointed out earlier. The effects of channelization works would, therefore, entail substantial environmental impacts proportional to the degree of rectification. Clearing and snagging operations would be the least damaging.

Below impoundments, downstream energy dissipation structures can be minimized in the region, allowing for gradual transition to natural stream-side habitats. Maintenance of 1.5 cfs (0.04 m^3/s) in Squaw Creek required no channel modifications downstream. The consistency of the flow will stabilize the populations downstream as well (28).

Environmental Assessment Procedures. (1) The Comanche Peak Station statement employed extensive use of consultants and broad ecological inventories. In contrast, the Paluxy River watershed project had no inventory, rather, typical use of game species in local areas only. (2) Regional effects were well discussed in the Comanche Peak Statement, such as 5 percent regional loss of riparian terrestrial habitat. The effects were not addressed from an ecological standpoint in the Paluxy River project, but regional socio-economic figures were included.

(3) Assessment of radiological effects was based on standard AEC procedures. However, as pointed out by the EPA (58), emission calculations were based on base-load operations rather than the load-following operation of the proposed plant.

Summary of Environmental Impact. (1) Discussion of socio-economic regional impact assessment is well developed in both statements. However, such coverage of environmental impact is lacking, reference the concentration of water development projects in a 50 mile (80.5 km) radius of Comanche Peak.

(2) Short term use vs. long term use of man's environment is not well documented. The Comanche Peak Statement discusses the necessity for electrical demand. The Paluxy River Statement discusses need for flood control and land treatment. Neither weigh the alternatives against environmental costs over the long run.

(3) Neither statement addresses secondary environmental impacts of the proposed action.

(4) Alternative development is not described in terms of environmental impact in either statement.

Diagrammatic Transects and Accompanying Data

Remote sensing plates and accompanying data are displayed as Fig. 19 and Table 10 respectively; the Grand Prairie transect is presented as Fig. 20. Fig. 19 includes low altitude photography (right), regional LANDSAT-1 imagery (lower left), and enlarged LANDSAT-1 imagery (upper left).

Low Altitude Photography. Limestone landforms predominate in the region. Uplands are moderately dissected in the north central area becoming more gently rolling southward to karst and highly dissected in the extreme southern extent. Floodplains are well defined in most areas being confined to channel banks such as found around the Middle Bosque River in the southeast.

Throughout the region, upland areas are well drained. Gullies are void of vegetation in upland hills where they remain grassed with ill-defined stream channels. Gullies become more deeply incised and V-shaped near confluences with major streams (Fig. 19). Generally, tributaries are short with parallel drainage noticeable in the southcentral area around the Middle Bosque River.

Bush-grass-hardwood associations occur in this region. Hardwoods become more noticeable in central uplands around bedded limestone slopes. Southern slopes are barren to sparsely vegetated and more northern gullies have some hardwoods. Floodplain areas are more densely vegetated with moderate understory in southeastern areas. Cultivation is variable in bottomlands in the north to extensive in the southern lowlands. Rangeland occupies southern and northern uplands, cultivation is practiced on parallel ridges of the central extent.

Stock trails and ponds are numerous in the southern and northern uplands. Roads are more random in range areas than in the cultivated uplands of the southcentral area. Farm and ranching communities are small, located at road intersections. Some permanent structures are found in cultivated floodplains.

Satellite Imagery. Summer imagery was reviewed for the north central region and fall imagery for the southern range. A regional transition area is obvious around the Brazos River in Hood County. Cultivation in the bottomlands of the Crosstimbers becomes less intense in the Grand Prairie region. Regionally, surface water seems abundant. Southward, little regional significance is noted except in extreme eastern areas of the North Central Prairie. The parallel southeast drainage pattern becomes evident southward as the Grand Prairie stands out with cultivated bottomlands of a different color intensity than the Blackland Prairie to the east and North Central Prairie in the west. Floodplain areas appear to be significantly darker and probably important as a local and regional wildlife habitat (Fig. 19).

FIG. 19. - Grand Prairie, Middle Bosque River, Bosque, McLennan and Corvell Counties. The stereopair at the right was made from aerial photography taken January 18, 1965 at a scale of 1:20,000. The LANDSAT-1 views (left) are black and white reproductions of color composite bands 4, 5 and 7 taken December 12, 1973. The five-mile transect is shown on the satellite imagery 1:1,000,000 (lower left) and 1:270,000 (upper left). The blocky topography with deep, steep-sided valleys and gullies is typical of massive horizontal sedimentary rocks.

LANDFORMS	Uplands	Floodplain	Uplands
LANDUSE	Agricultural Cropland and Rangeland	Pastureland and Good Quality Wildlife Habitat	Agricultural Cropland and Rangeland
PLANTS	Cedar- Oak Association inc. Prairie Grasses	Mesophytic Hardwoods with light understory inc. Native Pecan	Cedar-Oak Association inc. Prairie Grasses
ANIMALS	Upland Game Birds Predator	Furbearers Predators Turkey Deer	Upland Game Birds Predators

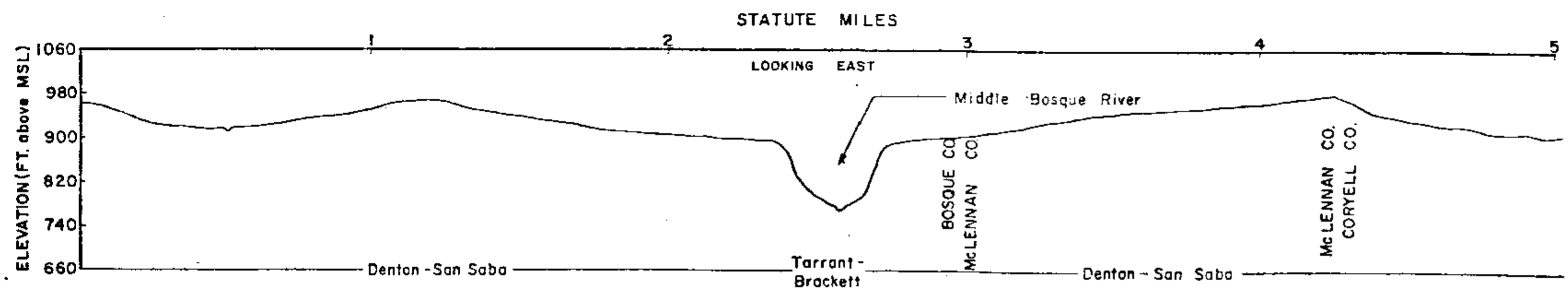


FIG. 20.- Grand Prairie Transect, Middle Bosque River, Bosque, McLennan, and Coryell Counties, Texas.

Table 10.- Grand Prairie, Middle Bosque River, McLennan, Bosque and Coryell Counties, Texas.

Landform (1)	Airphoto Pattern Elements (2)	LANDSAT-1 Elements (3)
Floodplain	A secondary stream through moderately sloping soils. Short tributaries, well drained. V-shaped gullies. Moderate understory in hardwood areas. Light to mottled tones.	Numerous streams in area. Dendritic drainage. Vegetation around drainage is dark. Cultivation is light colored.
Uplands	Gently rolling with parallel to dendritic drainage. Ridges between upland streams. Well drained. Short tributaries near floodplain are incised. Cultivation is predominant on ridges. Some bush-hardwood growth around gullies. Tones are lighter.	Moderately dissected with parallel drainage to the southeast. Elevation changes seem to be expressed by tonal characteristics indicating a bedded substrata. Cultivation is scattered throughout with patchy tones, light colored slopes and darker ridge tops.

Soils & Origin (1)	Description and Location (2)
Tarrant-Brackett (Alluvial)	Friable calcareous surface with many limestone fragments, 3-8 in., over friable granular calcareous clay, limestone chunks and discontinuous strata above chalky marl interbedded with limestone, or limestone bedrock at less than 12 in. beneath the surface.
Denton-San Saba (Residual)	Crumbly calcareous clay, 8-20 in., over crumbly strongly calcareous clay containing a few small $CaCO_3$ concretions with substrata of limestone interbedded with soft marl or limestone fragments and marl.

Table 10.- Continued.

Community Location (1)	Ecological Factors (2)
Bottomlands	Good quality habitats stretch along Middle Bosque River. Sharp delineation to cultivated or rangeland. Habitats are limited for raccoon, striped skunk, ringtail, opossum, turkey, fox squirrel, and white tailed deer which are considered scarce. Birds include robins, fringillids, and meadowlarks. Mesophytic hardwoods include American elm, hackberry, native pecan, sycamore, and live oak.
Uplands	Extensive agricultural land use. Birds may include robins, fringillids, meadowlarks, mourning dove, and bobwhite quail; the latter two are moderately abundant. Predators such as coyote and gray fox are increasing in numbers. Some stands of cedar and post oak, other species include winged elm, mesquite and juniper.

Data Source (1)		Acquisition Source (2)
Low-Altitude Photographs Jan 1965	AWX-4FF-293, 296	Western Aerial Photogrpahy Laboratory Program Performance Branch ASCS-USDA 2505 Parley's Way Salt Lake City, Utah 84019 Tel: AC 801, 524-5826 Price: $2.00 each

Table 10. - Continued

Data Source (1)		Acquisition Source (2)
LANDSAT-1 12-12-73	81507163335G200-C (False Color Composite)	EROS Data Center Data Management Center Sioux Falls, South Dakota 57198 Tel: AC 605, 594-6511 FTS: AC 605, 594-6151 Price: $7.00 for color composite
Topographic Map 1955 1956	Coryell Quadrangle Mosheim Quadrangle 1:24000	Texas Water Development Board Topographic Mapping Section P. O. Box 13087 Austin, Texas 78711 Tel: AC 512, 475-3191 Price: Free to State Agencies or Contractees
Biological Inventories	McLennan County Resource Inventory	Texas Parks and Wildlife Department John H. Reagen Building Austin, Texas 78701 Tel: AC 512, 822-4631 Price: Free
	Natural Resources Study for the North Texas Planning Region	Nortex Regional Planning Commission 1914 Kemp Boulevard Wichita Falls, Texas 76309 Tel: AC 817, 322-5281 Price: Free

Table 10. - Continued

Data Source (1)		Acquisition Source (2)
Biological Inventories	EIS Aubrey Lake Jan 1974	U. S. Army Engineer District P. O. Box 17300 Attn: Public Affairs Office Fort Worth, Texas 78102 Tel: AC 817, 334-2212 Price: Free
	EIS Commanche Peak Stream Electric Station Units 1 & 2 June 1974	Office of the Assistant General Manager E-201, Nuclear Regulatory Commission Washington, D. C. 20545

Gulf Coastal Prairie

General Description

The Coastal Plain covers almost ten percent of the United States; however, for purposes of this report, the Gulf Coastal Prairie will be limited to approximately nine million acres (36,000 km^2) of Texas marsh and 500,000 acres (2,200 km^2) of coastal wetlands. It extends from south of Corpus Christi eastward to the Louisiana border between 27°30' and 28°15' latitude and 94° to 98° longitude (Fig. 6, p. 36).

The Gulf Coastal Prairie is a nearly level, practically undissected plain with elevations less than 250 feet (76 m) above sea level. Rainfall increases from west to east. The western regional border occurs approximately where annual evaporation equals rainfall, 28 inches (71 cm). Precipitation in the eastern extent averages 56 inches (142 cm) annually whereas evaporation is less than 10 inches (25 cm).

The area overlays recent quaternary deposits. Topographic relief is minor, sloping coastward. Most primary river systems do not receive tributary flows within the area. Generally drainage is slow throughout with parallel minor streams entering directly into coastal marshes. Soils are generally acid and clayey with local variations evident inland and near wetlands (44).

Extensive land development and groundwater usage have increased compaction and subsidence in many areas. Agriculture crops consist of rice, grain, sorghum, cotton and livestock production. Bottomland hardwood vegetation is mainly oak. Near the coastal area, marsh grasses and the associated biome predominate.

Many species of wildlife abound in the area. For example, in Taylors Bayou Watershed the lower marsh and swamplands provide excellent habitat for waterfowl and fur-bearing animals. The J.D. Murphree Wildlife Management area, operated by the Texas Parks and Wildlife Department, comprises about 8,400 acres (34 km^2) and is located adjacent to Big Hill Bayou in the lower watershed area. The wildlife management area furnishes a prime example of a relatively undisturbed coastal marsh ecosystem with a full complement of marsh plants and wildlife. The management area is operated primarily as a waterfowl refuge with seasonal, controlled public hunting. About 25 different species of waterfowl either winter in or are native to the management area, including the mottled duck, blue-winged teal, stilt, purple and common gallinule, pied-billed grebe, snow goose, Canada goose, and blue goose. In addition, fur-bearing animals such as mink, skunk, raccoon, swamp rabbit, cottontail, muskrat and nutria inhabit the area. It also contains three relatively rare and protected species of wildlife, the river otter, the Texas red wolf, and the American alligator. All of these species contribute to and are important to the ecology of the marsh lands (15)

More than 7,540 species of birds have been indentified in Texas; this is more than any other state. Moreover, the largest numbers within the state have been documented on the central Gulf Coast (63).

Environmental Impact Reviews.

The Texas Gulf Coastal Prairie is characterized by extensive water development and utilization. Five environmental statements from this area were reviewed. Most were channelization works for flood control in densely urban-industrialized areas. Combined, work proposed in the five statements incorporate over 9,000 acres (36 km^2) of marshland for spoil deposition. This maintenance of marshlands is undoubtably the most important environmental consideration in the development of the region's water resources. Additionally, channel rectification is oftentimes needed to protect against the ever increasing runoff created by urbanization. In the western areas of this region, the Aransas National Wildlife Refuge, Padre Island National Seashore, and several state wildlife areas and bay systems are essential for the propagation of many marine commercial species as well as providing migratory water fauna and recreational areas.

One of the more controversial environmental statements is Wallisville Lake, Trinity River, Texas (39). This project proposes to inundate 7,200 acres (291 km^2) of estuarine nursery area and create a shallow reservoir covering 19,700 acres (80 km^2). It is to serve as the first lock and dam in the Trinity River Navigation Project as well as a reservoir for in-channel conveyance of industrial and irrigation waters from Lake Livingston. The statement elicited many comments and is currently in litigation concerning the adequacy of the environmental assessment.

Reservoirs. Sources of water supply in the Gulf Coastal Prairie include 100,000 acre-feet (120 million m^3) of storage capacity (18). Of this amount 13,500 acre-feet (16.6 million m^3) is controlled by the J.D. Murphee Wildlife management area. Also, in-channel conveyance of upstream reservoirs water for municipal and industrial water rights occurs in the coastal plain and accounts for substantial amounts of water used therein. Presently, extensive groundwater pumping currently balances supply and demand. However, this latter source has created severe land subsidence and salt water intrusion and, coupled with increased demand, is causing water users to look to other sources. Primarily, these sources are additional upstream impoundments. Regional impoundments are limited by the low topography and cost-effectiveness of other alternatives, i.g., desalinization and small local impoundments.

