Texas Coastal Management Program

PILOT STUDY OF THE ACTIVITY ASSESSMENT ROUTINE ECOLOGICAL SYSTEMS COMPONENT

Technical Paper No. 2

RPC, Inc.
Austin, Texas

August 1978

This is one of a series of technical papers concerning the activity assessment routine, which cover a variety of topics. For information concerning other technical papers in this series, or to order more copies of this paper, contact:

Elizabeth Christian Wilds
RPC, Inc.
1705 Guadalupe
Austin, Texas 78701

This program is funded in part through financial assistance provided by the Coastal Zone Management Act of 1972, administered by the Office of Coastal Zone Management, National Oceanic and Atmospheric Administration.

The ESC procedures described in this pilot study represent substantial refinements to those described in the draft ESC user's manual (July 1978). These revisions have been included in the final ESC user's manual (August 1978).

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF EXHIBITS

LIST OF TABLES

FINDINGS

Use of the ecological systems component of the activity assessment routine has been tested and demonstrated in a pilot study assessment of a proposed dredging project in Matagorda Bay. The ecological impacts of the project were assessed; the time, personnel, and data requirements for the assessment were identified; refinements to the methodology were made; and the ESC was evaluated in terms of its ability to meet the objectives of impact assessment and satisfy federal environmental report requirements. The findings of this study are:

1. The ESC provides a suitable statement of impacts comparable to that contained in the joint environmental report prepared for the proposed project; the analysis supports the statement of significant impacts prepared by the project sponsors.

2. The ESC is a better method of presenting the impacts in a format for interpretation by the policy makers.

3. The ESC provides better documentation of the ecological factors and impacts considered for legal purposes.

4. Time, manpower, and data requirements, and hence, overall costs to use the ESC as an analytical tool, are approximately the same as existing methodologies and would not lengthen the permitting process.

5. The ESC can be further refined and improved; however, it can be practically used in its present state where relevant in the permitting process.

6. The ESC can be used to partially fulfill federal environmental report requirements for assessment of ecological impacts.

ABBREVIATIONS

AAR - activity assessment routine

DO - dissolved oxygen

ER - environmental report

ERA - Energy Regulatory Administration

ESC - ecological systems component of the activity assessment routine

ESD - ecological systems diagram

FEIS - final environmental impact statement

FERC - Federal Energy Regulatory Commission

FPC - Federal Power Commission

JER - joint environmental report; specifically, Joint Environmental Report Respecting the Proposed Algeria II Project, Docket Nos. CP 73-258, et al., Vols. I-III, March 1, 1977, filed by the El Paso Eastern Company, El Paso LNG Terminal Company, and El Paso Natural Gas Company, with the Federal Power Commission

LNG - liquified natural gas

mg - milligram

mg/l - milligrams per liter

PEA - primary ecological alteration

ppm - parts per million

ppt - parts per thousand

TLM - total lethal minimum

TNRIS - Texas Natural Resources Information System

ACKNOWLEDGMENTS

RPC, Inc. wishes to acknowledge the efforts of the contributors to this report. The principal-in-charge was Ron Luke. The pilot study was managed by Andrew Reed. Principal researchers were Bruce Snyder, Chris Caran, Mills Tandy, Bill Brogden, and Bill Longley. Research assistants were Steve Minick, Denise Girard, and Rob McIntyre. The technical editor was Nancy Grona. Production assistance was provided by Lori Snyder, Kim Frazier, Susan Burt, and Kyle Pierce.

RPC expresses its gratitude to the El Paso LNG Terminal Company for the invaluable cooperation of its representatives during this study and acknowledges the assistance provided by public officials and other industrial representatives.

Ron Jones, President
RPC, Inc.

1. INTRODUCTION

The ecological systems component (ESC) is one component of the activity assessment routine. It is a process for identifying the impacts of a potential activity on natural ecological systems.

The ESC was developed at the direction of the governor of Texas and the state legislature as part of the Texas Coastal Management Program. It is meant to provide a systematic method of analysis for use by permitting agencies concerned with the effects of activities on biological resources. It also provides information that will help applicants for state permits, leases, or easements know what the concerns of state regulatory agencies are and how they can be accommodated. Additional documentation of the activity assessment routine and ecological systems component are contained in the Activity Assessment Routine Ecological Systems Component Draft User's Manual and the State of Texas Coastal Management Program Preliminary Hearing Draft.

This technical paper describes a pilot study of the ecological systems component of the activity assessment routine. The paper discusses the pilot study approach, the ecological impacts of the project studied, and an analysis of the pilot study in terms of resources required, refinements made in the ESC, and an evaluation of results and the ESC methodology as an assessment technique.

PURPOSE OF STUDY

The purpose of the pilot study was to test the ecological systems component of the activity assessment routine on an activity of a proposed coastal project. The results of the pilot study will be used to refine the ESC as documented in the draft user's manual and technical manual (Texas General Land Office, 1978a, 1978b). The pilot study also identifies the information, time, and personnel required to complete such an assessment.

To accomplish this pilot test, a somewhat artificial time limit of six weeks was established for the study. The assessment is based on data that could be immediately retrieved during the allotted time. The data used as well as data that could have been applied if available will be discussed in subsequent chapters. Also, a considerable amount of system refinement was made during the pilot study. Thus, time estimates for an assessment under more typical administrative conditions are provided.

APPROACH

The project selected for the pilot study is a dredging project proposed by the El Paso LNG Terminal Company. The purpose of the dredging is to deepen and widen an existing channel and to construct an approach channel, turning basin, docking basin, and barge basin. The approach channel will provide LNG carrier access from the Gulf of Mexico to the proposed LNG terminal site on Matagorda Bay in Calhoun County, Texas.

The dredging activity of the project was selected for study because it is a typical activity over which state agencies, the General Land Office in particular, have jurisdiction. In addition, the dredging aspects of the project primarily involve ecological systems which have been modeled during the development of the ESC. For this analysis, only the initial project dredging activity is considered. Maintenance dredging and dredged material disposal would be assessed separately; assessment of maintenance dredging would be an extension of the analysis of initial dredging. The same methodology would be applied to assess the ecological effects of these and other project activities.

A current project was chosen as a test case to simulate Phase I ESC implementation conditions. However, it is not the intent of this study to prejudge either the El Paso Algeria II project or the adequacy of reports prepared by the project sponsor or by a federal agency. The pilot study is a sample analysis of a project at a fixed point in time and, due to the evolutionary nature of such projects, does not represent subsequent project design modifications. In addition, the proposed dredging is analyzed in isolation from other project activities. Consideration of both of these factors may ameliorate, mitigate, or negate impacts identified in this assessment. For this reason, impacts reported in this paper must be viewed strictly within the context of this test case. Subsequent review of this project by regulatory agencies and interested parties must include consideration of related project activities and recent design modifications.

DESCRIPTION OF THE METHOD

The ESC relies on the ecological systems diagram as the mechanism for identifying ecological cause and effect relationships. The ecological systems diagram (ESD) is a graphic model of the constituents and processes of an ecosystem. The ESD incorporates information about organisms, chemical and physical factors, substrate, morphology, hydrology, and natural processes. These data and their interrelationships are graphically depicted using an energy circuit diagram language developed by H. T. Odum (1967, 1971).

Many of the relationships of the operation of natural systems are known generally, though not quantitatively. The graphic energy circuit diagram language developed by Odum describes natural systems. It allows visualization of the functioning of all facets of systems without the need for equations or other quantification. With similarities to electrical circuit diagrams, the ecological systems diagrams illustrate pathways of energy and material flow, storages and control devices, inputs, outputs, and energy transforming units.

Odum further developed his models into predictors by using analog computer techniques. His system models were empirical and they accurately simulated the operation of natural systems. He started with a systems diagram based on known natural system relationships. By using this system model to guide him in data collection, simple quantitative relationships were derived and translated into a working analog model.

In the ESC, the treatment of ecological modeling does not go beyond the graphic model stage; but much can be derived from these models. Most important is the logical relationships between system components - how they affect each other and interact. Second, directions of change and effects on mechanisms controlling system components can be determined. Finally, poorly understood relationships and areas where information is lacking become obvious. With some quantitative information, an ecological systems diagram as an organizing tool, and good judgment, an analyst may array the potential consequences of coastal activities in the assessment and raise critical issues that should be considered in project evaluation.

Due to the generalized nature of these models, there are limitations to their use which are expressed in the following assumptions and qualifications:

1. In the absence of site-specific data, the ecosystem is assumed to be homogeneous in time and space and without external perturbations.

2. Impacts on biota are assessed at the trophic level. Impacts on biota are

estimated by using the adult life stages of selected individual species to represent behavior of a trophic level.

3. Information concerning food habits, limits of mobility, and the energy budget of an organism are often lacking. Estimates of change in energy flow made in this study, therefore, may not be and should not be considered a precedence for subsequent assessments.

4. The methodology is not developed to a level of detail which allows identification of impacts on rare and endangered species or unique habitats. These issues would require specialized analysis. A complete analysis must include these factors. The ESC can be used to provide information for this consideration.

5. The ESC calculates the incremental impact of a project.

The ESC assessment methodology consists of a series of steps diagramed in Figure 1. These steps are: activity analysis, identification of primary alterations, use of the ecological systems diagram to identify first through nth order changes in ecological attributes, impact summary, and formulation of recommendations.

ACTIVITY ANALYSIS

Activity analysis is a procedure for transforming construction and operations processes into a set of elemental physical actions that can be analyzed with the ecological systems diagram. The basic physical actions are called subactivities. Subactivities describe manipulations of the physical and biological environment which lead to alterations of ecological systems. In the pilot study, the dredging activities include three subactivities: vehicle movement and operation, substrate removal, and water pumping.

PRIMARY ECOLOGICAL ALTERATIONS

Analysis of primary ecological alterations (PEAs) is the first step in identifying the impacts of a proposed activity. Primary ecological alterations are the direct ecological effects caused by an activity at the project site. They describe a change in a subsystem (such as in biota, physical or chemical properties, or energetics) of the ecological systems diagram and are stated in terms that can be related to an aspect of an activity or subactivity. Thus, PEAs are a screening or filtering system which directs the analysis to those portions of the ecological system that are most likely to be impacted by the proposed activity (see Figure 2). Consumer removal is an example of a primary ecological alteration.

Figure 1

ECOLOGICAL SYSTEMS COMPONENT GENERALIZED ASSESSMENT SEQUENCE

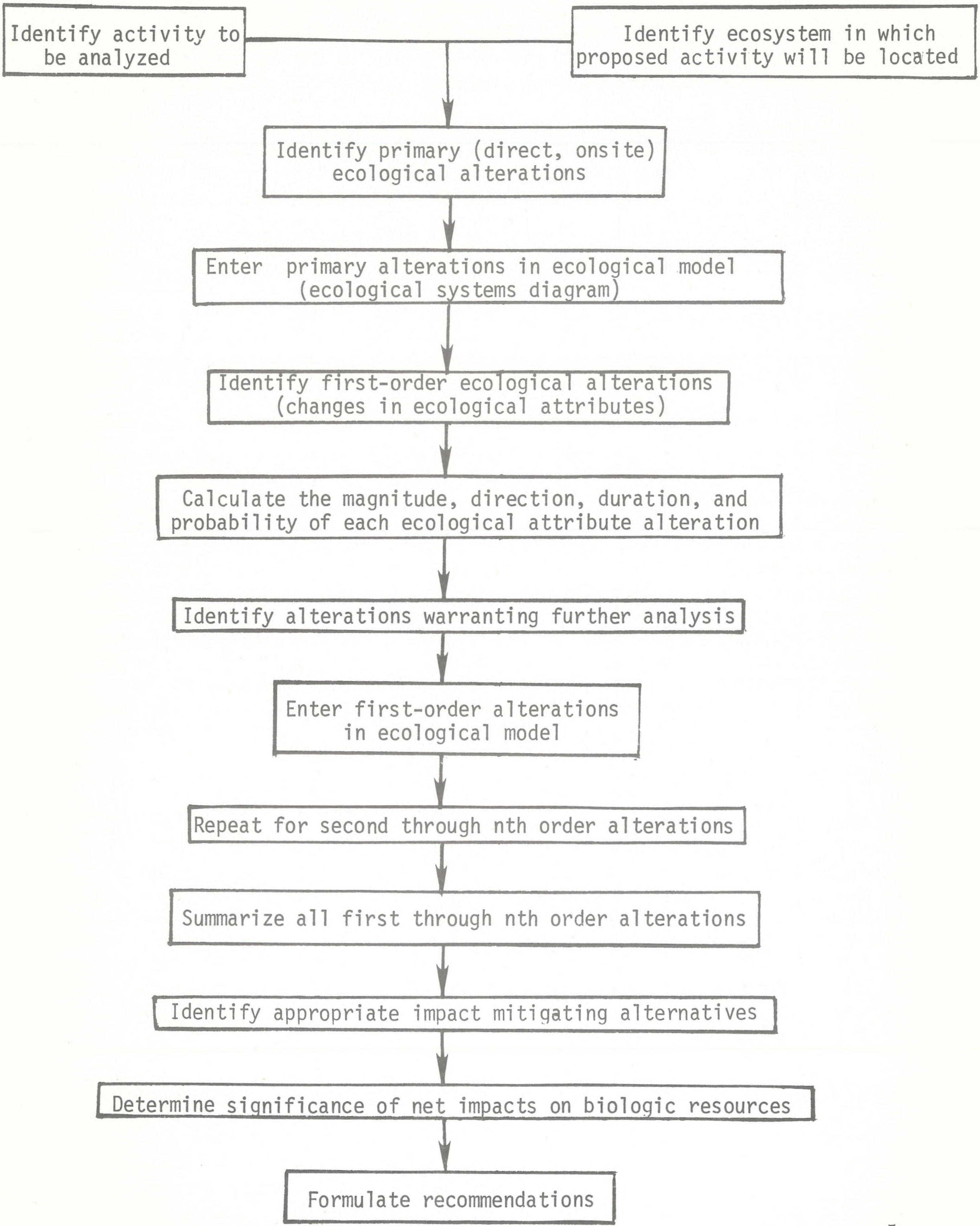


Figure 2

POTENTIAL PRIMARY ECOLOGICAL ALTERATIONS

If water flows in system, are these properties of flow increased/decreased?		Does subactivity add or remove these energies?	Are these physical properties immediately increased/decreased at subactivity sites?		Does subactivity directly add or remove these materials to/from the system? or from one place to another?		Does subactivity directly add or remove these biotic components to/from the system? or from one place to another?
Water from marine or estuarine sources	Water from land runoff	Physical effects	Subaqueous	Subaerial	Soil system	Water system	Biological effects
Water systems			Surface properties				
Rate of flow	Rate of flow	Kinetic energy to water	Water column depth	Slope (broad expanse)	Water	Inorganic materials (dissolved, colloidal, or particulate)	Vegetation removal - complete
Duration of flow	Duration of flow	Heat energy to water	Benthic sediment texture/ structure	Elevation (relative to surrounding area)	Particulate or dissolved inorganic materials (with any adsorbed molecules	Dissolved and particulate organic materials (nontoxic concentrations)	Vegetation replacement - complete
Frequency of flow	Frequency of flow	Heat energy to soil	Slope (stream grade, bottom morphology)	Texture/structure (soil)	Dissolved or particulate organic materials	Toxic materials (dissolved, adsorbed, particulate)	Vegetation removal - specific layers, parts, or species of plants
				Water infiltration rate	Toxic materials		Vegetation replacement - selected species or layers
				Soil depth			Consumer removal - complete
				Soil moisture			Consumer removal - selected species
							Consumer replacement - selected species

ECOLOGICAL ATTRIBUTE ALTERATIONS

After identifying the primary alterations resulting from the activity, each alteration is identified on the ecological systems diagram (Figure 3). The corresponding attribute for consumer removal, for example, may be the benthic community (organisms living on the bottom of a body of water). The ecological model is used to trace attribute alterations simultaneously from first through nth order changes. At each level of alteration, the magnitude, duration, direction, and probability of the attribute alterations are evaluated. Not all alterations are followed to determine subsequent alterations.

In the draft version of the ESC user's manual, few specific criteria were provided for measuring alterations, particularly for estimates of impact magnitude and duration. During the pilot study, it became apparent that criteria must be established to achieve consistency in the assessment and to clarify the determination of which do not require further analysis.

The definitions applied in the pilot study assessment are shown in Exhibit 1. These definitions represent the professional judgment of the analysts for this case and are not necessarily applicable to all cases. Such definitions should be established for each assessment performed. The format of the criteria used in the pilot study assessment is designed to produce consistent results and can be adapted to quantitative measurement when information is available.

