EMERGY ANALYSIS PERSPECTIVES, PUBLIC POLICY OPTIONS, AND DEVELOPMENT GUIDELINES FOR THE COASTAL ZONE OF NAYARIT, MEXICO

Report to
The Cousteau Society
and the
Government of Nayarit, Mexico

VOLUME 1:
Coastal Zone Management Plan and Development Guidelines

By

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September, 1992

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Volume 1: Coastal Zone Management Plan and Development Guidelines

TABLE OF CONTENTS

EMERGY ANALYSIS PERSPECTIVES, PUBLIC POLICY OPTIONS, AND DEVELOPMENT GUIDELINES FOR THE COASTAL ZONE OF NAYARIT, MEXICO

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INTRODUCTION

This document is the first of a two volume report to The Cousteau Society and the Government of the State of Nayarit, Mexico. It is an outgrowth of a 2 year study to develop recommendations for a master plan for the coastal zone of Nayarit. As part of our effort we conducted several Emergy analysis studies of fisheries, tourism, water use, and heath care within the coastal zone (given in Volume 2). These studies provided necessary background information for public policy decisions regarding the best use of resources and for determining carrying capacity of the coastal zone for future development. As part of our efforts, two Mexican students were trained in methods of emergy analysis and environmental planning.

Our intention from the outset was to develop recommendations for a Master Plan comprised of a complete set of planning documents that included a map of overall development potential, a regulatory framework and the necessary legislation for implementation. This volume, in essence then, is the Master Plan for the coastal zone. It contains a Land Use Management Plan, A Developers Handbook, and a Reserves and Protected Areas Plan, along with documentation. These comprise the set of planning documents that, if implemented, will achieve the State's goal of protecting the environmental and social/cultural resources of the coastal zone.

This volume is comprised of 4 parts :

Part 1: Resource Management Options - Part 1 provides the necessary background information that lays the framework for the management plan in 6 sections:

Section 1: The Coastal Zone of Nayarit - a description of the coastal zone and its environmental resources.

Section 2: Environmental Constraints and Opportunities for Development - a discussion of the development potential of the environmental resources within the coastal zone that includes criteria and suggested regulations for their protection.

Section 3: Social/Cultural Constraints and Opportunities for Development - A discussion of social and cultural issues that affect development potential that includes criteria and suggested regulations for minimizing development impacts.

Section 4: Goals and Objectives for Protecting the Environmental and Social/Cultural Resources - a compilation of goals and objectives that are an outgrowth of the environmental and social/cultural constraints and opportunities for development.

Section 5: The Regulatory Framework - suggestions for a development review board and a review process that will insure the execution of the management plan.

Section 6: Generation of the Plan - a summary section of the methods and background materials used in determining constraints and opportunities for development and the Overall Development Potential Map of the coastal zone.

Part 2: Proposed Land Use Management Plan - The Management Plan includes a regulatory framework and legislative component, written as an ordinance, so that it may be adopted as the key element for the protection of the coastal resources of the State.

Part 3: Handbook of Development Guidelines - Called the "Developers Handbook", Part 3 is the set of development guidelines for developers that provides information and instructions for developing within the coastal zone.

Part 4: Reserves and Protected Areas Plan - The Reserves and Protected Areas plan contains suggestions for preservation and management of areas of special significance.

PART 1: RESOURCE MANAGEMENT OPTIONS

SECTION 1: THE COASTAL ZONE OF NAYARIT

The physical and biological endowment of Nayarit is bountiful and rich in its potential for supporting multiple human activities. But it has its limits. Increasingly, humanity is learning that it must accept the ecological constraints set by these limits and recognize that fragile resources, once destroyed, cannot be easily replaced (Barlowe, 1979).

Nayarit's coastal zone contains many critical ecological areas, which are extremely vulnerable to destruction. For example, coastal wetlands provide a critical link between terrestrial and aquatic ecosystems and provide a vital service for the marine ecosystem. It is estimated that over 70 percent of all commercially valuable marine fishes rely on estuarine areas during at least part of their lives. Half of the biological productivity of the world's oceans occurs along the coast, and estuaries are the most productive fishing areas known on earth (Rau, 1980).

Nayarit Coastal Zone Biogeography

The State of Nayarit is located in the northwestern portion of central Mexico (Figure 1). It borders on the north with the states of Durango and Sinaloa, on the south with Jalisco, on the east with Jalisco, Durango and Zacatecas, and on the west with the Pacific Ocean, with a coastline length of 289 km.

In this report, the **Nayarit Coastal Zone (NCZ)** is divided into three general regions, according to characteristic geological features. The 3 zones are: (1) the North Pacific Coastal Plain Zone (NPCPZ), (2) the Central Neovolcanic Axis Coastal Zone (CNVACZ), and (3) South Sierra Madre Coastal Zone (SSMCZ). These zones are defined as follows:

(1) The North Pacific Coastal Plain Zone (NPCPZ) lies within the northwestern province of the state with a length of approximately 100 km. It is characterized by its low relief, and is comprised of great flood plains, lagoons and wetlands, and is aligned parallel to the coastline. This portion of the coastal plain consists of a fringe of large littoral ridges, which include numerous marshes interspersed between sand bars.

Most of the area's soils are alluvial, lacustrine and palustrine deposits, which come from the Cenozoic era and the Quaternary period. It is possible that peat deposits could be discovered in the coastal plain, as well as salt and other minerals which are formed under conditions similar to those that prevail in this province. Until recently there has not been much knowledge of the geologic resources in this region (SPP, 1981).

Due to the presence of sea water within the marshlands and parallel bar ridges, soils have high concentrations of salts, which make them incapable of sustaining agriculture, except when they are thoroughly washed. The predominant soil class is Solonchak (gleyco, ortico and takirico), as well as some Regosol eutrico.

The climate in this region is hot, and varies from dry to subhumid. The predominant vegetation associations are mangrove forest and low deciduous tropical forest. Halophytic vegetation predominates, but there are also medium deciduous tropical forests; induced grassland; palms; and salt marsh vegetation (see the following section for descriptions of the vegetation communities).

One important aspect worth mentioning is that this coastal plain extends into the Pacific Ocean, creating an ample continental shelf, which offers rich fisheries for the coastal communities. The Tres Marias islands are considered part of this province, but they are not included as part of this study.

(2) The Central Neovolcanic Axis Coastal Zone (CNVACZ) lies within the western part of the province, with a coastal length of approximately 80 km. It is characterized by a very complex physiography, with some plains and sierras which are part of the Neovolcanic Axis bordering the Pacific Ocean. The lithology of this zone is comprised of acidic, extrusive igneous rocks, and basic, intermediate and sedimentary rocks. The predominant soil present in the plain is Cambisol eutrico, while in the sierra Feozem haplico is the dominant soil, characteristics of being highly erodible at steep slopes.

The climate in this zone is hot subhumid, with winter rain less than 5% of the annual total. The vegetation that predominates is subdeciduous medium tropical forest, but there are also some mangrove communities, as well as irrigated and non-irrigated agriculture.

(3) The South Sierra Madre Coastal Zone (SSMCZ) lies in the northwestern part of the South Sierra Madre Province, which is one of the most complex and less known regions of Mexico. Its characteristic features are due to its relation with the Cocos Plate, which in turn gives this whole region a high seismicity, particularly in the coasts of Guerrero and Oaxaca.

The coastal length of approximately 110 km is characterized mainly by Sierra Vallejo, which has a mixed lithology. It also consists of coastal plain, with a delta at the border of Nayarit and Jalisco where the Banderas Valley is located, and some ramified valleys with an association of hills along the San Marcos River. These drain into the Pacific Ocean, and consist of alluvial soil surrounded by hills with volcanic rocks.

The predominant soil in this zone is the Feozem haplico, with the exception of a small band at the Banderas Valley consisting of Fluvisol eutrico soil. The climate of this region is mainly hot subhumid, with winter rains of less than 5% of the annual total. An exception is the area at the Banderas Valley, which is less humid than the others. The vegetation is dominated by subdeciduous, medium tropical forest, with areas of palms, mangroves, small patches of deciduous low tropical forest, and non-irrigated agriculture.

Description of Resources of the Coastal Zone

Vegetation

The following descriptions of resource characteristics are general for the coastal zone of Nayarit. The community types as identified here are shown on MAP 1--Land Cover. These are broad classes of vegetation associations, representing rather homogeneous stands of vegetation or human-dominated land uses. These broad classes of communities easily lend themselves to development of land-use management controls that will best protect the resources.

Ten major community or land-use types were identified in this study. They are described as follows:

1. **Sand Dunes (Dunas Costeras) (DC)**. This vegetation community is found on sand dunes located along the coastline, and has an important role in establishing and maintaining the structural integrity of coastal ecosystems, protecting the valuable estuarine and shoreland systems behind them from storm damage and erosion. In most instances, dune vegetation is found landward of sand beaches.

   Common species:
   (Opuntia dillenii) Nopal.
   Sea grape (Coccoloba spp) Uva Marina.
   (Bromelia pinguin) Timbiriche.
   (Pectis spp.)
   (Trianthema portulacastrum)
   (Okenia hypogea)
   (Jouvea straminea)
   (Prosopis juliflora)
   (Celtis iguanae)
   (Crateaeva tapia)
   (Acacia cochliacantha)
   (Crescentia alata)
   (Gouinia virgata)

2. **Mangroves (Manglar) (MA)**. Mangroves are found primarily around estuaries, coastal lagoons and marshes. Typical species include: white mangrove (Laguncularia racemosa), which is the dominant species overall in the mangrove forests of the NCZ; and red mangrove (Rhizophora mangle), taller than 20 m, dominant in fringing areas of the river deltas and near the inlets of lagoons. Behind these fringe and riverine forests, white mangroves occur in practically monospecific stands (Flores-Verdugo et al., 1990). Gomez-Pompa (1978) describes the presence of white mangrove as characteristic of perturbed zones or areas with higher

sedimentation; therefore, the presence of monospecific populations of white mangrove in estuaries and lagoons may indicate a drastic perturbation and high rate of sedimentation.

The presence of black mangrove (Avicennia germinans) is variable. It is very uncommon in Agua Brava lagoon, with isolated patches in the lagoons at Bahia de Banderas, but is the dominant species fringing the parallel linear coastal lagoons formed by stranded beach ridges. In this area it is possible to observe a distinct zonation pattern in a short transect, with white mangrove in the fringe, black in the middle, and buttonwood (Conocarpus erectus) on the top of the sand barriers (Flores-Verdugo et al., 1990). In some estuarine areas like that of La Tovara, there are mangrove-associated species such as cat-tail (Typha spp.), arrowroot (Thalia spp.) and knot-grass (Paspalum spp.), which is indicative of a higher freshwater input than the other mangrove areas in the northern coastal plain of Nayarit.

Common species:
White Mangrove (Laguncularia racemosa) Mangle blanco.
Red Mangrove (Rhizophora mangle) Mangle rojo o Candelon.
Black Mangrove (Avicennia nitida) Puyeque.
Buttonwood (Conocarpus erecta) Boncahui.
Arrowroot (Thalia spp.) Quento.
Cat-tail (Typha spp.) Tule.
(Paspalum spp.)
(Cynodon spp.)

3. **Wetland (Popal) (PO)**. This is an herbaceous community characteristic of swampy marshes of the coastal plain, with permanent water with depths of approximately 1 m. The vegetation is rooted at the bottom, but their broad leaves are above the water surface.

Common species:
Water-lilies (Nymphaea spp.) Lirio.
(Calathea spp.) Popoay.
Arrowroot (Thalia spp.) Quento.
Cat-tail (Typha spp.) Tule.

4. **Palms (Palmar) (PA)**. With a density of approximately 500 trees per hectare, this community is found in the parallel bars of the coastal lagoon system. There is one representative species: guacuyul (Orbignya guacuyule). In other areas, such as the southern part of the **NCZ**, another type of palm can be found, the palmetto (Sabal mexicana). This species is frequently present in humid and subhumid zones of low altitude. The northern limit of the distribution of the guacuyul palm is at Nayarit (Pennington and Sarukhan, 1968). Some palm communities are the product of human perturbation, while others are naturally occurring (Gomez-Pompa, 1978).

Common species:
(Orbignya guacuyule) Guacuyul.
(Sabal mexicana) Sabal.

5. **Deciduous Tropical Forest (Selva) (FS).** These are communities formed by arboreal vegetation, composed of a great mixture and number of species. They are fairly open, relatively low forests of broad-leaved trees, with some epiphytes and vines. Much of the foliage is lost in the dry season.

Three types of this category are classified according to the height of the trees in the community. The **High Deciduous Tropical Forest (Selva alta),** with tree heights greater than 30 m, is not found in the **NCZ.** The following types of Deciduous Tropical Forests are communities found within the coastal zone of Nayarit:

5a. **Medium Deciduous Tropical Forest (Selva mediana) (FSm).** Trees in this community attain heights of between 15-25 meters. During the driest part of the year they loose between 25-50% of their leaves. They are present under different climates, but mainly in areas with 1400 mm or more rain per year and with a pronounced dry season. This community is difficult to characterize, due to its diverse vegetative composition. It is composed of dry-tolerant species of the high tropical forest, along with representative species of more humid areas of the low tropical forest, plus some species which only grow in this community.

Common species:
(Enterolobium cyclocarpum) Guanacaste o Parota.
(Ficus spp.) Chalate o Higueron.
(Tabebuia rosea) Rosamorada.
(Ceiba petandra) Ceiba.
(Roseodendron donell) Primavera.
(Cochlospernum vitofolium) Rosa amarilla.
(Cecropia obtusa) Trompeta.
(Brosimum alicastrum) Capomo.
(Orbignya guacuyul) Guacuyul.
(Coccoloba spp.) Juanper.
(Bursera spp.) Palo Blanco.
(Pithecellobium dulce) Guamuchil.
(Hymenaea courbaril) Guapinol.
(Sabal spp.) Palma de viga.
(Acacia cornigera) Cornezuelo.
(Psidium guajava) Guayaba.
(Bursera simaruba) Papelillo.
(Trema spp.) Capulin.

(Croton draco) Sangre de Drago.
(Guazuma spp.) Guacima.
(Acrocomia spp.) Coyul.
(Byrsonima crassifolia) Nanche.
(Swietenia humilis) Venadillo.
(Hura polyandra) Haba.
(Vitex mollis) Ahuilote.
(Cedrela spp.) Cedro.
(Inga spuria) Guamo.
(Andira inermis) Tololote.
(Trichilia glabra) Limoncillo.
(Bursera simaruba) Jiote.
(Gliricida sepium) Cacahuananche.
(Lonchocarpus spp.) Cabo de hacha.
(Lysiloma divaricata) Tepemezquite.
(Karwinskia humboldtiana)
(Quercus spp.) Encino.
(Ipomoea spp.) Osote.
(Cordia elaeagnoides) Barcino.
(Astronium graveolens) Palo de cera.
(Annona squamosa)
(Heliocarpus spp.) Majahua.

5b. **Low Deciduous Tropical Forest (Selva baja) (FSb).** Vegetation in this community reaches heights of between 4 and 15 meters. Species of the low deciduous forest lose more than 75% of their leaves during the driest part of the year. This type of vegetation is found mainly in low hill areas and along some of the sierras, such as Sierra Vallejo, where it is the dominant community. The vegetation plays an important role in soil retention, protecting these areas from erosion.