Construction of the Allens Creek Nuclear Generating Station entails a 8,250 acres (33.4 km^2) cooling lake in the Brazos River Watershed (22). Blow-down from this facility will cause an average increase in total dissolved solids in the Brazos River of 0.8 percent. In addition, 750 acres (3.0 km^2) of pasture and cropland will be lost as well as 2,200 acres (9 km^2) of land required for transmission lines. These lines are largely over agricultural lands and are proposed to have minimal environmental impact in terms of habitat loss. The reservoir inundates 8 miles (12.9 km) of intermittent streambed of little value to aquatic production.

Channelization. In areas of low relief, such as the coastal prairie, channel rectification is a common technique for containing and directing urban and rural flood waters. Increased urbanization, notably in the Houston-Galveston area, has increased runoff and flood flows. Flood protection works may include saltwater intrusion dams (to protect irrigation waters) and channel rectification. These channels often include removal of substantial amounts of bottomland vegetation. For example, the Taylors Bayou Project (15) removed 3,180 acres (12.9 km^2) from wildlife production. In the Coastal Plain, the bottomland habitats may be the only source of many wildlife species (89). Alternatives consisted of: "no construction; varied stream dimensions and alternative spoil sites." Channelization through marsh or wetland areas aids in speeding runoff but also atypically drains these areas thereby affecting resident and migrant biota.

Even if the long term effects of channelization works near population centers in the coastal prairie are adverse, public projects provide for a more orderly development and prevent short termed private projects from being implemented.

Environmental Assessment Procedures. (1) The necessity of action for flood prevention for human environmental enhancement is stressed over the consequences of wildlife habitat losses.
(2) A consultant was used to assess the existing environment (Wallisville and Allen Creek Projects).
(3) Alternatives were developed to a limited degree because of the established land use in the area.
(4) Documentation of wildlife habitat losses was in terms of acreage of timberland, cropland, or marshland and associated biota.

Summary of Environmental Impact Reviews. (1) The regional environment was not addressed in any of the statements. The loss of marshland by dredge spoil could easily be quantified on a regional basis. For example, Wallisville Lake will inundate 2.4 percent of the Trinity Bay marsh area (39). The Allens Creek Statement contained extensive discussion of regional effects on the human environment in terms of economics, housing and public facilities but little on ecological changes.
(2) Public projects do provide for ordered planned land use potential

rather than local interest groups acting separately.

(3) The flood protection afforded by the channelization and salt water intrusion structures would allow for increased urbanization in the floodplain. This was only addressed under a discussion of current land uses.

(4) The loss of marshes and estuarine acreage should not be mitigated by the establishment of freshwater fisheries. The former is not yet tractable.

(5) Alternatives were not developed to any degree in any statements. The Allens Creek Statement contained no discussion of environmental effects of alternatives.

Diagrammatic Transects and Accompanying Data

Remote sensing plates and accompanying data are displayed as Fig. 21 and Table 11 respectively; the Gulf Coast transect is presented as Fig. 22. Fig. 21 includes low altitude photography (right), region LANDSAT-1 imagery (lower left), and enlarged LANDSAT-1 imagery (upper left).

Low Altitude Photography. The Gulf Coastal Prairie is a gently sloping relatively undissected plain, looking much like a deranged floodplain coastward. Toward the west, in the more arid regions, the streams are more deeply incised.

Stream channels are well defined in the west becoming marsh toward the east and coast. Drainage is largely parallel to south-southeast in the eastern section with northern tributaries much longer than southern ones. Narrow bands between drainage ways are extensively cultivated with intricate irrigation networks in the eastern extent. Drainage may be internal in some areas of irrigated lands (Fig. 21).

Gullies are flat in the humid eastern areas and often grassed or cultivated. Erosion appears in the more arid V-shaped gullies with evidences of downcutting and bank slippage. Heavier siltation occurs in major streams of the western areas as well.

Hardwoods dominate the eastern stream banks. Some mixed pine grade into hardwood-pine forest north of the physiographic region and in the east. Western areas have mesquite and other shrub brush associations with mixed oak around streams. Agricultural crops grade from riceland to cotton and miscellaneous (onion, watermelon) south-westward.

Photographic tones are generally mottled to grey to dark in agricultural areas. Shallow drainages are darker in the east and light colored in the arid southwest. Wooded areas are lightly textured in solid covered areas of the east to coarse in the sparce brushlands of the west. Pine stands are distinguishable by darker tones in the western areas.

Generally, the land is agricultural or rangeland throughout the region, man-made structures are widely dispersed along roadways. In western areas, roadways are not ordered whereas in eastern areas, a distinct rectangular pattern around irrigation ways is evident.

Satellite Imagery. Distinct regional changes to the north and vegetation changes to the west are evident. This highlights transition area determinations. Coastal marsh areas are also easily distinguished as they grade inland (Fig. 21). This could easily be used in regional impact assessment by noting the remaining similar areas not impacted by a specific project. Enlargement reveals intensity of agricultural production and scattered stands of hardwoods (Fig. 21).

FIG. 21. - Gulf Coastal Prairie, Peach Creek, Wharton County, Texas. This figure includes low altitude photography (stereopair on right) taken at a scale of 1:40,000 on January 16, 1972, LANDSAT imagery at a scale of 1:1,000,000 (lower left) and LANDSAT imagery at a scale of 1:350,000 (upper left). The LANDSAT imagery was taken May 3, 1973 and includes the five-mile transect. The satellite imagery displayed in the figure was copies from a color composite of bands 4, 5 and 7, and shows good contrast between the land uses. Meander scars can be observed in the stereopair on the right.

LANDFORMS		Coastal Prairie Floodplain	
LANDUSE	Agricultural Cropland		Agricultural Cropland and Rangeland
PLANTS	Oak-Hickory Association Inc. Oaks Hickory Also Inc. Rice Grain Sorghum Cotton	Transition Area Spp. common to both landuses	Post Oak Association Inc. Woody Invaders Oaks Also Inc. Rice Range Grasses
ANIMALS	Upland Game Birds Predators Peregrine Falcon (?) Migratory Waterfowl		Rich Avifauna Furbearers Predators Consumers

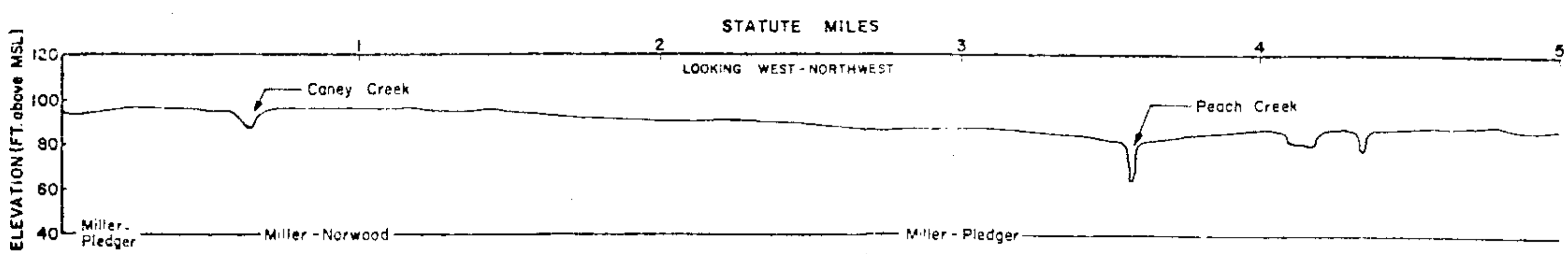


FIG. 22.- Gulf Coastal Prairie Transect, Peach Creek, Wharton County, Texas.

Table 11. - Gulf Coastal Prairie, Peach Creek, Wharton County, Texas.

Landform (1)	Airphoto Pattern Elements (2)	LANDSAT-1 Elements (3)
Floodplain	Entire transect area is in Colorado River bottomlands. The area slopes gently coastward. Stream channels are well defined. Tributaries are short. Small grassed gullies under cultivation. Vegetation in form of sparse hardwoods in slackwater areas especially around old meanders. Extensive agriculture. Cleared areas away from major drainage have extensive crop production. Around drainages, livestock rangeland and old fields predominant. Tones are gray to mottled with cultivation appearing darker.	Extensive agriculture in area. Sample site crosses a coastward corridor of floodplain. Drainage is parallel. Vegetation occurs in gray areas south of transect. Dark areas are under cultivation. Highways are clear in enlargement.

Soils & Origin (1)	Description and Location (2)
Miller-Pledger (Alluvial)	Crumbly, friable neutral to calcareous clay, 10-20 in.,over crumbly subangular blocky to very firm massive calcareous clay.
Miller-Norwood (Alluvial)	Crumbly calcareous clay or friable calcareous silt loam to silty loam, 9-25 in., over crumbly subangular blocky calcareous clay or very friable granular silt loam to silty clay loam.

Table 11. - Continued.

Community Location (1)	Ecological Factors (2)
Floodplain	Good habitat types around major drainage areas. Oak-hickory dominates with native pecan also present. Game birds are light throughout area. Furbearers include raccoon, opossum, striped skunk, mink, and rabbits. Coyotes, bobcats, and red wolf (threatened) may inhabit the area. White tailed deer also present. Rich in avi-fauna including the endangered Peregrine Falcon. Cleared areas have limited habitats due to extensive agricultural use. Some game birds appear in these areas as well as providing feeding grounds for many migratory waterfowl.

Data Source (1)	Acquisition Source (2)
Low-Altitude Photographs Jan 1972 A-40-48481-172, 152, 153, 154, 131, 130	Western Aerial Photography Laboratory Program Performance Branch ASCS-USDA 2505 Parley's Way Salt Lake City, Utah 84019 Tel: AC 801, 524-5826 Price: $2.00 each
LANDSAT-1 5-18-73 81289162615G200-C (False Color Composite)	EROS Data Center Data Management Center Sioux Falls, South Dakota 57198 Tel: AC 605, 594-6511 FTS: AC 605, 594-6151 Price: $7.00 per color composite

Table 11. - Continued.

Data Source (1)		Acquisition Source (2)
Topographic Map 1953	Wharton Quadrangle 1:24000	Texas Water Development Board Topographic Mapping Section P. O. Box 13087 Austin, Texas 78711 Tel: AC 512, 475-3191 Price: Free to State Agencies and Contractees
Soils Map 1962	Wharton County 1:155000	Texas Agricultural Experiment Station Texas A&M University Reed-McDonald Building College Station, Texas 77843 Tel: AC 713, 845-2413 Price: Free, limited to twelve per customer
Biological Inventories	Wharton County Resource Inventory Undated	Texas Parks and Wildlife Department John H. Reagen Building Austin, Texas 78701 Tel: AC 512, 822-4631 Price: Free
	Soil Survey Report Wharton County Mar 1974	United States Department of Agriculture Soil Conservation Service P. O. Box 648 Temple, Texas 76501 Tel: AC 817, 773-1711 Price: Reproduction

Table 11 . - Continued

Data Source (1)	Acquisition Source (2)
Biological Inventories: Status of Environment Studies Trinity River, Texas July 1975	U. S. Army Engineer District, Fort Worth P. O. Box 17330 Attn: Public Affairs Offices Fort Worth, Texas 76102 Tel: AC 817, 334-2212 Price: Free

High Plains

General Description

The High Plains is an extensive physiographic region which stretches from South Dakota almost to the Rio Grande. In Texas, its northern extent is broken by the Canadian River (part of the Rolling Plains physiographic region). Its southern boundary is south of 32° latitude, while on the west it is bordered by New Mexico. The eastern edge of the High Plains is the Cap Rock Escarpment with the Rolling Plains to the east and Edwards Plateau to the southeast (Fig. 6, p. 36).

Annual precipitation ranges from 14 to 21 inches (35-53 cm) and is greatly exceeded by 50 to 70 inches (127-178 cm) of annual evaporation. Topographic elevation varies from 3000 to 4000 feet (914-1219 m), increasing westward. Mean annual temperatures vary from 64°F (17.8°C) in the south to 56°F (13.3°C) in the northern areas.

The entire region is underlain by highly variable sedimentary materials of the Pliocene Age. The surface is blanketed by fine-grained, wind-deposited material. Soils are dark brown to reddish brown, deep neutral to calcareous clay loams and sands with subsoils of calcareous earths. Caliche is present in some areas and streambed soils are of minor extent, mostly calcareous alluvium (44).

Vegetation and wildlife resources are limited. The latter consists of quail in low to moderate densities, deer, cottontail, coyote, bobcat, ringtail, antelope, and turkey in low densities. Vegetation is characterized by mesquite-short grass associations.

Production of cotton and grains is the major land use on the plains. Irrigation water demand for over five million acres (20,235 km^2) of cropland has caused serious groundwater depletion (Fig. 23). Large areas of rangeland also require groundwater as do stock yards, industries and municipalities. At present usage rates, intrabasin transfer and groundwater management will be essential by the year 2020 (79).

Environmental Impact Reviews

In the Canadian River watershed and eastward to the Red River basin, water planners often exclude precipitation falling 5 miles (8.0 km) from any streambed from stream flow calculations. All of this precipitation either evaporates or percolates, greatly reducing the contributing watershed. Protection works sponsored by the Soil Conservation Service (SCS) are the predominant water development project. Since the SCS has been heavily involved in this area, large storage reservoirs and other alternatives outside its legislative realm, have not been included in the alternative selection process.

Reservoirs. No environmental impact statements for large storage reservoirs were available for this region. In light of the Texas Water Plan (1968) (79), problems and benefits of reservoirs in this area bear discussion. The High Plains is largely drained by playa lakes in connection with or independent of in-channel drainage. Streambanks and gulleys are susceptible to severe soil erosion. For example, the Draft Environmental Statement for Red Deer Creek Watershed (SCS) estimated 450,000 tons (460 million kg) of damaging sandy sediment are deposited on the Canadian River floodplain soils each year (37). Sediment accumulating in the channels and on the floodplain has increased flooding and damages and is encroaching upon the physical improvements on and

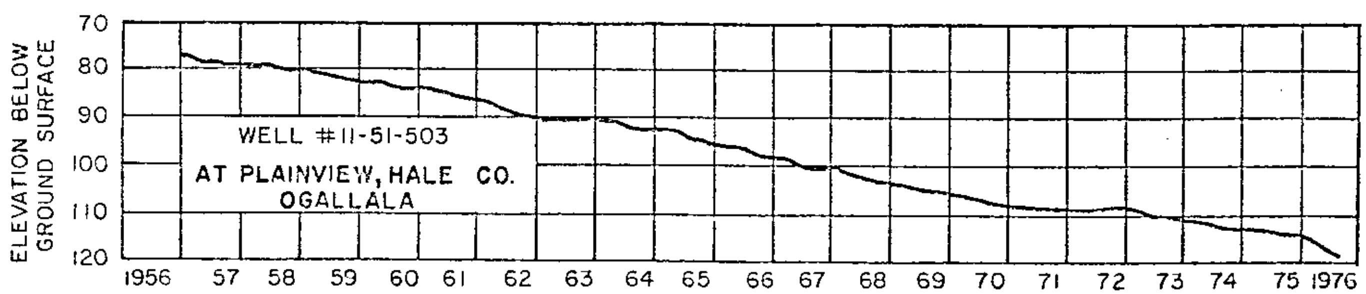


FIG. 23. - Groundwater Depletion, Ogallala Aquifer, High Plains, Texas (83).

bordering the floodplain.