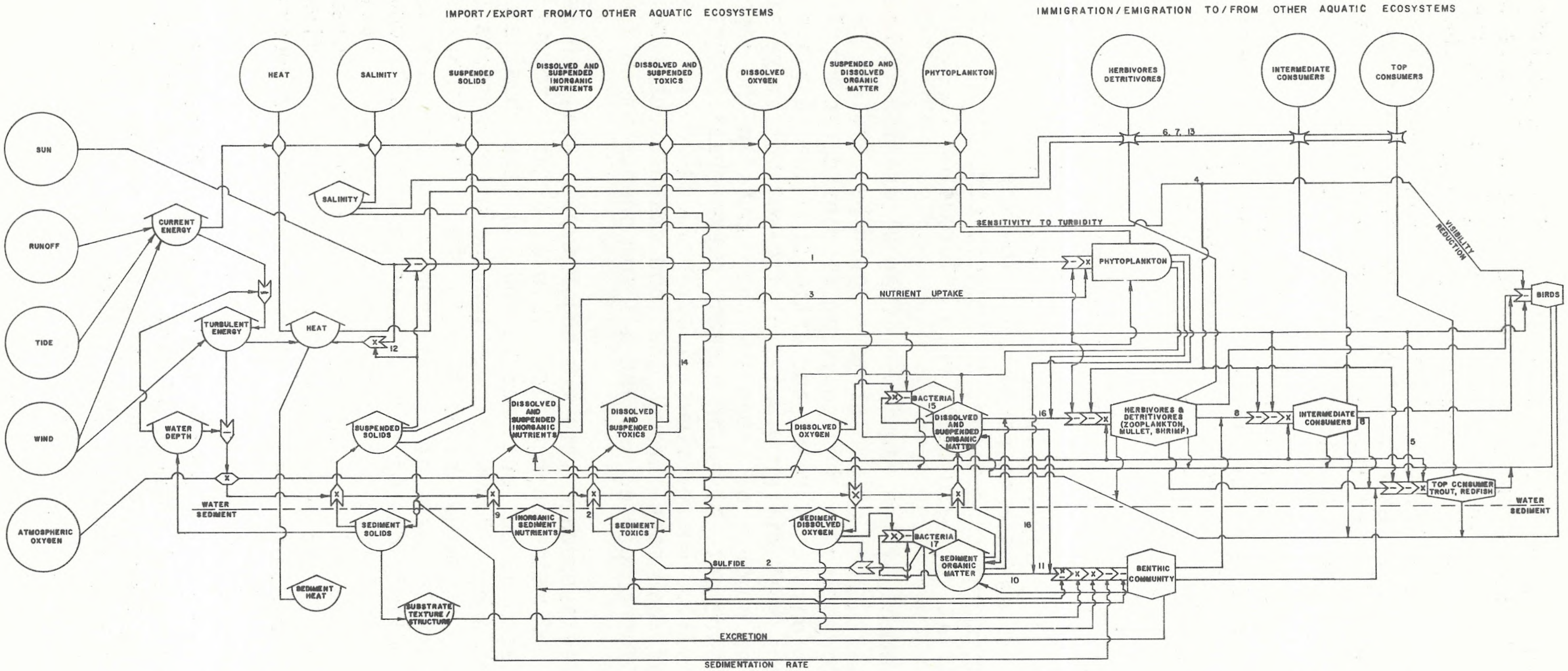
The recommended measurement of the magnitude of an alteration is based on energy flow principles. Other types of measurement could be used by the analyst. The evaluation of energy flows through the ecosystem is considered a reliable criterion for comparing the functional roles and estimating the relative importance of consumer populations that differ widely in size-metabolism relationships. Measurements based on numbers of organisms overemphasize the importance of small organisms, and measurements based on biomass overemphasize the importance of large organisms (Odum, 1971). Energy flows (i.e., production plus respiration) not only describe passage of food mass through the food chains, but also provide a more suitable index for comparing any and all components of an ecosystem.

These components readily segregate into two major types: (a) those involved in direct processing of major energy flows (biota, organic materials, and abiotic energy sources such as current energy) and (b) the physical attributes capable of controlling energy flows through the energy processors (oxygen, salinity, toxics, heat, etc.). Energy change then is the mechanism which permits the evaluation in comparable terms of system changes in many diverse functional relationships. The definitions of magnitude are determined by comparing the areal extent of an alteration (e.g., the acreage of a consumer's habitat altered or the areal extent over which an effect is caused) to the degree of alteration in energy flow (e.g., the percentage change of new energy flow from producers to the consumer compared to original energy flow from producers before habitat alteration).

The use of system energetics to evaluate functional relationships provides a mechanism for relating ecological changes of many types to one another in equivalent terms. Expressing impact magnitude in terms of energy flow changes, however, is a new concept to many people. They relate more readily to magnitude

Figure 3

ECOLOGICAL SYSTEMS DIAGRAM OF MEDIUM SALINITY BAY



1 - Armstrong and Hinson, 1973
2 - Bella, et al., 1972
3 - Bellis, 1974
4 - Bouma, 1976
5 - Bellis, 1974
6 - Copeland and Bechtel, 1974
7 - Copeland, Odum and Moseley, 1974
8 - Darnell, 1961
9 - Davies, 1975
10 - Fenchel, 1969
11 - Gray, 1974
12 - Jerlov, 1968
13 - King, 1971
14 - Lincer, et al., 1976
15 - Oppenheimer and Jannash, 1962
16 - Steele, 1970
17 - Volkman and Oppenheimer, 1962

Exhibit 1

EXAMPLE CRITERIA FOR IMPACT MEASUREMENT USED IN ANALYSIS OF EL PASO ALGERIA II PROJECT, MATAGORDA BAY

Duration

Short-term - an effect that lasts less than two years

Long-term - an effect that lasts more than two years

Magnitude

Medium Salinity Bay		Bay Transitional Area	
Magnitude Class	Definition	Magnitude Class	Definition
M1	insignificant	M1	insignificant
M2	insignificant	M2	insignificant
M3	insignificant	M3	insignificant
M4	insignificant	M4	insignificant
M5	insignificant	M5	small
M6	small	M6	moderate
M7	moderate	M7+	great
M8+	great		

(See Figure 4 and Table 1 for magnitude classes.)

Direction

Increase - an addition or enlargement of materials or energy

Decrease - a removal or reduction of materials or energy

Probability

Definite - certain to occur

Probable - may occur; supported by evidence strong enough to establish presumption but not proof

Possible - may or may not occur; evidence not strong enough to establish presumption

NOTE: These definitions represent a professional judgment by the analyst for the project. Because analysts may vary in their interpretations, these definitions should not be used as a standard for future assessments.

as expressed in terms of changes in a physical process, in numbers of organisms, or in changes in total biomass per unit area. Theoretically, it is possible to convert changes in energy flow to changes in numbers of organisms. Practically, however, the present state of quantitative ecological investigations and the availability of data needed to make such transformations is available for only some species and habitats and may be difficult and expensive to obtain. Therefore, a change in a specific number of organisms (i.e., consumers of various trophic levels) cannot be readily calculated with available data. Additional research is required to devise a technique to convert energy flow to numbers of organisms. This concept is discussed further in Chapter 4 of this report.

Matrices have been prepared to evaluate the magnitude of an alteration based on changes in energy flow. Professional judgment and expertise are used to interpret these matrices.

The matrix used in the pilot study to estimate the magnitude of a change in an attribute is shown in Figure 4. This matrix identifies zones or "classes" of magnitude change. Each class represents a range of change in energy or a proportional change in the attribute and a range of area over which the change takes place. The energy change and areal increments between magnitude classes are expressed logarithmically to capture the wide range of potential alterations and to provide equal proportions of change between classes. The slope of the line is such that the product of area times energy change per unit area is constant. In other words, the total change within an entire ecosystem is the same for a one percent change over 1,000 acres, a 10 percent change over 100 acres, or a 100 percent change over 10 acres.

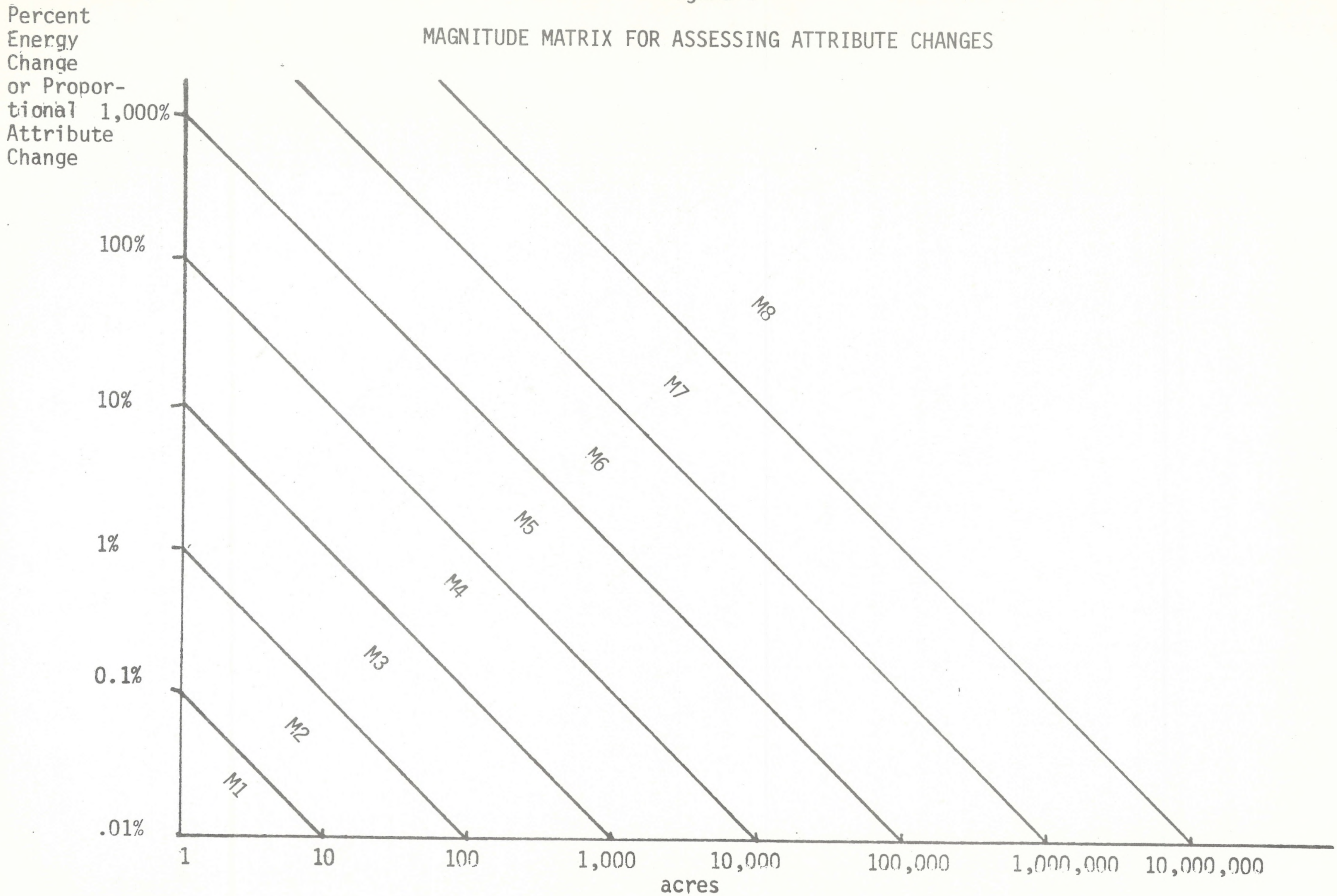
Each class is assigned a number (e.g., M1, M2) and these class designations remain constant for all analyses. The first step in using the magnitude matrix is to determine the number of classes the analyst wishes to distinguish in estimating magnitude for each ecosystem being analyzed. This determines the levels of detail the analysis will represent. Theoretically, all the magnitude classes (M1 through M8+) could be used. However, in dealing with larger ecosystems, it may be unnecessary to distinguish smaller magnitude impacts. This is an important judgment because it determines that impacts smaller than a given size (e.g., M5 through M1) (a) will be considered not significant and (b) will not be analyzed. This decision, in the pilot study, was based on a consensus of the analysts involved, the size of the ecosystem being analyzed, and the general capacity of the analysts to distinguish smaller impacts based on available data. The primary objective in making this decision was to ensure that significant alterations were not overlooked. The classes included in the medium salinity bay and bay transitional area magnitude judgments are shown in Figures 5 and 6.

In using the matrices to evaluate the magnitude of a change in energy, a set of formulas is used. These formulas are documented in the ESC user's manual. The analyst uses the formulas to calculate percent change in energy flow resulting from an altered producer or consumer. They include, where appropriate, terms to represent the range of a consumer's mobility and percent of diet altered.

The percent change in energy derived from the formulas and the area of alteration are plotted on the magnitude matrix. The magnitude class in which that alteration is located is recorded on the assessment worksheet.

Figure 4

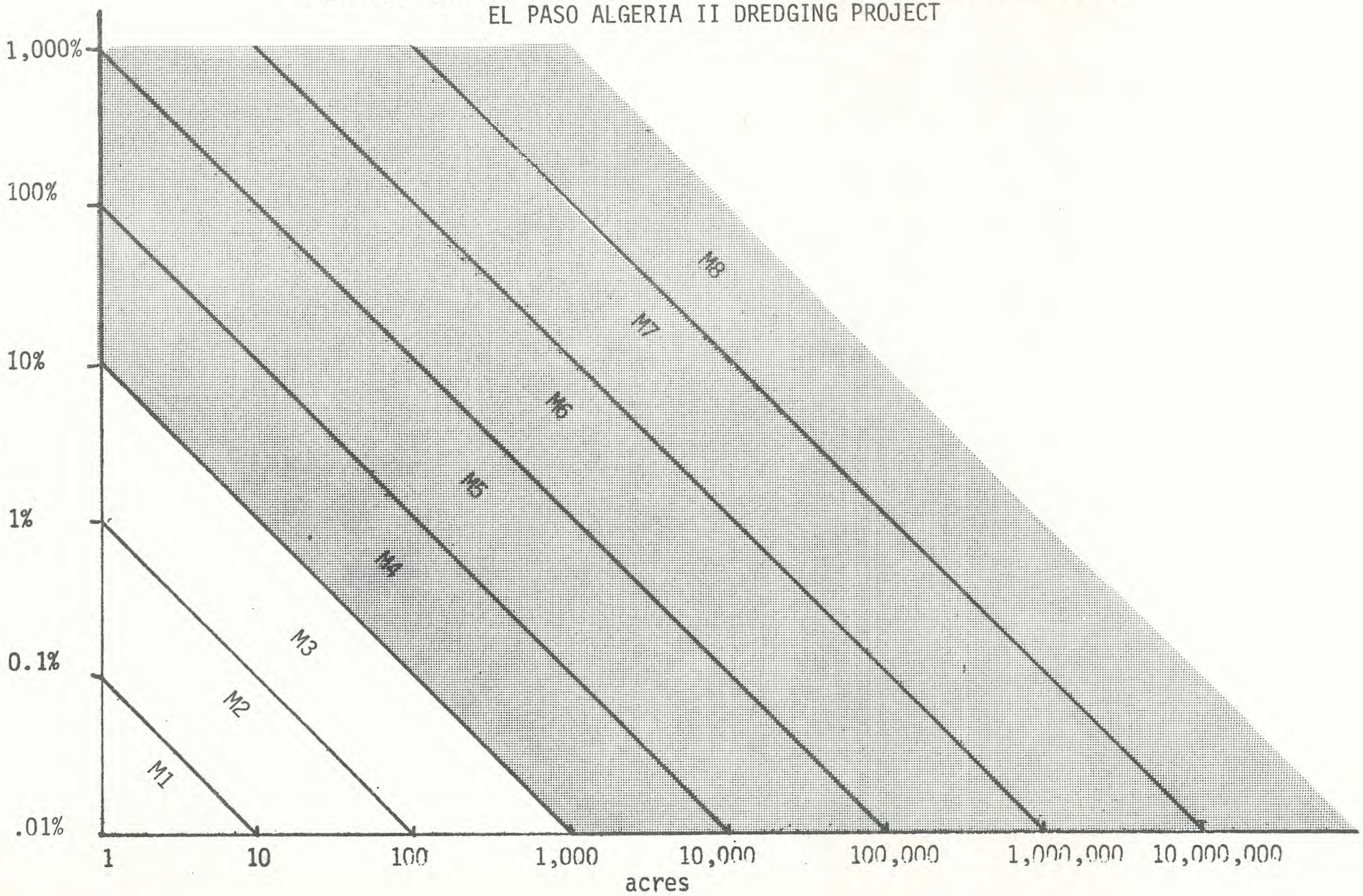
MAGNITUDE MATRIX FOR ASSESSING ATTRIBUTE CHANGES



This matrix is used for assigning magnitude class to an attribute alteration. Changes in attributes which process energy or can be translated into energy flow equivalents are evaluated in percent energy change. Attributes which do not have energy change equivalents are evaluated in proportional change of the attribute. Either estimate of percent change can be plotted on this matrix.