Common species:
(Coccoloba spp.) Juanper.
(Acacia cochliacantha)
(Cochlospernum vitofolium) Rosa amarilla.
(Enterolobium cyclocarpum) Guanacaste o Parota.
(Ficus spp.) Chalate.
(Brosimum alicastrum) Capomo.
(Tabebuia rosea) Rosamorada.

(Juliana adstringens) Cuachalate.

(Ceiba petandra) Ceiba.

(Cedrela spp.) Cedro.

(Cecropia obtusa) Trompeta.

(Hura polyandra) Haba.

(Inga spuria) Guamo.

(Ceiba spp.) Pochote.

(Pseudobombax ellipticum)

(Guazuma spp.) Guacima.

(Gliricida sepium) Cacahuananche.

(Sabal spp.) Palma de viga.

(Leucaena glauca) Tepemezquite.

(Acacia spp.) Huizache.

(Acacia pannatula) Tepame.

(Hymenaea courbaril) Guapinol.

(Cochlospernum spp.)

(Acacia cornigera) Cornezuelo.

(Heliocarpus spp.)

(Tabebuia spp.)

(Leucaena spp.)

(Byrsonima crassifolia) Nanche.

(Quercus spp.) Encino.

(Lysiloma acapulcensis) Tepeguaje.

(Belotia mexicana)

(Orbignya cohune) Coco de aceite o Palo mulato.

(Plumeria rubra) Rosa blanca.

(Bursera simaruba) Jiote o Papelillo.

(Acronomia spp.) Cuyul.

(Swietenia humilis) Venadillo.

(Brumelia persimilis)

(Andira inermis) Tololote.

(Roseodendron donnell)

(Psidium guajava) Guayaba.

(Croton draco) Jaral o Tacote.

(Pithecellobium dulce) Guamuchil.

(Cresentia cujute) Guastecomate.

6. **Halophytic Vegetation (Vegetacion Halofita) (H).** This vegetation association is developed in soils with a high content of salts. It is mainly found in the low lands of closed basins, and in the low areas surrounding estuaries, lagoons and salt marshes, where it is dependent on tides or periodic flooding. The vegetation is associated with mangrove forest.

Common species:
(Panicum spp.)
(Bromus spp.)
(Dactyloctenium spp.)
(Laguncularia racemosa) Mangle blanco.
(Rhizophora mangle) Candelon o Mangle rojo.
(Concocarpus erecta) Botoncahui.
(Cynodon spp.)
(Eleusine spp.)
Knot-grass (Paspalum spp.)
(Dactylotenium spp.)
(Acacia spp.)
(Avicennia nitida) Puyeque.
(Phithecellobium dulce) Guamuchil.
(Sporobolus spp.) Zacate malin.
(Batis maritima) Vidrillo.
(Acacia spp.) Huizachillo.
(Opuntia leptocaulis) Tasajillo.

7. **Induced Grassland (Pastizal Inducido) (Pi).** This type of vegetation appears when the original dominant vegetation of an area is eliminated either by clearing of land or in abandoned agricultural areas, as well as in burned areas due to frequent fires. Savanna is frequently included in this vegetation type.

Common species:
(Cynodon spp.)
(Sporobolus spp.)
(Bouteloua spp.)
(Chloris spp.)
(Muhlenbergia spp.)
(Dactyloctenium spp.)
(Aristida spp.)
(Byrsonima crassifolia) Nanche.

(Acacia spp.)
(Sabal spp.)
(Tabebuia spp.) Amapa prieta.
(Orbignya spp.) Guacuyul.
(Psidium spp.) Guayabo.
(Crescentia alata)
(Coccoloba barbadensis)
(Sapium spp.)
(Opuntia puberula)
(Rauwolfia tetraphylla)
(Schizachyrium hirtiflorum)

8. **Agriculture (Agricultura) (A).** This category includes all of those concepts related to the use of land and soil management with the purpose of producing crops. Classification is made on water use for crops and according to the length of time the crop grows on the land. Agricultural categories are as follows:

8a. **Irrigated Agriculture (Agricultura de Riego) (Ar).** These are areas transformed for the specific purpose of agriculture. The use of land is intensive, with alternated crops. This particular type of agriculture is practiced in those lands where the vegetative cycle of crops is assured by water from irrigation, for at least 80% of the year, for a certain period of time.

According to length of the crops:

(Ara) Irrigated agriculture, annual. This means that the crops spend no more than one year under cultivation. There may be crop rotation during a single year on the same land, or every other year. Included in this category are crops such as corn, beans, wheat, etc.

(Arp) Irrigated agriculture, permanent. This means that the crops spend a period of several years under cultivation, and generally more than 10 years.

Common species:

Sugar cane (cana de azucar), soy bean (soya), onion (cebolla), garlic (ajo), peanuts (cacahuate), corn (maiz), mango (mango), watermelon (sandia), tobacco (tabaco), banana (platano), rice (arroz), etc.

8b. **Non-Irrigated Agriculture (Agricultura de Temporal) (At).** This type of agriculture is practiced on those lands where the vegetative cycle of the crops depends on rain water. These lands could be left without cultivation for some time, but they must be under cultivation at least for 80% of the years for a certain period of time.

Common species:

Corn (maiz), soy bean (soya), peanut (cacahuate), banana (platano), mango (mango), etc.

Wildlife

Bernal Diaz del Castillo was the first to record some impressions of Mexico. He noted the striking variety in land types of the so called "New World". Even though the vegetation has been much altered, the basic types remain in vivid contrast as Diaz described them. Variety in Mexican topography, climate, and vegetation has given rise quite naturally to an equally varied animal life (Leopold, 1972). Unfortunately, the animal wealth is shrinking in both variety and abundance as the Mexican landscape is cleared and put to economic uses.

Birds

Nayarit abounds in birds. The following list includes the more important game birds, as well as the birds most likely to be seen by tourists and bird watchers. Eight major groups of birds are defined, which identifies them mainly with their habitat or importance as a resource for some human activities.

Each group is followed by a list of most of the species of birds known to inhabit the coastal zone of Nayarit, based on the works of scholars such as Edwards (1955, 1968); Gulick (1965); Leopold (1959, 1972); Arellano y Rojas (1956); and Peterson and Chalif (1973). The English common name of the bird is first listed, followed by scientific name and then the Mexican common name.

1. Marine and seashore birds: In this category are included all the birds whose habitat is mainly marine and or along the shore of the NCZ. Some of these may be resident or migratory.

Common marine and seashore birds:

Brown Pelican (Pelecanus occidentalus) Pelicano.

Frigate Bird (Fregata magnificens) Tijereta o Fragata comun.

Olivaceaus Cormorant (Phalacrocorax olivaceous) Pato buzo o Cormoran.

Black-necked Stilt (Himantopus mexicanus) Tildio grande

Heermann's Gull (Larus heermanni) Gaviota obscura.

Laughing Gull (Larus atricilla) Gaviota.

Ring-billed Gull (Larus delawarensis) Gaviota.

California Gull (Larus californicus) Gaviota.

Bonaparte's Gull (Larus philadelphia) Gaviota menor.

Bridled Tern (Sterna anaethetus) Golondrina marina collareja.

Royal Tern (Thalasseus maximus) Golondrina marina real.

Elegant Tern (Thalasseus elegans) Golondrina marina elegante.

Brown Noddy (Anous stolidus) Golondrina marina gorriblanca.

Red-billed Tropicbird (Phaethon aethereus) Rabijunco piquirrojo.

Blue-footed Booby (Sula nebouxii) Sula piesazulez.

Brown Booby (Sula leucogaster) Sula cuellioscura.

Willet (Catoptrophorus semipalmatus) Playero pihuihui.

Wandering Tattler (Heteroscelus incanus) Playero sencillo.

Spotted Sandpiper (Actitis macularia) Playero alzacolita.

Ruddy Turnstone (Arenaria interpres) Vuelvepiedras comun.

Surfbird (Aphriza virgata) Playero roquero.

Long-billed Curlew (Numenius americanus) Zarapito piquilargo.

Whimbrel (Numenius phaeopus) Zarapito cabezirrayado.

Semipalmated Plover (Charadrius semipalmatus) Chorlito

Killdeer (Charadrius vociferus) Chorlito tildio.

2. **Wading birds:** Included in this category are those birds that feed along shorelines or in shallow waters, mainly in estuaries and marshes. Some nest in the mangrove forest, and some only winter there.

Common wading birds:

Great Blue Heron (Ardea herodias) Mescuan.

Common Egret (Casmerodius albus) Garza comun.

Snowy Egret (Leucophoyx thula) Garza.

Egrets: (Egretta caerulea) Garza azul.

(Egretta tricolor) Garza vientriblanca.

Cattle Egret (Bubulcus ibis) Garza ganadera.

Yellow-crowned Night Heron (Nycticorax violaceus) Garza nocturna coroniclara.

White-faced Ibis (Plegadis chihi) Ibis obscuro.

Wood Stork (Mycteria americana) Ciguena americana.

White Ibis (Eudocimus albus) Borregon o Ibis blanco.

Roseate Spoonbill (Ajaia ajaja) Espatula.

Northern Jacana (Jacana spinosa) Jacana.

Boat-billed Heron (Cochlearius cochlearius) Macaco.

3. **Resident Waterfowl:** In this category are those waterbirds known to be resident in the NCZ, and that are important game birds, widely hunted either for sport or for food. Their habitat is mainly in the estuarine lagoons and marshes, as well as some freshwater bodies.

Common resident waterfowl:

Black-bellied Tree Duck (Dendrocygna autumnalis) Pato Pichichin.

Muscovy Duck (Cairina moschata) Pato real o Perulero.

4. Migratory waterfowl: Here are included the water game birds whose wintering grounds are located along the coastal zone of Nayarit. The habitat is mainly the same as that for the resident waterfowl.

Common migratory waterfowl:

Blue-winged Teals (Anas cyanoptera and Anas discors) Cerceta cafe y Cerceta de alas azules.

Green-winged Teal (Anas carolinensis) Cerceta de lista verde.

Pintail (Anas acuta) Pato Golondrino.

Baldpate (Mareca americana) Pato calvo o panadero.

Gadwall (Anas strepera) Pato Pinto.

Shoveler (Spatula clypeata) Pato cucharon o cuaresmeno.

Canvasback (Aythya valisineria) Pato Coacoxtle o borrado.

Redhead (Aythya americana) Pato cabeza roja o Guayareja.

Lesser Scaup (Aythya affinis) Pato Boludo.

Ruddy Duck (Oxyura jamaicensis) Pato Tepalcate o Sonso.

Snow Goose (Chen hyperborea) Ansar blanco

White-fronted Goose (Anser albifrons) Ganso frente blanca.

Coot (Fulica americana) Gallareta.

Common Gallinule (Gallinula cloropus) Gallareta frentiroja.

Purple Gallinule (Porphyrula martinica) Gallareta morada.

5. Terrestrial gamebirds: This category encompasses most of the widely hunted gamebirds whose habitat is terrestrial, and can be found in terrestrial areas bordering coastal marshes and estuaries, as well as forested areas of the coastland.

Common terrestrial game birds:

Rubescent Tinamou (Crypturellus cinnamomeus) Perdiz canela.

Crested Guan (Penelope purpurascens) Choncho o Faisan griton.

Chachalaca (Ortalis poliocephala) Chachalaca.

Tree Quail (Dendrortyx macroura) Codorniz coluda.

Douglas Quail (Lophortyx douglasii) Codorniz de Douglas o Chacuaca.

Red-billed Pigeon (Columba flavirostris) Patagona o Torcaza.

Mourning Dove (Zenaidura macroura) Huilota o Rundacha.

White-winged Dove (Zenaida asiatica) Paloma de Alas Blancas o Huilota Costera.

White-tipped Dove (Leptotila verreauxi) Alcabuz o Cuizula.

Ruddy Quail-dove (Geotrygon montana) Paloma montanera.

Inca Dove (Scardafella inca) Cocochita o Torcacita.

Rock Dove (Columba livia) Paloma domestica.

Red-billed Pigeon (Columba flavirostris) Paloma morada ventriobscura.

Common Ground Dove (Columbina passerina) Tortolita pechipunteada.

6. **Birds of prey:** This category includes the birds that prey on other vertebrates and reptiles, as well as those that feed on dead vertebrates and reptiles not killed by them.

Common birds of prey:

Red-tailed Hawk (Buteo jamaicensis) Gavilan.

Common Black Hawk (Buteogallus anthracinus) Aguililla.

Crested Caracara (Caracara cheriway) Quelele.

Black Vulture (Coragyps atratus) Zopilote.

Turkey Vulture (Cathartes aura) Aura.

Sparrow Hawk (Falco sparverius) Halcon Cernicalo.

Peregrine Falcon (Falco peregrinus) Halcon Peregrino.

Osprey (Pandion haliaetus) Aguila pescadora.

Zone-tailed Hawk (Buteo albonotatus) Aguililla aura.

Wood Owl (Ciccaba virgata) Mochuelo cafe.

Ferruginous Pygmy Owl (Glaucidium brasilianum) Tecolotillo rayado.

7. **Ornamental and singing birds:** In this category are those birds that are trapped for aesthetic purpose, either for their sheer beauty or for their singing. Also included are those species frequently sought by birdwatchers.

Common ornamental and singing birds:

Blue Mockingbird (Melanotis caerulescens) Mulato.

Common Mockingbird (Mimus polyglottos) Cenzontle.

Brown-backed Solitaire (Myadestes obscurus) Jilguero.

Loggerhead Shrike (Lanius ludovicianus) Carretero.

Yellow-winged Cacique (Cassiculus melanicterus) Calandria o Galantina.

(Aimophila ruficauda) Gorrion cachetinegro tropical.

(Passerculus sandwichensis) Gorrion sabanero comun.

Streak-backed Oriole (Icterus pustulatus) Calandria.

Military Macaw (Ara militaris) Guacamaya verde.

Orange-fronted Parakeet (Aratinga canicularis) Periquito o Cotorrita frentinaranja.

White-fronted Parrot (Amazona albifrons) Perico o Loro.

Lilac-crowned Parrot (Amazona finschi) Perico o Loro.

Vermilion Flycatcher (Pyrocephalus rubinus) Colorin.

Tropical Kingbird (Tyrannus melancholicus) Tirano tropical.

Elegant Trogon (Trogon elegans) Coa.

Citreoline Trogon (Trogon citreolus) Coa.

8. Other birds to watch: This category includes the rest of the birds that were not included in the other categories.

Colibris o Chuparrosas:

Long-tailed Hermit (Phaethornis suprciliosus)

Broad-billed Hummingbird (Cynanthus latirostris)

Cinnamon Hummingbird (Amazilia rutila)

Carpinteros o Chacos:

Golden-cheeked Woodpecker (Centurus chrysogenys)

Ladder-backed Woodpecker (Dendrocopos scalaris)

Pale-billed Woodpecker (Phloeoceastes guatemalensis)

Golondrinas:

Roughed-winged Swallow (Stelgidopteryx ruficollis)

Barn Swallow (Hirundo rustica).