In reality, evaporation, relief, and soil seepage losses make large reservoir construction impractical (87). Moreover, if a large reservoir were to be supplied by intrabasin transfer canals an atypical ecological area would be created.

Channelization. Several recent projects have dealt with channelization works for flood prevention (37, 78). Techniques include off-channel flood retarding structures in the eastern areas and play drainage around urban areas. This latter project was aimed at removing the health nuisance as well as flood control by filling in playa lakes with sediment dredged from the stream channel. Because of its urban nature, environmental effects would be mostly secondary. Specifically, the loss of wildlife habitat within the urban area would be negligible and not comparable to the health benefits derived by the human population. However, the increased flood protection and improved human environment could set the stage for further land development and loss of higher quality wildlife habitat as well as water quality deterioration. Unlined channels quickly become clogged with silt and maintenance costs are high (87).

Environmental Assessment Procedures. (1) An inventory of wildlife species present was included as a methodology to demonstrate regional low density and diversity.

(2) In areas where encroaching woody brush was to be removed, the replacement of native grasses favors natural species.

(3) In general lack of regional discussion was noted especially in "Red

Deer Creek, Environmental Statement" (SCS) which covers a transition area of the High and Rolling Plains along the Canadian River Watershed (37).

Summary of Environmental Impact Reviews. (1) Soil stabilization will enhance the small amount of wildlife supported in and around the streambeds and playa lakes.
(2) Land treatment measures which include herbicide application for brush control introduce these chemicals into streams and playas.
(3) Small off-channel floodwater retention structures create small grassland areas for wildlife habitats as well as accumulate sediments.

Diagrammatic Transects and Accompanying Data

Remote sensing plates and accompanying data are displayed as Fig. 24 and Table 12 respectively, and the High Plains transect is presented as Fig. 25. Fig. 24 includes low altitude photography (right), regional LANDSAT-1 imagery (lower left), and enlarged LANDSAT-1 imagery (upper left).

Low Altitude Photography. Playa lakes are the predominant characteristic of high plains photographs. Incised drainage ways increase in depth southward and from west to east in the central and southern areas. Dendritic drainage is common in the loose soils of the high plains. In some areas playa lakes drain into streambeds by either natural or artificial means. Erosion is common along steep stream slopes and headwater drainages do not always have precise gulleys. Irrigation flows create some outwash onto adjacent fields in the central area.

Vegetation in the form of brush-grass associations increases toward the south (Fig. 24). Likewise, the amount of uncultivated land increases southward. The northern area is extremely flat sloping eastward with increasing relief to hilly areas in the extreme southern extent.

Tones are generally light to mottled throughout with uncultivated areas appearing darker. In all cases, steep slopes appear darker even though they are cultivated in the north. Playa lakes appear mottled to darker at the center and generally tend to be larger in the north. Salt lakes within southern streams have dark tones.

Roadways form a rectangular system and small communities are located near streams. Gravel pits are abundant throughout the region along streamways, playas, and in hilly areas of the south.

Satellite Imagery. Photographs of the central region reveal highly reticulated cultivation patterns. Playa lakes are light colored in summer periods and indistinguishable in cultivated areas during spring. Uncultivated areas are darker and increase in size to the west along streams. Also uncultivated areas are evident around large playas, probably due to salt concentrations. Physiographic boundaries are clearly delineated in all areas. Critical areas may appear as uncultivated tracts or highly cultivated floodplains (Fig. 24).

FIG. 24.- High Plains, Sulphur Springs Draw, Terry County, Texas. The stereopair on the right is from aerial photography taken March 26, 1969 at a scale of 1:20,000. Regional LANDSAT-1 imagery with the five-mile transect was taken April 7, 1973 and shows the extensive agricultural use. The black and white reproductions of a color composite of bands 4, 5 and 7 are at scales of 1:1,000,000 (lower left) and 1:350,000 (upper left). The stereopair covers too small of an area to show the Buffalo Wallows or Playa Lake characteristic of the High Plains.

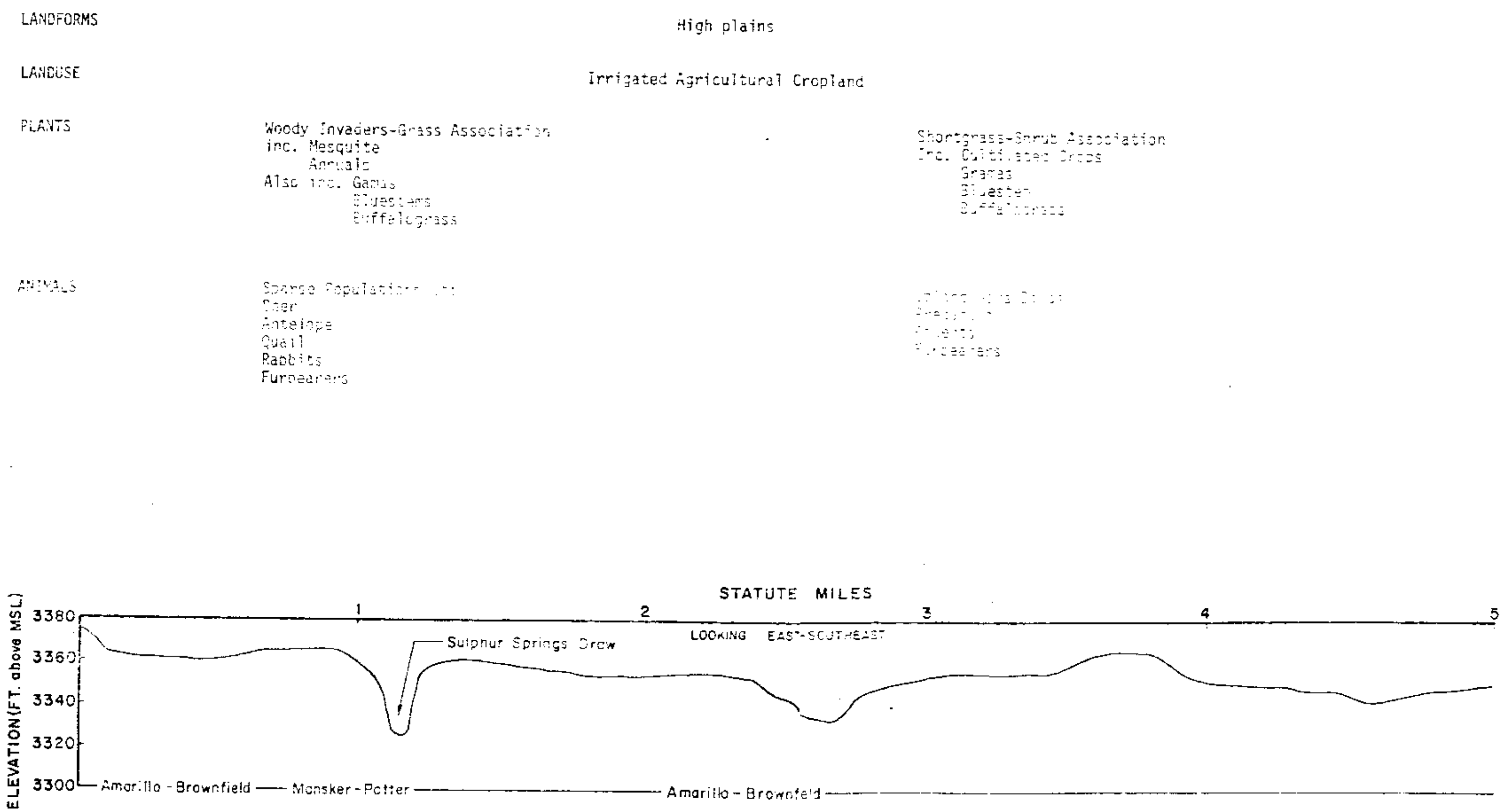


FIG. 25.- High Plains Transect, Sulphur Springs Draw, Terry County, Texas.

Table 12. - High Plains, Sulphur Springs Draw, Terry County, Texas.

Landform (1)	Airphoto Pattern Elements (2)	LANDSAT-1 Elements (3)
Floodplain	Extremely narrow, poorly developed flattened gulley. Excellent drainage with cultivation extending into gullies in many areas. Some steeper slopes are vegetated with scrub bushes and grasses. Erosion evident on unvegetated slopes. Slope soils are extremely light where exposed, gray on gully floor and dark where vegetated with shrubs. Some mining located near road intersection.	Distinguishable on regional view as dark area or line which alters rectangular cultivation patterns. Enlargement reveals lack of delineation and therefore no significant wildlife habitat areas in floodplain. Some uncultivated areas are probably rangeland, appear darker and may support scattered populations of wildlife.
Uplands	Extensive agricultural utilization make wildlife habitat almost non-existant. Some erosion on light colored gullies. Uplands are gray or darker where idle.	Easily identifiable as being under extensive agricultural use. Transition area to different soil type appears on lower left (southeast). Parallel drainage also evident. Playa lakes are visible as dark areas in light cultivated patches.

Soil & Origin (1)	Description and Location (2)
Mansker-Potter (Fluvial)	Friable neutral to calcareous sandy loam, clay loam, or loam, 4-12 in., over strongly calcareous friable granular clay loam with $CaCO_3$ concretions in lower region or hard caliche becoming soft to chalky with depth, $CaCO_3$ horizon at 12-20 in., upland areas.

Table 12. - Continued.

Soil & Origin (1)	Description and Location (2)
Amarillo-Brown Field (Alluvial)	Friable neutral to slightly acid sand, sandy loam, snady clay loam, or loamy sand, 6-28 in.,over friable coarse prismatic and granular porous neutral sandy loam or light sandy clay. $CaCO_3$ at 38-60 in., gulleys are gently sloping.

Community Location (1)	Ecological Factors (2)
Bottomlands	Woody plants are present along streambanks with grasses. These may include mesquite and annuals with sideoats, grama, cane bluestem, silver bluestem, white tridens, plains bristlegrass, blue grama and buffalograss. Populations of all fauna are relatively low but may include deer, antelope, quail, rabbits, and some furbearers. Information is sketchy and assimilated from remote sites.
Uplands	Some short grass-shrub associations where not cultivated. Upland game birds present in some areas. Coyotes, rabbits, bobcat, and skunks are present as well as pheasant, mourning dove and others. Rodents and predators are also present. Extensive cultivation. Sketchy information from remote sources.

Table 12. - Continued.

Data Source (1)		Acquisition Source (2)
Low-Altitude Photographs March 1969	CRM-4KK-302, 303, 251, 252	Western Aerial Photography Laboratory Program Performance Branch ASCS-USDA 2505 Parley's Way Salt Lake City, Utah 84019 Tel: AC 801, 524-5826 Price: $2.00 each
LANDSAT-1 4-7-73	81258165345G200-C (False Color Composite)	EROS Data Center Data Management Center Sioux Falls, South Dakota 57198 Tel: AC 605, 594-6511 FTS: AC 604, 594-6151 Price: $7.00 per color composite
Topographic Map 1966	Wellman Quadrangle 1:24000	Texas Water Development Branch Topographic Mapping Section P. O. Box 13087 Austin, Texas 78711 Tel: AC 512, 475-3191 Price: Free to State Agencies or Contractees
Soils Map 1962	Terry County Soils Map 1:141000	Texas Agricultural Experiment Station Texas A&M University Reed-McDonald Building College Station, Texas 77843 Tel: AC 713, 845-2413 Price: Free, limited to twelve per customer Also: See Soil Survey Report, Terry County (below)

Table 12. - Continued.

Data Source (1)		Acquisition Source (2)
Biological Inventories	Running Water Draw EIS Feb 1971	U. S. Army Engineer District, Fort Worth P. O. Box 17300 Attn: Public Affairs Offices Fort Worth, Texas 76102 Tel: AC 817, 334-2212 Price: Free
	Red Deer Creek EIS April 1975	United States Department of Agriculture Soil Conservation Service P. O. Box 648 Temple, Texas 76501 Tel: AC 817, 773-1711 Price: Free
	Soil Survey Report Terry County Feb 1962	United States Department of Agriculture Soil Conservation SErvice P. O. Box 648 Temple, Texas 76501 Tel: AC 817, 773-1711 Price: Free

North Central Prairie

General Description

These undulating prairies and nearly level valleys lie immediately east of the Rolling Plains and are bordered on the east by the Crosstimbers physiographic region. On the south, the North Central Prairie borders the Edwards Plateau and extends northward to the Red River. It lies between 98° and 99° longitude and 33° and 34° north latitude (Fig. 6, p.36).

Mean annual precipitation varies from 25 to 30 inches (64 to 76 cm). Elevation increases to the west from 900 to 1500 feet (274-457 m). Evaporation generally exceeds rainfall as the former mean is approximately 45 inches (114 cm) annually.

The North Central Prairie overlies cretaceous outcroppings which dip gently coastward and inlay Eocene formations to the south. Upland soils are generally light, slightly acid loamy sands in the east to brown sandy loam to silt loams in the west. Subsoils are clayey. Some areas have stony soils. The bottomlands are neutral to calcareous alluvial soils (s4, 4).

Native vegetation is mainly little bluestem, sideoats, hairy and blue grama, Indian and buffalo grass. Scrubby trees and shrubs, mainly post oak and mesquite, and cacti grow rather thickly in places (59). Agricultural practices include ranchland, grain sorghum, wheat, oats, peanuts, fruits, and cotton.

Game animals include quail, turkey, dove, ducks, geese, and deer. Other small game species are skunk, badger, coyote, bobcat, squirrel, and raccoon as well as a host of small mammals such as moles, bats, carnivoirs, rodents, rabbits, and armadillos. Game fish include bass, crappie, perch, and channel catfish (59,32).

Environmental Impact Reviews

Two environmental statements were available for review from the North Central Prairie area (32, 35). The Kickapoo Creek project is a typical PL83-566 watershed improvement plan whereas the Palo Pinto project entails expansion of an existing gas fired electrical generation station. The average cooling water temperature rise through the proposed station will be 15.6°F (8.67°C). The net effect will be an average temperature rise in the lake of 2.24°F (1.24°C) at 100 percent loading factor. This additional unit will meet on additional load growth estimated to 1978.