Figure 5

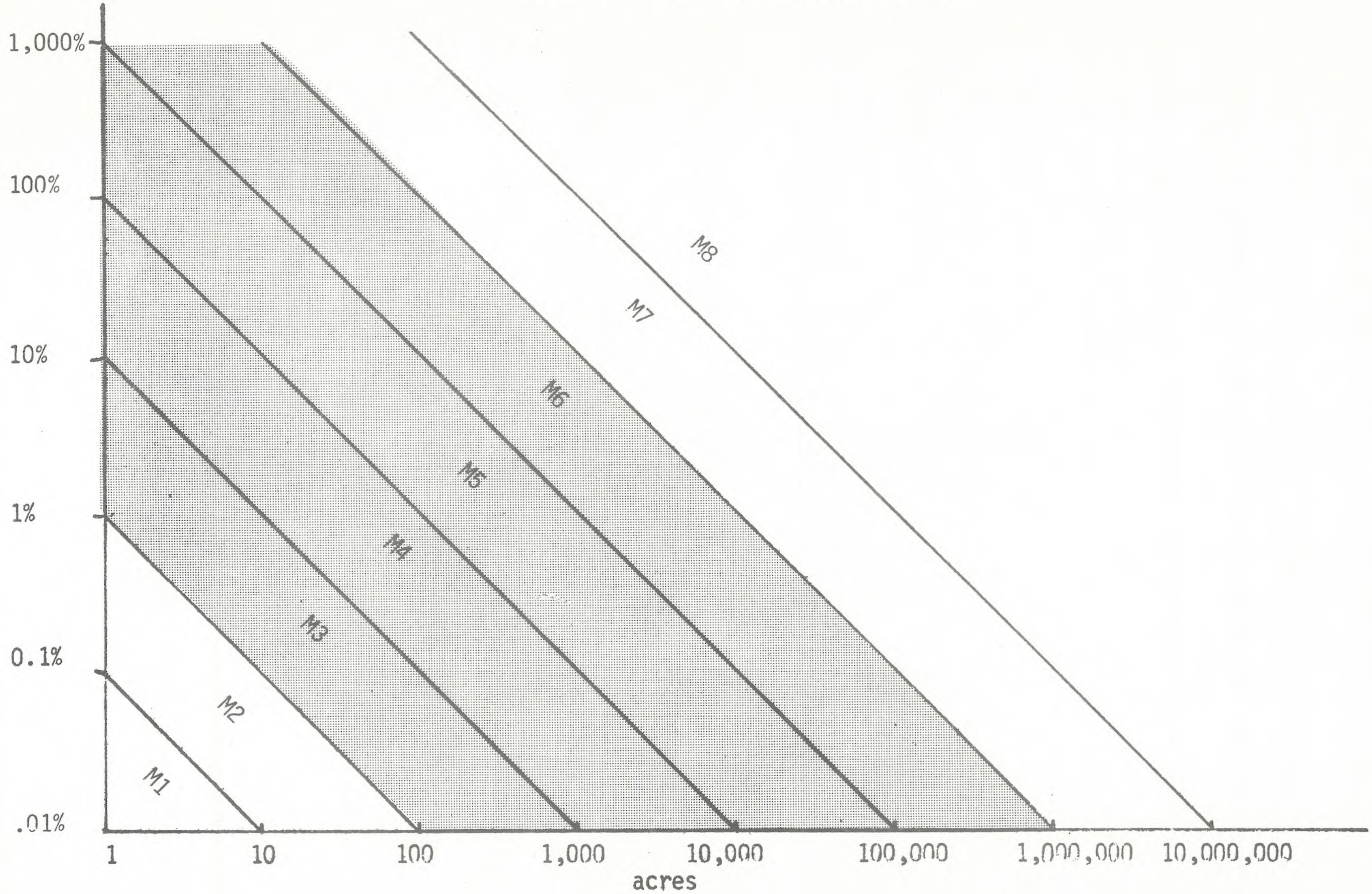
MAGNITUDE CLASSES DISTINGUISHED IN MEDIUM SALINITY BAY ASSESSMENT
EL PASO ALGERIA II DREDGING PROJECT



Note: This represents a professional judgment by the analyst for this project. Because analysts may vary in their interpretations, this should not be used as a standard for future assessments.

Figure 6

MAGNITUDE CLASSES DISTINGUISHED IN BAY TRANSITIONAL AREA
EL PASO ALGERIA II DREDGING PROJECT



Note: This represents a professional judgment by the analyst for this project. Because analysts may vary in their interpretations, this should not be used as a standard for future assessments.

The magnitude of a change in attributes which affect energy processing by Class A attributes, but which do not themselves constitute main-line energy processors, must be determined indirectly. Generally, changes in Class B attributes are described initially in absolute values or in percentage of absolute values. These values are determined by the analyst during the subactivity assessment by estimate or analogy. Table 1 is used to correlate a change in an attribute value with a range of percentage change in that attribute or with an expression of the percentage change in equivalent energy flow.

The proportional change in an attribute and its energy flow equivalent shown in Table 1 are expressed in percentages. The percentage figure may be used to determine the appropriate magnitude code representing either change in energy or proportional change in the attribute. The values and percentages are derived from scientific literature and represent a professional judgment for the pilot study assessment. Other analysts may use different interpretations.

The analyst also determines, by estimate or analogy, the area (in acres) over which the change will be effected. Using the magnitude matrix (Figure 4), the analyst then plots the numerical percentage change along the ordinate (vertical) axis of the matrix, and the area over which the change occurs along the abscissa (horizontal) axis. The point of intersection will fall within a diagonal zone on the matrix labeled M1 through M8. The zone number is the magnitude code which the analyst records on the assessment worksheet.

Professional judgment and human bias are clearly present in the use of these matrices. Their value, however, comes from an explicit statement of the values and the consistent application of these values throughout the analysis.

Code designations for "duration" on the assessment worksheets serve to categorize the time dimension of attribute alterations. The catagories of duration used in the pilot study were short-term and long-term, although other classes of duration could have been used. Short-term alterations are here defined as those effected within and persistent for two years or less. Long-term effects occur over a period in excess of two years from commencement of the subactivity and/or persist longer than two years. Duration codes designating short-term (Sh) and long-term (L) effects appear on the worksheets prepared for the pilot study. Instantaneous effects (those which persist for hours or days) were accounted for in the 1° attribute alterations and are designated for short-term.

Selection of the two-year time interval as the basis for distinguishing short-term from long-term alterations was derived from consideration of periodic events, migrations, reproductive and productivity cycles, etc. in an ecosystem. Passage of two calendar years ensures that at least one full cycle of seasons follows the perturbation, thereby accounting for seasonally dependent recovery. The importance of these definitions is not that they are quantitatively precise; a substantial amount of research would be required to verify them. The purpose of the criteria is to provide an explanation for the analyst's measurements, to establish a "yardstick" for distinguishing the size and duration of impacts, and to achieve consistency in judgment throughout an assessment.

In addition to defining the magnitude, duration, direction, and probability of an impact, it was also necessary to establish criteria for distinguishing

Table 1

CORRELATION BETWEEN ABSOLUTE CHANGE OR VALUE AND PROPORTIONAL CHANGE[1] OR EQUIVALENT ENERGY FLOW CHANGE[2] IN CLASS B ATTRIBUTES, MEDIUM SALINITY BAY AND BAY TRANSITION AREA ECOSYSTEMS[3]

NOTE: Absolute values marked with an asterisk (*) should be expressed in terms of percent proportional change in the attribute; values not marked with an asterisk should be expressed in terms of percentage energy flow equivalents. In both cases, the percentage figure at the head of the column in which the value appears should be used to describe the order of change in the attribute on the magnitude matrix (Figure 4).

Attribute	Direction	Change on the Order of 1%	Change on the Order of 10%	Change on the Order of 100%
Dissolved oxygen	D	Change of approximately 0.1 ppm[4]	Concentration of 5 ppm*	Lethal limit: concentration of 1 to 3 ppm (depending upon species)* or 100% mortality or exclusion of sensitive species
	I	Change of approximately 0.1 ppm*	Not defined	Lethal limit: 180% saturation (gas bubble disease)* or 100% mortality or exclusion of sensitive species
Sediment dissolved oxygen	D	Change of approximately 0.1 ppm (in interstitial waters)*	Concentration of 2.5 ppm*	Lethal limit: concentration of less than 1 ppm* or 100% mortality or exclusion of sensitive species
	I	Change of approximately 0.1 ppm (in interstitial waters)*	Not defined	Not defined (lethal limit presumably less than 180% saturation*)

(continued)

(Table 1 continued)

Attribute	Direction	Change on the Order of 1%	Change on the Order of 10%	Change on the Order of 100%
Salinity	D	Change of approximately 1 ppt[5]*	Change of approximately 10 ppt* or shift in stress condition from optimum for major species	Minimum concentration of 1 ppt* or higher concentration if lethal limit of major species is reached or if major species are excluded
	I	Change of approximately 1 ppt*	Change of approximately 10 ppt* or shift in stress condition from optimum for major species	Maximum concentration of 55 ppt* or lower concentration if lethal limit of major species is reached or if major species are excluded
Dissolved and suspended toxics	I	1/100 of TLM[6, 7]* or analytical detection limit	1/10 TLM for nonpersistent[7]* toxic materials; 1/20 TLM for persistent toxic materials[6]*	TLM for most sensitive major species or group[7]* or 100% mortality or exclusion of sensitive major species
Sediment toxics	I	1/100 of Environmental Protection Agency screening level* or analytical detection limit	1/10 of Environmental Protection Agency screening level*	Environmental Protection Agency screening level* or 100% mortality or exclusion of sensitive major species
Suspended solids	I	Detectable (visible) increase*	10% increase from ambient concentrations* or 10% reduction in photosynthesis or onset of stressful conditions for major species	Lethal limit for major species (approximately 5,000 mg/l)[7]* or reduction in photosynthesis by 90% or more
	D	Detectable (visible) increase*	10% decrease from ambient concentrations* or 10% increase in photosynthesis	100% increase in photosynthesis
Sediment solids	I or D	Detectable, to 1 inch accumulation or reduction*	More than 1 inch to less than 1 foot accumulation or reduction* or 10% decrease in energy processing by affected sensitive organisms	1 foot (or more) accumulation or reduction* or 100% decrease in energy processing by affected sensitive organisms
Substrate texture structure	I or D	Detectable change in substrate texture and/or structure* or detectable effects on sensitive organisms	Partial change from ambient sediment grade (clay/silt, sand, gravel, hard surface) to a different grade, or partial change in substrate structure (degree of sorting and/or particle aggregation)* or 10% change in composition of biotic community or in energy processing by sensitive organisms	Complete change from ambient sediment grade (clay/silt, sand, gravel, hard surface) to a different grade, or complete change in substrate structure (degree of sorting and/or particle aggregation from low to high or high to low)* or 100% change in composition of biotic community or in energy processing by sensitive organisms

(Table 1 continued)

Attribute	Direction	Change on the Order of 1%	Change on the Order of 10%	Change on the Order of 100%
Dissolved and suspended inorganic nutrients	I or D	1% change (I or D) in concentration and/or in total mass*	10% change (I or D) in concentration and/or in total mass* or 10% change in plant biomass or in photosynthetic activity	100% change (I or D) in concentration and/or in total mass* or 100% change in plant biomass or in photosynthetic activity
Inorganic sediment nutrients	I or D	1% change (I or D) in concentration and/or in total mass*	10% change (I or D) in concentration or in total mass* or (in bay transition area ecosystem) 10% change in plant biomass or in photosynthetic activity	100% change (I or D) in concentration or in total mass* or (in bay transition area ecosystem) 100% change in plant biomass or in photosynthetic activity
Water depth	I or D	1%	10%	100% or exclusion of major species or groups
Heat (in water)	I or D	0.1^oF[7]	1^oF[7]	10^oF[7] or lethal limit of sensitive major species, or exclusion of major species or groups
Sediment heat	I or D	0.1^oF[7]	1^oF[7]	10^oF[7] or lethal limit of sensitive major species, or exclusion of major species or groups

NOTE: This table represents an interpretation of published data by the analyst. The standards implied here should not be used arbitrarily in other assessments to which these values may pertain.

[1]Proportional change in an attribute, expressed as a percentage

[2]Percentage change in energy flow equivalents

[3]See: Technical Paper "Attribute Alterations" for discussion of values cited

[4]ppm = parts per million

[5]ppt = parts per thousand

[6]TLM = total lethal minimum

[7]Where these values are superseded by agency policy, or standards, the standards will be used.

attributes which are potentially altered seriously enough to warrant further analysis (that is, evaluation of the related attributes indicated on the ecological systems diagram).

For purposes of the pilot study, the effects that were followed to the next level of interaction are illustrated in Figure 7. The only exception to these criteria occurs when an alteration begins to repeat itself within the same cause-and-effect chain. In these instances the evaluation is terminated. As with the definitions of magnitude and duration, the criteria for determining when to continue analysis of a sequence of alterations should also be defined by the analyst for each assessment.

DOCUMENTATION

An important feature of the ESC is documentation of each step in the analysis. This is accomplished by recording each PEA and attribute alteration on an assessment worksheet (Figure 8). This worksheet contains a record of the attributes considered in the analysis and their estimated significance. It also contains references to literature, data, other models, and assumptions made to justify each judgment. Such worksheets, if included as support information for an assessment, not only serve as an audit trail for the analysis, but also constitute a reference for future assessments of similar projects.

IMPACT SUMMARY

The ecological attribute alterations are summarized to produce a net impact statement. This involves four steps. In the first step, all alterations except those which were not continued in the assessment are extracted from the assessment worksheet and grouped in a summary table. A summary table prepared for the pilot study is included in Technical Paper No. 3. These alterations are summarized by aggregating all effects on an attribute and comparing the direction, magnitude, probability, and duration of each effect in terms of energy and material flow changes.

This is necessary because a subactivity may have several different effects on an ecological attribute. For instance, one facet of the subactivity may cause an increase in vegetation by changing water flow characteristics while another facet of the subactivity causes a decrease in vegetation by direct removal.

The list of aggregate effects on an ecological attribute is analyzed to determine the net changes. These are then described in an impact narrative which highlights the significant alterations. At this step, the analyst translates the magnitude classes (M1, M2, M3, etc.) into terms which describe the importance of those changes, such as in significant, small, moderate, or great. The magnitude classes could be defined in terms earlier in the process, when the magnitude classes are first delineated, but experience suggests that these terms are more easily defined later in the analysis when all alterations can be viewed in context. The definitions applied in the pilot study for each

Figure 7

CRITERIA FOR DETERMINING WHEN TO FOLLOW A SEQUENCE OF ALTERATIONS

Duration	Magnitude: Continue	Magnitude: Terminate
Medium Salinity Bay		
Long	cumulative M5, M6, M7	M1, M2, M3, M4, M5
Short	M6, M7	M1, M2, M3, M4, M5
Bay Transitional Area		
Long	cumulative M4, M5, M6	M1, M2, M3, M4
Short	M5, M6	M1, M2, M3, M4

Figure 8

SAMPLE ASSESSMENT WORKSHEET

SUBACTIVITY:

ECOSYSTEM:

PRIMARY ECOLOGICAL ALTERATIONS	1° Attribute Alteration					2° Attribute Alteration					3° Attribute Alteration					COMMENTS
		D	M	Di	P		D	M	Di	P		D	M	Di	P	

ecosystem analyzed are given in Exhibit 1. Defining classes of magnitude according to these terms requires a judgment by the analyst which reflects the policies of his agency or organization. This judgment is based on such factors as the size and abundance of the ecosystem, the sensitivity of the ecosystem to change, the successional stage of the ecosystem and its net productivity, other human-induced perturbations occurring in the system, and the relationship of the ecosystem to other contiguous associated systems (e.g., migration pathway, etc.)

After defining the magnitude classes, a narrative of the attribute alteration is prepared, using the defined terms. In the process of preparing the narrative, the analyst, using the summary table of attribute alterations, describes each series of alterations starting with 1° alterations. (A separate table summarizing 1° alterations may be prepared to aid organization of the narrative. See Table 1.) Cumulative small changes and moderate and great changes are emphasized in the summary. In the pilot study, a separate narrative for each dredging segment was prepared. This is not an essential step in the assessment; it served as an organization aid for the analyst. These segment summaries are contained in Technical Paper No. 3.

The third step is to review the alterations to determine those that may be alleviated or mitigated by modifying the project design, engineering method, or timing of the activity. In the pilot study assessment, the relevant project modifications identified would produce only negligible improvements and therefore do not warrant recommendation.