Grey-breasted Martin (Progne chalybea).

Swallow (Stelgidopterix serripensis).

Martin pescadores:

Belted Kingfisher (Megaceryle alcyon)

Green Kingfisher (Chloroceryle americana)

Other Common Birds:

(Cacicus melanicterus) Tordo aliamarillo.

(Icterus pustulatus) Bolsero pustulato.

(Agelaius phoeniceus) Tordo sargento.

(Bombycilla cedrorum) Ampelis americano.

(Lanius ludovicianus) Verdugo americano.

Cactus wren (Campylorhinchus brunneicapillus) Matraca desertica.

Happy wren (Thyrothorus felix) Troglodita feliz.

Boat-tailed Grackle (Cassidix mexicanus) Zanate.

San Blas Jay (Cissilopha san-blasiana) Chereque.

Magpie Jay (Calocitta formosa) Urraca.

Fish Crow (Corvus ossifragus) Cacalote.

Raven (Corvus corax) Cuervo.

Lesser Roadrunner (Geococcyx velox) Correcamino o Faisancillo.

Groove-billed Ani (Crotophaga sulcirostris) Ticuz o Chicurra.

Pauraque (Nyctidromus albicollis) Tapacamino pucuyo.

Mammals

The following is a list of most of the mammals that can be found in the coastal zone of Nayarit, some of which are threatened or endangered in Mexico or in other parts of the world:

Common opossum (Didelphis marsupialis) Tlacuache.

(Marmosa canescens) Tlacuachin.

Nine-banded armadillo (Dasypus novemcinctus) Armadillo.

White-sided jackrabbit (Lepus alleni) Liebre.

Mexican cottontail rabbit (Sylvilagus cunicularis) Conejo.

Eastern cottontail rabbit (Sylvilagus floridanus) Conejo.

Gray squirrel (Sciurus colliaei) Ardilla.

Coyote (Canis latrans) Coyote.

Gray fox (Urocyon cinereoargenteus) Zorra gris.

Ring-tailed cat (Bassariscus astutus) Cacomixtle.

Raccoon (Procyon lotor) Mapache.

Coati (Nasua narica) Tejon o Coati.

Weasel (Mustela frenata) Comadreja.

Hooded skunk (Mephitis macroura) Zorrillo listado.

Spotted skunk (Spilogale pygmaea) Zorrillo manchado.

Hog-nosed skunk (Conepatus mesoleucus) Zorrillo.

River otter (Lutra annectens) Nutria o Perro de agua.

River otter (Lutra longicaudis) Nutria o Perro de agua.

Jaguar (Felis onca) or (Panthera onca) Jaguar o Tigre.

Ocelot (Felis pardalis) Ocelote o Mojocuan.

Margay (Felis wiedii) Tigrillo o Winduri.

Puma (Felis concolor) Puma o Leon de montana.

Jaguarundi (Felis yagouaroundi) Oncilla o Jaguarundi.

Bobcat (Lynx rufus) Gato montes.

Collared Peccary (Pecari tajacu) Jabalin o Pecari de collar.

White-tailed deer (Odocoileus virginianus) Venado cola blanca.

Bats/Murcielagos:

Balantiopteryx plicata

Diclidurus virgo

Noctilio leporinus (Murcielago pescador)

Pteronotus davyi

Pteronotus parnellii

Pteronotus personatus

Mormoops megalophylla

Glossophaga comissarisi

Glossophaga soricina

Choeronyscus godmani

Leptonycteris sanborni

Sturnira lilium

Chiroderma salvini

Artibeus intermedius

Artibeus jamaicensis

Artibeus phaeotis

Artibeus toltecus

Centurio senex

Desmodus rotundus (Vampiro)

Natalus stramineus

Myotis fortidens

Lasiurus borealis

Lasiurus ega

Lasiurus intermedius

Rhogeessa parvula

Nyctinomops aurispinosus

Molossus ater

Molossus molossus

Rats & Mice/Ratas y Ratones:

Oryzomys melanotis

Oryzomys palustris

Reithrodontomys fulvescens

Peromyscus banderanus

Peromyscus perfulvus

Baiomys musculus

Sigmodon mascotensis

Neotoma alleni

Liomys pictus

Reptiles

Studies on the herpetofauna of Nayarit have not been published yet, but there is good information on the Mexican herpetofauna generally, published by Smith and Smith (1977). Based on this synopsis, and other bibliographic resources such as Gulick (1965) and HABB et al., (1990), the following list of reptiles of the coastal zone of Nayarit has been compiled:

Aquatic Reptiles:

American crocodile (Crocodylus acutus) Caiman o Cocodrilo.

Water snake (Natrix valida) Culebra de agua.

Marine Reptiles:

Sea Turtles:

Leatherback (Dermochelys coriacea) Tortuga Laud o de Canal.

Green turtle (Chelonia mydas) Tortuga verde o Cahuama.

Olive ridley (Lepidochelys olivacea) Tortuga Golfina.

Hawksbill (Eretmochelys imbricata) Tortuga de Carey.

Sea Snakes:

Yellow-bellied sea snake (Pelamis platurus) Serpiente Marina.

Terrestrial Reptiles:

Mexican iguana (Iguana iguana) Iguana verde.

Spine-tailed iguana (Ctenosaura pectinata) Iguana negra.

Beaded lizard (Heloderma horridum) Escorpion.

Spiny swift (Sceloporus sp.) Lagartija escamosa.

Lagartijas/Lizards:

Gecko (Peropus mutilatus)

(Phyllodactylus lanei)

Anole (Anolis nebulosis) Camaleon.

Race Runner (Cnemidophorus sp.)

Skink (Eumeces callicephalus)

(Eumeces parvulus)

Snakes/Culebras:

Poisonous Snakes:

Mexican rattlesnake (Crotalus triseriatus triseriatus) Vibora de Cascabel.

Mexican moccasin (Agkistrodon bilineatus) Cantil.

Coral snake (Micrurus diastema distans) Coralilla.

Non-poisonous Snakes:

Boa (Constrictor constrictor imperator) Boa o Ilamacoa.

Ring-necked snake (Diadophis dugesii)

(Lampropeltis triangulum nelsonii)

(Lampropeltis triangulum schmidti)

Garter snake (Thamnophis sp.)

Other Snakes:

(Hypsiglena torquata) Culebra.

(Masticophis striolatus) Culebra corredora.

Turtles/Tortugas:

Mud turtle (Kinosternon hirtipes)

(Kinosternon integrum)

Endangered Wildlife Species

One of the most important aspects of environmental conservation is the protection of endangered or threatened species. The world conservation community has focused much of its attention on the plight of tropical forests. Millions of hectares have been transformed to logged forest or shifting cultivation, and several other millions had been entirely lost (permanently cleared) for agriculture, grazing lands, various kinds of plantations, and other land uses, such as industrial or urban use. Deforestation is high in some areas of the world, and most of the forest on these so called "hotspots" of deforestation will be completely disturbed in less than thirty years. An assault of this magnitude will have profound consequences on the global pool of species. At the present time, the recorded extinction rate for higher vertebrates has been kept at a respectable 151 species over the past 400 years. Tragically, however, for every species listed as endangered or extinct, at least a hundred more will probably disappear unrecorded (Wilcox, 1988).

The presence of highly valuable species of wildlife in the coastal zone of Nayarit requires urgent measures for protection and conservation. The following is a list of the species listed by the IUCN (HABB, 1990) as threatened or endangered species for Mexico, which are found in the coastal zone of Nayarit:

Mammals:

Ocelot (Felis pardalis) Ocelote.

Jaguarundi (Felis yagouaroundi) Jaguarundi.

Margay (Felis wiedii) Tigrillo o Winduri.

Jaguar (Panthera onca) Jaguar.

River otter (Lutra longicaudis)

Reptiles:

American crocodile (Crocodylus acutus) Caiman o Cocodrilo.

Green turtle (Chelonia mydas) Tortuga Verde o Cahuama.

Leatherback turtle (Dermochelys coriacea) Tortuga Laud o de Canal.

Hawksbill turtle (Eretmochelys imbricata) Tortuga de Carey.

Olive Ridley turtle (Lepidochelys olivacea) Tortuga Golfina.

Birds:

Peregrine falcon (Falco peregrinus) Halcon Peregrino.

Crested guan (Penelope purpurascens) Choncho.

Osprey (Pandion haliaetus) Aguila Pescadora.

Common black hawk (Buteogallus anthracinus) Aguililla Negra.

Zone-tailed hawk (Buteo albonotatus) Aguililla Aura.

Orange-fronted parakeet (Aratinga canicularis) Cotorrita Frentinaranja.

SECTION 2: ENVIRONMENTAL CONSTRAINTS AND OPPORTUNITIES FOR DEVELOPMENT

INTRODUCTION

The **Nayarit Coastal Zone** (NCZ) has for a long time been a great prospect for the development of tourism, and in recent times for the development of aquaculture and other fisheries-related activities. The pressure which has lately been exerted for the development of the coastline will tend to shrink undeveloped lands and strain environmental resources, if it is not properly planned for and controlled. The importance of determining, prior to development, where the most suitable and most sensitive lands are, and setting in place guidelines and regulations to insure that they will remain intact, cannot be overstated. Their value to wildlife, economic vitality, and future generations should not be overlooked. Fortunately, the State government has considered the potential consequences if development is not regulated and properly planned, and has stated its desire that the environmental resources of the NCZ should be protected.

Presumably, without a wider perspective, that is, without a landscape perspective, effective planning and management that might preserve portions of the landscape mosaic is not possible. The first stage in developing a landscape perspective is to identify environmental constraints and opportunities for development. The second stage is to recommend development guidelines and a regulatory framework that will ensure that development is consistent with the goals of environmental protection.

The quality of an environment results from an interplay of both natural ecological communities (e.g., forest, wetlands, grasslands) and lands which have been put to residential, commercial and agricultural uses. Often, most emphasis is placed on the developed uses and little attention is given to maintaining a portion of the landscape in wild and scenic uses. Sometimes it is quite difficult to express the value of these wildlands to regions that are experiencing rapid development pressure, since wildlands are in great supply (and therefore little valued) and development lands are in short supply (and therefore much valued) (Brown, 1989). The value and importance of wildlands is often seen when they are already overdeveloped and not much is left to conserve or protect.

The value of environmental resources to tourist economies is increasingly recognized, as travelers all over the world seek destinations that have not become overdeveloped. Resources that are treated as integral parts of a tourist development plan become no-cost, self-sustaining amenities that have the potential to increase total number of tourists, number of tourist days and, ultimately, total revenues received (Brown, 1989). In addition, a healthy environment is essential for economic vitality.

The coastal zone of Nayarit offers a unique and relatively pristine environment that is rich in marine and terrestrial resources. These resources may become the basis for expansion of the state economy through increased tourist revenues. The importance of these resources to developing the tourist potentials of the coastal zone of Nayarit cannot be overstated.

Sound resource management should involve: (1) preservation of unique ecological communities, (2) preservation of important wildlife habitats, (3) development of a network of wildlands, (4) regulation of development impacts, (5) enhancement of existing ecological communities and wildlife habitats, and (6) encouragement of site-sensitive development patterns (Brown, 1989). By incorporating these principles, it is expected that development in the NCZ will avoid, and in some areas reverse, the decline in environmental quality and will enhance the terrestrial and marine environments through careful development siting and management. Issues related to the development of the NCZ can be grouped into three broad categories: those related to the direct losses of unique ecological communities and environmental services; those related to secondary impacts of development; and those resulting from increased human access.

Direct and Indirect Effects of Development Activities

Direct Losses of Ecological Communities

As lands are developed to accommodate human uses, by necessity the natural organization of vegetation cover is altered. For the most part, the development process clears land of vegetation, recontours the land surface where necessary, and covers the land with roads, buildings and landscaping. As a result, a portion of the landscape is directly converted from natural ecological communities to developed lands.

Generally, the loss of ecological communities directly impacts wildlife that depend on these areas for feeding, breeding, and nesting sites. The more widespread the development, the greater the area disturbed and the greater the losses of wildlife species. Compact development that leaves large contiguous areas of lands undeveloped helps to maintain ecological communities and wildlife populations.

The wildlife habitat value in developing landscapes is more related to the size of undisturbed lands than to the total area. With a given area of undisturbed land, the best configuration is one that produces large blocks of interconnected wildlands instead of many small patches (Harris, 1984). Connections (or corridors) between wildlands help to increase their value as wildlife habitat. The increased mobility and exchange of wildlife species and individuals between wildland patches helps to ensure continued viability of wildlife populations and increased access to food and cover.

Secondary Impacts on Ecological Communities

The most important secondary impacts from development are: 1) erosion of unstable lands, resulting in sedimentation and increases turbidity in downstream areas, and 2) release of waste by-products (sewage, solid wastes, and storm water runoff) to the environment. These are considered secondary impacts since the development of lands results in secondary affects on the surrounding environment. Secondary impacts, for the most part, are avoidable with proper siting and regulation.

The severity of potential impacts from erosion and downstream sedimentation is related to the physiographic characteristics of coastal lands. The NCZ is divided into 3 physiographic regions as described in Part 1, Section 1 of this volume: the North Pacific Coastal Plain Zone (NPCPZ); the Central Neo-Volcanic Axis Coastal Zone (CNVACZ); and the South Sierra Madre Coastal Zone (SSMCZ). This division clearly depicts two different types of terrain: a northern coastal plain, and a mixture of plains, hills and sierras in the south, where some terrain is relatively rugged, with areas of extreme slope.

The northern coastal plain (NPCPZ), while prone to floods, has relatively flat terrain, and the severity of erosion potential is low (although still important). The southern portion of the NCZ, which includes CNVACZ and SSMCZ, has more relief. The high relief, combined with sparse vegetative cover and highly erodible soils, creates conditions of soil instability that are easily aggravated.

Areas that are cleared for development have the potential of affecting down-slope areas if cuts, clearings and excess materials are not stabilized rapidly. Once soil surfaces are exposed, the energy in rainfall is not dissipated by vegetation, and soil particles are easily lifted from the soil surface and carried down-slope with surface runoff. Continued exposure to rainfall removes soil from the bases of rocks, eventually causing them to loosen and tumble down slope.

In all, once erosion on the higher slopes begins, the effect on down-slope ecological communities can be extremely devastating. First, eroded materials may be deposited in down-slope locations in sufficient quantity to bury vegetation. Second, loosened rocks that have sufficient energy may clear paths in vegetation as they roll downhill, exposing additional soil and increasing the potential for further erosion. And third, soil that is repeatedly exposed to rainfall may erode faster than vegetation can become established in sufficient quantity to stabilize the slope.

Secondary impacts can easily affect an area equal to or greater than the area that was originally cleared. Indeed, one of the greatest potential impacts is increased sedimentation and turbidity in nearshore waters that may extend over several thousands of hectares after a single rainfall event. Yet these impacts are easily controlled if proper development guidelines are implemented, and land owners are encouraged to pay particular attention to erosion control measures. In general, shoreland developments should be regulated so that the amount of impervious surface is minimized and barren soils are rapidly stabilized.