The environmental impacts of this cooling lake are discussed in terms of other cooling reservoirs in Texas. It is noted that Palo Pinto Lake and other such reservoirs maintain a healthy rough to game fish ratio of 3:2 by weight. Other impoundments in the state, not used for cooling, obtain such a ratio during early years but soon the rough fish predominate and the fishing success declines (35).

An impact assessment is necessary for this project because the applicant filed for a low interest loan with the Rural Electrification Administration. As pointed out in the statement, if this loan is denied, other sources will be obtained and no impact assessment will be required. However, the applicant fails to point out that air and water emissions will still have to comply with state permits.

Reservoirs. Siltation, salt concentrations, and evaporation are primary considerations for surface water impoundments. It is estimated that 50 percent of all the water from surface lakes is removed by sun and wind. This further complicates the salinity problem and demands management of good quality water (59). Downstream effects of reservoir construction would be primarily increases in salinity. Since 1941, the weighted-average monthly concentrations of total dissolved solids in water released and spilled from nearby Possum Kingdom Reservoir have exceeded 1,000 mg/l more than ninety percent of the time, 1,300 mg/l fifty percent of the time, and have reached 3,500 mg/l during drought periods (79). This pollution of the Brazos River by natural salt sources in the upper basin prevents the effective use of the main-stem waters for municipal, industrial and agricultural purposes, particularly as sources of water for the towns in the region (59).

Off channel impoundments are difficult to justify as multipurpose. In the Kickapoo Creek watershed most of the stream channels are usually dry except during times of surface runoff (32). This is generally the case throughout the region. For these reasons, six single-purpose floodwater retarding structures were planned for Kickapoo Creek. To be constructed over an eight-year installation period, these structures and accompanying land treatment measures will decrease sedimentation in main channel reservoirs as well as city water supply off-channel reservoirs. In addition, these permanent sediment pools will provide upland game wildlife habitat which more than amply replaces the habitat lost to construction.

The construction of off-channel floodwater retention structures should account for downstream effects on water quality in the long term (6). The Kickapoo Creek Project includes water quality determinations by an independent commercial laboratory.

Channelization. Streams of the North Central Prairie are generally not of sufficient capacity to warrant consideration of channelization works. Moreover, high sediment loads would increase maintenance costs and require bank stabilization techniques.

Downstream effects would include the usual increased velocities and altered flooding sequence. The latter would be of little concern in this region because floodplain ecosystems are not characterized by large slackwater areas or dense vegetation. Increased velocities on the other hand, could increase scour and erosion. It should be noted that channelization was not considered as a feasible alternative for the Kickapoo Creek Watershed flood control plan (32).

The Kickapoo Creek Project statement points out that there are 337 floodwater retarding structures, 3 multipurpose structures, 156 miles (251 km) of channel work constructed or planned for 25 watershed projects in the Brazos River Basin. If all remaining projects which appear feasible were installed, a total of 690 floodwater retarding structures would be constructed and 280 miles (450 km) of channel work would be installed in the basin (32). The statement does not begin to assess the environmental impact of this basin plan limiting the discussion to long term habitability and economic well being of the entire area. This extensive amount of channel work alone would have definite impact on the stream fisheries of the basin.

Environmental Assessment Procedures. (1) Employment of a water quality laboratory to determine certain parameters for the Kickapoo Creek project seemed like a waste of funds. Data were available from existing sources, and its saline quality is well known. Furthermore, the construction of flood water retention structures and land treatment measures will not measurably alter the natural salinity regime.

(2) Reference to similar conditions in existing cooling lakes in the Palo Pinto Project shed light on the existing and expected environment as compared with similar situations rather than the ambient quality. The necessity of construction is well documented.

(3) Neither statement includes extensive primary species lists.

(4) The enhancement of the human environment compared to wildlife losses was mitigated by substantial economic benefits in both cases.

Summary of Environmental Impact Reviews. (1) Neither the Kickapoo Creek or Palo Pinto Projects included discussion of downstream effects on water quality.

(2) Discussion of terrestrial habitat effects were addressed in both statements. Neither included detailed discussions of long-term vs short term effects. For example, the increase in available electric power will be followed by increased urban and industrial development. This latter phenomenon will cause the loss of additional upland habitat on a regional basis.

(3) Development of environmental consequences of alternatives was not fully covered. An alternate site for the Palo Pinto Project would require considerably more land and transmission facilities, but alternate power sources were only mentioned. The development of these sources should necessarily be included since the planned expansion is an interim measure until 1978. Likewise, watershed alternatives were not developed in the Kickapoo Project.

Diagrammatic Transects and Accompanying Data

Remote sensing plates and accompanying data are displayed as Fig. 26 and Table 13 respectively, and the North Central Prairie transect is presented as Fig. 27. Fig. 26 includes low altitude photography (right), regional LANDSAT-1 imagery (lower left), and enlarged LANDSAT-1 imagery (upper left).

Low Altitude Photography. The central portion of the area was viewed with low altitude photographs. The gently sloping moderately dissected uplands are distinguishable from the terraces and rather wide floodplain.

Upland areas are well drained with a dendritic drainage pattern. Numerous ponds are located on secondary tributaries. Likewise, the floodplain area and terraces are well drained.

Stream gullies are rectangular in shape, oftentimes siltation is so heavy that the exact channel location is not readily apparent. The main stream of the Brazos River is also choked with sediments, many meander scars are in the floodplain.

Bush vegetation is present throughout but predominates in the uplands. On the rolling rangeland, the bushes are low and blend well with the grasses. On the gully slopes, vegetation consists of larger bushes more evenly spaced with bare soil exposed. Hardwoods are present in the bottomlands, in some places along the lower reaches of tributaries, and on the floodplain meander scars.

Upland areas are light gray with lighter, unvegetated to sparsely vegetated gully slopes. Cultivated lands are darker and finely textured. Terrace soils are mottled to light. Bottomlands are gray whereas bottomland cultivation reveals light colored soils. Sediments in stream channels are light colored (Fig. 26).

Road nets appear in rectangular patterns and are distinguishable from winding livestock trails on the rangeland. Contour plowing is practiced on the uplands but seldom appears in the bottomland terrace cultivation plots.

Satellite Imagery. Regional views of the area reveal substantial amounts of agricultural land use. These areas are light colored and surround the drainage ways. The narrow habitat afforded by stream side vegetation is distinguishable in the enlargement. Nearby, surface water impoundments are plentiful. The light area around the streams appear to provide corridors of like tones which may be significant ecologically (Fig. 26).

Fig. 26. - North Central Prairie, Brazos River, Young County, Texas. The stereopair on the right is from low altitude photography taken November 30, 1967 at a scale of 1:20,000. The regional LANDSAT-1 reproductions (left) were made from a color composite dated July 4, 1973 and are at a scale of 1:1,000,000 (lower left) and 1:350,000 (upper left). Black dots on the LANDSAT-1 imagery are cloud shadows. The braided stream channel indicates high sediment load in the river and the sharp bend indicates rock control.

LANDFORMS	Uplands	Terrace	Floodplain	Terrace
LANDUSE	Rangeland	Rangeland-Cultivation	Agricultural Cropland (Rangeland)	Rangeland-Cultivation
PLANTS	Scrub Oak-Mesquite Grassland Association inc. Mesquite Bluestem Grasses Gramas		Hardwood-Grass Association inc. Native Pecan Elm Oaks Also inc. Bluestems Indiangrass	Scrub Oak-Mesquite Grassland inc. Mesquite Bluestem Grasses Gramas
ANIMALS	Upland Game Birds Transitory Waterfowl Predators		Furbearers Squirrel Quail Turkey Deer Rabbits	Upland Game Birds Transitory Waterfowl Predators

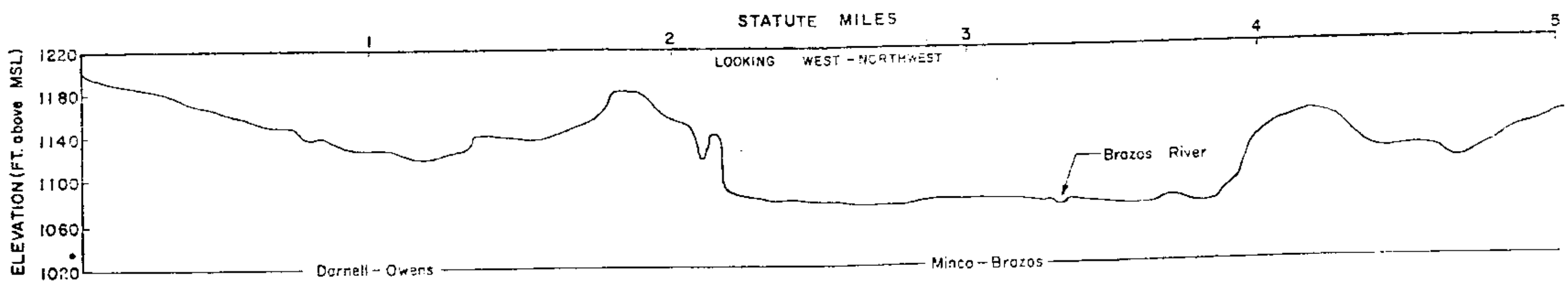


FIG. 27.- North Central Prairie Transect, Brazos River, Young County, Texas.

Table 13. - North Central Prairie, Brazos River, Young County, Texas.

Landform (1)	Airphoto Pattern Elements (2)	LANDSAT-1 Elements (3)
Floodplain	Well defined floodplain to one mile in width. Series of mobile meanders and bends. Well drained with heavy siltation braided in places. Hardwoods adjacent to streams with scrub hardwoods, mesquite and grasses on old meander scars. Bottomlands are gray with eroded stream banks very light colored.	Floodplains are well delineated by agricultural land uses. The lighter areas around the streams also give good contrast to the dark vegetated areas on the stream banks and in meanders. These cattle areas are large in some areas and should support some wildlife species.
Terraces	Flattened terraces adjacent to floodplain. Little appearance difference from uplands. Resistant uplands often intercept terrace formation especially at sharp bends in main channel flow. Mottled soils.	Uncultivated upland areas appear evenly textured and gray. An east-west transition is evident with agricultural land use becoming more intense eastward (bottom of regional satellite view). Surface water is regionally abundant with little agricultural production appearing on adjacent lands. Terraces are not readily distinguishable. Enlarged satellite photograph has light agricultural areas parallel to dark stream side vegetation. Although these areas may appear as well drained terraces they are actually cultivated uplands.
Uplands	Well drained, moderately dissected uplands with dendritic drainage. Numerous ponds on short secondary tributaries. Gullies are rectangular with heavy siltating often occluding stream channel. Moderately textured bushy vegetation, evenly spaced. Several hardwoods present around gulleys and slopes. Gray tones or light where denuded. Cultivated areas are mottled with contour plowing. Livestock trails also evidence of rangeland.	

Table 13. - Continued.

Soils & Origin (1)	Description and Location (2)
Minco-Brazos (Alluvial)	Friable slightly acid to calcareous silt loam to loamy fine sand, 12-25 in., over friable porous neutral to alkaline silt loam to very fine sandy loam or calcareous sand to loamy sand stratified with silt or clay.
Darnell-Owens (Residual)	Friable slightly acid fine sandy loam or calcareous clay, 5-10 in., over noncalcareous sandstone or very firm blocky to massive calcareous clay grading into calcareous shaley clay at 15-30 in depth.

Community Location (1)	Ecological Factors (2)
Bottomlands	Pecan trees, a few elms and oak may be the only hardwood species. Grasses include bluestem, switchgrass and Indian grass. Overgrazing has caused increases in hackberry, elm, Texas wintergrass and wildrye. Sparse habitats exist on rangeland for furbearers such as badger, skunk, raccoon and others. Squirrels may also be found as well as quail, turkey, and dove. Intensive land use for grazing with some cultivation where land treatment measures are applied for wind and water erosion. Sketchy information.
Terraces and Uplands	Occasional post oak, live oak and shin oak occur in the uplands. Mesquite-grass associations are dominant. Grasses include bluestem, gramas and buffalograss. Hardwoods, where present, are scrubby. Fauna includes upland game birds, some transitory water fowl, coyote, rabbit, bobcat, and badger. Freshwater fisheries exist most years. Sketchy information from remote sources.

Table 13. - Continued.

Data Source (1)		Acquisition Source (2)
Low-Altitude Photographs	CWU-1JJ-191 195	Western Aerial Photography Laboratory Program Performance Branch 2505 Parley's Way Salt Lake City, Utah 84019 Tel: AC 801, 524-5826 Price: $2.00 each
LANDSAT-1 7-4-73	81346164135G200-C (False Color Composite)	EROS Data Center Data Management Center Sioux Falls, South Dakota Tel: SC 605, 594-6511 FTS: AC 605, 594-6151 Price: $7.00 for color composite
Topographic Map 1966	Proffitt Quadrangle 1:24000	Texas Water Development Board Topographic Mapping Section P. O. Box 13087 Austin, Texas 78711 Tel: AC 512, 475-3191 Price: Free to State Agencies or Contractees
Soils Map 1962	Young County Soils May 1;139000	Texas Agricultural Experiment Station Texas A&M University Reed-McDonald Building College Station, Texas 77843 Tel: AC 713, 845-2413 Price: Free, limited to twelve per customer

Table 13 . - Continued

Data Source (1)		Acquisition Source (2)
Biological Inventories	Erath County Soil Survey Jan 1963	United States Department of Agriculture Soil Conservation Service P. O. Box 648 Temple, Texas 76501 Tel: AC 817, 773-1771 Price: Free
	Natural Resources Study Mar 1973	Nortex Regional Planning Commission 2414 9th Street Wichita Falls, Texas 76301 Price: Free

Post Oak Belt

General Description

The Post Oak Belt Region follows the northeast to southwest tertiary formations. It lies between the Blackland Prairie and Coastal Prairie extending northward to the East Texas Timberlands. It stretches from 98° to 95°30' longitude and approximately 29° to 31°30' latitude (Fig. 6, p. 36).

Mean annual precipitation ranges from 32 inches (81 cm) in the southwest to 46 inches (117 cm) in the east. Evaporation increases southwestward from 10 inches (25 cm) to 30 inches (76 cm). Elevation increases to the northeast from 250 to 500 feet (76-152 m) (44, 4).

Soils grade from clay loams in the southwest becoming more calcareous to the north and arid sandy soils in the extreme northeast. The coastward edge of the region actually contains reminant Blackland Prairie soils. Some investigations include these isolated areas in the Blackland Prairie (82). However, because of climatic differences, the ecotypic expression is different from the Blackland Prairie.

Uplands are used primarily for pastureland but potentially support post oak, hickory, blackjack oak, elm, and cottonwood in the east, grading to mesquite-oak associations in the southwest. The bottomlands support grain sorghum, cotton, corn, forage crops and pecan production. White-tailed deer, squirrels, quail, rabbits, dove, opossum, wolf, bobcat, fox, and some turkey are common in the region. The southern bald eagle historically occurs within the area (75, 3).