After summarizing all attribute changes, the analyst must translate the energy and material flow changes to overall impact of the activity (or subactivity) on the biological resources. Because human use values have not been incorporated in the ecological model, it is necessary to relate these changes in energy flow to terms that can be evaluated by the decision maker - typically, changes in numbers, density, or productivity of commercial and sports-important species or habitats of concern to the permitting agency. For most marine systems, data that would provide a direct translation from changes in energy flow to changes in numbers of organisms and other quantitative information are not available. Therefore the analyst must use the information derived through the evaluation of attribute alterations and his professional judgment to estimate the significance of impacts of subactivities, activities, and the project on biological resources in terms that are meaningful to the decision maker.

In this step, the analyst considers the significance of changing the energy and material flow with respect to the size of the project, size and abundance of the ecosystem, sensitivity of the ecosystem to changes, and other perturbations. As with the definition of insignificant, small, moderate, and great changes, this judgment should reflect the policies of the agency or organization. This judgment integrates all changes caused by this project into an overall statement of the significance of the effects of the activity (or subactivity) on biota or habitats in the ecosystem.

This judgment should then be integrated by the decision maker with the factors such as the social and economic impacts of the project and public resource management policies in deciding the appropriate action to be taken on a permit application. This final step is not included as part of the pilot study.

SEQUENCE OF ANALYSIS FOLLOWED IN THE PILOT STUDY

In assessing the proposed dredging project, the first step was an analysis of the dredging activity to determine the appropriate subactivities to be assessed. Three subactivities involved in dredging were identified:

1. Vehicle movement and operation
2. Substrate removal
3. Water pumping associated with movement of the substrate

The most complex subactivity of dredging is substrate removal. The other two subactivities are functionally related to substrate removal and do not independently produce any significant impacts. Therefore, they were not analyzed in this assessment.

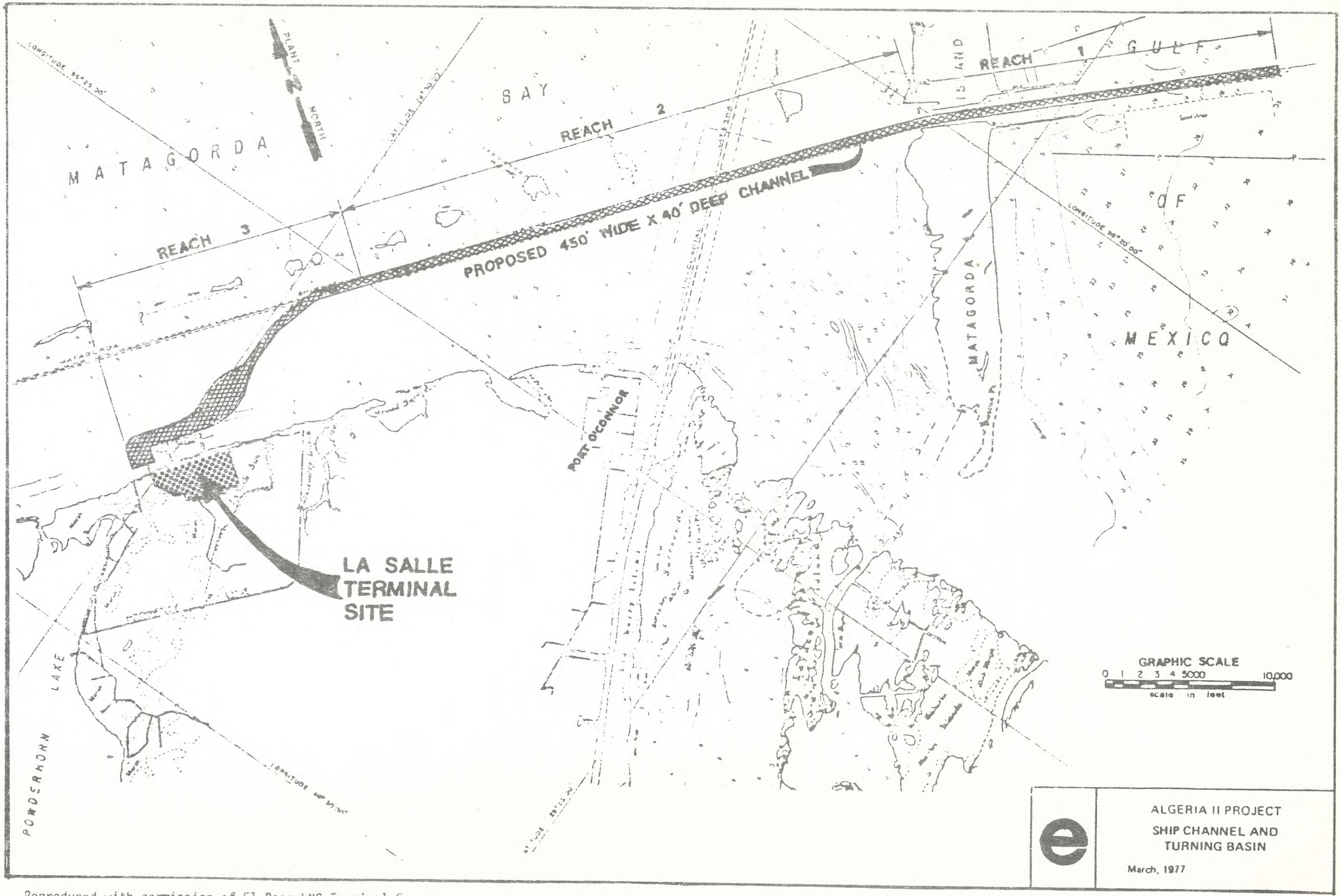
Substrate removal in this project is divided into three segments: (a) enlargement of the existing ship channel, (b) dredging of the approach channel, and (c) dredging of the turning, docking, and barge basin. As shown in Figure 9, the proposed dredging involves widening and deepening a seven-mile reach of the existing Matagorda Bay Ship Channel from its existing width of 200 feet and depth of 36 feet to a width of 450 feet and depth of 40 feet. The portion of the channel dealt with in the analysis does not include that extending from Matagorda Peninsula into the Gulf (Reach 1 in JER). A new channel approximately 6,200 feet long will be dredged to approach the terminal. The total area of the channels is 438 acres. Approximately 166 acres of this area is in existing channel; approximately 272 acres of the channel will be new dredging. A turning basin 2,000 feet in diameter and contiguous docking and barge basins will be constructed at the end of the approach channel. The turning, docking, and barge basins together cover 297 acres. (Note: These figures are assumed accurate within 10 percent.)

The next step in the analysis is identification of the ecological systems in which the proposed channels are located. The data base used for this process is a series of 1:24,000-scale maps of coastal ecosystems prepared by the Texas General Land Office. The ecosystem classifications used were derived from the Bureau of Economic Geology biologic assemblage delineations contained in the Environmental Geologic Atlas of the Texas Coastal Zone (McGowen et al., 1976). The two channel segments of the project are located in a medium salinity bay ecosystem. A portion of the barge basin is located in a bay margin (bay transitional area) ecosystem.

The bay transitional area is defined as the bay margin within the three-foot depth contour. This unit is differentiated from the bay proper by sandier substrate, greater wave and turbulent energy, and greater variability of temperature and salinity. From one point of view, this area might be regarded as a particular habitat within a bay system rather than a distinct system itself. On the basis of the map base used, no more than 50 acres of the project facilities fall within the bay transitional area. Due to the changes evidenced by this high-energy shoreline, a more recent data source may demonstrate that this figure is generous. This 50 acres represents less than nine percent of the total area of new dredging.

Figure 9

GENERAL LAYOUT OF LA SALLE TERMINAL



Reproduced with permission of El Paso LNG Terminal Company

The assessment was conducted in three segments. The dredging of the primary channel and approach channel were assessed together. Distinctions between enlarging the existing channel and totally new dredging in the approach channel were made where appropriate. The portion of the turning, docking, and barge basins in the medium salinity bay and the bay transitional area were analyzed separately. The effects of each segment were documented and summarized separtely. The effects of all the dredging were then summarized together.

2. ANALYSIS OF THE PILOT STUDY

The analysis of the ecological assessment pilot study considers four matters: (a) data requirements, (b) findings of the impact assessment, (c) time and personnel required to conduct the assessment, and (d) an evaluation of the efficacy of the ESC as an assessment technique.

DATA REQUIREMENTS

Data requirements of the pilot study are described here in order to (a) identify the types of data used in the analysis and their sources and (b) indicate data needs. Data for which a need was identified but which were not available during the study included information thought to be obtainable but which could not be secured in the limited study interval. These data also include information thought not to be presently obtainable from any source but which, if available, may have improved precision of the assessment by increasing the analyst's confidence in evaluating pertinent attribute alterations. Data thought not to be obtainable from any source constitute topics which would warrant priority designation in future state-supported research and data collection efforts. However, in this case, additional data would not have altered the summary of net impacts.

The list of data needs is not intended to suggest shortcomings on the part of the project proponent or the federal review agency, nor is it meant to imply that the pilot study analysis is incomplete without the inclusion of such data. In fact, a feature of the ESC procedure is the capacity to organize pertinent available data in a manner such that information gaps may be clearly denoted and the analysis may be continued despite these gaps. The purpose of identifying data gaps is to establish priorities for future state-supported research.

Data which are used in the assessment become part of a retrievable file tailored to the broadly applicable ESC format. Such information may become part of the collections held in the Texas Natural Resource Information System and thereby made readily accessible to any interested party.

The data used to assess ecological impacts of dredging in conjunction with the La Salle Terminal project can be divided into two major categories: field data and secondary information. Field data consist of information specific to the project site and may be considered "raw" data or "baseline" data. Such data are collected by measuring various environmental parameters on the site or in the ecosystems of concern. Field data can also be obtained from existing records of monitoring/sampling. Engineering data on the proposed project are included in field data.

Secondary data consist of information about ecological functions and interrelationships described by the ecological systems diagram (ESD). These data are usually generic or analogous and are not specific to the project and site, although site-specific data, if available, are used. Such data are used to calibrate the ecological model and apply to geographic areas which can be characterized by the model. Secondary data may be derived from scientific literature describing a particular ecological relationship, the results of other modeling efforts, or any reputable source.

It should be noted that these two categories are not mutually exclusive. For instance, field data pertaining to the project site may be reported in secondary sources; for example, there is an increasing effort to make water quality monitoring data and biologic sampling data more available through the Texas Natural Resource Information System.

PILOT STUDY DATA SOURCES

Within the two broad categories identified above, further subdivision of data can be made on the basis of source. The following types of data have been used during the process of completing the pilot study:

1. Data supplied by the project sponsor in the joint environmental report (JER)

2. Data from the final environmental impact statement (FEIS) prepared by the Federal Power Commission

3. Secondary information obtained from external sources

Technical Paper No. 3 outlines data used in the pilot study. Two points should be emphasized in discussing the information which was used. (a) It is a characteristic of the ESC that potential impacts of an activity at a general ecosystem level can be identified with a minimum of information input. The best available data are simply incorporated into elements of the ESC and predictions of impact are derived accordingly. Better data serve to refine the assessment and to define the quality impact predictions, but the ESC is capable of discriminating between meaningful and extraneous data. (b) In the process of this study, many sources of secondary data were reviewed to clarify particular ecological relationships. The assessment procedure was, however, reliant to a substantial degree on baseline and engineering data supplied by the applicant.

In addition, three categories of data were recognized which would have been useful in the pilot study but were not available to the analysts.

These data include:

1. Baseline data that could have been used in the ESC, but were not published in either the joint environmental report or the FEIS: Many of such data could be found in the references used to compile the JER or the FEIS, but they were unavailable for the ESC study.

2. Secondary information which is thought to be available but was not used due to time limitations: Such data could include reports generated by the applicant subsequent to close of the FERC/ERA hearing record.

3. Secondary data of unknown availability: Such data could be in the state or federal files, reports, etc. on the Matagorda Bay system, or they may not exist.

Many of the baseline data which were not available for this pilot study are thought to be presently nonexistent. These deficiencies in the assessment information base, if eliminated or satisfied, would have undoubtedly resulted in a more exact prediction of impact. It is felt, however, that sufficient data, including both baseline and secondary information, were available to complete an assessment which adequately represents the expected impacts of the activity investigated. The provision of all data needed would not have altered the results (predictions) of the study but would have made possible a more precise definition of impact. Data needs, therefore, which were not met in this particular pilot application of the AAR, were not considered critical to the capacity of the procedure to identify potential project impacts.

Information requirements of the pilot study were largely satisfied by the applicant's environmental report, the federal FEIS, and external literature. Additional data needs, both for site-specific and secondary information, have been identified. The list of unavailable data should not be interpreted as data which the project sponsors should be required to collect. The list is provided as an indication of data needs which are relevant for future data collection efforts sponsored by the state.

FIELD DATA/BASELINE DATA REQUIREMENTS

The joint environmental report (JER) and final enviornmental impact statement (FEIS) contain quantitative data on specific site parameters, general descriptive environmental information, and engineering data and specifications. For purposes of this analysis, the FEIS and JER were generally found to agree and to contain similar information. In the documentation of the pilot study worksheets, reference to one of the documents does not necessarily mean that similar data are not also available in the other document. It should also be noted that many of the data which were compiled for federal requirements, while relevant to the project, were not specifically required for the ESC analysis and therefore were not used for the pilot study. Data obtained from the JER and FEIS are described in Technical Paper No. 3.

Several points were noted in the analysis for which site-specific baseline data were not readily available. These are outlined in Technical Paper No. 3. It is assumed that much of this information has been collected by the project sponsor and would have been available to the pilot study had time allowed. However, artificial time constraints imposed during the study prohibited solicitation of supplementary data from the applicant.

SECONDARY DATA REQUIREMENTS

During the assessment, secondary information was sought to clarify particular ecological relationships that had been isolated by the ESC analysis. Due to limitations of personnel and time, not all secondary data needs were completely satisfied. Technical Paper No. 3 lists the sources and the types of secondary information incorporated into the assessment. These sources include scientific journals, textbooks dealing with estuarine systems or effects of activities on these systems, and government reports such as the Texas Department of Water Resources water quality sampling program. Secondary information which was not available during the pilot study is also described in Technical Paper No. 3. Of this information, much is thought to be accessible, given sufficient research time and personnel. However, some of this information is not considered to be available and could be obtained only through original research.

As an example of the distribution of data sources cited by the ESC in this test, attribute alterations resulting from proposed channel dredging in the medium salinity bay ecosystem are shown sequentially in Technical Paper No. 3 with the associated data source or sources. A comparison of this list of data sources and of secondary data sources demonstrates that each attribute may have associated with it more than one utilized data element or identified data need. For example, data on intermediate consumers are classified as baseline data which were not immediately available. At the same time, some secondary information pertinent to intermediate consumers was found, but a need for additional secondary sources is recognized. In many cases, the use of one source of information in making a decision does not preclude the possible existence of better data elsewhere. Likewise, data from a number of sources, both site-specific and general, may be used to evaluate one attributable alteration, as is evident in Technical Paper No. 3.

INFORMATION GAPS

Types of data which were not available for this pilot study have been discussed above. Technical Paper No. 3 includes lists of those attributes for which data are lacking for this analysis. It should be noted that this lack of data may be primarily due to time constraints placed on this analysis. Many of these data are known to be available as the result of the applicant's preconstruction monitoring program. The categorization of attributes in Technical Paper No. 3 also identifies areas in which additional information was sought. Data needs which would have improved the accuracy of estimations for this pilot study which have been recognized are summarized here:

1. Detailed site hydrography
2. Movements and migrations of estuarine organisms
3. Food habits of estuarine consumers
4. Abundance of estuarine organisms

It has been stated previously that many of these data needs could have been satisfied under less rigid (artificial) time constraints in the pilot study; the applicant has obtained data which would satisfy many of these needs. Much of the information that was found to be lacking, however, is probably nonexistent and could be provided only through a specialized research effort. Such a study would not usually be required of a project applicant; responsibility for highly specialized information of this type would typically lie with the state's natural resource agencies. Data needs which have been identified as important for a more accurate ESC assessment may help to establish research priorities in the future.

SUMMARY OF IMPACTS ASSOCIATED WITH SUBSTRATE REMOVAL FOR ALL DREDGING SEGMENTS

Information from the project sponsor indicates that dredged material disposal (a separate activity) is going to be restricted to upland sites. Because substrate removal represents the most extensive and complex subactivity defining dredging, this assessment is a description of the major construction impacts that will occur in the bay environments as a consequence of the La Salle Terminal project.

The impact summary focuses exclusively on the construction effects of the subactivity "substrate removal" for enlarging part of the Matagorda Ship Channel as well as dredging the approach channel, docking, turning, and barge basins in the medium salinity bay and bay transitional ecosystems. The (somewhat artificial) boundary between the medium salinity bay and the bay transitional area has been previously established at the three-foot isobath. Therefore, the study considered the bay transitional area as extending shoreward from the three-foot depth. Operational aspects of the proposed LNG facility to be served via the access channels and basins, prescribed maintenance dredging of the channels and basins, dredged material placement, ship traffic, and all other activities associated with these facilities have been intentionally omitted from the analysis.