Indirect Impacts Resulting from Increased Access

If a previously undeveloped area is suddenly easily accessed by an increasing number of people, indirect losses of environmental quality will result. In addition, the impacts of wastes like sewage effluent and garbage from an increasing population can cause significant deterioration. Indirect losses associated with an increased presence of human population include: trampling and cutting of vegetation, increased erosion, pollution, increased occurrence of fire, and the flight of wildlife (Brown, 1989).

Wherever human use of the landscape increases, the potential for the decline in the overall quality of the area is increased. Through increased traffic, waste, noise, and the like, greater stress is placed on the ecological communities of the area. Both vehicular and foot traffic trample vegetation and expose the soil to the action of wind and rain. Increased gathering of wood, seeds, fruit, and wildlife may over-exploit the resources and drive them to extinction (Brown, 1989). The northern area of the coastline has been used as a hunting ground for several wildlife species, such as waterfowl, jaguar, bobcat, collared peccary, rabbit, and quail. Some trade with exotic birds is also a current practice.

The demand for marine resources in areas surrounding urban concentrations usually far exceeds sustainable yields. First, the increased population density increases demand. Second, urban populations with higher income also increase demand. And third, urbanization often results in a high concentration of poor who, by necessity, extract resources from the local environment.

While the direct impacts of conversion are somewhat easier to visualize and are generally assumed to be of primary importance in maintaining a high quality environment, the indirect effects associated with development often have greater potential to compromise environmental quality. To minimize indirect impacts, access to selected areas of the coastal zone need to be controlled, and the secondary impacts from waste products and erosion need to be regulated.

The release of waste by-products from developed areas is another important secondary impact. Development within the coastal zone affects the both quality and quantity of surface water after storm events. With increased areas of impervious surface, the speed and volume of runoff from developed lands after storm events are increased. Stormwater runoff carries with it silt and sediments, oil residues, heavy metals, and trash.

Increased population density means increased spatial density of wastes. Where populations are concentrated in the coastal zone, human and industrial wastes are often discharged in ocean outfalls, often untreated. Further inland, sewage wastes from developed areas are usually discharged to a nearby river that carries them downstream toward nearshore waters and estuaries. In some areas of the world, a third alternative for sewage waste management is the injection of untreated sewage directly into below-ground aquifers.

Solid waste disposal in the coastal zone is problematic. Often, solid wastes are dumped in "low" areas (marshes and mangrove swamps) or directly in the ocean. Accumulations of solid wastes in streets, if not removed regularly, are washed with the next rainfall to the nearshore environment.

The impacts of the release of waste by-products from developed lands act to stimulate aquatic production, and often cause changes in fresh water and marine community structure. When high-nutrient waters characteristic of sewage outfalls come in contact with coral reefs or sea grass beds, the over-nutrification often shifts communities to lower diversity ones, having lower values as nursery grounds or for artisinal fishing. Over-nutrified lakes and streams have lower dissolved oxygen, and fish populations often shift to less commercially-desirable varieties.

ACTIVITIES IMPACTING COASTAL RESOURCES

There are 4 main activities that occur (or potentially may occur) within the NCZ that are directly related to the quality of its marine and terrestrial resources. These include: tourism development, marine construction, mariculture development, and fishing. In addition, two broad areas of activities, development in rural watersheds and development activities in urban watersheds, while not necessarily within the coastal zone, have profound impacts on coastal resources and have been included in the analysis of human impacts. Table 2.1 lists marine related activities, major problems associated with each activity, and their primary and secondary impacts on the terrestrial and marine environments of the coastal zone. Brief discussions of each activity are given next.

Tourism Development

Tourism development has become an important alternative for needed foreign currency throughout the world in developing countries. In island nations with extensive coastal shorelines and associated beaches, reefs and marine grass beds, the potential is significant. Limitations to resort development are both external and internal. The major external limitation is developing a sufficient "market share" to warrant increased resort development, and while all indications are that world tourism is still growing, it represents a limitation not easily overcome. Often, in the rush to develop tourist resorts, the very resources which attract tourists are neglected, not protected, and lost. Once gone, reefs, beaches, and coastal habitats are not easily replaced.

In the Nayarit, like many other places world-wide, the major internal limitation is the lack of adequate infrastructure in the form of road networks, airports, public water supplies, and waste treatment technologies. Provision of the needed infrastructure represents a significant investment that must be financed from external sources. The net benefits from tourism development under these circumstances are questionable, when both economic and environmental costs are considered (Brown and Murphy, in press; Oliver-Smith et al., 1989). As a result of this lack of public infrastructure, many hotels are required to provide their own services at varying degrees of success and efficiency.

Major Problems and Resulting Impacts

The major problems and resulting primary and secondary impacts from the three main activities of tourism development are summarized in Table 2.1. The general trend is an increase in the pressure on the local environment as tourism development increases. The major problems that result can be grouped into 3 broad areas: (1) release of pollutants, (2) direct conversion of terrestrial and marine habitats, and (3) increased demand for resources.

Release of pollutants. There are several sources of pollutants resulting from tourism development in the coastal zone. The largest is domestic sewage from beach-front hotels and ancillary developments. Other sources of pollutants include stormwater runoff, dumping of solid wastes, and oil and fuel from marinas and boat operation. In some areas, the dumping of solid wastes directly into coastal waters can represent a significant source of potentially hazardous material.

In well-mixed surf zones and tidal locations the ultimate consequences of ocean outfalls for domestic sewage are disputed. The enrichment of marine waters that are notoriously low in available nutrients may actually increase productivity, yet net increases in productivity alone may not justify the practice. Since both of these communities depend on extremely clear waters, over-enrichment from sewage outfalls and the resulting increases in algae production can have serious impact on water transparency, and thus on coral reefs and marine grass beds (Snedaker and Getter, 1985). Coral reefs are particularly sensitive to toxins that may be released as non-point sources of storm water runoff or from marinas (fuel and oil).

Maintenance of good water quality is not only important to marine organisms, it can seriously affect human use of marine resources as well. With the release of sewage and non-point source stormwater runoff, water quality can be negatively affected to the point that recreational uses and harvest of marine resources for consumption are impaired.

Table 2.1 **Matrix of coastal related activities, problems, and impacts**

Activities	Major Problem	Coastal Impacts: Primary	Coastal Impacts: Secondary
I. Tourism Development- Hotel & infrastructure construction & operation	Release of pollutants & toxins	Water pollution	Shifts in comm. structure of marine habitats, violation of safe water quality standards
	Direct conversion of terr. & marine habitats	Loss of habitat & foodchain support	Shifts in community structure, decreases in organism abundance, loss of fishery potential
	Increased resource demand	Overfishing/other resource depletion	Collapse of reef community, loss of fishery potential, destruction of terrestrial habitats
Marina construction & operation	Direct conversion of terr. & marine habitats	Loss of habitat & foodchain support	Destruction of reefs & terr. habitats, loss of fishery potential
	Release of toxins	Water pollution	Alteration of marine systems & violation of safe water quality standards
Recreational activities	Increased boating/diving	Physical destruction/water pollution	Destruction of reefs & grassbeds
II. Marine Construction	Dredging	Physical destruction/ turbidity increases	Destruction of reefs/grassbeds/mangroves & other terr. communities
III. Mariculture Development	Digging/bulkheading	Physical destruction/ turbidity increases	Loss of mangrove, salina, and marine grassbed ecosystems; Impacts on ecosystem interconnections
IV. Fishing	Overfishing	Loss of fishery/ habitat destruction	Collapse of fishery

Table 2.1 (continued)

Activities	Major Problem	Coastal Impacts Primary	 Secondary
V. Activities in rural watersheds	Inflows of sediments	Increased turbidity	Loss of marine ecosystems
	Inflows of toxins/nutrients	Water pollution	Alteration of marine ecosystems & violation of safe water quality standards
	Altered freshwater inflows	Increased &/or decreased freshwater inflows	Alteration of estuarine/mangrove ecosystems
VI. Development of urban watersheds	Inflows of sediments	Increased turbidity	Loss of marine ecosystems
	Inflows of toxins/nutrients	Water pollution	Alteration of marine ecosystems & violation of safe water quality standards
	Altered freshwater inflows	Increased freshwater inflows	Alteration of estuarine ecosystems
	Increased resource demand	Overfishing/other resource depletion	Collapse of fishery/reef communities
	Solid waste dumping	Water pollution	Aesthetics/damage to marine organisms

While many beaches have well-mixed surf zones, others can easily concentrate human wastes resulting in dangerously high levels where water quality standards for human recreational use are exceeded. While indications are that some marine organisms (bottom fish) do not concentrate trace metals from sewage outfalls (Mearns, 1981) there is still cause for concern regarding benthic invertebrates, filter feeding mollusks, and other invertebrates like crabs, shrimp, and lobster.

Direct conversion of terrestrial and marine habitats. With the construction of tourist resorts, marinas and associated infrastructure, terrestrial communities like beach and dunes, back dune areas, mangroves, and areas of salina are directly converted. Often, coral reefs are removed or channels blasted to provide access to open waters. Marine grass beds and mangrove swamps are often dredged to provide boat access to marinas. These conversions are direct and irreparable.

The connections between terrestrial and marine habitats, the values of fringing mangroves and reefs as buffers against storm waves, not to mention the importance of many of these habitats to indigenous and migrating fauna, make their conversion problematic. Conversion of any of the coastal communities, because they are tightly coupled, causes loss of habitat value and food chain support throughout the coastal zone. The impacts are manifested in shifts in the community structure of reefs and grass beds, decreases in the abundance of certain marine organisms, and the eventual loss of fishery potential.

Increased demand for resources. The international tourist consumes nearly 20 times the resources that a local citizen consumes (Brown and Murphy, in press). The net effect of an increased population of tourists is to increase demands on the environment to a much larger degree than would occur with "normal" population growth.

Wherever concentrations of human populations increase, there is an increased demand for resources from the surrounding environment. Tourism development increases the demand for fishery resources, potable water, land, labor, and even such obscure resources as palm fronds for thatching of beach front palapas. With increased demand comes the potential for over-exploitation. Many of the reefs and grass beds throughout the world in tourist areas exhibit indications of over-fishing of such desirable marine organisms as lobster, conch, and the larger reef fish (Snedaker and Getter, 1985).

The demand for curio items like corals and sea shells can easily outstrip the potential of the marine environment to provide them on a sustainable basis in areas of intense tourist development. As these resources are exploited, associated secondary impacts include the complete collapse of reef communities. These communities cannot sustain high levels of harvest of top levels of the food chain without serious shifts in populations of lower food chain organisms (McClanahan, 1991). Economic dislocation of artisanal fisherman follows the initial increase in income and numbers of fishermen as over-exploitation eliminates the resource base upon which they depend.

Current Status in the NCZ

Sewage treatment is probably the single most important service (other than potable water supply) necessary to protect the health and safety of people living (or visiting) in the coastal zone, and yet it is the one most often neglected by public and private development. In many areas of the coastal zone, development, whether for tourism or urban expansion, is not serviced by a central sewage treatment system, or small package facilities. The common practice is to discharge wastes directly to nearshore waters. Public waste treatment facilities in the coastal zone are inadequate. The consequences are staggering. Virtually all existing development in the coastal zone and much of the new development either discharges domestic sewage untreated directly into coastal waters or uses leach-fields or septic pits where space and soil types permit. All of these practices degrade the quality of the resource base for tourism and threaten the health of the permanent population and visitors alike.

In areas of existing tourism development, and radiating outward along the coasts, associated impacts on the marine and terrestrial communities are pervasive. Wherever beach-side development of tourist resort facilities was observed, complete alteration of beach and dune communities throughout the immediate area of each complex was standard practice. Associated road networks and nearby commercial developments contributed further to destruction of dune and back-dune vegetation.

Evidence of destruction of reef communities and marine grass beds is more difficult to document without extensive investigation. The mechanical disturbance of marine grass beds has become a serious problem in areas where there is heavy boat traffic and may be surmised to be of minor importance in most of the coastal zone, since the number of boats and marinas in areas of seagrass bed communities is relatively small. The construction of beach groins is standard practice in many beach-side developments that results from constructing too close to the water's edge. Beaches are by nature shifting systems, at times having a positive flow of incoming sand and at times having a negative balance. Once constructed, groins rob "downstream" locations of their sand supply. The problem of beach erosion is displaced from one location to the next with the net effect that no net increase in beach is achieved. There was little evidence of beach groins and jettys within the NCZ.

Discharge of sewage to nearshore waters resulting directly from tourism development, while occurring at most locations of coastal development, was relatively small in magnitude except in Bandaras Bay. Tourism development in the Bandaras Bay can be surmised to be contributing to an already-serious situation, since many direct discharges to the nearshore waters already exist.

Marine Construction

Major Problems

The construction, maintenance, and operation of port facilities can represent a significant impact on the environment. Dredging of habitats for port creation, channel maintenance, and release of toxins and other pollutants are the major problems. A brief discussion of each follows.

Dredging and jetty construction. In nearshore waters, deep water access to ports for ocean going vessels must be provided and maintained. The process of dredging, whether for new port construction or for maintenance of existing facilities, directly converts marine and terrestrial habitats, increases turbidity, and can be a source of pollutants from accumulations in sediments. The process of dredging converts habitat directly, and disposal of dredge spoil often further damages habitat. Physical destruction of habitats threatens listed wildlife species, impacts fisheries, and causes loss of sediment trapping capacity and loss of storm surge protection.

Release of toxins, sewage, and garbage. In both nearshore waters and deep water shipping lanes, the release of ballast, sewage, and garbage can pose a threat to marine resources. Ballast often contains toxic substances which, if released in open waters, probably do not reach concentrations that may be significant. Yet oil residue often forms tar mats that are unsightly and unpleasant to tourists and present an ecological problem on beaches and fringing reefs. Sewage discharges at sea do not present the problems of shore-based discharges. Open sea dumping of garbage is problematic because of the prevalence of non-biodegradable plastics that foul beaches and can be ingested by marine mammals, fishes, and birds.

Current Status

Little is known concerning the current status.

Mariculture

General Description

Typically, the construction of ponds for mariculture occurs in salina areas. The salinas are often upland, but immediately adjacent to mangroves, but are sometimes found next to bays or lagoons separated from these open water systems by a natural dike of coral rock or sand bar. Sometimes upland fringes of mangroves are converted, and in the more serious cases ponds are constructed next to estuaries within mangrove forests. In field surveys of the coastal zone, there is evidence of mariculture operations in the NPCPZ.

Major Problems

Where mariculture operations are constructed directly within mangrove communities, estuarine food chains can be seriously degraded from the loss of organic matter inputs. Large expanses of mariculture ponds immediately upland from mangrove communities alter, and in the worst cases, eliminate overland flow of rain water into the mangrove. The increased soil salinities that result can kill trees.

Access by local populations to open waters via tidal creeks can be inhibited, and in some cases mariculture dikes provide access to mangroves for wood cutting that otherwise may not have been possible. Increases in suspended sediment load from mariculture pond construction are temporary, but erosion of constructed dikes can be a long-term source of sediments if not stabilized.