Environmental Impact Review

Although several impact statements dealt with transition areas of this region, none reviewed was entirely within its borders. Palmetto Bend Dam and Reservoir is a good example (34). This project lies in the Gulf Coastal Plain but its northern reaches and environmental effects will impose on the Post Oak Belt.

Palmetto Bend Reservoir will inundate 13,700 acres (55.4 km^2) at maximum water surface of stage one. At the same time it will eliminate 40 miles (64.4 km) of stream habitat and create an (182,000 acre-feet) (224 million m^3) aquatic habitat. Perhaps the most important environmental consequence will be the alteration of flows into Matagorda Estuary. Accounting for return flows, evaporation, and spillage, a loss of 45,000 acre-feet (56 million m^3) annually or 2.5 percent of the annual flow will be realized (34).

These types of consequences could be expected for almost any type of water resource development in the Post Oak Belt. The proximity of the estuaries and the ecologically rich bottomlands are important resources in and of themselves. Bottomland flooding prevents cultivation in many areas and maintains these lowlands as some of the richest in the state.

Reservoirs. Soils of the north eastern extent are unsuitable for water impoundment. Rapid seepage can be expected from most soil types and most have moderate to severe limitations for non-agricultural uses (69). Towards the southwest, soils become of variable perviousness and the lack of topographic relief becomes important. For example, the Palmetto Bend Dam will be 12.3 miles (20.8 km) long and require 2.6

million cubic yards (1.9 million m^3) of fill (34).

Downstream effects are important for water impoundment in the Post Oak Belt. The additional loss of bottomland hardwoods through altered flooding, higher minimum water levels, and stream clearing will further confine species of fauna and flora. Estuarine effects are of commercial concern as variations in freshwater inflows as well as sediment and nutrient reductions are involved.

The larger streams of this region support a relatively large stream fisheries, primarily catfish. The creation of impoundments will destroy this type of fisheries but create a larger, more diverse resource. Aquatic plant infestation is a recognized threat but little discussion is directed to the herbicide applications that will be needed as a control for these aquatic pests. The hardwoods which are allowed to remain for fisheries propagation also provide wind breaks and nutrient sources for emergent plants. The "jungle" area of Lake Livingston is a prime example (68).

Channelization. Streams of the Post Oak region are less intermittent and support lush streamside habitats. Since most high flows result from storm runoff, the necessity is created to control large amounts of water and protect valuable agricultural land. Land use finds most of this agricultural land to be flood prone as most upland areas are used for pastureland. Although channelization appears to provide an adaptable alternative to accomplish these benefits, special techniques will be required to protect the bottomland habitats. Bank stabilization, floodways, levees and even off channel impoundments may be more environmentally acceptable.

It is possible that water requirements for the coastal urban communities or estuarine maintenance will require channelization through this region for conveyance of impounded upstream waters. Loss of meanders will reduce channel capacity, increase velocities and reduce fish spawning areas. The capacity of the existing channel should be utilized as much as possible to reduce both costs and adverse impacts.

Environmental Assessment Procedures. (1) Short-term vs. long-term productivity are easily justified in terms of fisheries production. However, the Post Oak Belt not only serves as a transition area between east and west and north and south, but also is an ecotone for many aquatic species (7).

(2) Impoundment of surface water supplies for future water needs is also justifiable for out-of-region areas. The impact on in-region resources is difficult to mitigate except as in (1) above and for recreational pursuits.

(3) Municipal and industrial return flows will be needed for estuarine maintenance (34, 27).

(4) Loss of bottomland hardwoods is important from a regional view. Large reservoirs will inundate many acres because of low topographic relief (34).

Summary of Environmental Impact Reviews. This section is omitted because of the absence of pertinent environmental statements.

Diagrammatic Transects and Accompanying Data

Remote sensing plates and acompanying data are displayed as Fig. 28 and Table 14 respectively; the Post Oak transect is presented as Fig. 29.

Fig. 28 includes low altitude photography (right), regional LANDSAT-1 imagery (lower left), and enlarged LANDSAT-1 imagery (upper left).

Low Altitude Photography. Most major rivers flow through this region on a northwest to southeast trek. Floodplains are broad and well defined. Terraces are present in some areas at the base of the uplands. Uplands are gently to moderately rolling with some deeper incision in the southwest. Upland areas are well drained in most locations. Some areas of the east central portion may be poorly drained along primary tributaries. Dendritic drainage prevails throughout. Northern primary streams are longer and more gently sloping than southern ones. Bottomlands are moderate to poorly drained. Most floodplains have oxbows and slackwater areas around meanders (Fig. 28).

The gently rolling nature of the uplands varies somewhat toward the southwest. Streams become more deeply incised in the uplands and secondary channels are well defined. Erosional gullies are evident wherever slopes are not vegetated. Elsewhere erosion is well contained with many secondary channel water retention ponds. Siltation of main stem reservoirs is heavy throughout, appearing less in the southwest.

Vegetation consist of mixed hardwoods to hardwood-bush in the southwest and pine-hardwood in the northeast. Cultivation is practiced on some upland areas but mostly in floodplains. Bottomland hardwoods are dense adjacent to streams and in meander areas. Understory is present in uplands and bottomlands, diminishing in the southwest.

Photographic tones vary from light to medium gray in the uplands. Vegetated areas are darker. Some mottled soils appear in the southwest uplands. Bottomlands are mottled throughout to dark gray. Stream sediments are light colored with large white sand bars in most major streams.

Pastureland is the primary upland land use with some cultivated areas. Bottomlands are mostly cultivated crops with some pastureland adjacent to main stems (Fig. 28). Roadways are rectangular around cultivation in floodplain and follow ridgelines or parallel major rivers. Some housing structures are located in the floodplains notably in the southwest.

Satellite Imagery. Extensive agricultural use of the floodplain is evident. A clear junction area is noticeable between the East Texas Timberlands, Coastal Prairie and Post Oak areas (Fig. 28). An absence of surface water impoundments is noticeable in the area since large impoundments are seen in the east, and north. The patches of Blackland Prairie present in the Post Oak area are distinct in the northeast. Drainage is largely parallel through the region. Streams display numerous meanders indicative of low relief. Dark colored stream lines reveal vegetation which lines the stream beds and appears in some slackwater areas (Fig. 28).

FIG. 28. - Post Oak Belt, Brazos River, Washington and Waller Counties, Texas. The The low altitude photography for the stereopair was taken November 15, 1966 at a scale of 1:20,000. The LANDSAT-1 imagery was taken May 9, 1973 and the copies are at scales of 1:1,000,000 (lower left) and 1:350,000 (upper left). Heavy sediment load can be observed in the Brazos River along with meander scars along the river.

LANDFORMS	Floodplain		
LANDUSE	Agricultural Cropland with some Rangeland		
PLANTS	Post Oak-Mesquite Grassland inc. Elm Red Cedar Also inc. Prairie Grasses		Bottomland Hardwoods inc. Elms Oaks Cottonwood
ANIMALS	Upland Game Birds Predators		Furbearers White tailed Deer Squirrels Gray Fox Red Wolf (E) Migratory Waterfowl

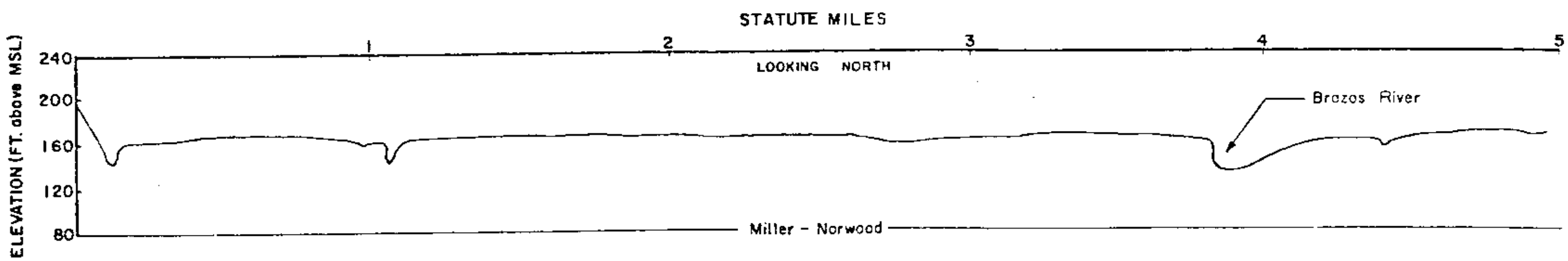


FIG. 29.- Post Oak Belt Transect, Brazos River, Washington and Waller Counties, Texas.

Table 14. - Post Oak, Brazos River, Washington and Waller Counties, Texas.

Landform (1)	Airphoto Pattern Elements (2)	LANDSAT-1 Elements (3)
Floodplain	Extremely broad floodplain, poorly drained in many areas with tributaries paralleling main channel before confluence. Meander scars on main channel, sand bars, and active bank cutting is noticeable. Floodplain tributaries are also eroded where denuded of vegetation. Gulleys are U-shaped. Hardwoods adjacent to the streams and in low areas around oxbows and confluences. Dark tones where cultivated with mottling in many areas or light colored cultivation.	Dark, narrow vegetation bands evident along main channel. Slackwater areas also evident on large dark vegetation stands. Degree of meandering is indicative of low relief. Noticeable lack of numerous tributaries.
Uplands (includes floodplain away from streamside)	Not actually present in photographs, but described as area away from stream channel, oxbows, etc. Moderately well drained with dendritic drainage. Hardwoods and underbrush on terraces and gentle upland slopes. Hardwoods are scrubby but more dense in qulleys. Grassed pastureland present on terraces and uplands. Light gray to dark in some gulleys.	Slight tonal variation between broad floodplain and upland areas. Excellent transition noticeable between light colored Post Oak and dark colored East Texas Timberlands. Numerous small surface water impoundments throughout indicates rather high ground water table.

Table 14. - Continued.

Soils & Origin (1)	Description and Location (2)
Miller-Norwood (Alluvial)	Friable strongly calcareous silt loam to silty clay loam or crumbly calcareous clay, 9-25 in.,over very friable granular silt loam or silty clay loam or crumbly subangular blocky calcareous clay throughout floodplain.

Community Location (1)	Ecological Factors (2)
Bottomlands	Elms, oaks, and cottonwoods are the dominant hardwoods with yaupon and haws in the understory. Species include willow oak, water oak, live oak, winged elm, water elm, and hackberry. The fauna is comprised of white tailed deer, wild turkey, quail, squirrel, raccoon, opossum, mink, gray fox, red fox, bobcat, ringtail cat, and is within the range of the endangered red wolf.
Uplands (includes floodplain away from streamside)	Extensive cultivation or pastureland restricts habitat availability. Some post oak, blackjack oak, live oak, winged elm, hickory, red cedar and mesquite. Prairie grasses are also present where not overgrazed. Fauna include upland game birds and predators as well as migratory water fowl. Hardwoods, when present, are on slopes.

Table 14. - Continued.

Data Source (1)	Acquisition Source (2)
Low-Altitude Photographs GGO-2HH-158 159, 178, 179,-5HH-197, 198-6HH-96	Western Aerial Photography Laboratory Program Performance Branch ASCS-USDA 2505 Parley's Way Salt Lake City, Utah 84019 Tel: AC 801, 524-5826 Price: $2.00 each
LANDSAT-1 10-4-72 81451162245G200-C (False Color Composite)	EROS Data Center Data Management Certer Sioux Falls, South Dakota 57198 Tel: AC 605, 594-6511 FTS: AC 605, 594-6151 Price: $7.00 for color composite
Topographic Map 1961 Daniels Quadrangle 1:24000	Texas Water Development Board Topographic Mapping Section P. O. Box 13087 Austin, Texas 78711 Tel: AC 512,475-3191 Price: Free to State Agencies or Contractees
Soils Map 1961-1962 Washington and Waller Soils Maps 1:155000 1:144000	Texas Agricultural Experiment Station Texas A&M University Reed-McDonald Building College Station, Texas 77843 Tel: AC 713, 845-2413 Price: Free, limited to twelve per customer

Table 14. - Continued.

Data Source (1)		Acquisition Source (2)
Biological Inventories	Trinity-Brazos Game Management Survey 1960	Texas Parks and Wildlife Department John H. Reagen Building Austin, Texas 78701 Tel: AC 512, 822-3356 Price: Free
	<u>Ecology of Navasota</u> W. J. Clark 1973	Texas Water Resources Institute Texas A&M University College Station, Texas 77843
	Environmental Studies lower Navasota River 1973	U. S. Army Engineer District P. O. Box 17300 Attn: Public Affairs Office Fort Worth, Texas 76102 Tel: AC 817, 334-2212 Price: Free

Rio Grande Plain

General Description

The Rio Grande Plain occupies the extreme south Texas area from the Rio Grande Delta north to the Balcones Escarpment. On the west, this region is bounded by the Rio Grande River; it extends eastward generally along a line where evaporation and rainfall are equal. It covers an area from 29°15' to 26° latitude and from 101° to 98°30' longitude (Fig. 6, p. 36).

Average annual rainfall increases eastward from 18 to 30 inches (46 to 76 cm). Evaporation increases westward from 30 to 70 inches (76 to 178 cm) annually (44). The climate is semi-arid.

The surface geology is principally of Eocene origin. It is banded eastward in alternating units of sand, silt, and clay or shale. Alluvium and terrace deposits are composed of sand, silt, clay and gravel materials which overlap bedrock units in the vicinity of streams and rivers.

Vegetation is predominantly mesquite and other woody invading species and natural and introduced grasslands. In the four county area of Webb, Zapata, Jim Hogg and Starr, rangeland accounts for 93 percent of the land use (67). These brush grassland associations grade to the northeast into brush-hardwood associations (mesquite-oak forest). All other vegetation is in the form of agricultural crops. Irrigated vegetables, rice, fruits and cotton are grown around the Rio Grande and eastward dryland farming produces grains and cotton.

The fauna is moderate to lightly abundant over the region. Present are deer, javelina, rabbit, dove, quail, squirrel, wild turkey, and many species of non-game birds and mammals. Fisheries resources are confined to range ponds, some riverine fisheries, flood water retarding pools, and over 3 million acre-feet (3.7 billion m^3) of large surface water impoundments. The latter is largely the International Falcon Reservoir on the Rio Grande River (2.7 million acre-feet) (3.3 billion m^3) and Lake Corpus Christi (297,600 acre-feet) (367 million m^3).

Endangered species include the gray wolf, ocelot, jaguarundi, brown pelican, southern bald eagle, peregrine falcon and Eskimo curlew (67).

Environmental Impact Reviews

Water resource development is essential to the economic growth of the Rio Grande Plain. The entire area depends upon some form of agricultural products. Flood control and irrigation are of concern near the Rio Grande River. Eastward, water supply and flood control are necessary.