It is also important to note that the process of constant project modification and the unavailability of supplemental field data at the time of the assessment will alter certain assumptions on which evaluation of the pilot study was based. Therefore, some conclusions or potential impacts discussed in the summary may be invalid in light of the present situation. The assessment must also be considered in the context of the pilot study. The prediction of potential impacts described pertain solely to environmental changes associated with only one of many other component subactivity analyses. Several other analyses of comparable comprehensiveness would be required before an assessment of the net environmental impacts associated with the El Paso LNG facility can be determined. Many of the environmental effects described in the following discussion may prove insignificant when evaluated in context with other construction, operational, and maintenance aspects of the project.

Impacts projected here may be, and in several cases will be, overshadowed or mitigated by the effects of those other construction, operational, or maintenance activities of the LNG terminal. The scope of the pilot study was narrowly defined in order to facilitate preliminary testing and demonstration of the analytical procedure. However, the ESC methodology can be used to analyze other aspects of the project, as will be discussed in subsequent chapters of this report.

SUMMARY OF NET IMPACTS OF ALL DREDGING SEGMENTS

In order to describe and summarize the findings of the assessment, it is necessary to first define the magnitude matrix classes. In the pilot study, attribute changes in the medium salinity bay receiving magnitude class designations M6 (if the effects are cumulative over the long term), M7, and M8 are analyzed further. In the bay transitional area, changes designated M5 (cumulative), M6 and M7 receive continued analysis. The numerous energy changes designated as classes M1 through M6 (noncumulative) in the medium salinity bay and classes M1 through M5 (noncumulative) in the bay transitional area are not followed. The assessment worksheets list the magnitude class of each attribute evaluation. In the pilot study, impact summary, four terms are used to describe magnitude: not significant, small, moderate, and great. The definitions of these terms are shown in Figure 10. These definitions are fundamentally statements of professional judgment. This judgment may be the responsibility of the analyst, a group of experienced biologists/ecologists, or the policy makers of an agency. A group of experienced biologists established the magnitude definitions for the pilot study. Important ecological considerations which factored into the execution of professional judgment were: ecosystem size; ecosystem abundance in the Texas coastal zone; ecosystem susceptibility to external stress; net productivity potentials; the extent of other perturbations present, and ecosystem maturity. The summary is based on the identification and analysis of over 470 different ecosystem interactions and energy relationships. In compiling this narrative, a summary list of attribute alterations which were determined to produce subsequent effects is prepared, as shown in Technical Paper No. 3. Net 1^{o} attribute alterations are displayed (see Table 2) and subsequent effects following from these alterations are described. This summary is titled "Changes in Ecological Attributes."

An example of the impact assessment worksheets prepared for this study is shown in Figure 11. All worksheets documenting the assessment and detailed summaries of the impacts of each dredging segment of the project are contained in Technical Paper No. 3.

Figure 10

MAGNITUDE DEFINITIONS
MEDIUM SALINITY BAY AND THE BAY TRANSITIONAL AREA ECOSYSTEMS
EL PASO ALGERIA II PROJECT DREDGING ASSESSMENT

Magnitude Class	Magnitude Term
Medium Salinity Bay	
M1 through M5	not significant
M6	small
M7	moderate
M8 and higher	great
Bay Transitional Area	
M1 through M4	not significant
M5	small
M6	moderate
M7 and higher	great

Note: This represents a professional judgment by the analyst for this project. Because analysts may vary in their interpretations, this should not be used as a standard for future assessments.

Table 2

FIRST-ORDER SYSTEM CHANGES ASSOCIATED WITH SUBSTRATE REMOVAL FOR THE MEDIUM SALINITY BAY AND BAY TRANSITIONAL ECOSYSTEMS

	Magnitude					
	Medium Salinity Bay			Bay Transitional Area		
1^{o} Attribute Alterations	Small	Moderate	Great	Small	Moderate	Great
Short-term attribute increases						
Dissolved and suspended inorganic matter		x		x		
Dissolved and suspended organic matter	x				x	
Dissolved and suspended toxics	x			x		
Suspended solids	x			x		
Short-term attribute decreases						
Benthic community		x			x	
Inorganic sediment nutrients		x			x	
Sediment dissolved oxygen		x			x	
Sediment organic matter/bacteria		x			x	
Sediment toxics	x			x		
Substrate texture		x			x	
Long-term attribute increases						
Water depth			x			x
Current energy	x	x			x	
Long-term attribute decreases						
Benthic community	x			x		
Sediment solids		x			x	
Macrophytes					x	
Sediment microalgae					x	

NOTE: These are the ecological alterations that generate all subsequent ecosystem changes which require evaluation. Magnitude estimates are in terms of energy flow or equivalent material change.

Figure 11

EXAMPLE WORKSHEET

SUBACTIVITY: Substrate removal (channel dredging)

SHEET 1 OF 9

ECOSYSTEM: Medium Salinity Bay

D: Duration [long term (L); short term (Sh)]
M: Magnitude [M4 through M8; see Technical Paper 2 for definitions]
Di: Direction [increase (I); decrease (D)]
P: Probability [definite (Df), probable (Pr), possible (Po)]

	PRIMARY ECOLOGICAL ALTERATIONS	1° Attribute	D	M	Di	P	2° Attribute	D	M	Di	P	3° Attribute	D	M	Di	P	4° Attribute Alteration	5° Attribute Alteration	COMMENTS
1.	Consumer removal complete (1)	benthic community	Sh	M7	D	Df													Complete removal from 438 acres. ΔE/E=100%. 100% instantaneous loss of energy flow over area based on channel dimensions
2.							intermediate consumers	Sh	M6	D	Pr								Over 5000 acres of inter. cons. feeding range; ΔE/E = 1-(0.5[(0x438)+4562]+0.5(5000)/5000)= 0.044x100
3.												intermediate consumer migration	Sh	M4	D	Po			Decrease of migration of intermediate consumers to other ecosystems; magnitude is difficult to estimate.
4.												birds	Sh	M6	D	Po			ΔE/E= 1-(0.5[(.956 x 5000)+ 95000]+0.5 (100,000)/100,000)=0.0011x100% over 100,000 acres - assuming birds range over entire bay area; the ΔE/E for this acreage indicate small change in energy flow
5.																			from the site area to birds; impact on bird populations maybe less because of their mobility and behavioral flexibility in feeding habits. Birds not confined to single ecosystem.
6.												top consumers	Sh	M6	D	Pr			ΔE/E= 1-(0.33[(.956 x 5000)+11000]+0.67(16000)/16000) = 0.0045 over 16000 acres; Simmons + Breuer (1962) cited in Jackson (MS) indicate this range ("within 5 miles").
7												bacteria/dissolved and suspended organic matter	Sh	M5	–	Pr			Contribution by any single consumer group is insignificant in short-term.
8												dissolved + susp. inorganic nutrients	Sh	M5	–	Pr			Same as previous comment.
9.												dissolved oxygen	Sh	M5	–	Pr			Same as above comment.
10												benthic community (offsite)	Sh	M5	D	Po			Increased predation off-site because of reduced carrying capacity on-site.
11												herbivores and detritivores	Sh	M5	D	Po			Same comment.
12							top consumers	Sh	M6	D	Pr								ΔE/E=1-(0.33[(0x438)+15562]+0.67(16000)/16000)= 0.009x100% over 16,000 acres
13.												diss. + susp. inorg. nutrients	Sh	M5	–	Pr			Contribution by any single consumer group is insignificant in short-term.
14.												bact./diss. + susp. organic matter	Sh	M5	–	Pr			Same comment.
15.												benthic community (off-site)	Sh	M5	D	Po			Displaced top consumers exert additional pressure on benthic consumers off-site.
16.												intermediate consumers	Sh	M5	D	Po			Displaced intermediate consumers may adjust their diet to compensate for reduction in benthic community.
17.												dissolved oxygen	Sh	M5	–	Pr			Effect of non-consumption is insignificant.
18.												top consumer migration	Sh	M6	D	Pr			"Decrease" denotes net emigration; also implied is reduced immigration because of diminished carrying capacity on-site.
19.												herbivores and detritivores	Sh	M5	D	Po			Additional predation by top consumers because of reduced "availability" of benthic organisms.
20.							inorganic sediment nutrients	Sh	M6	D	Pr								Contribution by any single consumer group is insignificant in short-term.
21.																			
22.							bact./sediment organic matter	Sh	M6	D	Pr								See previous comment re sediment nutrients. This link refers to benthics contributing to sediment organics via egestion and decomposition.
23.							sediment dissolved oxygen	Sh	M5	–	Pr								Removal of benthics should not markedly affect sediment d.o. tensions. Effects overshadowed by lowered d.o. in sediment from 1°AA & PEA#5.

The next step in the summary is a translation of the identified changes of ecosystem maintenance or productivity as expressed by shifts in species abundance, species diversity, or habitat and community types. At this step the complex energy flow changes, identified and discussed in the first summary are synthesized into an impact statement which describes the important net changes in terms of ecosystem maintenance and/or productivity. Professional judgment is heavily relied on to make this transition because of the general lack of quantitative data at the ecosystem level and the absence of tested procedures for evaluating such data. The significance of changes at this level is discussed in the Overview and Interpretation of Biologic Impacts.

Overview and Interpretation of Biologic Impacts

Substrate removal will occur for a total of 36 months. A total of approximately 735 acres (685 acres of medium salinity bay and 50 acres of bay transitional area) including existing channel and bay bottom will be removed by a hydraulic cutterhead dredge. About 23 percent of this area represents acreage within the existing channel alignment which has been dredged.

Deleterious effects on two ecosystems can be expected to occur as a consequence of the proposed dredging operation. Biotic (e.g., producers and consumers) and abiotic (e.g., substrate texture-structure, dissolved oxygen, and current energy) components or "attributes" of each ecosystem would be affected to varying degrees. Those effects would be brought about by (1) direct site alterations sustained during the excavation process and/or (2) diffusion of direct alterations of attributes to other, dependent (but not directly affected) attributes. The chain of reactions and interactions among ecosystem components that ensues from the construction activity can be traced throughout and between ecosystems and includes both short- and long-term effect effects.

The capacity of ecosystems to resist impact, restore losses, and moderate alterations generally tends to reduce the time interval and area over which perturbations are expressed. The principal long-term effects of the dredging operation on environmental attributes would result from "permanent" modifications (e.g., increased water depth) of the environment rather than from transitory, ecosystem-mollified effects regardless of their initial magnitude. The resilience of a "healthy" environment is a contributing factor limiting the range of predicted impacts.

Because the roughly 600-acre project area represents less than one percent of the medium salinity bay ecosystem in Matagorda Bay, the proposed dredging activity alone would not be expected to threaten ecosystem maintenance. Long- and short-term effects of the activity off-site are minor in comparison to the total ecosystem, as well. No appreciable concentrations of toxic substances would be mobilized by dredging. The use of a hydraulic cutterhead dredge with spoil containment on land greatly reduces the potential dispersion of suspended solids that might be expected with other dredging techniques. The direct loss of benthic organisms (bottom-dwelling invertebrate animals) and, in the bay transition ecosystem, macrophytic vegetation (rooted aquatic plants) and sediment algae constitute the most significant reduction in biotic attributes on-site. This loss has consequent effects on higher order consumers (predators and herbivores) on-site and bay-wide. Nonetheless, an appreciable reduction in numbers of organisms throughout the ecosystem is not clearly demonstrable. Permanent modifications of the ecosystem (including increased water depth and tidal exchange) may produce changes in the composition and diversity of the benthic community, but the net energy flow from benthic organisms to consumers cannot be predicted with certainty by this method of analysis.

To improve the precision of the analysis, additional hydrographic data based on site-specific models would be needed. Because the ESC predicts impacts from the user's knowledge, site characteristics, and project design criteria, the analysis can be only as subtle as the data provided.

The following summary integrates the results of evaluating the three separate dredging segments in two ecosystems. A separate summary for each dredging segment by ecosystem is found in Technical Paper No. 3.

The net effect of the significant changes associated only with substrate removal and not incorporating interactions associated with other construction/operational phases can be summaried in the following sequential conclusions:

1. Loss of the benthic community through direct removal and, to a lesser extent, because of siltation effects causes a moderate short-term and a small long-term decrease in energy flows to higher trophic levels from this source.

2. Approximately 569 acres of bay bottom formerly inhabited by a diverse benthic community would be removed and replaced by benthic organisms typically encountered on channel bottoms. Changes in energy flows suggest a long-term recovery of the former bay benthic community in terms of diversity and abundance of former species is probably less than complete in the new basin and channel environments. This is a result of altering several important environmental functions such as water depth, current energy, and turbulent energy. These are factors that regulate many other physical processes, which in turn control growth, development, and recovery of the benthic community. The replacement community may or may not have equal or higher energy flow.

3. The net reduction in benthic energy flow, precipitated by direct removal and perpetuated to a degree by permanent alterations of regulating physical processes can be traced through the food chains and consequently has bay-wide and inter-ecosystem implications.

4. Reduced but unquantified energy flows from the benthic community are transferred via complex interactions to higher trophic levels including organisms (mullet, shrimp, redfish, speckled seatrout, Gulf menhaden, etc.) which move throughout the Matagorda Bay system.

5. Considering the changes identified in 1 through 4 above, it is anticipated that the subactivity substrate removal (dredging) will be of small or low significance in altering the maintenance of the medium salinity bay and bay transitional ecosystems of Matagorda Bay.

Summary of Changes in Ecological Attributes

Substrate removal generates 11 primary ecological alterations on the site. These alterations cause changes in 13 to 15 different first-order ecosystem attributes, depending on the ecosystem examined. The same 13 first-order attributes are changed in both medium salinity bay subunits. In the bay transitional ecosystem, two additional attributes are changed. These changes can be categorized according to duration, magnitude, direction of change, and ecosystem (Table 2). Unless otherwise noted, the discussion of impacts is pertinent to both ecosystems. Impact differences between and within ecosystems will be noted when appropriate.

The small increase in suspended solids in the water column caused by dredging produces a turbidity cloud around the dredging operation. This plume can instantaneously increase the concentration of suspended solids in the surrounding waters by 100 mg to 5,000 mg per liter. The best water quality information available during the study indicates background levels of suspended solids fluctuate widely, ranging in concentrations from 30 to 1,780 mg per liter. The photosynthetic rate of phytoplankton will be temporarily reduced over a total area of about 32 acres by the increased suspended solid concentration during the course of all dredging operations. The zone of increased suspended solids typically extends no more than a radius of 15 feet from the cutterhead at any one point in time. Simultaneously, disturbance of the bottom sediments releases moderate quantities of inorganic nutrients into the water which the phytoplankton can utilize, thus partially compensating for the effects of turbidity. The net result is an insignificant reduction in phytoplanktonic productivity, which lasts no more than a few days. Due to the increase in water depth in the bay transitional area, phytoplanktonic productivity will replace (in the long-term) the primary production formerly contributed by the macrophytes and sediment microalgae that were unable to inhabit depths to which light could not penetrate.

Although the increased turbidity levels are short-lived, reduction in energy flow from nearby nondredged benthic communities is small. Settling of the suspended solids from the turbidity plume buries and reduces the number of benthic species as well as species abundance within a 15-foot radius of the hydraulic cutterhead. The less heavily silted zones may experience a temporary inhibition of benthic productivity for several weeks. However, even the most heavily silted nondredged sites achieve nearly 100 percent recovery within two years. Mobile fish and macroinvertebrates (in fringe areas) can move away from highly turbid zones and, consequently, experience little direct effect.

Long-term removal of the bottom sediments causes a moderate long-term increase in water depth in the new channel and basin areas of the medium salinity bay. A great long-term increase in water depth occurs in the bay transitional area. Removal of the bottom sediments causes a small long-term reduction in benthic community energy flow and sediment dissolved oxygen. Subsequent hydrographic effects will differ between the channels and the basins.

In the existing and approach channels, the most important consequence of increasing water depth is a probable small long-term decrease in the dissolved oxygen levels of the channel waters and bottom sediments, particularly in the lower strata and in the warmer months. Increased water depth results in insignificant instantaneous increases in current energies. The cumulative long-term results of increased current energies on salinity levels are small. The alteration is expected to increase mean bay-wide salinities by 0.4 ppt, which is well within the tolerance range of bay biota and should cause no biotic changes. For the shallow areas of bay bottom adjacent to the existing channel which will be dredged to the 40-foot depth, there will be an insignificant to small long-term increase in salinity levels of approximately 5 ppt after the channel is widened and deepened. This increase is due to an inundation of the new channel area by the saltwater wedge extending from the Gulf. Previously dredged deep-water, channel bottoms will experience an insignificant relative change in salinity. As a consequence of reduced oxygen levels at the new channel bottom, the concentrations of sediment toxics, principally sulfides and ammonia, can be expected to show small to moderate increases depending on what predredging conditions existed. (One data point indicated DO levels as low as 4.6 mg per liter at the 30-foot depth compared to 6.5 mg per liter at the 10-foot depth. However, the lack of comprehensive sampling data in the channel make evaluating the frequency and duration of this condition difficult.) Formerly undredged areas will experience the greatest relative change. In previously undredged bay bottom areas, a much greater relative change will occur. For the existing channel, the change in depth and consequent secondary effects are relatively small in comparison. The operational aspects of the terminal facility (i.e., cold-water discharge and ship and barge traffic) may increase water turbulence and subsequent mixing to the extent that conditions contributing to low dissolved oxygen concentrations may be overshadowed and nullified. An assessment of such off-setting processes would be made in the final project impact statement.