Current Status

Based on 1989 data, the largest concentration of shrimp mariculture ponds is in the San Blas area (20), and the total for the entire coastal zone of Nayarit was nearly 28 ponds. The area of shrimp mariculture ponds that have been constructed was estimated as 597.5 ha, although only 144.5 ha were in operation. It is estimated that Nayarit has about 91,000 ha of coastal lands that are physically developable for mariculture and is considered to have the second highest potential for developing a shrimp mariculture industry. The annual growth rate of aquaculture production in Nayarit between 1987-89 was over 44%, one of the highest in the world, and production from shrimp mariculture on a per capita basis was higher than the average for Mexico, Latin America and the world.

Fishing

General Description

Mostly at an artisanal level, the fishery of Nayarit is dominated by demersal species. The major fishing zones are the Bay of Bandaras and Cape San Blas areas which dominate the coastal fishery as the source for the largest portion of total annual catch. With increased coastal development, the potential for over-fishing the entire marine fishery is significant. In addition, resulting from increased local demand at urban centers and in areas of tourism development, local stocks can easily be depleted.

Major Problems

Over-fishing causes collapse of the fishery when harvest is greater than population recruitment and growth rates. Once the fishery begins to decline, increased effort to sustain yields results in decreased catch to effort ratios. Often, prices rise reflecting the scarcity of supply, which in turn continues to place increased pressure on declining fish stocks. Once collapsed, economic dislocation of fishermen results, and increased imports of fish and fish products are necessary.

Current Status

There are 14 fishing communities with a fleet of 303 small boats and approximately 790 fisherman in the Bay of Bandaras fishery. The 1990 catch was estimated as 1764 MT with a total value of 10380 million pesos, or U.S. $3.7 million.

Activities in Rural Watersheds

General Description

The primary activities of concern are agriculture, deforestation, and hydroelectric and irrigation projects. Agricultural activities contribute to sediment transfer and the introduction of pesticides, herbicides, and nutrients to the marine environment. Deforestation contributes to the transfer of sediments and alteration of timing and volumes of freshwater inputs to the coast. The construction and operation of dams alters discharge regimes of major rivers, and thus the timing and volume of fresh water entering the marine environment.

Major Problems

The major problems in the coastal zone that result from rural watershed activities, whether agriculture, forestry, or dams, can be grouped into three areas: (1) inflows of sediments, (2) inflows of toxins and nutrients, and (3) altered fresh water inflows.

Inflow of sediments. Agricultural practices and deforestation act to increase sediment transfer to the coastal zone, yet hydroelectric dams can trap sediments and, as a result, minimize negative coastal zone impacts that may have otherwise occurred. On the other hand, productivity of estuaries and river delta areas depends on an adequate supply of sediments and organic matter from terrestrial sources. There are numerous examples, worldwide, where loss of sediment inputs has caused irreparable damage to coastal fisheries, and even erosion of delta land masses (e.g., the collapse of the herring fishery at the mouth of the Nile River [George, 1972], or the loss of wetlands at the Mississippi River delta).

The impacts of alteration of sediment inputs to marine environments can result from either too much sediment input or too little. Where sediment loads increase, the impacts are sedimentation and increases in turbidity in nearshore areas with subsequent loss of grass beds and reefs. Where sediment inputs are diminished because of diversion or impoundment behind dams, loss of marine productivity and even erosion of shorelines (resulting from a negative balance between erosional and depositional forces) can result.

Inflows of toxins and nutrients. Agricultural watersheds and dispersed rural populations without adequate sewage treatment can add significant amounts of agrochemicals and human wastes to river systems via runoff, which are in turn carried to the marine environment. Toxins interfere in biochemical processes, can be magnified in food chains to humans, and can ultimately result in the collapse of marine fisheries and ecological functions of marine systems receiving them. Increased nutrient inputs can be beneficial, especially if there is a significant harvest of organisms (and thus removal of nutrients) from the receiving marine ecosystem. Yet in many areas, over-enrichment results in declines of fragile ecosystems like corals and seagrass beds and eventual collapse of marine fisheries and ecological function. In all, with increased inflows of toxins and human sewage, safe water quality standards are violated and waters are rendered unsafe for human uses.

Altered freshwater inflows. The volume and timing of freshwater inflow to marine systems is critical. Modification of inflows causes rapid fluctuations in salinity and disrupts the saltwater-freshwater interface. With reduced flows, higher salinity water migrates inland, and flushing of soil salinity from mangroves is impaired. With increased discharges, marine organisms that are adapted to higher salinity waters migrate seaward or become extinct. Changes in the periodicity are detrimental to coastal organisms that cannot adapt to fluctuations in salinity, often pushing ecological communities in the saltwater/freshwater interface toward lower diversity and lower yield systems.

Current Status

There is a paucity of reliable data on the levels of contamination and sewage enrichment of fresh water inputs and nearshore coastal environments. The evidence of problems and impacts remains anecdotal.

Activities in Urbanized Watersheds

General Description

Whether increasing in size, or remaining relatively stable in spatial extent, urbanized watersheds affect water quality, timing, and quantity. Increased area of impervious surface increases the speed and volume of runoff after storm events. Stormwater runoff carries with it silt and sediments, oil residues, heavy metals, and trash.

Increased urbanization and population density means increased spatial density of wastes. Where urban populations are concentrated in the coastal zone, human and industrial wastes are often discharged in ocean outfalls, often untreated. Further inland, wastes from urban concentrations are usually discharged to a nearby river that carries them downstream to the coastal zone.

Solid waste disposal in the coastal zone is problematic. Often, solid wastes are dumped in "low" areas (marshes and mangrove swamps) or directly in the ocean. Accumulations of solid waste in streets, if not removed regularly, are washed with the next rainfall to the nearshore environment.

The demand for marine resources in areas surrounding urban concentrations usually far exceeds sustainable yields. First, the increased population density increases the demand. Second, urban populations with higher income also increases demand.

Major Problems

Altered freshwater inflows. Alteration of the hydrologic regime through increased impervious surface has two deleterious impacts on nearshore waters. First, during storm events nearly all rainfall runs off the urban area immediately, because there is little soil or surface storage. Second, during drier periods of the year there is less base flow in rivers and streams with large urban concentrations, since runoff during rain events is so high. Altered timing and volumes of freshwater inflows causes greater fluctuations in the salinity of nearshore waters, seriously impacting species composition, lowering productivity, and ultimately decreasing stability of marine ecosystems. The net result in human terms is the decline of nearshore fisheries.

Inflows of toxins and nutrients. Liquid wastes from industry and human sources are serious threats to the nearshore marine environment if concentrations exceed the capacity of the environment to assimilate them. Factors affecting the assimilation capacity are: type and concentration of the waste, type of community receiving the wastes, and other abiotic factors, such as mixing of the nearshore waters, rainfall, and soils (in terrestrial communities). The impacts of discharges of human and industrial wastes in the coastal zone are relatively straightforward: they cause water pollution, which in turn causes alteration of marine communities, poses human health risks, contaminates nearshore fisheries, and increases eutrophication that contributes to the decline of coral reefs and seagrass beds.

Inflows of sediments. Sediment transfer to the marine environment from urbanized areas can be significant. Where sediment loads increase, the impacts are sedimentation and increases in turbidity in nearshore areas, with subsequent loss of grass beds and reefs.

Increased resource demand. Increased demand for resources from urbanized areas in the coastal zone is probably the single biggest factor affecting the sustainability of nearshore fisheries. Ultimately, without strict controls on use of resources, whether fisheries, beaches, or wildlands, the quality deteriorates with increased populations, and the ecological systems that produce the resources eventually collapse, undergoing regression to a simpler, earlier successional community.

Solid waste dumping. Dumping of garbage in the coastal zone is problematic because of improper handling and location of dumps. The practice of using wetlands, direct dumping in coastal waters, landfills located next to river floodplains, and build-up of garbage in streets results in release of solid wastes and landfill leachate directly to surface waters. The prevalence of non-biodegradable plastics in garbage can foul beaches and can be ingested by marine mammals, fishes, and birds. Landfill leachate contains many toxic compounds and metals that can represent serious threats to marine communities and, ultimately, human health.

Current Status

In the developed areas of the coastal zone the volume of freshwater runoff from urban areas is estimated to be more than double what it was prior to development (using a runoff coefficient of 80%). There are no estimates of the amount of sediment and trash/garbage that is carried annually to nearshore waters via stormwater runoff from urbanized lands.

Where urban populations are connected to a sewage system, the systems are usually inadequate. In many areas, there are no centralized sewage systems. All "treated" sewage is discharged either to rivers (which discharge to nearshore waters) or discharged through ocean outfalls. Untreated sewage is either discharged on-site through septic tanks and leach beds, or discharged to rivers or nearshore waters. In other words, effectively, there is little or no sewage treatment in the coastal zone.

Current demand for coastal resources like firewood and fishery products is difficult to estimate. However, as an example of the pressure on the environment to provide resources, an estimate of the demand for charcoal in the San Blas area using an annual consumption of 0.4 m^3/capita (Cobb et al., 1991) and standing stock in mangroves of 25 m^3/ha, suggested an annual rate of potential deforestation of the mangrove community of about 15 hectares per year.

Summary and Recommendations for the Coastal Zone

Given in Table 2.2 is a ranking of the main activities in the NCZ by the following 8 criteria: hydrologic importance, socio-economic importance, ecological importance, irreversibility, temporal trends, spatial scale, urgency, practicality.

From the ranking and our review of the coastal environment, we have developed several main conclusions and general policy recommendations that are given next.

Major Conclusions

Consideration of the review of the activities, problems and impacts in the coastal zone has led to 5 main conclusions:

1. The human impacts in the coastal zone at the present time are reversible, but continued development without attention to resource management will exacerbate the problem.
2. There is a serious paucity of adequate data with which to make accurate assessments of the scale and magnitude of problems, and to guide interventions and public policy, especially in the areas of:
    a. natural resource inventories
    b. fishery status
    c. water quality
3. The most critical problem in the NCZ zone is increased demand for resources (most prominent is fishery resources) from:
    a. tourism development
    b. increased urbanization
4. The second most important problem in the NCZ is freshwater inflows to nearshore waters, especially related to:
    a. sediments and organic matter
    b. contaminants
    c. pulsing of fresh water inflows (timing and volume)
5. The third most critical problem in the NCZ is "multi-use" conflicts, manifested as cumulative impacts. For example:
    a. cumulative impacts of pollution, loss of freshwater inputs, and over-fishing in fisheries;
    b. cumulative impacts of loss of fresh water inputs, wood cutting, and mariculture construction on mangroves.

Recommendations

Four recommendations follow from these conclusions:

1. Increase the quality and quantity of data related to the amount and quality of coastal zone resources, their use, and the impacts of human activities.
2. Maintain and enhance freshwater inflows to the nearshore waters, but at the same time decrease sediments and contaminants.
3. Develop a better understanding of the cumulative impacts of human activities in the coastal zone that can guide policy and management.
4. Develop a comprehensive master plan and resource management plan for the NCZ to guide future development.

Table 2.2 Ranking of Environmental Impacts in the Coastal Zone

Activity/Problems	Hydrological Importance	Socio-Economic Importance	Ecological Importance	Irreversibility	Trends	Scale	Urgency Gravity	Practicality	Total
Tourism Development									3.375
Release of Pollutants	1	4	2	1	5	2	3	4	2.75
Habitat Conversion	2	3	5	5	4	2	5	2	3.5
Inc. Resource Demand	1	5	5	5	5	3	4	3	3.875
Marina Development									2.875
Release of Pollutants	1	2	1	3	5	2	2	2	2.25
Habitat Conversion	2	3	3	5	5	2	4	4	3.5
Recreation Activities									
Increased Boat/Diving	1	3	4	3	5	3	2	3	3
Marine Construction									2.375
Channel & Jetty Const.	3	2	3	3	4	2	2	1	2.5
Release of Pollutants	1	2	2	4	4	2	2	1	2.25
Maricult. Development									
Habitat Conversion	2	2	3	5	4	2	2	4	3
Fishing									
Overfishing	1	5	5	4	4	5	4	4	4
Act. in Rural Watersheds									3.958
Inflow of Sediments	4	3	4	5	5	4	5	3	4.125
Inflow of Pollutants	1	5	4	4	5	4	4	2	3.625
Alt. of Freshwater Inflows	5	4	5	3	5	4	4	3	4.125

Table 2.2 (continued)

Activity/Problems	Hydrological Importance	Socio-Economic Importance	Ecological Importance	Irreversibility	Trends	Scale	Urgency Gravity	Practicality	Total
Dev. Urban Watersheds									3.75
Inflow of Sediments	4	2	4	4	5	3	2	2	3.25
Inflow of Pollutants	1	4	5	4	5	4	5	2	3.75
Alt. Freshwater Inflows	5	4	5	3	5	4	5	2	4.125
Inc. Resource Demand	1	5	5	5	5	5	5	3	4.25
Solid Waste Dumping	1	3	4	2	4	4	5	4	3.375

RESOURCE MANAGEMENT ALTERNATIVES

To manage the natural resources of the NCZ, a two-pronged approach is suggested. First, the sensitivities and importance of the various vegetation communities are given, with general suggestions for effective management. In this way particular requirements, regulations and guidelines can be tailored to ecological communities no matter where they are located within the NCZ. Second, areas of the landscape are identified that are mosaics of ecological communities which, because of their ecological character, location, and potential for wildlife habitat, are designated as Reserves and Protected Areas. It is suggested that these areas be given special consideration and treatment as whole units, with regulations and guidelines for development tailored to minimize development and maximize wildland potential.

Ecological Systems

Community types that are important and/or have particular sensitivities to development, and their value or reason for sensitivity, are as follows:

Mangrove Areas

Mangroves form dense, almost impenetrable thickets which buffer the physical forces of storms. They clean water by trapping silt, nutrients, and toxic substances, and they prevent land erosion. Equally important, they play a leading role in providing wildlife habitat, and in the general ecological productivity of the northern coastal zone of Nayarit, specifically in NPCPZ.

The mangrove ecosystem is the critical feeding and breeding area for many shore birds, reptiles, and amphibians, and certain mammals. It is a major nursery ground for many economically important animals, including commercially harvested fish such as mullet, sport fish (snook, snapper) and shrimp. Part of this benefit derives from the brackish water conditions, which afford protection of the juveniles from predation, but the primary productivity of the plant community itself is also of great importance. The detrital food chains that support fisheries production are fueled by the food-generating activities of mangroves (Burnes, 1983). Mangrove values can be summarized as: productivity, wildlife habitat value, and rarity.

The most important mangrove areas are located in the northern coastal zone, but there are some small patches as well in the southern areas. Mangrove forests constitute an area of approximately 1340 square kilometers, according to the vegetation maps from INEGI and SPP (1981).

The Teacapan-Agua Brava-Marismas Nacionales Coastal Lagoon system is one of the most extensive areas of mangroves on the Pacific coast of North America, and is mostly located in the State of Nayarit. Another important mangrove system is that located almost as a continuation of the system already mentioned above and comprises the Mexcaltitan Lagoon, Boca de Camichin, Boca del Asadero and San Blas-La Tovara system. The southern coastal zone has some mangrove patches located at Punta el Custodio, Barra de Ixtapa, Punta Chila, and Quelele Lagoon.