Six impact statements were reviewed for this area. Most addressed the impacts of the proposed projects on nearby estuarine areas. The latest project, Choke Canyon Reservoir (26), will reduce freshwater flows into Corpus Christi Bay by 10 percent. Similarly, the Lower Rio Grande Flood Control project will increase subsurface drainage and flush accumulated salts from irrigation land into Laguna Madre, increasing the salinity (12).

Elsewhere in the region, water development may directly impact on agricultural cropland or terrestrial wildlife habitat. Cibolo Creek Reservoir, for example, will inundate 10,000 acres (40 km^2) of wildlife habitat and 24 miles (39 km) of streamside habitat (27). Since this project is in a transitional zone between the Gulf Coastal Prairie, Edwards Plateau and the southern extent of the Blackland Prairie, its terrestrial habitat may be of regional significance.

Solids are high in waters of this region. The Bureau of Reclamation estimates a range of 171-533 mg/l total dissolved solids (TDS) for the year 2020 conditions in Choke Canyon Reservoir (26). Likewise, the Cibolo Reservoir is estimated to have a TDS range of 257-1090 mg/l (27). In the San Felipe Watershed, an unnamed tributary contains 8000 mg/l total suspended solids which is diluted to 330 mg/l by its confluence with San Felipe Creek. A project affecting flow volumes of San Felipe Creek will then increase total suspended solids concentrations downstream (13).

Reservoirs. Construction of large multi-purpose reservoirs has occurred on both the eastern and western boundaries of the region. The central area has marginal flows and excessive evaporation. However, the *Texas Water Plan* (79) proposes intrabasin transfer of water for demands in the San Antonio-Nueces Coastal Basin, Nueces-Rio Grande Coastal Basin, and the Nueces River Basin. The latter includes Choke Canyon Reservoir which would require 60 percent return flow of municipal and industrial water for downstream and estuarine maintenance.

The bottomlands of the eastern region contain some hardwoods, and mesquite. This habitat type grades with adjacent physiographic regions and therefore may constitute a ecologically significant transitional area. Inundation of a large area of streamside habitat and stream fisheries may be mitigated by the creation of the aquatic fisheries and recreational facilities (27). By controlling land use and providing wildlife mitigation measures, an increase in the diversity and numbers of effected species may result. Likewise, losses in agricultural production locally may be more than compensated by flood protection and the availability of quantity and quality water regionally. Although reservoir construction would have similar effects in the central areas, large impoundments in the southern area would involve valuable irrigated croplands.

Channelization. The most extensive channelization project reviewed for this report was the Lower Rio Grande Valley, Texas, Flood Control and Major Drainage Project (12) which involves 164 miles (263 km) of single-purpose channel improvements for floodwater removal and 1,394 miles (2242 km) of multiple-purpose channel improvement for flood prevention and surface and subsurface drainage. Since the entire project area is highly developed agricultural land, the direct terrestrial and aquatic wildlife impacts are negligible. However, one purpose of the project is to improve subsurface drainage and remove accumulated irrigation salts. This will increase salinity in Laguna Madre and deliver available pollutants to the estuaries at a faster rate, thereby reducing their degradation time.

Although the project will commit 28,000 acres (113 km^2) to canal works it will eliminate the local uncoordinated projects which do not address the environmental impact. Phase III land treatment measures will improve wildlife habitat on some higher pastureland. Other projects within the region provide flood protection which serves as an incentive for the application of land management practices (29).

Environmental Assessment Procedures. (1) Impact is assessed on the basis of enhancement of the human environment. Because of extensive agricultural use of the land, improvements which increase the potential

productivity outweigh the detrimental effects on the sparce wildlife.
(2) Water resource development in the region will effect estuarine flows in almost every case. These effects are difficult to assess and usually given in terms of tons of fish harvest lost per year.
(3) Inundation of bottomland vegetation in the eastern region is mitigated by the establishment of a water-side habitat and recharge of the Edwards Aquifer. In the central areas, its loss is regionally insignificant brush-grass associations.

Summary of Environmental Impact Reviews. (1) Agricultural potential was established early in all statements to out-weigh any adverse ecological changes.
(2) The lack of exact knowledge of estuarine life cycles and flow regimes was identified but quantified only in terms of commercial species.
(3) Recreational pressures were realized only on the Cibolo Reservoir Project as extending the impact on terrestrial species.
(4) In all cases, regional impacts were not addressed except in regard to estuarine management.
(5) In all cases, alternatives were not developed; in the case of the Lower Rio Grande Project, alternatives were not included.

Diagrammatic Transects and Accompanying Data

Remote sensing plates and accompanying data are displayed as Fig. 30 and Table 15 respectively; the Rio Grande Plain transect is presented as Fig. 31. Fig. 30 includes low altitude photography (right), regional LANDSAT-1 imagery (lower left), and enlarged LANDSAT-1 imagery (upper left).

Low Altitude Photography. The Rio Grande Plain begins as a flat, broad floodplain in the extreme southwest and grades into a gently rolling plain with exposed bedded sandstone in the northwest.

Drainage patterns are largely internal in the irrigated croplands of the Rio Grande valley to dendritic and slightly dissected northward and eastward. Main channels have few tributaries around the Nueces River. River meanders are small laterally (Fig. 30).

The northern portion of the region has the most pronounced erosional features. Hillsides of banded sandstones produce vegetated gullies that disperse in the large floodplains. Erosion is essentially non-existant in the internally drained agricultural areas of the southwest. The south central area has some erosion around major streams, but tributaries are shortened with vegetation in gully bottoms.

The region's vegetation can be largely characterized by invading brush species on large areas of overgrazed rangeland. Some introduced tropical plants occur in the southwest and a mesquite-oak association begins to occur in the northeast. Well managed rangelands may contain extensive grassland areas and evidence of brush control measures in the south central area.

Irrigated croplands appear dark to mottled in the southeast. Orchards are finely textured with light soils. In other areas, vegetated bottomland areas are darker, abruptly changing to coarse, gray brush-grassland areas. Exposed sandstone in the northwest is light colored (Fig. 30).

The entire area is characterized by intensive agricultural use. Livestock production predominates in almost the entire central, northern and eastern areas. In the latter region, some row crops are produced.

Roads are few in number, rectangular in irrigated areas and running along ridgelines in the northwest. Stock ponds are evident at the base of the sandstone hills in the northwest and near groundwater pumping in south central areas.

Satellite Imagery. Two seasons of LANDSAT-1 imagery were obtained for the northwestern part of the region in the vicinity of the Nueces River. The photographs immediately pointed out the extent of agricultural development along the river system. Land divisions were evident away from the streams in obtuse blocky sections with little reflective vegetation. The regional transition to the north is also clearly evident (Fig. 30).

Seasonal tonal and color differences were also noted. Considerably less reflective vegetation was present in the late fall, indicating a sizable seasonal crop in the bottomlands. Summer rangelands were lighter than in other seasons because of increase reflectance of dry soils.

FIG. 30. - Rio Grande Plain, Nueces River, Dimmit County, Texas. The low altitude photography (right) was taken April 6, 1969 at a scale of 1:20,000. Regional LANDSAT-1 imagery is of band 7, 1:1,000,000 (lower left) and 1:350,000 (upper left). The dark vegetation along the streams tend to delineate the drainage pattern. The light tones and lack of surface drainage on the uplands in the stereopair indicates internal drainage.

LANDFORMS	Uplands	Floodplain	
LANDUSE	Rangeland	Rangeland and Cropland	Rangeland
PLANTS	Oak-Mesquite Association inc. Scrub Oak Prairie Grasses	Oak-Mesquite Association inc. Live Oak Post Oak	Oak-Mesquite Association inc. Live Oak Prairie Grasses
ANIMALS	Upland Game Birds Predators	Furbearers Predators Southern Bald Eagle (E) Peregrine Falcon (E) Moutain Lion (R)	Upland Game Birds Predators

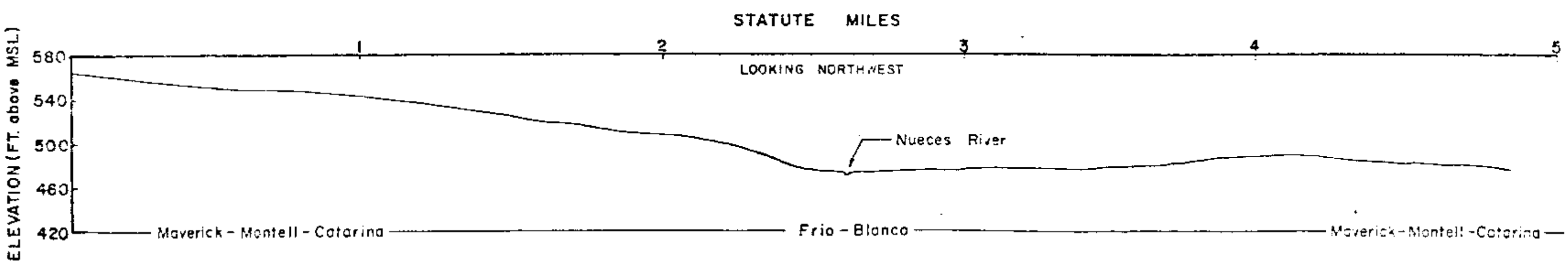


FIG. 31.- Rio Grande Plain Transect, Nueces River, Dimmit County, Texas.

TABLE 15.- Rio Grande Plain, Nueces River, Dimmit County, Texas.

Landform (1)	Airphoto Pattern Elements (2)	LANDSAT-1 Elements (3)
Floodplain	Nearly level, well drained with numerous small meanders. Erosion active along gullies. Well defined streams become flattened in this area. Vegetation is hardwoods throughout abruptly changing at the uplands. Vegetation gives dark tones with soils lighter where cleared.	Appears to be regional transitional area from light, agricultural to darker rangeland. Enlargement reveals large light cultivated areas. Darker vegetation appears only to occur along drainages. Possible important wildlife habitats.
Uplands	Gently rolling bedded sandstone with lightly dissected dentritic drainage. Erosion on hillsides. Bottomland hardwoods end abruptly with shrubs and grasses. Coarsely textured gray vegetation with light soils.	Light colored cleared agricultural land gives evidence of well drained or droughty soils. Darker vegetation along streams yields to mottled grayish pastureland. Enlargement shows the extent of cultivation still in this transition area.

Soil & Orgin (1)	Description and Location (2)
Frio-Blanco (Alluvial)	Granular friable to fraible strongly calcareous loam, clay loam, clay loam or silty loam, 12-40 inches, over granular to blocky subangular strongly calcareous loam, clay loam, or silty clay underlain by beds of rounded limestone and gravel at depths below 3 feet.

TABLE 15.- Continued

Soil & Orgin (1)	Description and Location (2)
Maverick-Montell-Catarina (parent rock)	Crusty, firm, crumbly, or friable granular calcareous clay with occasional shell and chert fragments, 8-25 inches, over compact to very blocky calcareous or saline clay changing with depth. Lower regions may contain concretions of $CaCO_3$, calcareous shale interbedded clay or shale, or salt and gypsum crystals.

Community Location (1)	Ecological Factors (2)
Bottomlands	Live oak adjacent to streams grading into mesquite away from streams. Sparse habitat available for white tailed deer, javelina, and furbearers. Mountain lions (endangered) and endangered avifauna including the southern bald eagle and peregrine falcon as well as gray wolf, jaruarundi, gray fox, bobcat, and coyote may be present.
Uplands	Post and live oak are present in the gulleys and around eroded hillsides. Upland game birds such as quail and mourning and white winged dove as well as predators are present. Mesquite is predominante on most lands.

TABLE 15 .- Continued

Data Source (1)		Acquisition Source (2)
Low Altitude Photographs Mar., 1969	DOK-5KK-73 -74	Western Aerial Photography Laboratory Program Performance Branch ASCS-USDA 2505 Parleys Way Salt Lake City, Utah 84019 Tel: AC 801, 524-5826 Price: $2.00
LANDSAT-1 6-29-74	81706163505G200-C False Color Composite	EROS Data Center Data Management Center Sioux Falls, South Dakota 57198 Tel: AC 605, 594-6511 FTS 594-6151
Topographic Map 1939	Big Wells Quadrangle 1:62500	Texas Water Development Board Topographic Mapping Section P.O. Box 13087 Austin, Texas 78711 Tel: AC 512, 475-3191 Price: Free to State agencies or contractees
Soils Map 1965	Dimmit County Soils Map 1:305000	Texas Agricultural Experiment Station Texas A&M University Reed-McDonald Bldg College Station, Texas 77843 Tel: AC 713, 845-2413 Price: Free, limited to twelve per customer

TABLE 15.- Continued

Data Source (1)		Acquisition Source (2)
Biological Inventories	Choke Canyon EIS Dec., 1975	United States Department of the Interior Bureau of Reclamation Southwest Region Herring Plaza Box H-4377 Amarillo, Texas Tel: AC 512, 397-5641 Price: Free
	Rio Bravo Resource Conservation and Development Plan	South Texas Development Council 1104 Victoria Street, Suite 2 P.O. Box 1365 Laredo, Texas 78040 Tel: AC 512, 722-3995 Price: Free

Rolling Plains

General Description

The Rolling Plains physiographic region is located in north central Texas. It is bordered on the west by the Cap Rock Escarpment of the High Plains, by the Red River on the northeast, by the Edwards Plateau on the south, and by the North Central Prairie on the east. The largest land concentration lies between 99° to 102° longitude and 31° to 36° latitude. It extends northward to include the Canadian River basin, incised through the High Plains, and includes the Gypsum Plains, an outwash of the High Plains as well. The entire area is gently rolling to deeply incised along stream channels, with many large flat areas (Fig. 6).

Topographic elevation varies from 1000 to 3000 feet (305-914 m), increasing to the south and west. Mean annual precipitation grades from 18-28 inches (46-71 cm) from southwest to northeast. Annual evaporation is 70 to 45 inches (178-114 cm) respectively.

The area is largely of Permian Age clay and sand. Red beds and limestone, deposited around 280-230 million years ago, are parent materials for most of the soils of the Rolling Plains. At the western extent, east of and below the Cap Rock Escarpment, younger sedimentary rocks of Triassic Age outcrop. These rocks consist of shales, sandstones and limestone from 230-180 million years ago. Outwash from cretaceous limestone influences the southern soils of the region (44).

Upland soils are pale brown through reddish brown to dark grayish brown, neutral to calcareous sandy loams, clay loams and clays over reddish calcareous, loamy to clayey calcareous, alluvial soils (44).

The Rolling Plains contains mesquite, juniper, and Shinnery Oak uplands. Short grasses are also abundant. Some salt cedar is encroaching in the bottomlands. Rangeland is the largest land use with dryland and irrigated cultivation also important.

Suitable habitats exist for quail in the uplands. Bottomland areas contain few deer, fox squirrel, rabbits, coyote, bobcat, and opossum. Other fur bearers are also present (71, 70). Generally large mammals are not abundant owing to the lack of habitat.