In the basins area, a deep depression is created where none existed before. Five long-term moderate magnitude changes occur as a result. There are long-term moderate increases in sediment solids and current energy. There are also moderate long-term decreases in turbulent energy, dissolved oxygen (of the lower water strata), and suspended solids. The potential decrease in dissolved oxygen concentration in the lower levels and the increase in sediment solids are the changes of greatest consequence to the benthic biota, particularly in terms of regulating growth and recovery. Once again, the operational aspects of cold-water discharge, seawater intake, and vessel traffic in the basin may significantly overshadow the potential effects predicted by the analysis of reduced dissolved oxygen concentrations. But in the event that reduced dissolved oxygen levels do occur due to reduced turbulence and vertical mixing of the water column, a moderate reduction in energy flow through the benthic community would be expected. The number of species may be reduced and the total biomass may also be less. A small decrease in energy flow through the herbivore and detrivore, intermediate consumer, and top consumer components would be predicted, based on a reduction of energy flow through the food chain as a consequence of reduced contributions from benthic community and the possibility of occasionally anoxic water conditions in the basin which would discourage higher consumer use of the site.

Reduced turbulence due to increased water depth (future operational aspects are not considered) would restrict the resuspension of sediment solids, resulting in a net equilibrium shift between suspended and bottom sediments toward sediment solids. The sedimentation rate in the basin area could increase. The change in sediment texture due to increased sediment organic matter, and the accumulation of finer grain-size particles would become an important regulator of species composition of the recovering channel-type benthic community that would replace the original bay benthics.

A moderate increase in sediment toxic materials would be expected due to hydrogen sulfide production conditions resulting from lowered dissolved oxygen concentrations at the bottom surface (considered in the absence of future operational aspects that could alter turnover rates and water temperatures) and the general association of toxic materials with fine-grain sediments. This would be especially true in the bay transitional area. All of these factors (altered dissolved oxygen concentrations, sediment toxics, sediment texture, and salinity) would be expected to contribute to species composition changes of the benthic community.

Substrate removal for construction of the channels and basins directly removes a total of 735 acres of substrate presently supporting bay and channel benthic communities of varying qualities. Sedimentation of a total of 32 acres for all dredging segments as a result of increases in suspended solids in areas adjacent to the dredging causes additional benthic community impairments of varying magnitudes, depending on the areal extent of the heaviest silt deposits.

Recolonization and restoration of the bay community type in the adjacent areas begins immediately and proceeds to reestablish former levels in six months to two years.

The benthic community type that recovers within the newly dredged areas is expected to differ from the original bay community type (at least in terms of species composition). A decrease in benthic species diversity has been identified, showing diversity reductions from 53 species sampled on the channel lip to 13 species sampled at the channel bottom. Several factors contribute to this difference, among which are the bottom disturbances caused by maintenance dredging, trawling activities of shrimpers, and the different environmental regime of the bottom. It is uncertain whether total long-term benthic community energy flows will differ significantly from preconstruction levels as a consequence of changes in community types. This depends on the composite effects of altered sediment and dissolved oxygen concentrations, salinities, sediment toxics (principally hydrogen sulfide and ammonia), sediment texture and, in the channels at least, current energy regimes.

Recovery of the channel bottom community, which is also expected to appear in the basin bottoms, begins immediately after substrate removal stops.

Community recovery, in terms of species diversity, but not necessarily of numbers, is 80 percent complete within two years. In the dredged sites, the bay bottom community is permanently displaced by types adapted to channel bottom conditions. However, the proposed maintenance dredging schedule renders the long-term consequences irrelevant. The net effect of direct removal of the benthic community and the simultaneous alteration of the environmental conditions which regulate community recovery processes is determined to be a moderate decrease in energy flows available to higher trophic levels.

In the medium salinity bay there will be a short-term small decrease in energy flow through the herbivore and detritivore component (e.g., mullet, shrimp, and crab), as more than 685 acres (including existing channel, new channel dredging, and basins area) of their food resource base, sediment organic matter, is removed with the substrates. A small short-term decrease is also indicated in the bay transitional area for herbivores and detritivores, as well as for intermediate consumers, for the same reason. Long-term water quality changes (e.g., occasionally lower dissolved oxygen concentrations) in the new basin areas may preclude herbivores and detritivores from reestablishing their original levels of utilization. This concern is probably of little consequence in the channels. Whether decreased energy flow causes decreased numbers of organisms depends on the ability of the mobile herbivores and detritivores to procure alternate foods available in nearby areas and on the distance to such sites.

The intermediate consumers which depend upon the altered site for food but are capable of moving to other sections of the bay ecosystem (e.g., Atlantic croaker, spot, and Gulf menhaden) also experience a short-term small decrease in energy flow, as energy flow from portions of their food supply is decreased through several different pathways. Direct removal and sedimentation effects cause a small short-term decrease in available energy from the benthic community. Benthic community sensitivity to sedimentation rate, especially in the turning, docking, and barge basins, is partially counterbalanced by increased influxes of sediment organic matter and, therefore, is probably of slightly less concern than the effects of direct removal. Herbivores and detritivores also experience short-term small decreases in the medium salinity bay and, therefore, provide less energy. Equivalent changes of herbivores and detritivores in the bay transitional area are considered insignificant. Small long-term reductions in intermediate consumers' energy flows are expected in the medium salinity bay as a consequence of the long-term change in the food supply. In the bay transitional area, a smaller long-term reduction in flow is expected due primarily to the much smaller areal extent of the dredging. The loss, if any, of a specific number of intermediate consumers cannot be calculated with existing data.

Reductions of energy outputs from the benthic community, and especially components of the intermediate consumers, mean an insignificant to small short-term reduction in energy input to top consumers such as speckled trout and redfish. Long-term small decreases in energy flow to top consumers are expected as a result of long-term small decreases in energy flows from the new basin and channel benthic communities of the medium salinity bay. The bay-wide mobility of top consumers reduces the impacts associated with moderate to small decreases of the benthic community energy exports. The great mobility and extension food base from which energy is derived make it unlikely that top consumer populations will permanently decrease solely as a result of this subactivity.

In the bay transitional area, top consumers will experience an insignificant or perhaps a long-term change in energy flow due to the various effects caused by the removal of the benthic community, increased suspended solids (turbidity), reductions in dissolved oxygen levels due to increased suspended solids, and an increase in dissolved and suspended toxics. The most significant long-term factors for top consumers will be the degree of benthic community recovery from initial dredging operations and the water quality in the basin, particularly the equilibrium that develops between dissolved oxygen and sediment oxygen levels following implementation of operational phases. The species composition and age structure of higher level consumers using the bay transitional area will probably change since the basin area will be more similar to the medium salinity than to the previous bay margin in terms of physical water/substrate configurations and food resource availability.

Because the area experiencing substrate removal represents less than one percent of the medium salinity bay ecosystem in Matagorda Bay, the reduction in energy flow throughout the bay as a result of the proposed dredging activity alone would not be expected to threaten ecosystem maintenance or produce a noticeable bay-wide loss of organisms. Long- and short-term effects of the activity off-site are minor in comparison to the total ecosystem; consequent ecosystem changes are expected to be of low significance.

The only feasible mitigation measures that suggest themselves are: (a) use of engineering techniques that reduce the amount of suspended solids generated and (b) reduction of the areal extent of the substrate removal. However, the proposed hydraulic excavation method is a technique that inherently produces minimal amounts of suspended solids and, compared to background turbidity levels, additional turbidity controls would produce only marginal improvements. The areal extent of the dredging presumably represents the minimum amount of excavation necessary to provide ship access. Therefore, mitigation measures in addition to those presently incorporated in the project design are not recommended.

RESOURCES REQUIRED TO PERFORM PILOT STUDY

The ESC pilot study was conducted over a six-week period. Nine staff members were involved in the project, although only two staff persons worked on the study full time. The study team consisted of one project manager, five research associates, and three research assistants. The qualifications and specialties of the staff are shown in Table 3.

Six basic tasks were performed during the pilot study: methodology refinement, data collection, data analysis, recording of the analysis, summarizing the impacts, and supervision.

As Table 4 shows, a total of 1,149 hours was spent on these tasks. A large percentage (43 percent) of the total pilot study time was spent on

Table 3

PROJECT PERSONNEL ESC PILOT STUDY

Staff	Background
Project Manager	MS in resource planning
	Experience in conducting and managing environmental impact assessments
Research Associates	PhD in ecology/evolution
	PhD in marine ecology
	PhD in chemical oceanography
	MS in wildlife biology/botany
	BA in geology/terrestrial biology
	All have experience in environmental impact assessments
Research Assistants	MA in urban/environmental planning
	BA in biology
	BA in biology
	Limited experience in environmental assessment

Table 4

ACTUAL TIME ALLOCATIONS BY STAFF MEMBER FOR ESC
PILOT STUDY ASSESSMENT OF DREDGING

Task	Project Manager (1)		Biologists/Res. Assoc. (5)		Research Assistant (3)		Total	
	Hours	Percent	Hours	Percent	Hours	Percent	Hours	Percent
System Refinement	10.40	20%	393.03	44%	94.00	46%	497.43	43%
Data Collection	5.20	10%	95.83	11%	78.00	38%	179.03	16%
Data Evaluation/Analysis	0		152.53	17%	0		152.53	13%
Recording Analysis	0		202.31	23%	32.00	16%	234.31	20%
Summary	0		35.15	4%	0		35.15	3%
Supervision	36.4	70%	14.15	2%	0		50.55	4%
Total Person Hours	52.0	100%	893.00	≈ 100%	204.00	100%	1,149.00	≈ 100%
Percent of Total		4%		78%		18%		100%

refining the ESC methodology. The refinements will be discussed in a subsequent section of this analysis. The next largest percentage of time (20 percent) was devoted to recording the analysis. This is not an unexpected result, as a major feature of the methodology is rigorous documentation of the ecological factors considered and their significance to the impact analysis. The time required for documentation can be reduced through the use of computer programs. This aspect will also be discussed in subsequent sections. About 16 percent of the total time commitment was in data collection, and 13 percent of the time was spent on data evaluation/analysis. The remaining seven percent was spent on summarizing the project impacts and supervision.

Of the total staff time spent on the project, 78 percent was contributed by the research associates (biologists/ecologists). The research assistants account for 18 percent of the staff time, and the remaining four percent was contributed by the project manager. About 44 percent of the research associates' time and 46 percent of the research assistants' time was spent on data collection, evaluation, and analysis. The project manager spent 70 percent of his time on supervision, 20 percent on system refinement, and 10 percent on data collection.

Table 5 provides an estimate of the amount of time that would be required to assess a similar dredging activity in like ecosystems given the system refinements, clarifications, and experience gained in the pilot study. These estimates suggest about a 50 percent reduction in the time spent on the pilot study. The majority of this reduction is in time spent on system refinement. The estimated time for data collection and data evaluation analysis have also been reduced slightly because the large amount of secondary data (data for calibration of the ecosystem model) collected during the pilot study will be available for subsequent assessments.

As each assessment adds to the collection of secondary data, the time spent on this task will decrease. A more significant reduction in data collection time was not estimated because subsequent assessments may require more time spent in collection of field data than was spent on such collection as part of the pilot study. As was discussed in the first part of this section, a substantial amount of field data used in the pilot study was previously compiled by the project sponsors.

As the assessment procedure becomes more routinized and the staff becomes more familiar with the methodology and data sources, the time required should decrease. The addition of a standardized procedure for storage and retrieval of secondary information used in judging the significance of alterations in ecological relationships, as well as improved familiarity with sources of field data, should expedite data collection and evaluation time. In addition, the implementation of computer programs for assessment documentation and recording procedures now being developed should decrease the amount of time required, as indicated in Table 5.

Although a total of nine individuals participated in the pilot study, the optimal assessment team would be much smaller. It is estimated that an ideal team size would be three research associates, one research assistant,

Table 5

ESTIMATED TIME ALLOCATIONS FOR DREDGING ASSESSMENT GIVEN CHANGES IN ESC AS RESULT OF PILOT STUDY[1]

	Manual		Computer-aided[2]	
	Hours	Percent	Hours	Percent
Data collection	136	24%	136	28%
Data evaluation/analysis	128	22%	128	26%
Recording analysis	232	40%	150	30%
Summary	32	6%	32	6%
Supervision	48	8%	48	10%
Total hours[3]	576	100%	494	100%

[1]Time requirements for assessing dredging/substrate removal with latest refinements and data gathered during pilot study.

[2]Estimate based on most feasible computer-assistance concepts presently under development.

[3]Total lapsed time for manual assessment is 19 working days (1 project manager, 1 research assistant, 3 research associates); total elapsed time for computer-assisted assessment is 16 working days.

and one project manager. A team of this size could assess the dredging project in approximately 19 working days if the research associates were assigned full time. The project manager could participate in several such teams. Of course, the size of the assessment team required ultimately will depend on the time that can be allocated to each assessment. This will be discussed further in an estimate of the time required to assess other component activities in the La Salle Terminal project.

COMPARISON OF THE IMPACT ASSESSMENT METHODOLOGIES OF THE EL PASO JOINT ENVIRONMENTAL REPORT AND THE AAR ECOLOGICAL SYSTEMS COMPONENT

INTRODUCTION

The effects of dredging operations of El Paso's proposed LNG terminal in Matagorda Bay were evaluated as a test of the ecological systems component (ESC) of the activity assessment routine (AAR). In order to evaluate the method, the ESC assessment was compared to the joint environmental report (JER) for the project, which was prepared by conventional means of assessing environmental impacts.

The joint environmental report prepared by the project sponsors was used as an example of a conventional assessment for purposes of this comparison. It should be noted that this comparison is not intended as a judgment of the adequacy of the JER for this project, and, in fact, is considered an exemplary assessment using conventional techniques. Furthermore, the authors recognize that the project sponsors have prepared documents supplementary to the JER which were not reviewed in this comparison.

COMPARISON OF APPROACHES

In comparison to conventional assessments, the ESC is found to be a better method of analysis. This conclusion is based on three criteria:

1. Ability to predict the impacts resulting from a proposed activity

2. Documentation and presentation of the impacts so that they can be understood and used by the decision maker

3. Preparation of a record of the analysis which will satisfy existing laws and withstand public and judicial scrutiny

The ESC satisfactorily meets the first criterion; the statement of impacts is of comparable quality to that contained in the JER. The ESC identifies changes in the ecosystem resulting from the proposed project but does not identify any significant biological impacts not also addressed by the conventional assessment. The pilot study did not (a) identify areas for which substantial additional data collection would change the outcome of the assessment, nor (b) indicate specific aspects of the proposed dredging operation which could be changed to reduce or mitigate impacts, except by reducing the areal extent of dredging, particularly in shallow bay transitional areas. The most conspicuous need for additional analysis concerned the effect of the widening and deepening of the ship channel on hydrographic conditions within Matagorda Bay.

Development of improved models for this purpose cannot reasonably be expected of an individual applicant. The need has been recognized by relevant state agencies.

The ESC provides a better method of meeting the latter two criteria. It presents the impacts in a format that can be clearly interpreted and used by the decision maker; it provides an audit trail for considerations and judgments; thus, it provides an adequate and easily defended record.

The major methodological differences between the ESC and a conventional assessment are (a) the ESC's explicitly defined and consistently applied criteria for measuring and evaluating impact magnitude and duration, (b) the ESC's capability to determine and justify how far to carry an analysis of indirect effects, and (c) use of documentation procedures in the ESC to support and defend the conclusions.

3. CHANGES MADE IN THE ESC

One of the objectives of the pilot study application of the ecological systems component was to identify areas in the methodology in need of refinement and to make improvements in the system where possible. There are two major types of refinements made in the ESC during the pilot study: methodological and data collection. In addition, experience gained in the pilot study is being applied to development of computer programs for documentation procedures. These refinements and others will appear in the revised ESC user's manual to be published in August 1978.

METHODOLOGY CHANGES

Three major refinements were made in the ESC methodology during the pilot study: (a) changes in the sequence of impact determination, (b) refinement of procedures for measurement of the magnitude of an alteration, and (c) clarification of procedures for determining when to continue a series of analysis.