Beaches

The ocean shoreline is nature's defense against the attack of storms, waves and currents. Ecologically, the beach is a unique environment occupied by animals adapted to the high stress and constant motion of the beach sands, such as crabs and clams. There are also many temporary residents, such as sea turtles that come to nest on the beach. Countless shore birds feed at the water's edge and nest on the upper beach areas. Thus, its importance in nesting endangered sea turtle species, and its erosion potential should not be underestimated.

The north coastal zone beaches of the NCZ have an important geological history. The sedimentary structure of the continental terrace of the NPCPZ was studied by Curray and Moore (1964). It is a wide coastal plain of coalescing alluvial plains and deltas, covered by littoral and alluvial late quaternary sediments. Its importance derives from the marshy strand plain of about 250 abandoned, regressive beach-dune ridges. This coastal plain slopes gently upward to the foothills of the Sierra Madre Occidental. These foothills, the western banks of the Sierra Madre, and the drainage basins of the rivers of the Costa de Nayarit can generally be summarized as middle Tertiary volcanic, probably Oligocene to Lower Pliocene, which range from andesite to rhyolite in composition (Curray and Moore, 1964).

The strand plain, which averages about 9.7 kilometers wide, overlaps the seaward-dipping floodplain of the Rio Grande de Santiago and smaller adjacent rivers to the north and south. The maximum width from the present beach to the oldest ridge is about 14.5 kilometers. The strand plain contains about 280 parallel ridges formed by successive accretion from the shoreline of low, narrow beach ridges, overlying longshore bars. The sands are, in turn, locally overlain by marsh, lagoon and younger alluvial deposits of the regressive sequence.

The southern coast of Nayarit (CNVACZ and SSMCZ) is characterized by a rocky, steep coastline starting south of San Blas, where it projects seaward as a double point (Curray and Moore, 1964). The continental shelf adjacent to this rocky coastline is narrow, and is cut by a deep trough, probably structural, which enters Bahia de Banderas and Valle de Banderas near Puerto Vallarta, Jalisco. This rocky coastline is constantly interrupted by sand beaches, some of which are covered by coral reef fragmentation and deposition, like those on Bahia de Jaltemba at Rincon de Guayabitos and Punta Mita in Bahia de Banderas.

Sand Dunes

Because of their value for habitat and geological stability, and their severe potential for erosion, sand dunes are vital ecological areas. Sand dunes serve as nesting grounds for countless shorebirds, many of which come to feed at the water's edge. They also provide habitat for foxes and other mammals that prey on insect-eating shrews, bats and mice. White-tailed deer and rabbits graze on dune grasses and succulent plants (Clark, 1983).

Coastal sand dunes are formed when currents and waves move sand from offshore deposits to the beach zone, from where wave action and wind will move the material above the level of high-tides, to be incorporated by vegetation into terrestrial dunes. The vegetated dunes, specially those of the windward beaches, are subject to erosion from winds and storm waves. Their protective covering of vegetation acts to stabilize the dune sands and minimize wind and, to a lesser extent, wave erosion. Denuded of vegetation, they are exposed and susceptible to wind erosion.

Deforestation and water abstraction are just two of the activities by which man has altered sand dune systems. Other activities, such as mineral extraction (sand mining), waste dumping, golf course construction, and outdoor recreation, are part of the process which has in some instances destroyed sand dune communities. Because dune formations are fragile, activities of man that cause even slight alterations to them may lead to significant disruptions. When both shifting and stable dunes are destroyed, there is nothing left to stabilize the remaining sea of drifting sand but man himself (Clark, 1983). However, there is a growing recognition that the dune system should not be over-managed.

Other Coastal Wetlands

Landward of the mangrove forests and beach and dune systems, where there is no slope or a slightly depressional landscape, and where drainage is poor and there is sufficient rainfall, freshwater and brackish marshes often prevail. Dominated by sedges, shrubs and herbaceous plants, they are often very productive ecosystems, providing important habitat for a variety of indigenous and migrating birds as well as herpetofauna, reptiles and mammals.

Generally, marsh wetlands are wet year round, but may dry out occasionally during the drier times of the year. Hydrology, especially the period and depth of inundation, is extremely important, dictating species composition. Marshes that remain wet year-round have the greatest populations of fish and invertebrates, which form the basis for wading bird populations. There are extensive areas of marsh wetlands in the NPCPZ within the Teacapan-Aqua Brava-Marismas Nacionales Coastal Lagoon and the Mexcaltitan Lagoon.

Tropical Deciduous Forest

The importance of this forest rests on its rarity, due to the severe degradation that has occurred from a long history of extensive grazing, frequent burning, and agricultural use. In some areas this system has even been eliminated. It is also an important seed source, and provides valuable wildlife habitat. The main areas of tropical deciduous forest in the NCZ are located in the southern coastal zone, from Bahia de Matanchen to Sierra Vallejo. Some patches of tropical deciduous forest are also located in the northern coastal zone, like those north and south of Playas Novillero. The most important are these are located along Bahia de Matanchen, between Punta el Caballo and Punta el Custodio; between Boca de Chila and Playa el Naranjo; and those which are a continuation of Sierra Vallejo, which are located between Rincon de Guayabitos and Lo de Marcos, between Sayulita and Higuera Blanca, and between Punta Pantoque and La Cruz de Huanacaxtle.

Guts

Guts are extremely steep, forested drainage areas in mountainous terrain. While not a community type by themselves, the forested guts of the NCZ are fragile, existing in a relatively precarious balance between fire and the forces of water erosion and vegetative stabilization. Because of their steep slopes, and the fact that they act as drainage ways, concentrating surface waters that run off the ridges and side slopes of the surrounding hills, actions that disturb vegetative cover may cause significant erosion and downslope damage to both developed areas and ecological communities.

Coral Communities

Coral reefs are among the most biologically productive, taxonomically diverse, and aesthetically celebrated communities in the world. Hundreds of coral communities have been injured or destroyed by accelerated sedimentation. This is due to many causes, including poor land management, dredging for marinas, and unregulated land clearing in adjacent watersheds causing accelerated fresh water runoff, sand removal for construction and beach replenishment, and chronic overfishing.

Corals are so central to the integrity of the reef community that when they are killed the migration or death of many other reef animals ensues. It often takes badly damaged coral reef communities several decades to recover completely, even under the most favorable circumstances (Johannes, 1983). Coral communities in the NCZ are located at la Pena de Jaltemba, in Bahia de Jaltemba or Rincon de Guayabitos, and at Las Islas Marietas in Bahia de Banderas, as well as on the rocky coastline in small patches from San Blas to La Cruz de Huanacaxtle.

Seagrass Beds

Seagrass beds are extremely productive nearshore communities that provide a large quantity of food for grazers such as fish, green turtles, shrimp and crabs, and are nursery grounds for many commercial fish including snapper and grunt and several invertebrates including lobster. While the grasses themselves are productive, they also provide a substrate upon which rich communities of algae grow, increasing the nutritive value and grazing opportunities for many organisms.

Seagrasses are sometimes associated with coral communities because, like the corals, seagrasses require clear, shallow water; but unlike the corals, they require a soft substrate. Rarely are seagrasses associated with coasts dominated by mangroves, because of the organic-stained waters that often discharge from them on the falling tide, lowering water transparency. Seagrasses are sensitive to toxins, elevated temperatures from thermal discharges, and over-enrichment that increase phytoplankton production, lowering light transmittance through the overlying water. Areas near large river discharges, where turbidity is high and where fresh water inflows may lower salinity of near coastal waters, are not conducive for seagrasses.

Seagrasses are found throughout the shallow, clear, protected marine waters. Distribution of seagrass beds in the coastal zone is not known.

Managing Development Impacts on Ecological Systems

Development of the NCZ can easily result in the decline of environmental quality through improper siting, secondary development impacts and increased human access. On the other hand, development offers the potential to reverse recent trends in deterioration and enhance the overall environmental quality through controlled siting that has minimum primary and secondary impacts, and that controls access to important wildland management areas. The following paragraphs outline generalized development techniques and principles that may be used to guide development and serve as the beginnings of a regulatory framework that will ensure the continued existence and enhancement of the terrestrial and marine resources of the NCZ.

Construction Criteria for Protection of Ecological Communities

1. Down-slope wasting of cut material from roads and housing pads should be minimized under all circumstances.
2. Clearing of vegetation for housing sites should be kept to a minimum, with permits required for the cutting of any tree having diameter at breast height (DBH--1.3 meters above ground) greater than 10 cm, or height greater than 4 meters.
3. Permits should be required for any excavation and/or filling that involves greater than 20 cubic meters of material.
4. Wherever possible, access roads should follow the natural contours of the site to avoid unnecessary cutting and filling.
5. Cleared building sites should be revegetated with appropriate native plant species as soon as possible, to avoid erosion and down slope sedimentation.

Planning and Design Criteria for Protection of Ecological Communities

1. To minimize unnecessary clearing and loss of ecological communities, with subsequent loss of wildlife habitat, development density should be concentrated in as small a portion of the total site area as possible.
2. Because of the potential for significant erosion and increased sediment transported to the nearshore environment, with consequent negative impacts on nearshore marine habitats, areas of intense development should be concentrated in the watersheds of salt ponds and wetlands, where sediments will be intercepted and will not contribute to nearshore turbidity.
3. Windward slopes of the southern coastal zone (CNVACZ and SSMCZ), which may be dominated by vegetation that is in a constant state of stress from salt, drying winds, and destructive wind velocities, will not recover and recolonize disturbed areas as readily as other community types. Disturbance of the windward slopes should be minimized, and any development should be confined to small patches at low slope and low elevations. Clustered development, with 80-90% of the vegetation left intact, should be encouraged.
4. The wetlands (Humedales) of the **NCZ**, such as mangrove swamps, salt marshes and "popales", represent a unique environmental resource. Their importance to the wildlife of the **NCZ** and potential importance to the tourist industry should be weighed heavily before any proposals for their dredging or filling are approved, especially on the projects related to shrimp aquaculture and channel dredging.
5. Because of their importance as seed sources for reforestation of the **NCZ**, all tropical deciduous forest areas should be considered as candidates for a conservation designation.
6. Because of their rarity and important function as providers of habitat for fishery species, all coral community patches in the **NCZ** shall be protected and considered for conservation designation.

Recommendations for the Protection of Ecological Communities

Tree Protection:

1. The cutting of live trees for charcoal production, or for domestic purposes such as posts, should be prohibited. This use is inappropriate in resort areas. These trees are worth more for enhancement of scenery and undisturbed wildland than for other purposes. Cleanup of downed material pushed over as a necessary part of construction is permissible and desirable.
2. All rubber, mahogany, eardrop, poinciana, kapok, and other landscaping trees should be preserved. They are appreciated by tourists for their exotic look, and most of them could serve for several landscaping and aesthetic functions.
3. All trees over 20 cm DBH shall be preserved where practical, and in no case shall such trees be cut for the purpose of landscaping. All trees over 30 cm DBH shall be strictly preserved. They should be incorporated into the design instead of being treated as an obstacle.
4. Groves of large trees should be preserved. There are always groves in likely areas of development. Areas with an 80% crown closure and trunks over 12.5 cm DBH for every 20 square meters shall be preserved.

Gut Protection:

1. No construction or land clearing should be done within 30 meters of any gut with a bare rock bed or clearly discernable bed 1 meter or more in width, except that access roads may cross such guts at a right angle, on a concrete road dish or with an adequate culvert or bridge.

Roadways Design and Construction:

1. Access roads from any development shall have trees planted in irregular groups, at least 10 trees per 30 meters on the high side, and groups of at least 5 trees in every low spot where water runs off. Trees on the higher side should be ornamental or shade trees where practical, or Spanish cedar in windy places.
2. Below the outfall of culverts and road dishes, a pavement of rubble shall be set so that a top rock overlaps and covers the inside half of the rock beneath. This rubble bed shall follow the diverted water course until it re-enters the old gut bed. If there is no old gut bed present, an apron of protective vegetation of grass and trees may be used to spread the water. Sinks will not be used in the **NCZ**.
3. All road fill slopes shall have grass planted along the contour, with sprigs 30 cm apart, in rows which are less than 1 meter apart.
4. Pathways across barrier dunes to the beach, whether created by management, guests or the public, shall be raised above the dune surface on wooden walkways, and additional vegetation shall be established to confine traffic to the path.
5. Secondary roads shall be located so as to avoid cutting through areas of tropical deciduous forest, mangrove forest, or estuarine lagoons and marshes where possible. In any instance that a propose road is planned to do any of the above, the **Nayarit Coastal Zone Environmental Protection Council (the Council)** should withhold

approval of the road design and proposed subdivisions until after consideration of comments presented by SEDUE, SARH, and consultants or other qualified representative selected by the **Council**.

Fire Control and Wind Protection:

1. The burning of grass shall be strictly controlled. Any intentional fire set to burn or clear grassland or to improve feed value or for other purposes shall be at moisture conditions sufficient to make a slow burning fire and shall be set to back into the wind.
2. Fire resistant trees, such as tamarind or others, shall be planted on the upwind border of any developed property with grassland area prone to fire.
3. Fire breaks and wind breaks shall be planted in an irregular or clumped line rather than a straight line. Several species of plants should be used in any particular planting.
4. Windbreaks may utilize casuarina, almond, coconut, cedar, and eucalyptus. Combination windbreaks and firebreaks are possible. Additional plants can be used to thicken the line and add texture and color.

Wildlife Resources

From the perspective of wildlife and natural resources, management alternatives are centered primarily on reducing the impacts of development action. Summarized in the paragraphs that follow are the most significant wildlife habitats on the coastal zone of Nayarit. Lists of species of wildlife found or expected in the NCZ are given in Section 1.

Birds

Large numbers of birds have been observed in the northern portions of the NCZ, mainly at the Teacapan-Agua Brava-Marismas Nacionales system, where the aquatic habitat offers a valuable home for thousands of resident an migratory birds, especially waterfowl. Leopold (1972) ranked this area as number one in Mexico, with a population estimated around 405,000 migratory ducks and 34,000 resident ducks. Thus, the importance of this ecosystem for the preservation of waterfowl should not be underestimated.

Migratory waterfowl and shorebirds have been experiencing dramatic declines in recent years in their North American breeding areas, primarily because of climatic change. Their survival depends in large part on finding non-breeding habitats in the tropics where they spend more than half of their life histories (Norton, 1989). The possibility of gradual or incipient loss of wetland habitat in the NCZ will contribute to this decline.

Habitat preservation is one of the most important measures that can be taken in order to protect wildlife. Any development proposal should be carefully examined in order to determine the impact of a particular project on wildlife; and in the specific case of bird habitat, dredging shall be prohibited except when the **Council** otherwise considers it necessary.

Mammals and Reptiles

Managing the natural resources of the NCZ and fostering the development of eco-tourism requires that there be a concerted effort to protect the various vegetation communities and implement wildlife management programs, in order to monitor population densities and foraging capacity. The concept of wildlife corridors, in which linkage is maintained between undeveloped areas, will be critical for sustained breeding units of deer, jaguar, ocelot, jaguarundi, bobcat, margay, collared peccary, alligator, as well as the myriad of other life forms that are key elements to the ecological balance.

Central to management will be the role of a Wildland Management Unit within the Council, which could assist in the development of land management guidelines, monitor on-going activities, and prepare education programs that would be used to increase public awareness of environmental concerns.