Environmental Impact Reviews

The Rolling Plains area contains 3.4 million acre-feet (4.2 billion m^3) of surface water storage. The Texas Water Plan does not include any reservoirs from this region in its Texas Water System of intrabasin transfer. However, a proposed east-west canal system will transport water to areas of this region if required. Sufficient ground water resources are present to meet most regional requirements to the year 2020 (79).

Only one impact statement was reviewed for this region, Beals Creek, Big Spring, Texas, a channel realignment of 5.6 miles (9.0 km) of urban floodway (77). This particular project was entirely within the confines of Big Spring, Texas. Emphasis was placed on the disturbance of the local aquatic habitat with no reference to changes in the downstream flooding sequence. Clearly, benefits accruing to the human environment through flood-protection and possible health problems of ponded water were the overriding factors. No consideration was afforded the potential pollution associated with increased urbanization after flood proofing (short term use vs long term productivity).

Reservoirs. The largest existing impoundment in the Rolling Plains is Lake Meridith in the panhandle area. The broad Canadian River floodplain is a difficult site for reservoir construction because of heavy siltation and the relatively small effective watershed. In theory, the watershed is quite large, but because of high seepage and evaporation rates rainfall impacting more than five miles (eight km) from the river channel does not normally contribute to its flows.

Generally, streams are deeply incised in the Rolling Plains but little relief is available once the bank full stage is reached. Salinity control is also a problem, many streams of this region contain in excess of 3000 mg/l dissolved solids (79). Several structures have been built to impound the more saline tributaries of the Brazos River. Environmental effects of larger reservoir construction would not be too profound in terms of habitat and vegetation losses. However, extensive agricultural practices are conducted adjacent to most streams in the eastern extent.

Salinity is also a problem in the waters of the Red River Basin which originate from this and adjacent regions. A 190 million dollar Red River chloride control plan has been undertaken by the U.S. Army Corps of Engineers (85).

Channelization. Since many streams in the Rolling Plains are intermittent, a significant fisheries resource does not exist. For example, the Beals Creek project did not have an aquatic impact because no fish were present in the stream (77). Channelization works in this environment becomes important when downstream waters or terrestrial habitats are affected. Downstream effects may include increased siltation, increased velocities and changes in salinity concentrations. Effects on terrestrial habitats may be regionally significant since adequate habitats are scarce within the area. Likewise, the cut-off of meanders could not effect a non-existent fisheries resource but may disturb slackwater areas conducive to wildlife habitation.

Environmental Assessment Procedures. (1) The sparse aquatic and terrestrial wildlife is not affected by small scale projects. Regionally, the effect may be minimal even with large scale projects. (2) Improvement of the human environment is easily documented and often overrides adverse wildlife impacts.

Summary of Environmental Impact Reviews. (1) A notable failure to include adequate discussion of alternatives was found in the Beals Creek Projects. (It should be noted the early 1971 date of this report indicates it was one of the first EIS's prepared).
(2) Failure to adequately assess the downstream effects was also noted.
(3) Short term vs. long term environmental changes did include discussion of potential productivity on protected lands, but did not include these in discussion of potential adverse impacts.

Diagrammatic Transects and Accompanying Data

Remote sensing plates and accompanying data are displayed in Fig. 32 and Table 16 respectively; the Rolling Plains transect is presented as Fig. 33. Fig. 32 includes low altitude photography (right), regional LANDSAT-1 imagery (lower left), and enlarged LANDSAT-1 imagery (upper left).

Low Altitude Photography. The Rolling Plains contain gently sloping, moderately dissected uplands in the northeast. Southward, the uplands are not as dissected. Floodplains are narrow throughout with short tributaries generally confluencing at right angles.

Upland drainage is good with short tributaries displaying dendritic patterns. Gullies are U-shaped in the northeast on moderately dissected slopes. In the south, gullies are widened toward the main stream with steep slopes and flat bottoms (Fig. 32). Stream channels are loaded with sediments and the exact channel bed may be indiscernable, especially in the northern extent. Some major streams have abrupt direction changes against dissecting bluffs.

Small bush vegetation predominates the region. Larger bushes are present on the stream slopes and in the bottomlands. These larger bushes, probably salt cedar, are more widely spaced. In undisturbed upland areas bush-grass associations are widespread.

In the southern portion, the undisturbed uplands are finely textured light gray (Fig. 32). In the more dissected northern uplands, tones are mottled, almost reticulated light ridge tops with rough textured gully slopes. Bottomlands are darker gray with more dense vegetation. Cultivation adjacent to the streams yields mottled light tones. Gravel strip mining in the southern areas is light colored.

Road networks are generally rectangular in nature with ranching operations located at road intersections or adjacent to the floodplain. Numerous floodwater retarding structures are evident in the northern area on the short, incised tributaries. Land treatment measures are also present in the form of windbreaks and contouring. In the south, some farming takes place on the ridges.

Satellite Imagery. Imagery of the south central portion of the region was obtained for late summer. A distinct corridor is evident around the Double Mountain Fork of the Brazos River in Stonewall County (Fig. 32). The color and texture are different from surrounding areas and appear to provide a southeast-northwest corridor of uncultivated land. This corridor could be an important ecological migration route or ecotone. Surface water is not regionally abundant in the area.

FIG. 32. - Rolling Plains, Double Mountain Fork Brazos River, Stonewall County, Texas. Low altitude photography on right is at a scale of 1:20,000 and was taken March 27, 1970. The LANDSAT reproductions were from a color composite of bands 4, 5 and 7, and are at a scale of 1:1,000,000 in lower left and 1:250,000, upper left. The braided stream pattern in the river indicated high sediment load. The U-shaped gullies indicate a more resistant material above the shale.

LANDFORMS	Uplands		Floodplain	
LANDUSE	Rangeland	Rangeland	Agricultural Cropland	Rangeland
PLANTS	Pasture Grasses inc. Bluestem Sideoats Gramas Also inc. Scattered Shrubs		Bottomland Hardwoods inc. Cottonwood Hackberry Also inc. Grasses	
ANIMALS	Predators Upland Game Birds Rodents		Predators Furbearers Whitetailed Deer Turkey	

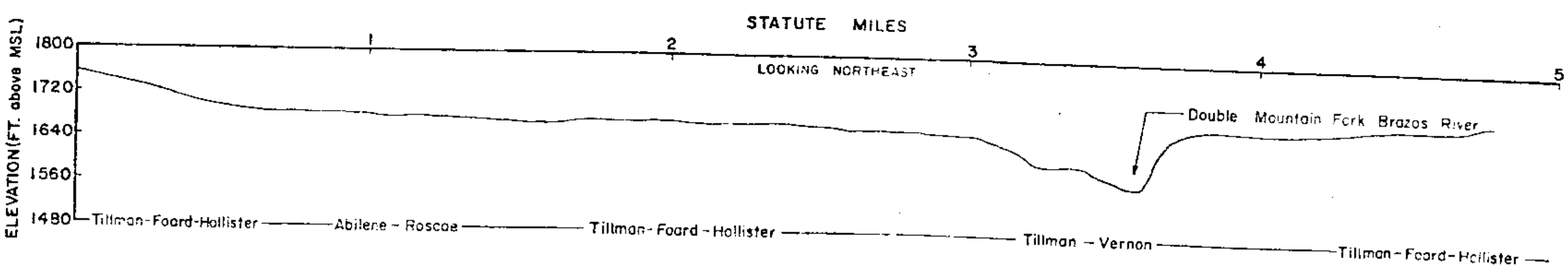


FIG. 33.- Rolling Plains Transect, Double Mountain Fork Brazos River, Stonewall County, Texas.

Table 16. - Rolling Plains, Double Mountain Fork, Brazos River, Stonewall County, Texas.

Landform (1)	Airphoto Pattern Elements (2)	LANDSAT-1 Elements (3)
Floodplain	Narrow floodplain confined to stream channel. Short tributaries enter main stream at right angles. Drainage is good. Severe gully erosion near confluence with main channel. Finely textured brush grass association. Some larger bushes in gully areas. Gray tones with light colored erosional features. Strip mining in proximity to stream.	Entire river area has much lighter tone than surrounding areas. Cultivation adjacent to streambed is evident. Light colored stream channel evidence of siltation. Relatively large surface water impoundment east of transect.
Uplands	Gently sloping uplands with incised gullies near major tributaries. Drainage is short and good. Severe erosion in short gullies with flattened bottoms. Largely grasses with encroaching brush. Cultivation adjacent to streams. Largely gray with light cultivated areas and dark bushes.	Darker areas with patchy cultivation. Light colored areas appear to provide an east-west corridor of similar habitat. Cultivation is more intense northeast of the transect site.

Soils & Origin (1)	Description and Location (2)
Tillman-Vernon (Alluvial)	Friable noncalcareous to weakly calcareous clay, clay loam, or loam, 5-11 in.,over very firm noncalcareous clay to unweathered calcareous shale or shaly clay at 8-15 in. below the surface.

Table 16. - Continued.

Soils & Origin (1)	Description and Location (2)
Abilene-Roscoe (Terrace)	Friable neutral to alkaline clay, clay loam, or loam, 6-12 in., over friable subangular blocky noncalcareous clay or firm weak blocky calcareous clay, grading with depth into firm blocky calcareous clay over soft caliche or $CaCO_3$ horizon with depth.
Tillman-Foard-Hollister (Residual)	Friable neutral to mildly alkaline clay or clay loam, 5-12 in., over very firm blocky neutral to slightly alkaline clay or friable blocky subangular alkaline silty clay, grading into friable to firm blocky weakly to strongly calcareous clay with a horizon of $CaCO_3$ below 35 in.

Community Location (1)	Ecological Factors (2)
Bottomlands	Limited to narrow borders along the streams, several hardwood species are sparsely present. Occasional cottonwood or hackberry tree with little understory and poorly developed grasses predominant. White tailed deer are present in low numbers as are turkey and squirrels. Other furbearers include coyote, bobcat, badger, raccoon and gray fox are sometimes present in the bottomlands. Patches of buffalo grass and curly mesquite may be the only inhabitants of eroded gulleys.
Uplands	Pasture grasses include bluestem, sideoats, blue grama, switchgrass, dropseed, and lovegrass. Scattered shrubs are present in some areas. Cultivation on deeper soils of cotton, grain sorghums and some wheat. Predators such as coyote are sparse. Rodents are present in moderate numbers. Heavily used as pastureland which restricts populations of quail.

Table 16. - Continued.

Data Source (1)	Acquisition Source (2)
Low-Altitude Photographs March 1970 COH-2LL-251, 253, 235, 236	Western Aerial Photography Laboratory Program Performance Branch ASCS-USDA 2505 Parley's Way Salt Lake City, Utah 84019 Tel: AC 801, 524-5826 Price: $2.00 each
LANDSAT-1 8-10-73 81383164645G200-C (False Color Composite)	EROS Data Center Data Management Center Sioux Falls, South Dakota 57198 Tel: AC 605, 594-6511 FTS: AC 605, 594-6151 Price: $7.00 per color composite
Topographic Map 1962 Frog Mountain Quadrangle 1:24000	Texas Water Development Board Topographic Mapping Section P. O. Box 13087 Austin, Texas 78711 Tel: AC 512, 475-3191 Price: Free to State Agencies or Contractees
Soils Map 1963 Stonewell County Soils Map 1:145000	Texas Agricultural Experiment Station Texas A&M University Reed-McDonald Building College Station, Texas 77843 Tel: AC 713, 845-2413 Price: Free, limited to twelve per customer

Table 16. - Continued

Data Source (1)		Acquisition Source (2)
Biological Inventories	Stonewall County Game Survey 1968	Texas Parks and Wildlife Department John H. Reagen Building Austin, Texas 78701 Tel: AC 512, 822-4631 Price: Free
	Natural Resources Study 1973	Nortex Regional Planning Commission 2414 9th Street Wichita Falls, Texas 76301 Tel: AC 817, 322-5281 Price: Free
	Soil Survey of Stonewall County Jan 1975	United States Department of Agriculture Soil Conservation Service P. O. Box 2460 Abilene, Texas 79604 Tel: AC 817, 773-1771 Price: Free

Trans-Pecos

General Description

West of the Edwards Plateau and south of the High Plains is the Trans-Pecos physiographic region. Its eastern edge is the Rio Grande River and is contained between 102° and 106°30' longitude and 29° and 32° north latitude (Fig. 6, p. 36).

This area contains the highest point in the state, 8751 feet (2667m), and ranges in elevation to 2500 feet (762 m). Annual precipitation increases from 8 inches (20 cm) in the west to 14 inches (36 cm) in the east. Evaporation decreases from southwest to east from 90 to 70 inches (229 to 178 cm) (44).

The Edwards Plateau overlies recent deposits but the regolith is shallow and sandy in some areas exposing tertiary formations. Mountains are undifferentiated igneous rock and the extreme south bend area contains some cretaceous exposure. Upland soils are light reddish brown to brown clay loams, clays and sands (mostly calcareous, some saline) over reddish, loamy to clayey calcareous, gypsic or saline subsoils. Former areas are dark grayish brown to reddish brown, silt loams to clayey calcareous, alluvial soils (some saline).

Regionally, vegetation varies from oak, pinion, and ponderosa pine forest in the mountains to short grasses and desert shrubs (including salt cedar) in the plains. Bottomlands contain bunch grasses, mesquite and desert shrubs (44). Some cultivation occurs in bottomland areas where the salt content is low enough.

Game species include deer, quail, antelope, mourning dove, fur-bearers, squirrels, bobcats, coyote, mule deer, and mountain lion (29,16).

These species are not considered abundant since approximately 95 percent of the area is rangeland (44).

Environmental Impact Reviews

Since most of the region is used for rangeland, vast wildlife areas are available. However, the long grazing history of domestic animals and habitat removal by bottomland cultivation has made wildlife scarce throughout the area (23). Locally,abundant habitats are available in the mountainous areas and in Guadalupe Mountains State Park. In the north central area (Culberson and Hudspeth Counties) only a small fisheries resource exists because of extended droughty periods.

Reservoirs. Alpine Lake Project south of Alpine, Texas may well be typical of impoundments throughout the region. It proposes the construction of a 12,710 acre-feet (15.7 million m^3) reservoir for flood control, municipal and industrial water supply,and general recreation. Also, a 16,000-foot (4880 m) diversion structure was included to divert discharges from an adjacent stream (23). The project will undoubtedly enhance the human environment by providing recreation facilities and decreasing groundwater depletion by providing a surface water supply. Wildlife will benefit through the creation of a fisheries resource and water supply.

Elsewhere in the region, the creation of a permanent surface water supply may be more difficult to justify. The ephemeral mountain streams of the watershed channel flash flood flow directly into the city of Alpine. Population concentrations in the proximity justify a regional recreation resource. Also, construction materials are available locally (23).

The newly created reservoir will provide a fisheries resource where none existed. Therefore, no loss of present resource will be realized. Recreation pressure will preclude extensive use of the reservoir for wildlife enhancement. Downstream, flood protection and dependable water supply will encourage future development and municipal expansion with their attendant environmental problems.