SEQUENCE OF IMPACT ANALYSIS

In previous applications of the ESC, each primary ecological alteration was followed independently through the systems model from first to higher order alterations (see sequential analysis, Figure 12). This approach tends to isolate a sequence of impact events; it does not allow the analyst to look at other impact sequences occurring simultaneously and determine the impact on an attribute.

This approach has been changed to allow simultaneous consideration of alterations (see simultaneous analysis, Figure 12). In this method, all first-order alterations are considered together and evaluated determining the magnitude, duration, direction, and probability of each alteration. Then all second-order alterations are determined and evaluated. All third-order alterations resulting from the second-order changes are then evaluated, and so on. This allows a screening of alterations at each level. Alterations can also be evaluated in context with other alterations to identify overlapping, counterbalancing, and cumulative effects.

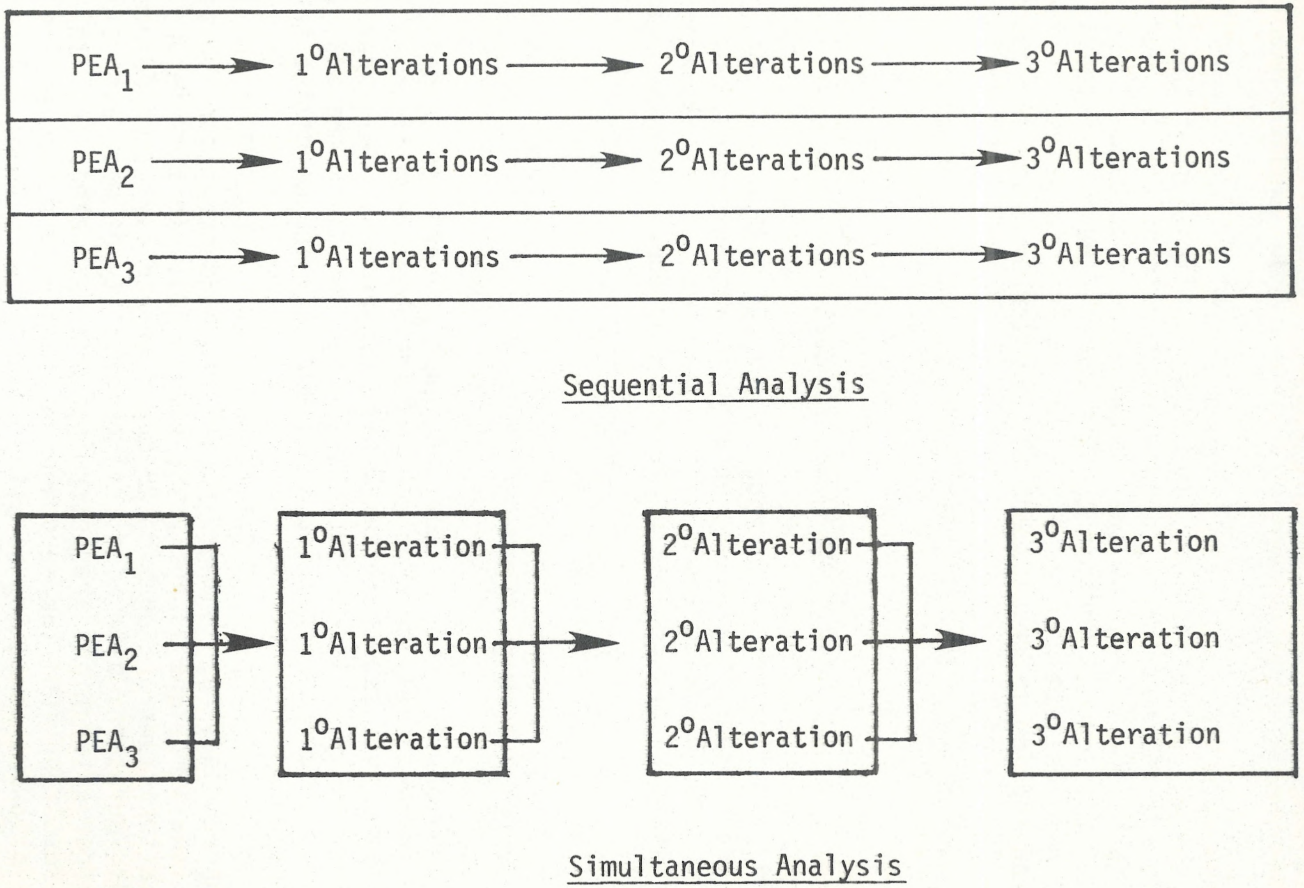


Figure 12

ILLUSTRATION OF SEQUENTIAL vs. SIMULTANEOUS ANALYSIS

IMPACT MEASUREMENTS

In the draft version of the ESC user's manual, few specific criteria were provided for measuring attribute alterations, particularly for impact magnitude and duration estimates. During the pilot study, it became apparent that criteria must be established to achieve consistency in the assessment and to clarify the determination of impacts.

As described in Chapter 1 of this report, definitions have been established for measurement of the magnitude and duration of an alteration, and direction and probability definitions have been clarified. A convention has been established for evaluating the magnitude of an alteration based on a calculation of percent change in energy flow compared to the area of alteration. This convention is thought to be applicabe to a wide range of ecosystem types and sizes; however, definitions of the magnitude and direction classifications must be established by the analyst for each assessment. The importance of these definitions is not that they are quantitatively precise; a substantial amount of research would be required to verify them. The purpose of the criteria is to provide an explanation for the analyst's measurements, to establish a "yardstick" for distinguishing impacts, and to achieve consistency in judgment throughout an assessment.

As a result of the pilot study, it has also been concluded that sufficient data for marine systems are not available to accurately translate changes in energy flow to a change in numbers of organisms, their density, or productivity. However, due to a general lack of experience in considering energy flow alterations in making policy-level decisions concerning a proposed project, this interpretation must be provided by the analyst. Thus, until better data are available, this interpretation will be based largely on a judgment by the analyst. However, such a judgment should be well founded in the comprehensive analysis of attribute alterations provided through application in the ESC.

CRITERIA FOR CONTINUING A SEQUENCE OF IMPACTS

In using a descriptive ecological model to determine impacts, it is necessary to distinguish which cause/effect relationships are potentially altered seriously enough to warrant further evaluation. This is necessary because, literally, everything is connected to everything else, but not all interactions and alterations are important in maintaining ecosystem balance. During the pilot study, criteria were established for consistently determining whether or not to continue to follow a pathway of ecological impacts as indicated by attribute relationships contained in the ecological systems diagram. The criteria prepared for making this decision are based on the magnitude and duration of an alteration (see Figure 7 in Chapter 1). The only exceptions to these criteria occur when an alteration begins to repeat itself within the same cause/effect chain. In these instances, the evaluation is terminated and an appropriate comment is made.

DATA-RELATED REFINEMENTS

Prior to the pilot study application of the ESC, only conceptual data requirements had been specified. During the pilot study, an attempt was made to clarify the types of data inputs required to perform an ecological assessment. As was discussed in the first part of this analysis, these data can be classified as field and engineering data and secondary information. Based on the experience gained in the pilot study, a system for storing, classifying, and retrieving secondary data corresponding to the ecological systems diagram is being refined. This system will be based on the Data Reference Index described in the ESC draft user's manual (page IV-2). Continued developments in defining data input requirements will be discussed in a subsequent section of this paper.

COMPUTER ASSISTANCE FOR ESC

One of the most time-consuming tasks in conducting an assessment with the ESC is the time spent recording each of the alterations evaluated, together with comments, calculations, and references. A series of computer programs is being developed to assist in the task.

In the proposed system (see Figure 13), the computer functions as a "bookkeeping" agent, taking care of all bookkeeping details while the operator makes decisions on the magnitude, direction of change, and other variables. The computer stores all decisions made during the evaluation of a single subactivity within a single ecological system, together with all comments and annotations. At any point during a session, all previous decisions and comments are available for review.

The status of the program development is as follows:

1. Program SETUP: This program is used to create or modify the description of each ecological systems diagram. It provides input to EVAL (through LISTS) in tasks 2 and 4 indicated on Figure 11. This program is coded and running, and operator instructions and documentation are in progress. Some minor revisions may be needed.

2. Program LISTS: This program is used to summarize attribute relationships and to check the systems diagrams created by SETUP. Program LISTS is running, and documentation is in progress.

3. Program EVAL: This program is used in evaluation of attribute alterations. It will perform tasks 1, 3, 5, 6, 7, 8, and 9. Program EVAL is in the system planning stage.

All programs are being developed in FORTRAN IV on the University of Texas CDC 6400 TAURUS time-sharing system. It is anticipated that the program could be adapted to run in BASIC on a 64k microcomputer. Transfer to the TNRIS Univac system would require an estimated reprogramming time of one person-month.

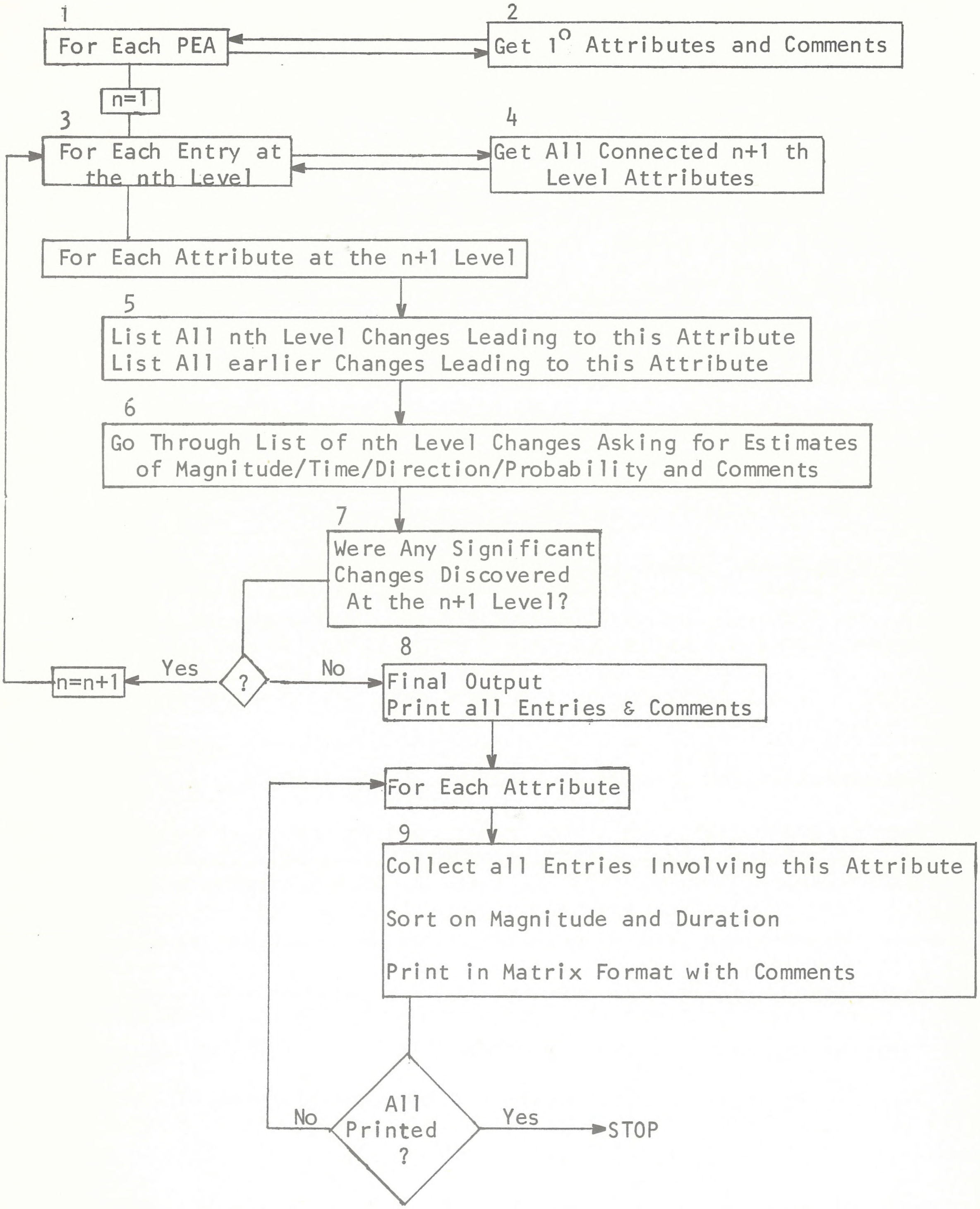


Figure 13

PRELIMINARY FLOWCHART OF MAIN DOCUMENTATION PROGRAM

4. ANALYSIS OF OTHER PROJECT ACTIVITIES

The pilot study of the ecological system component assessed only the dredging phase of the La Salle Terminal project. However, dredging is only one component of a series of related activities that an agency might review. In this section, an estimate will be proveded for the resources required to assess a larger number of such activities.

If, as an example agency, the General Land Office were reviewing the La Salle Terminal project, the activities to which the ESC would be applied would probably include: initial dredging, maintenance dredging, spoil disposal, construction of the docking facilities, and bulkhead/seawall construction. The following analysis describes the time and staff that would be required to assess these activities.

RESOURCES REQUIRED

Estimates of the time allocations by assessment task and by project activity are shown in Table 6. These estimates are based on the estimated time required to assess the dredging activity (Table 5) and on the assumption that the assessment time devoted to system refinement in the pilot study would not be required. Because there is no experience in assessing activities other than dredging, the estimated complexity of each activity was compared to the dredging assessment, and comparable time was allocated by task. Figure 14 shows a projected work plan for assessing the activities related to dredging.

Table 6 also indicates staffing requirements for the assessment. If two calendar months (45 working days) were allotted to assessing a project of this type, optimal staff composition would be three full-time research associates - one Ph.D. and two Masters level or equivalent (135 working days); one part-time research assistant (32 working days); and one part-time project manager (12 working days). A total of 1,424 hours would be required to assess the five related activities.

Table 6

ESTIMATED TIME ALLOCATIONS FOR
ANALYSIS OF LA SALLE TERMINAL PROJECT
ACTIVITIES OF CONCERN TO GLO[1]

Estimated Time Allocations (Hours) by Task by Project Activity[2]

	Revised Est. Dredging	Maint. Dredging	Spoil Disp.	Docking Facility	Bulk-head	Total
Data Collection	136	12	120	12	48	328
Data Evaluation	128	16	120	12	64	340
Recording Analysis	232	16	240	20	80	588
Summary	32	4	24	4	8	72
Supervision	48	4	24	4	16	96
Total Person Hours	576	52	528	52	216	1,424

Staffing Requirements

Type of Personnel	Number	Time Person-Days
Project Manager	1	12
Biologist/Res. Assoc.	3	134 (45 days each)
Research Asst.	1	32

Minimum Assessment Time: approximately 45 working days (two months) with computerization, approximately 39 working days

[1]Includes maintenance dredging, spoil disposal, construction of docking facility, and bulkhead construction, and revised time allocation for dredging canal; manual mode; for computerization, decrease time by 27 days.

[2]Based on Figure 6, Table 5.