The establishment of hiking and canoe trails, and the use of guided tours with individuals trained in nature interpretation, could provide the link between tourist development and environmental conservation in the NCZ. Wildlife regions connected by a system of corridors and documented trails would provide resort operators with an opportunity to exploit the growing market in travellers interested in unique landscapes and exotic animals. In addition, long-term scientific study of these regions could be enhanced through their designation as Environmental Study Areas. This would allow trained biologist to regularly monitor flora and fauna and prepare environmental impact assessments on an on-going basis.

The tourist potential for guided tours of various wildlife species and their habitats is extremely high, since most visitors to the coastal zone have never seen these animals in the wild. This activity constitutes an excellent substitute for wildlife hunting, and will help preserve the natural resources of the coastal zone on a sustainable basis, without disturbing the ecological balance, taking advantage of the wildlife presence in the area for the economic development of the region.

Recommendations for the Protection of Wildlife

1. Limit marine development schemes to few areas (e.g., Playas Novillero, Boca de Camichin) and protect small water bodies, such as those found at Marismas Nacionales between Puerta de Palapares-Santa Cruz-San Andres. Protect mangrove forests, estuarine lagoons and salt marshes for their diversity of species, which of itself could form the basis for tourism activities in the NCZ.
2. Prepare a Development Strategy for the northern NCZ that includes a natural resource base for continued use by resident and migratory shore and water bird species.
3. Development schemes should preserve all water bodies, brackish and freshwater marshes, and mangrove areas of the coastal zone, such as the Teacapan-Agua Brava-Marismas Nacionales system, Mexcaltitan-San Blas-La Tovara system, Cala Jolotemba, Cala Porterillos, Caleta Mita, Estero el Custodio, Laguna las Tortugas, Laguna Encantada, Boca de Chila, Barra Ixtapa, Boca el Naranjo, Estero de Punta Raza, Lo de Marcos, Los Ayala, San Francisco, and Quelele Lagoon.
4. Development of hillsides should not exceed the 150-meter elevation contour, and sedimentation traps must be installed to abate degradation of water quality of all water bodies where construction is planned.

5. Protect tropical deciduous forests where endemic birds may be observed any time of the year. This is especially true for the southern NCZ, where the abundance of tropical deciduous forests is higher than in the northern NCZ. This ecosystem affords accessible habitat for wildlife observers who can experience tropical forest fauna with some extraordinary opportunities.
6. Nature trails, wildlife corridors and wildland areas should be established as an integral part of all proposed developments.
7. A Mammals and Reptiles Recovery Plan, which will halt population declines and initiate recovery of threatened species, should be developed for the entire NCZ.
8. A stray dogs management program, which will control and possibly reduce their population numbers throughout the NCZ, should be established.

Marine Resources

The marine resources of the NCZ may be divided into two major groups, related to the type of shoreline. The first (the NPCPZ) is basically an intertidal sand beach and sand flats, while the second (the CNVACZ and SSMCZ) is primarily dominated by intertidal rocky shores, with the presence of some small intertidal sand beach bays and coves.

The most economically important marine resource in the NPCPZ is shrimp, which is dependent on the estuarine lagoons and mangrove systems found in this region. In general, the northern area of the NCZ supports a rich shrimp fishery, not only for Nayarit but for other states as well. The southern coastline consists mostly of rocky shore, and has a more diversified marine resource base in terms of its potential for the tourism development. It includes good scuba diving areas, small coves and bays for sailing moorings, and beaches more suitable for aquatic sports facilities such as waterskiing, windsurfing, sailing, snorkeling, kayaking, scuba diving, and deep sea fishing for dolphin, marlin and sail fish.

The fisheries resources of the southern NCZ are more diverse than the norther resources, with the presence of lobster, shrimp, red snapper, octopus, clams, oyster beds, etc. The steep, erodible nature of some areas of the southern NCZ, with heavy rainfall in summer and early fall, make these marine resources particularly susceptible to sediment and turbidity from terrestrial sources. Large scale development, which will change run-off patterns, introduce pollutants into nearshore waters and increase coastal erosion, should be avoided.

Recommendations for the Protection of Marine Resources

1. Protect sea turtle habitat at beaches known to be selected by sea turtles for nesting. Encourage low density use of beaches and dunes. Develop use regulations to protect turtle nesting.
2. Protect the Isla Jaltemba coral community as part of the Marine Park/Reserve system of the NCZ.
3. Establish a fisheries research program. Priority should be given to establishing catch limits, protected seasons and sustainable yields, to minimize overexploitation of the fisheries of the NCZ. Methods of fishing such as "Almadrabas", which is employed along the shoreline, may threaten recruitment and lead to stock reduction. Careful analysis of these techniques must be done to evaluate their potential environmental impact. Ecological

and population studies on several other species, such as lobsters, clams, and popular seafood species, should be conducted in order to establish catch limits, seasons and sustainable yields, to prevent overexploitation and the eventual decline of these resources.

4. Establish marine aquaculture research programs for restocking heavily-fished species such as lobster, snapper, snook, clams and shrimp. Such studies may help avoid conflicts of water use and/or potential environmental impacts such as mangrove clearing for shrimp farming.
5. Develop environmental education programs to help prevent further destruction of the sea turtle populations.
6. Include the coral communities of Isla Isabela, Isla Jaltemba, and Islas Marietas in a coral communities management protection plan.
7. Work with SEPESCA and the fisheries schools and fishermen to identify fish reserves to enhance fisheries production and to provide a research site for the fisheries schools.
8. Develop marina/boating use guidelines to take into account fishing grounds and seasonal needs of fishermen.
9. Protect and manage fishing grounds and oyster beds, through the development of guidelines and regulations for water-oriented use of bays and coves which undergo users' conflicts.
10. Prevent recreational spearfishing by tourists, and encourage local residents not to spearfish.

SUMMARY AND RECOMMENDATIONS

This discussion has stressed that the natural resources of the Nayarit Coastal Zone are unique and integral components of the development that will follow the completion of the recommended **Nayarit Coastal Zone Management Plan** (see Part 2 of this volume). It was suggested that an approach to resource management be taken that: 1) recognizes the values and sensitivities of individual ecological communities, and encourages development to accommodate them; and 2) recommends that a broader perspective be taken to manage terrestrial resources of the NCZ, by establishing a series of Reserves and Protected Areas (see Part 4 of this volume) that are interconnected and in close enough proximity that they act as one unit and not as series of single isolated reserves. Seven areas were designated as Reserves and Protected Areas. Within these areas, development may still be accommodated, but should be subject to stricter controls to insure that it will not interfere with the primary focus of the area. The 7 proposed Reserves and Protected Areas are shown on Map 26, and are as follows:

1. **Marismas Nacionales Complex.** This complex is comprised of the Teacapan-Agua Brava-Marismas Nacionales system, which is one of the largest mangrove systems on the Pacific coast of North America. It consists of tidal channels, seasonal floodplains, coastal lagoons, mangrove swamps, halophytic vegetation, palms, and tropical deciduous forest. Along with this mosaic of ecological communities the Marismas Nacionales Complex supports a very important high-diversity fish community (Flores-Verdugo et al., 1990).

2. **Mexcaltitan Lagoon**. This area has characteristic similar to the Teacapan-Agua Brava-Marismas Nacionales system, and could be considered to be a continuation of it, although it is supported by different tributaries. One of the important aspects of this lagoon is the presence of a peculiar human settlement with historical roots, and particularly important cultural aspects. This is Mexcaltitan Island, a fishing village that should be preserved and incorporated into the ecologically balanced development of the coastal zone. Similar to the previous system analyzed, this lagoon supports an important artisanal fishery, and serves as a nursery ground for commercially important species such as shrimp and fish. The mangrove communities in this area are as important as those on the Teacapan-Agua Brava-Marismas Nacionales system.

3. **San Blas-Matanchen Complex**. This complex is formed by the estuarine system surrounding the historical ports of San Blas and Matanchen. Another important mangrove community, this system supports the nursery grounds for shrimp and other important species such as oyster, snapper and snook, as well as other important wildlife populations such as alligators, waterfowl, shorebirds, jaguar and other wildcats. The presence of a natural spring at La Tobara, which is connected to the estuarine system through a series of winding channels with exuberant mangroves and other aquatic vegetation, makes this area an important tourist attraction.

4. **Santa Cruz-Chacala Complex**. This complex, which lies between the town of Santa Cruz and the Ensenada Chacala, consist of a somewhat pristine tropical deciduous forest that ends nearly at the edge of the cliffs. It has beautiful scenic vistas, with potential for natural trails and eco-tourism activities.

5. **Ensenada Jaltemba**. The presence of Isla la Pena at Ensenada de Jaltemba with its coral communities makes this an important area to be managed as a Reserve/Protected Area. The coral communities on the Pacific coast at this latitude are so unique, that any measures should be taken for the preservation of this community.

6. **Lo de Marcos-Sayulita Complex.** The same explanation given for Ensenada de Jaltemba can be made for this complex. In addition, the presence of tropical forest vegetation and the palm community associations in this area makes it an important site for trail development, for eco-tourism activities, and for preservation of an ecosystem type that has been disappearing within the NCZ.

7. **Punta Mita-Las Marietas Complex**. The Marietas Islands have important aesthetic beauty, and are an important scenic vista for Punta Mita. These islands are located in an area where several whale species arrive to complete their reproductive cycles (HABB, 1990). They also constitute an important nesting ground for several seashore birds.

Compatible use of ecological communities by developers and resource planners is essential for the NCZ, in order to maintain the quality of natural heritage and diversity and economic variables for sustained eco-tourism. If maintenance of Nayarit's biodiversity and provision for eco-tourism are equally important to the development of the

Coastal Zone, these diverse goals should be compatible. Wildlife conservation and parkland legislation must be considered concurrently with the Nayarit Coastal Zone Management Plan, in order to maintain sustainable use of the resources of the Coastal Zone.

Development of the NCZ that takes a shorter view of the resources, or that is not cognizant of the values and sensitivities of ecological communities, runs the risk of diminishing the natural appeal of the area. The goal of the regulatory framework that will follow (Parts 2-4 of this volume) is the successful integration of developed lands with the terrestrial resources of the Nayarit Coastal Zone. This is best achieved through a "partnership relationship" of humanity and nature.

The creation of a Marine Park/Reserve is an immediate need, to manage the nearshore waters and shoreline for conservation the marine resources of the NCZ. Special management rules, such as those listed above, along with an overall fisheries and recreational management program, could help to ensure long-term use of the renewable marine resources of NCZ. Special protected areas could be best administered within the overall umbrella of a Marine Park/Reserve in NCZ. This concept is compatible with national legislation, and is also compatible with the desire of the government of Nayarit to attract tourism, and thereby stimulate the economy.

SECTION 3: SOCIAL/CULTURAL CONSTRAINTS AND OPPORTUNITIES FOR DEVELOPMENT

INTRODUCTION

Factors determining the quality and success of development projects include environmental impacts and local human and social concerns. Just as there are environmental constraints and opportunities, social issues also present development constraints and opportunities. As J. Ingersoll (in Finsterbusch et al., 1990) explained, while demonstrating that social/cultural impact assessment (S/CIA) is both essential and possible in poor countries:

> First, it is ***essential*** because people's social and cultural organization presents significant resources as well as constraints for development efforts. The features of their social landscape are as real--if less apparent to outsiders--as features of their natural, technical, and economic landscape. Second, SIA is ***possible*** because methods exist in trying to optimize these human resources and cope with these constraints. In the face of grinding poverty, development officials usually move too quickly to some technological "quick fix", ignoring subtle social issues, which are always closely interconnected with the natural, technical, and economic landscape. In conditions of poverty, people's social and cultural organization are always part of the solution, as well as part of the problem to be solved.

Both the general population and public officials from the majority of developing nations have become increasingly aware of the complex problems generated as a result of development, especially those of the tourist industry (Turner, 1973). As part of this awareness, they are seeking increased consideration for their well-being, including participation in the planning, implementation, and economic benefits of development projects, while at the same time safeguarding their natural resources. In other words, they are seeking a more equitable plan for everyone, including the environment (Bryant and White, 1982; Conyers and Hills, 1984; Derman and Whiteford, 1985; Finsterbusch et al., 1990; OECD, 1988; Turner, 1973; United Nations, 1974 a,b, 1978; World Resources Institute, 1992). Maurice F. Strong (First Executive Director of the United Nations Environment Programme) explained very clearly the importance of local participation in development planning at the 1972 United Nations Conference on the Human Environment and coined it, **"eco-development."** He defined it as:

> ...harmonizing the economic, ecological, and social factors so as to make best use of indigenous resources and skills in producing a sustainable pattern of development that will best accord with the values, needs, and aspirations of the people concerned (in Beale, 1980).

Background

Historically, development projects in third world nations were intended to boost the local economy, while at the same time increasing profits for the developer. Yet, instead of upgrading the socioeconomic conditions of the local population, these projects often worsened their condition. Routinely, the knowledge, experience, and technology in industrialized nations has been transferred to the third world without concern for the differences in local environmental, social and cultural organization. Many of the problems associated with technology transfer were related to the objectives and strategies of the development planning, and how these in turn clashed with the local social, political, cultural and economic conditions and aspirations (Bryant and White, 1982; Canter et al., 1988; Carley and Bustelo, 1984; Conyers and Hills, 1984; Derman and Whiteford, 1985; Finsterbusch and Wolf, 1977; Finsterbusch et al., 1990; Lee, 1985; OECD, 1988 a,b; Turner, 1973; United Nations, 1978; World Resources Institute, 1992). Derman & Whiteford (1985) go further by suggesting:

> Although national governments and international agencies have provided vast sums of money to development, many projects have not only failed to improve the lives of the poor but in some cases have *created additional* social and economic problems.

Realizing these past failures, international aid agencies like the United Nations, the United States Agency for International Development (USAID), the World Bank, the Organization for Economic Co-operation and Development (OECD), etc., have all included in their requirements for assistance, some form of social impact assessment. Many countries, like the U.S. have, or are now taking similar steps as well (Bryant and White, 1982; Carley and Bustelo, 1984; Conyers and Hills, 1984; Derman and Whiteford, 1985; Finsterbusch et al., 1990; Freeman et al., 1980; and OECD, 1988a,b).

In establishing policies regarding development along the **Nayarit Coastal Zone (NCZ)**, these issues should be addressed and given high priority. Already, local community concerns and questions have been raised regarding recent tourist development activities along Nayarit's southern coast (Darling, 1990; and personal communication).

Community Development Issues

Local community issues, which should be of concern to developers and converted into objectives which should be addressed in their proposals, include: health, education, labor, housing, immigration, economics, politics, culture, recreation, and transportation, among others. All these are so-called quality of life or social indicators which are inherently altered as a result of development projects brought into an area where humans already exist (Bryant and White, 1982; Carley and Bustelo, 1984; Conyers and Hills, 1984; Finsterbusch and Wolf, 1977; Finsterbusch et al., 1990; Freeman et al., 1979; Lee, 1985; OECD, 1988a,b; WHO, 1981). Social indicators are important for assessing the human and environmental conditions prior to development, and can later serve as tools for monitoring, evaluating, and measuring where and how the selected project has progressed or regressed.