Channelization. Channel works in this region are unusual in that they normally entail diversion canals for overland floodwater interception over large areas. Unlike conventional channelization works that involve existing, natural drainage ways. Two of these canals were proposed, one 1300 foot (396 m) near El Paso and a 55,000 foot (16,800 m) one to the east in Culberson County (29, 16) (Fig. 34). This type of structure is used in this region because of the high intensity, short span precipitation patterns.

Construction of these diversion canals received very little impact assessment. A lengthy canal of this sort would effectively alter wildlife movement and social patterns by dividing large tracts of land, (especially in the Three Mile Creek Project). The receiving streams would also be subjected to altered flood flows and scouring.

However, wildlife abundance may not be noticeably affected because of the low existing populations. The human environment on the other hand, would be materially benefited in both cases by flood protection and increased production potential.

Land treatment measures are largely ineffective within the region, again because of the intensity and duration of flood flows.

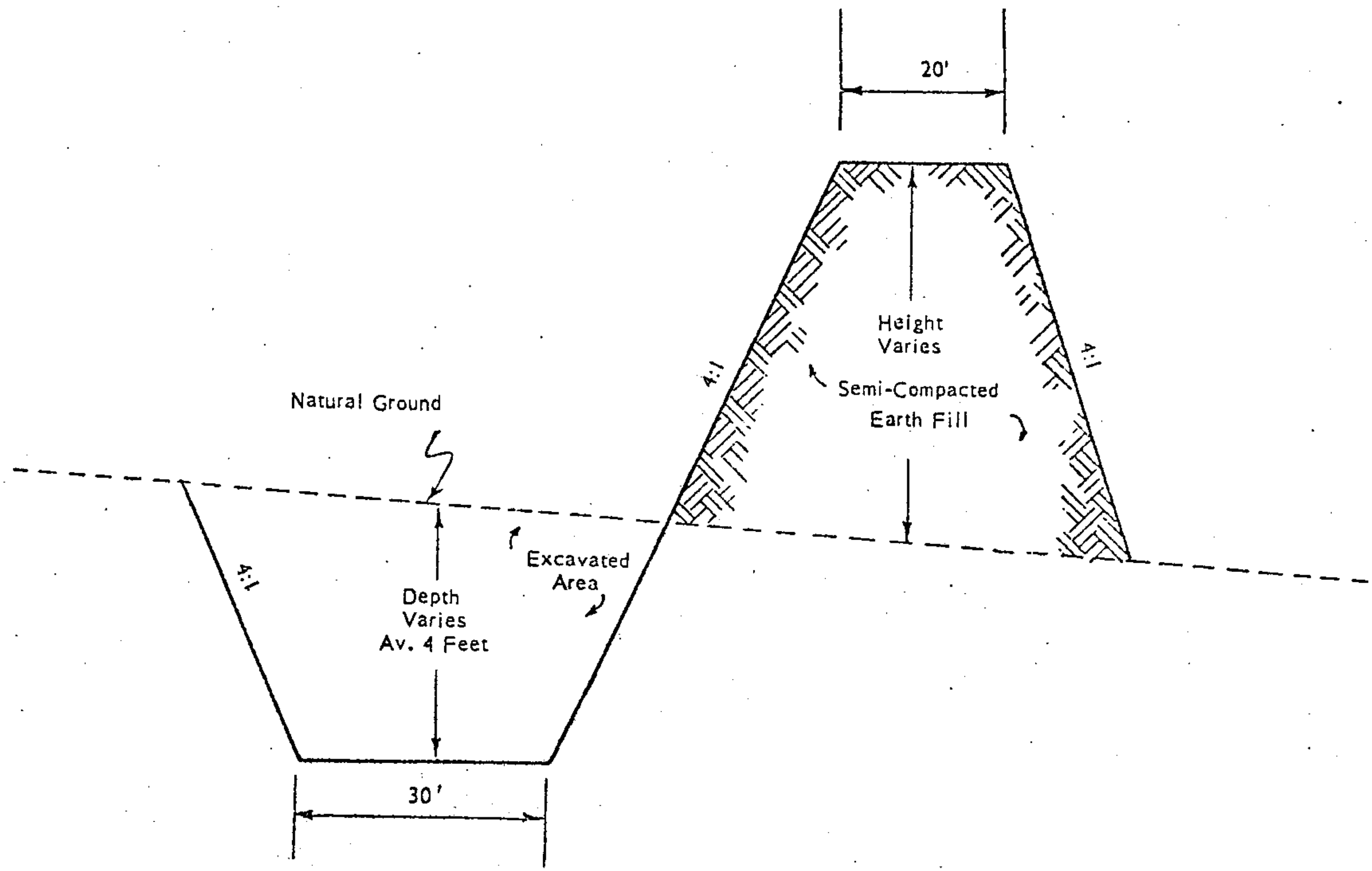


FIG. 34 .- Typical Cross Section, Floodwater Diversion, Trans-Pecos Physiographic Region (16).

Environmental Assessment Procedures. (1) A repeated reliance on minimal impact because of depressed wildlife populations was noted.
(2) The enhancement of the human environment overrides minimal adverse impacts as described in (1) above.
(3) No extensive wildlife inventories were taken, dependence on secondary data was adequate. The El Paso Local Protection Project included an extensive secondary data list of indigenous species (29).
(4) Regional aspects of development are negligible because of vast amounts of similar habitat.

Summary of Environmental Impact Reviews. (1) An almost complete lack of alternative development was apparent.
(2) The small amount of environment assessment of the extensive channelization works in the three-mile Creek Project was inconsistent with even the most scarce wildlife resources.
(3) Generally, water development in the Trans-Pecos provides enhancement of the human environment as well as creating and supplementing wildlife habitat.

Diagrammatic Transects and Accompanying Data

Remote sensing plates and accompanying data are displayed in Fig. 35 and Table 17 respectively; the Trans-Pecos transect is presented as Fig. 36. Fig. 35 includes low altitude photography (right), regional LANDSAT-1 imagery (lower left), and enlarged LANDSAT-1 imagery (upper left).

Low Altitude Photography. The Trans-Pecos area is characterized by gently to steeply sloping uplands with moderately to deeply dissected slopes. Floodplains are relatively broad (Fig. 35).

Upland areas are well drained in the west but retain some internal drainage in the eastern extent. Western drainage is parallel arroyos with short feeder streams. Bottomlands are well to moderately drained. The Pecos River floodplain has meander scars and some slackwater areas.

Erosional features consist of dissected upland slopes. Gullies are V-shaped on slopes throughout the region and in the arroyos of the west. Some arroyos are highly braided. Eastern streams are rectangular shaped with numerous meanders.

Creosote bush is dominant throughout the region and spots the uplands with small evenly spaced vegetation. Western arroyos have slightly more dense growth and the eastern internal drainage pools have the most dense vegetation (Fig. 35). Cultivated crops appear in bottomlands in some areas.

Photographic tones are generally light throughout to slightly darker in bottomlands. Stream sediments are light colored in contrast to streamside vegetation.

Cultural features are sparse throughout the region. Road networks parallel streams on high ground whenever possible. Farming operations may be located at the base of upland slopes or on uplands. Cultivation is more intense in floodplains or where canals are present.

Satellite Imagery. Imagery of the eastern portion of the region reflects agricultural concentrations in the floodplain in both spring and fall photographs. This is located mostly on the western bank of the

Pecos. A sharp contrast is evident of lightly mottled area to the east of the Pecos River and the heavily dissected western bank (Fig. 35). Analysis of the photograph may point out the ecological significance of the Pecos as a range limit to many species. It may be an ecotone area of considerable taxonomic importance. The nature and regional importance of the floodplain are emphasized in the enlargement (Fig. 35).

FIG. 35. - Trans-Pecos, Pecos River, Ward and Reeves Counties, Texas. This figure includes low altitude aerial photography (stereopair on right), taken January 1, 1960, at a scale of 1:20,000. The LANDSAT-1 imagery at left was reproduced from a color composite of bands 5, 6 and 7 at a scale of 1:1,000,000 (lower left) and 1:350,000 (upper left). The LANDSAT-1 imagery was taken October 23, 1973. The dark vegetation along the drainage channels help delineate the drainage pattern on the LANDSAT-1 imagery. In the stereopair the light toned soils tend to be sandy.

LANDFORMS	Upland	Terrace	Floodplain	Terrace	Upland
LANDUSE		Poor Quality Rangeland	Isolated Cultivation	Poor Quality Rangeland	
PLANTS		Dessert Shrub Grassland inc. Threeawns, Sand Dropseed, Creosote Bush	Mesquite-Salt Cedar Bottoms	Dessert Shrub Grassland inc. Threeawns, Sand Dropseed, Creosote Bush	
ANIMALS			Cottontail Rabbit, Gray Fox, Kit Fox, Moutain Lion (R), Skunk; Mule Deer, Jackrabbit, Bobcat, Raccoon, Badger		

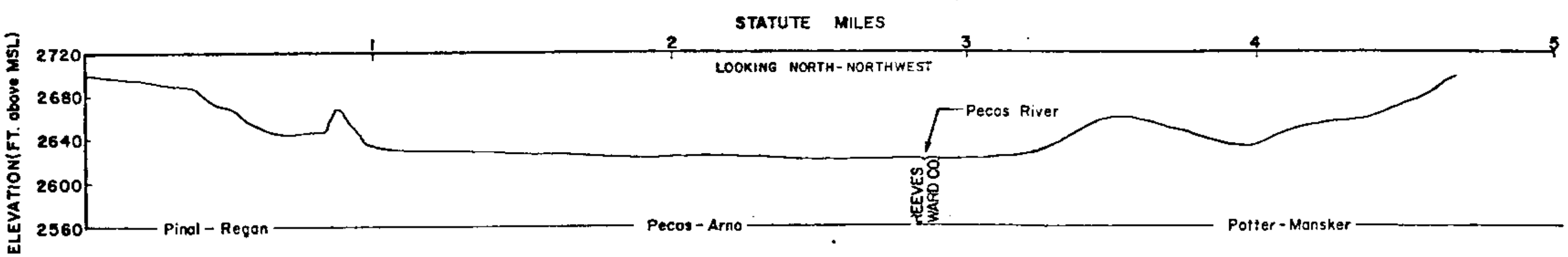


FIG. 36.- Trans-Pecos Transect, Pecos River, Ward and Reeves Counties, Texas.

Table 17. - Trans Pecos, Pecos River, Ward and Reeves Counties, Texas.

Landform (1)	Airphoto Pattern Elements (2)	LANDSAT-1 Elements (3)
Floodplain	Broad floodplain with few drainage gulleys. Meandering river has many slackwater areas and meander scars. Gullies leaving the uplands tend to flatten and loose distinct flow patterns after entering floodplain. Brush vegetation throughout with few hardwoods adjacent to stream. Cultivation scars present. Light colored soils darkened by bush vegetation.	Broad floodplain is clearly evident. Parallel drainage from the west slope may indicate major physiographic or soil delineation by river channel. Sparsity of adjacent dark tonal quality emphasizes regional importance as a quality habitat area. Enlargement shows the transition area aspect as western floodplain is much larger than abrupt eastern slope.
Uplands	Terraces are present in some areas but difficult to separate from uplands. Uplands are well drained, gently to moderately rolling, with clear delineation at floodplain. Drainage is dendritic to parallel on slopes to internal in many areas. Vegetation sparse except in low upland internal drainage areas. Soils are light colored except where darkened by patchy vegetation.	Parallel patchy nature of uplands is evidence of rolling nature with internal drainage and dense shrub vegetation. Cultivation appears in lower left of regional view. Mottled tones of eastern side contrast with drainage patterns of western uplands.

Soils & Origin (1)	Description and Location (2)
Pecos-Arno (Alluvial)	Crumbly strongly calcareous and frequently saline clay to clay loam, 8-20 in., over strongly saline clay or firm subangular blocky clay with embedded crystallized salts. (Below Elev. 2650 ft)

Table 17. - Continued.

Soils & Origin (1)	Description and Location (2)
Potter-Mansker (Fluvial)	Friable and frequently calcareous loam, sandy loam, or clay loam, 4-12 in., over friable strongly calcareous clay with $CaCO_3$ concretions in lower part or caliche, hard to soft and chalfy with depth. (East bank above Elev. 2650 ft)
Pinal (Gravelly)-Reagan (Upland Soils)	Friable calcareous gravelly sand loam, silty clay loam or silt loam, 4-12 in., over friable strongly calcareous sandy loam or granular silty clay loam, underbedded by caliche cemented gravel or 50-70% $CaCO_3$ friable chalk. (West bank above Elev. 2650 ft)

Community Location (1)	Ecological Factors (2)
Bottomlands	Salt cedar, grasses, forbs are all understory species usually at a minimum density. High saline content of soil prohibits cultivation in most areas. White tailed deer as transients are occasional visitors to these areas. Scaled quail, mourning dove, coyote, bobcat, as well as other furbearers such as raccoon, ringtail cat, opossum and badger are all somewhat restricted to the denser areas of salt cedar bottomlands.
Uplands	Extremely sparse vegetation except in mesquite draws. Where sufficiently dense all species inhabitating salt cedar bottomlands may be found in this draw. Some jackrabbit present elsewhere.

Table 17. - Continued

Data Source (1)	Acquisition Source (2)
Low-Altitude Photographs Jan 1960 — DWR-6AA-24, 25; DWS-5AA-122, 121	Western Aerial Photography Laboratory Program Performance Branch ASCS-USDA 2505 Parley's Way Salt Lake City, Utah 84019 Tel: AC 801, 524-5826 Price: $2.00 each
LANDSAT-1 10-23-73 — 81457165655G200-C (False Color Composite)	EROS Data Center Data Management Center Sioux Falls, South Dakota 57198 Tel: AC 605, 594-6511 FTS: AC 605, 594-6151 Price: $7.00 per color composite
Topographic Map 1961 — Sand Lake and Sada Lake Quadrangles 1:24000	Texas Water Development Board Topographic Mapping Section P. O. Box 13087 Austin, Texas 78711 Tel: AC 512, 475-3191 Price: Free to State Agencies or Contractees
Soils Map 1963 — Ward and Reeves County Soil Maps 1:139000 1:270000	Texas Agricultural Experiment Station Texas A&M University Reed-McDonald Building College Station, Texas 77843 Tel: AC 713, 845-2413 Price: Free, limited to twelve per customer

Table 17. - Continued.

Data Source (1)		Acquisition Source (2)
Biological Inventories	Permian Basin Game Management Study 1960	Texas Parks and Wildlife Department John H. Reagen Building Austin, Texas 78701 Tel: AC 512, 822-4631 Price: Free
	Regional Academic Inventory Undated	Arthur H. Harris Museum of Arid Land Biology Department of Biology Univeristy of Texas at El Paso El Paso, Texas