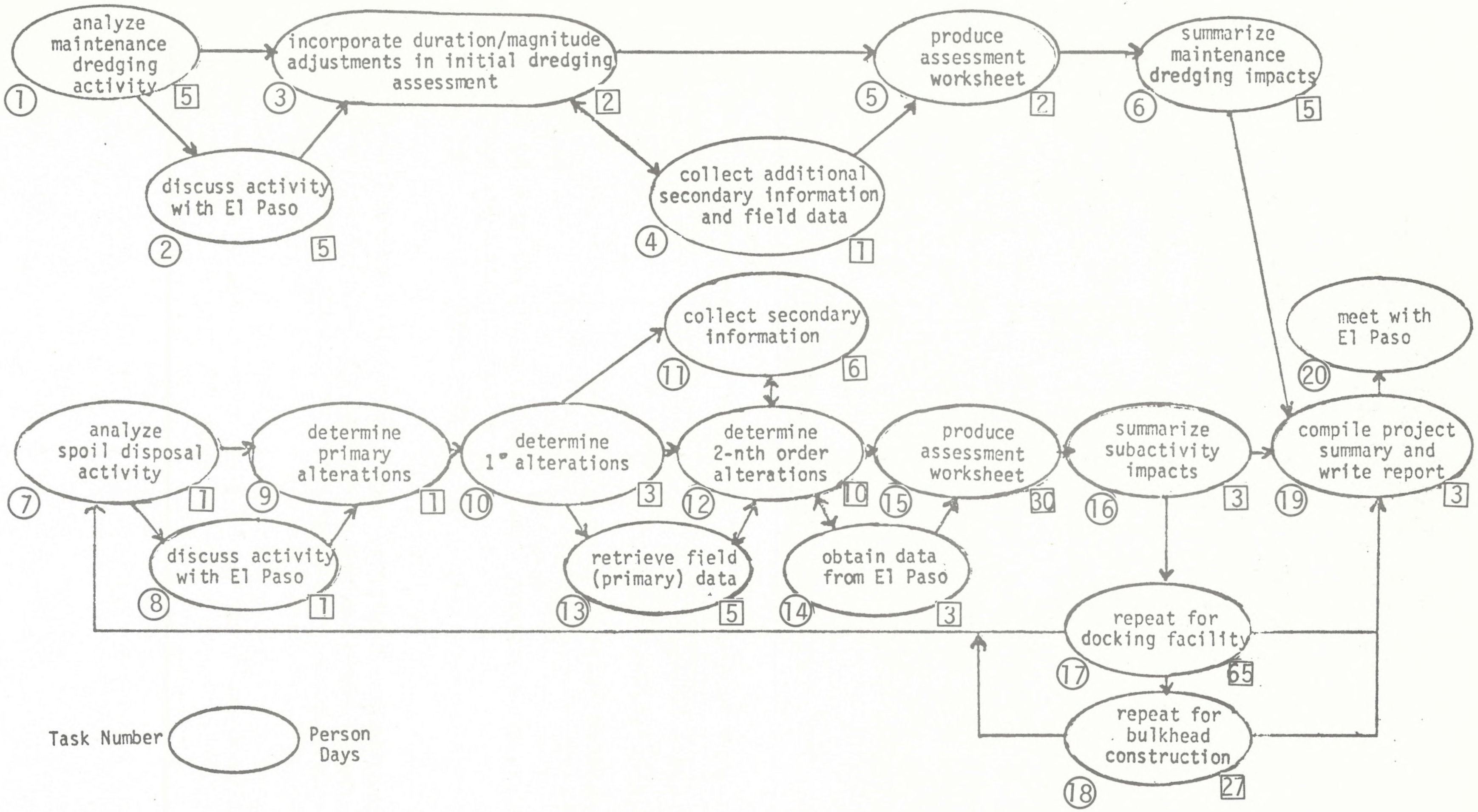


Figure 14

FLOWCHART FOR ASSESSING REMAINING DREDGING-RELATED ACTIVITIES

ABILITY TO SATISFY FEDERAL ENVIRONMENTAL REPORT REQUIREMENTS

This section discusses the degree to which an assessment of ecological impacts using the ESC meets the requirements of a federal agency for preparation of an environmental report. The purpose of this analysis is to provide an indication of the capability of the ESC to provide an assessment which would not only meet state agency criteria but would also be acceptable documentation for federal agency certificate, license, and permit applications. If the ESC is acceptable, considerable duplication could be avoided if the project sponsor or applicant used the ESC in both federal and state permitting.

The basis for making this comparison is rather narrow. The only large-scale application of the ESC has been the pilot study. A comparison can be made between the results of the pilot study, Federal Power Commission (FPC) guidelines for preparation of an environmental report (applications under Section 7C of the Natural Gas Act pursuant to Order No. 415-C), and the environmental report prepared by the La Salle Terminal project sponsors as support information for a Federal Power Commission certificate. The Texas Coastal Management Program is presently holding discussions with other federal agencies on this matter.

The FPC guidelines for preparing an environmental report for a certificate under the Natural Gas Act require a comprehensive description of the existing environment and the impacts of project construction, operation, and maintenance on the environment. The ESC is a method for determining ecological impacts - that is, alterations of an ecological system which may have an adverse or benign effect on biological resources. Thus, the ESC is not a complete environmental assessment. It is intended to complement other existing air and water quality assessment methods.

The specific sections of an environmental report which are required to address ecological impacts are outlined in Table 7, and an indication of the extent to which the ESC addresses these sections is provided.

This analysis indicates that the ESC adequately addresses a majority of the ecological issues required in an FPC environmental report. The ecological sections of the "Description of the Existing Environment" (Section 2) would be based on the prepared ecological systems diagrams and their accompanying descriptions. Supplementary site-specific information would be required for more detailed species delineations. The ESC may also be useful in describing hydrology and hydrography (Section 2.4.2). The ecological impacts of the construction and operations phase (Section 3.2) can be satisfied by the ESC with the addition of information on rare and endangered species. Information derived through the impact assessment can be used to identify measures to enhance, avoid, or mitigate adverse environmental effects (Section 4) by focusing on the specific cause of an alteration. Sections 5 (Unavoidable Adverse Impacts), 6 (Short-Term Uses vs. Long-Term Productivity), and 7 (Irreversible or Irretrievable Committments) are based largely on the impacts identified in Section 3. Additional information on endangered species would be required. The ESC

Table 7

ECOLOGICAL SECTIONS OF AN ENVIRONMENTAL REPORT BASED ON FPC GUIDELINES

Section	Description	Extent Addressed by ESC
2 2.2 2.2.1 2.2.1 2.2.2	Description of the Environment Species of Ecosystems Species Communities and associations Unique and other biotic resources	Ecological models and ecosystem descriptions provided; general species types delineated; field sampling necessary to identify rare and endangered species and more specific species on site
2.4.2	Hydrology and Hydrography	Ecological models and ecosystems can be used to help describe surface water physical and chemical characteristics; may also require physical measures
3.1.2	Environmental Impacts on Species and Ecosystems - Construction	Assesses effects on trophic levels and ecosystem; can identify change in critical parameters and trophic level impacts for endangered species if known to exist in ecosystem
3.1.5	Waste Disposal Impacts	Can be used to assess ecological impacts of waste disposal
3.2.2	Environmental Impacts on Species and Ecosystems - Operation and Maintenance	Assesses effects in trophic levels and ecosystem; migrations; ecosystem alterations and imbalances; can identify changes in critical parameters and trophic level impacts for endangered species
3.2.5	Solid Waste	Can be used to assess ecological impacts of solid waste
3.2.7	Maintenance	Can be used to assess ecological impacts of maintenance activities
3.2.8	Accidents and catastophies	Can be used to assess ecological impacts and system capability to absorb impacts

(continued)

(Table 7 continued)

Section	Description	Extent Addressed by ESC
4	Measures to enhance the environment or to avoid or mitigate adverse environmental effects	Can be used to identify measures to avoid or mitigate adverse ecological effects or enhance, restore ecosystem; can identify specific source of effects for focus of control measures and enhancement/restoration
5	Unavoidable adverse environmental effects	Identifies unavoidable impacts on ecosystems
5.2	Uses preempted and unavoidable changes	
5.3	Loss of environmental quality	
6.1	Short-term uses	Identifies short- and long-term ecosystem alterations
6.2	Long-term productivity	
7	Committment of resources	Identifies ecosystem resources commited; can identify changes in critical parameter/habitats for rare and endangered species
7.2	Endangered Species and Ecosystems	
8	Alternatives	Can be used to summarize ecological effects of alternative sites, activities, designs

could also be used in Section 8 (Alternatives to the Proposed Action) to summarize the comparative ecological impacts of alternative sites, designs, methods, or activities.

With some supplementary information, the ESC could be used to fulfill the requirements for ecological assessment in an FPC environmental report. The ESC was designed as an analytical method and, therefore, is most directly applicable to describing the ecological impact of an activity. It can be useful, however, in describing the existing environment, determining controls for mitigating impacts, and analyzing alternatives.

The FPC guidelines do not specify a method of analysis for ecological impact, and a comparison between the ESC method and conventional assessments (see Chapter 2 of this report) indicates that the ESC should be acceptable for preparing an environmental report.

5. FUTURE DEVELOPMENT OF THE ESC

Ecological impact assessment is still an emerging field. Because assessment methodologies have not been long established nor extensively applied, most methods undergo a fairly rapid evolution. This is evidenced in the ESC by the refinement made during the last year of development and, more significantly, by the refinements made during the pilot study. In keeping with this evolutionary nature, several areas of future development have been identified which would enhance and refine the ESC.

DEVELOPMENT OF ADDITIONAL ECOLOGICAL MODELS

To date, ecological systems diagrams have been constructed for 13 ecosystems: medium salinity bay, bay margin, tidal flat, tidal stream, salt marsh, brackish marsh, freshwater marsh, coastal prairie, fluvial woodland, maritime woodland, levees and spoil banks, delta marsh, and brush-grass complex. For the ESC to have a broader geographic application, additional models are needed. Modeling efforts should focus first on the remaining coastal and adjacent upland ecosystem. New modeling efforts should also concentrate on man-made systems such as channels, spoil islands, bulkhead/pilings, and agricultural systems. Priorities for new ecological systems diagrams include:

<u>Marine Systems</u>

1. Grassflat
2. Nearshore Gulf
3. Channel
4. Submergent spoil
5. Oyster reef

<u>Upland Systems</u>

1. Upland grasslands
2. Inland swamps
3. Freshwater marsh
4. Ponds and lakes
5. Freshwater streams
6. Upland forest
7. Row crop

DEVELOPMENT OF A PROJECT SCREENING SYSTEM

An analysis of the resources required to conduct the pilot study assessment suggests that initially the procedure should be applied only to larger projects. The experience gained and the data and assessment worksheets compiled can then be applied to a more rapid assessment of smaller projects.

A screening process should be established to consistently and predictably determine the projects to which the ESC should be applied. This screening system could include a variety of factors. The dominant criterion should be the potential of the project for significant impact. Thus, a preliminary assessment using criteria such as weighted primary alterations may be necessary to identify projects which should be assessed with the ESC. Until such a system can be developed, however, a more arbitrary screening process based on project size, for example, should be developed.

DEVELOPMENT OF A SUBROUTINE FOR IDENTIFYING IMPACTS ON RARE, ENDANGERED, OR THREATENED SPECIES

The ESC is capable of identifying alterations in habitats and food sources and resulting effects on biotic trophic levels. At present, the systems model is not sufficiently detailed to identify potential changes in particular species of biota. To improve this capability in the routine, particularly for rare, endangered, and threatened species, a subroutine is needed which would "red-flag" potential threats to individual species. This can be accomplished by categorizing known rare, endangered, and threatened species present in a particular ecosystem by trophic level and habitat requirement. These can then be related to the ecological model such that an identified change in either a trophic level or habitat feature can be evaluated for its effect on specific species.

REFINEMENT OF INTERCONNECTIONS BETWEEN SYSTEMS

In identifying the ecological impact of an activity, it is important to trace the effects not only through the system in which the activity is located, but also into adjacent and connected systems. The ESC has been designed to trace these impacts by considering typical imports and exports to and from a system.

One aspect of continued development of the ESC would be to refine these intersystem linkages. This can be done by: (a) examining the pattern of distribution of ecosystems on the Texas coast to determine a frequency of occurrence of adjacent ecosystems; and (b) for those systems that are more frequently adjacent to one another, examining the inputs and exchanges of material or energy and documenting these linkages consistently on each ecosystem diagram. By thus verifying that ecosystem imports and exports match between systems that are typically adjacent to each other, the analyst can couple the models to trace significant impact leaving one system (export) and entering an adjacent systems (import). In addition, this facilitates an analysis of cross-system impacts resulting from a development over a larger area or a lineal development crossing many ecosystems.

EXPANSION OF DATA FILES AND DATA REFERENCING SYSTEM

One of the advantages of the ecological systems approach to impact assessment is that the analyst can consider a comprehensive series of ecological relationships that would be potentially altered by the activity. To adequately judge the significance of an alteration in an ecological attribute or relationship, the analyst requires two types of information. First, quantitative information describing the ecological relationships shown on the ecosystem diagram is necessary. This might include scientific papers and results of modeling and simulation experiments concerning such relationships as nutrient uptake by the benthic community, feeding habits of waterfowl species, or the relationships between macropore water storage and soil structure. This type of information can be made more available by creating a system of data files for the attribute interrelationships on the systems diagram. These data files would also contain the literature used initially to construct the diagram, supportive information, photographs and documentation of applicable models, and estimates of threshold values or standards.

The second type of information required in use of the systems diagram is site-specific baseline information. Although much of this information can (and should) be collected at the site of the proposed activity, there is often a significant amount of previously collected data monitoring the attributes or relationships of concern. A system for referencing this information has been designed (see draft ESC user's manual, pp. IV-3-12), but at present it is only in the conceptual stage.

As experience is gained in application of the ESC and in construction of supporting data files, input requirements for project-specific data can be more clearly identified. Eventually a list of the types of data required to conduct and ESC assessment should be compiled for major activity/ecosystem types. This list should specify data that must be supplied by a project sponsor (field data and engineering data) and field and secondary data to be collected by the analyst.

INVESTIGATION OF METHODS FOR AGGREGATING IMPACTS

In the present stage of development, impacts identified through the ESC are based on analysis of individual project activities or subactivities in the ecosystem in which they occur. These individual impacts are summarized to produce a statement of the total project impacts. However, there is no well-defined methodology for integrating several alterations of an ecological attribute which occur in several ecosystems as the result of several different activities over varied time frames. Consequently, cumulative, additive, or synergistic effects may be understated. A technique for considering these effects may be derived through the use of computerized manipulations which provide a capability of recalling and comparing all similar alterations over several project activities. A program which includes these functions is currently under development. See previous sections of this report for additional discussion.

RESEARCH AND DEVELOPMENT OF PROCEDURES FOR EXPRESSING THE SIGNIFICANCE OF CHANGES IN ENERGY FLOW IN TERMS OF INDIVIDUAL SPECIES

The present version of the ESC uses reductions in energy flow as the units for measuring the magnitude of an alteration of an ecological attribute. Ultimately, it would be desirable to be able to translate these changes in energy flow to changes (reductions, increases, or alterations in behavior) in individual species of organisms.

Theoretically, this translation can be expressed in terms of an energy "budget" for an organism (see Figure 15). An organism expends the energy it receives for a variety of functions: growth, maintenance or standard metabolism, migration, reproduction, foraging, and digestion. At different stages in its life cycle, an organism will expend varying amounts of energy on each function. Thus, a reduction in energy flow to an individual may, depending upon its life cycle stage and the type, amount, duration, and time period of the alteration, affect the amount of energy an organism has available to maintain the energy budget. By understanding the composition (type, age, sex, etc.) and density of species at a site, and the response of organisms to change in environmental parameters, energy flow alterations could be translated to species changes in individual species of organisms.

This process is significantly beyond the capabilities of existing information. However, it is recognized as a desirable objective, and research efforts should be designed to address this need.

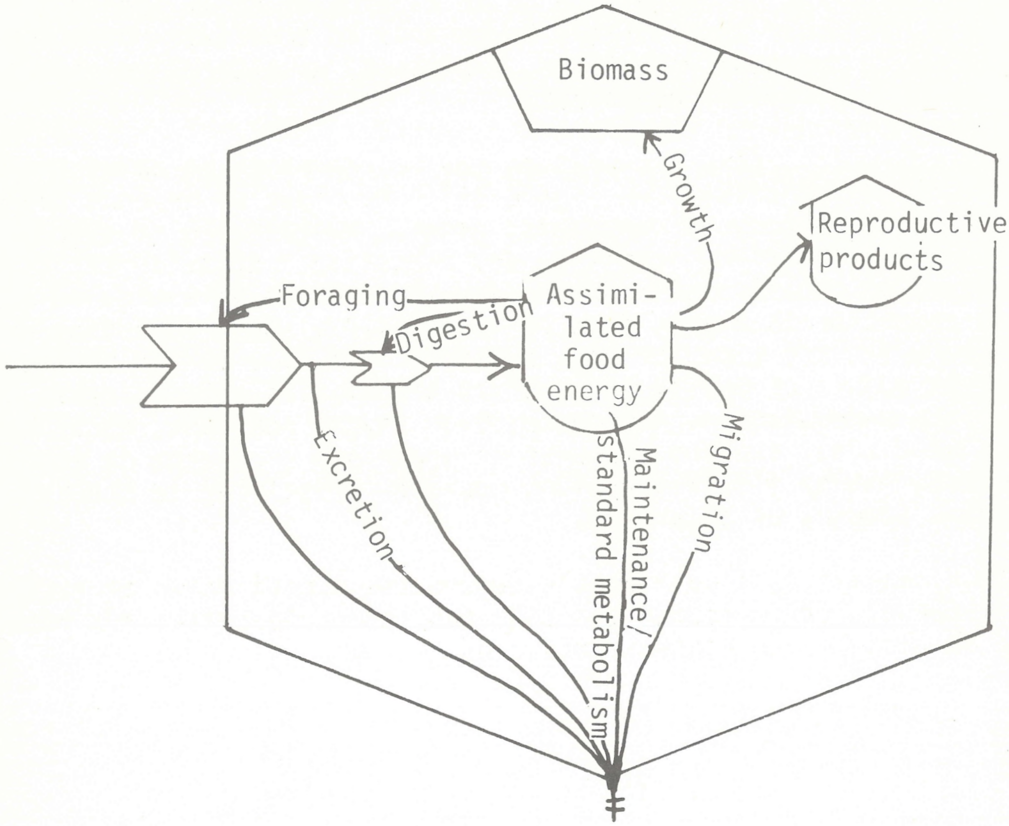


Figure 15

ENERGY BUDGET FOR AN INDIVIDUAL ORGANISM