Purpose

This section will outline specific recommendations and guidelines related to social impact assessment of development proposals in the **NCZ**. Of vital importance, and fundamental to this plan, is the formulation of a pivotal committee under the **Nayarit Coastal Zone Environmental Protection Council (the Council)** which will be called the **Community Participation Committee (CPC**--see also Section 5). Its responsibilities are to review the social impacts of all proposed development plans. The CPC's role is to guarantee, through an advising, reviewing, and monitoring process, that local social concerns and issues be adequately and appropriately addressed in the design and implementation of all development projects. Based on its findings, the committee submits recommendations to the **Council** for approval or disapproval of an applicant's proposed development plan.

GOALS AND OBJECTIVES

Goals

The overall goal which should prevail is to design a development review process which will provide the information and mechanisms necessary for reviewing, informatively and intelligently, development proposals. The primary objective of the review process is to assist in determining if a proposed project will be sustainable, compatible with local human communities, and contribute to social well-being.

In fulfilling the desires of the people and government of the State of Nayarit, while at the same time not discouraging development because of cumbersome regulations and restrictions, the following specific objectives are proposed:

I. Develop a Master plan containing guidelines and recommendations which can be utilize for the purpose of planning, reviewing, assessing, selecting, monitoring, and evaluating the social/cultural implications of proposed developments.

II. Develop and implement guidelines and recommendations designed to facilitate the project review and implementation process by minimizing administrative red tape, complexity, time and, therefore, costs to all parties (reviewers and developers) involved.

Recognizing that conditions and people continuously change, these guidelines and recommendations should **not** be established on a permanent basis but rather, they should be periodically assessed and modified as needed. Discouragement and frustration on the part of developers shall be avoided by not having them go through many different government agencies for their project approvals. Instead, development approval will be determined the Council.

METHODOLOGY

To achieve the goals and objectives for incorporating social/cultural concerns in the development review process, it is suggested that a local Community Participation Committee(s) (CPC) be established under the **Council**.

Purpose

To assure that local community issues, concerns, and desires are adequately addressed during the project review by the **Council**, the **Council** should require from the developer a social/cultural impact assessment (S/CIA) that evaluates past, present, and future socioeconomic conditions of the area or areas where the development is proposed; provides mitigation for negative impacts; and plans for development integration into the area.

The Duties of the CPC are as Follows:

A. Review the S/CIA studies, results, and policies for all coastal zone development within their respective area.

B. Based on it's review findings, submit to the **Council** recommendations regarding its acceptance, denial or modification.

C. Through its review process, assure that compliance with the goals and objectives of the Master Plan pertaining to social/cultural concerns have been achieved in all proposed projects.

D. Establish, as needed, ad-hoc subcommittees to help expedite and fulfill the CPC's purpose and function.

E. To act as a vehicle for voicing the concerns of the community, as well as serving as a link between the **Council** and the developer in the following manner:

1. One of its members and an alternate shall be elected by the CPC to sit as an official voting member of the **Council** when development proposals for the CPC's area are considered. As a **Council** member, he/she can then represent the CPC's views and lobby for its positions relative to development proposals.
2. To serve as a direct source for information and advice to developers regarding community issues during the planning, implementation, monitoring, and evaluation stages of a development project.
3. To serve as a source for local community input and information to the **Council**.

Process

The CPC's role is to save the **Council** time, and inform the public at large about all projects proposed for their area. It can act as the initial screening body for the **Council** by reviewing a developer's S/CIA studies, results, and proposed policies. During this initial review, all the major and minor details which are missing or need to be revised or eliminated can be worked out. This should be conducted with sufficient time in advance to provide participation from the local communities, through the following suggested activities which the CPC and developers should be responsible for:

1. Announcements through the local and regional media and radio of the proposed project and its policies. The announcement should provide the CPC's address or a telephone number where the public can write or call to express their opinions and ideas.
2. Organize local town meetings where the plan can be presented (by the developer or his representative), discussed, debated, have questions answered, etc. One or more CPC members must be present in order to document and follow up on the main issues and concerns expressed. One or more of the developer's representatives are required to be present for answering questions regarding the plan.
3. Members of the CPC and representatives from the proposed project should conduct personal interviews with members of the community to gather their opinions and concerns regarding the plan, so that they may be taken into consideration.

Once the plan seems in order, and all relevant community input has been obtained, it will then be passed on to the **Council** with the CPC's recommendations for the final review process.

REQUIRED IMPACT ASSESSMENT STUDIES AND POLICIES

S/CIA studies can be conducted utilizing established models and techniques outlined by authorities in this field, e.g.: Derman and Whiteford, 1985; Finsterbusch and Wolf 1977; Finsterbusch et al., 1990; Conyers and Hills, 1984; United Nations Environmental Programme (UNEP); OEDC; World Bank; and USAID. It should be stressed, as some of these authors have pointed out, that these studies should be tailored to the local social, cultural, economic and environmental conditions (Carley and Bustelo, 1984; Conyers & Hills, 1984; Derman and Whiteford, 1985; Finsterbusch et al., 1990; Freeman et al., 1980; OECD, 1988a,b). To facilitate this goal, participation from the community and the hiring of local nationals knowledgeable in this field (planners, administrators, sociologist, anthropologists, etc.), as well as other workers, should be part of the plan.

At the very least, the following objectives and specific requirements relative to social/cultural issues shall be addressed in the S/CIA for proposed developments. The proposed project should:

A. Protect and promote the health and safety of the people and environment in which it is located. This includes the air, water, soil, animals, and vegetation. To accomplish this, the S/CIA for the proposed development project shall:

1. Determine the current health needs of the local population and project the future needs created from the changes imposed by the development.
2. Assess and report existing endemic diseases, especially the communicable, host-parasitic, water and vector-borne ones that the project will contribute to. Offer solutions for combating and preventing the further spread of these diseases.
3. Determine, using formulas prescribed by the **Council**, monetary contributions for the construction and equipping of a hospital capable of providing all the major preventive and primary medical care services for employees, their families, and the local community.
4. Determine, using formulas prescribed by the **Council**, monetary contributions for the staffing, operating, and maintenance of the health care facility.
5. Develop plans for providing physical examinations for all employees--a mandatory hiring requirement before an employee is officially hired.
6. Develop plans for provision of bimonthly health education and disease prevention seminars sponsored in cooperation with local health authorities.

B. Protect and promote good educational standards for all age groups of the local community. To accomplish this, the S/CIA for the proposed development project shall:

1. Determine the current educational needs of the local population and project the future needs created from the changes imposed by the development.
2. Determine, using formulas prescribed by the **Council**, monetary contributions for the construction and equipping of a school capable of providing the necessary educational needs for employees, their families, and the local community.

3. Determine, using formulas prescribed by the **Council**, monetary contributions for the staffing, operating, and maintenance of the school facility.

C. Protect and promote good housing standards for the local community. To accomplish this, the S/CIA for the proposed development project shall:

1. Determine the current housing needs of the local population and project the future needs created from the changes imposed by the development.
2. Determine, using formulas prescribed by the **Council**, monetary contributions for the construction of homes for employees, their families, and the local community.
3. Determine, using formulas prescribed by the **Council**, monetary contributions for the staffing, operating, and maintenance of a home care and community improvement office facility.

D. Protect the local community and cultural organization. To accomplish this, the S/CIA for the proposed development project shall:

1. Assess and report the total labor force requirements, current labor pool, and the present and future impact of the development on supply and demand of labor.
2. Estimate projected demographic changes in the local population that will result from the development, relative to: numbers, age, sex, and social, economic, labor, and educational status.
3. Assess problems arising from the social, economic, and cultural differences between the local residents, immigrants, and visitors.

E. Protect and promote recreational opportunities and parks for the local community. To accomplish this, the S/CIA for the proposed development project shall:

1. Determine the current parks and recreational needs of the local population and project the future needs created from the changes imposed by the development.
2. Determine, using formulas prescribed by the **Council**, monetary contributions for the construction and equipping of said local parks and recreational activities so that they may be capable of meeting the needs of employees, their families, and the local community.
3. Determine, using formulas prescribed by the **Council**, monetary contributions for the staffing, operating, and maintenance of said parks and recreational facilities.

F. Protect and promote the provision of adequate public services (water supply, sewage, solid waste disposal, communication, and transportation) for the local community. To accomplish this, the S/CIA for the proposed development plan shall:

1. Determine the current public service needs of the local population, and project the future needs created from the changes imposed by the development.
2. Determine, using formulas prescribed by the **Council**, monetary contributions for the construction and equipping of said public services so that they may be capable of meeting the needs of all employees, their families, and the local community.

3. Determine, using formulas prescribed by the Council, monetary contributions for the staffing, operating, and maintenance of said public services.

G. Respect, protect, and promote past, present, and future cultural sites, traditions, and activities. To accomplish this the S/CIA for the proposed development plan shall:

1. Identify and preserve all known and suspected archeological sites and ruins, and provide an archeological site protection and mitigation plan.

H. Protect and promote the local economy. To accomplish this, the S/CIA for the proposed development project shall:

1. Assess and report the impact of the development on access by local residents to goods and services and provide specific recommendations, guidelines and mitigation to control local prices and supplies of goods and services.

I. Promote good working standards. To accomplish this the S/CIA for the proposed development project shall:

1. Assess and report employee wages, benefits, work schedules and intended standards for working conditions and safety.

SECTION 4: GOALS AND OBJECTIVES FOR PROTECTING THE RESOURCES OF NAYARIT

The process of developing the set of planning documents for the Coastal Zone of Nayarit followed the general outline of: (1) goal articulation, (2) data collection and synthesis, and (3) plan generation. The goals and objectives are stated fully in the **Nayarit Coastal Zone Management Plan (the Management Plan**--see Part 2 of this volume), and are summarized below.

1. The **Nayarit Coastal Zone Environmental Protection Council (the Council)** recognizes that Nayarit Coastal Zone (NCZ) has unique environmental resources, the conservation of which is essential to maintain the natural diversity of plant and animal species and habitat, including those of economic value such as commercial and sport fisheries.

2. The **Council** recognizes that, in order to maximize tourism and related development opportunities, it is critical to: maintain the diversity and aesthetic quality of the **NCZ**; create a secure, safe and aesthetically pleasing land management and community environment; and minimize damage to structures by natural events.

3. The **Council** adopts the following goals for the **Management Plan** and the **Handbook of Development Guidelines and Considerations for the Nayarit Coastal Zone** (the **Handbook**-- see Part 3 of this volume):

   Goal 1 It is the goal of the **Council** to adopt, amend as appropriate, and annually review the **Management Plan**; to monitor and evaluate the progress of land development and environmental protection of the **NCZ**; and to enforce the provisions of the **Management Plan** during the planning period following adoption of the **Management Plan**.

   Goal 2 It is the goal of the **Council** to develop the **NCZ** in a manner that promotes the economic and social welfare of present and future residents and visitors of Nayarit, by means of conservative and judicious utilization of the irreplaceable natural resources of the coastal zone.

   Goal 3 It is the goal of the **Council** to guide development in a manner that: preserves the environmental and cultural integrity, species diversity and scenic quality of the **NCZ**; promotes development patterns that avoid areas of natural hazard; and minimizes cost and maintenance of public facilities and infrastructure.

In addition to these three goals, the planning team recognized nine objectives that it felt were important to achieve sustainable and environmentally compatible development of the **NCZ**. These objectives were the driving force behind the analysis of the **NCZ** resources; development of the **Reserves and Protected Areas Plan**; analysis of fiscal impacts of development; and, ultimately, the formation of the **Management Plan** and the **Handbook**. The objectives are summarized as follows:

1. Establish terrestrial and marine resource protection districts.
2. Create development patterns that protect scenic vistas and aesthetic quality, and that are consistent with historic architectural traditions.
3. Plan for and provide proper level and timely public facilities and services.
4. Establish policies and regulations to minimize potential damage to property and life resulting from natural hazards.
5. Maximize positive economic and social benefits of development, within national socio-economic interests.
6. Balance land management and environmental protection with accommodation of vested rights of landowners and citizens.
7. Monitor, evaluate, and change the **Management Plan** and the **Handbook** as needed.
8. Develop procedures, and assist the Minister in the administration of laws regarding land development and environmental protection of the **NCZ.**

SECTION 5: THE REGULATORY FRAMEWORK

INTRODUCTION

A land use management plan is composed of two interrelated elements: a set of maps or physical plans that indicate the spatial arrangements of proposed land use zones and districts and a written set of guidelines that describe design, construction and operation regulations. Together, these two elements comprise the "regulatory framework" by which development is controlled and growth is managed. In addition, if the framework is to have the force of law, it needs to have a legislative component and a regulatory apparatus. The following sections give suggestions for the responsibilities of government and developers that will achieve the management plan's objectives.

First, the creation of a development review board called the **Nayarit Coastal Zone Environmental Protection Council (the Council)** is suggested and its duties and responsibilities are outlined. Then, the responsibilities of developers are outlined, including required impact assessments and proposed development surcharges.

NAYARIT COASTAL ZONE ENVIRONMENTAL PROTECTION COUNCIL

The Council will act as the final development review board to insure that all development proposals within the coastal zone are consistent with the goals and objectives of the Master Plan. All Applications for Development Approval (ADA) will be reviewed by **the Council** and **the Council** will either recommend approval or denial to the State. The following are suggestions for composition, funding, and responsibilities of **the Council**.

Council Membership

The composition of the Board members should be representative of the varying sectors (environmental, community, and local government) affected by development. Priority for recruitment should be given to residents of the state representing the following divisions:

Environmental

Environmental sector: ecologists, environmentalists, biologists and members of related active organizations.

Social and Cultural

Community, Recreational and Cultural sector: sociologists; social workers; community workers and organizers; religious representatives; urban planners; architects; engineers; sports, recreation, and physical educators; indigenous tribe members; anthropologists/archaeologists; entertainment industry people, and members of related active organizations.

Educational sector: teachers, school administrators and secretaries, and students.

Health sector: doctors, nurses, public health officials and technicians, microbiologists and lab technicians, environmental sanitation engineers/officials, and folklore and other traditional healers (i.e., "curanderos"). The "Medical Ecologist" can also be included under this section.

Economic

Economics and Labor sectors: food and product manufacturers, distributors and retailers; farmers; ranchers; fisheries industry workers/owners; local tourist-related industry workers/owners; labor unions; and restauranteurs.

Political

Government Agencies: officials and representatives from the federal, state and county governments responsible for authorizing any related building and development permits, especially those from SEDESO, SARH, SEP, SSA and INEGI agencies among others.

Incorporating the recommendations of this report and, with the cooperation of SEDESOL (Secretaria de Desarrollo Social), previously known as SEDUE (Secretaria de Desarrollo, Urbano, y Ecologico), the State of Nayarit shall be responsible for:

1. Determining the mechanism for recruiting **the Council**'s membership. Suggestions for this include:
    a. Holding State-wide elections.
    b. Electing some members and appointing others.
2. Determining the total **Council** membership number, composition, and duration of service.
3. Awarding stipends to the membership, of which the amount and schedule of payments shall be determined by the State.
4. Providing **the Council** with the appropriate and adequate facilities, funds, and administrative and support staff, so that it may fulfill its duties and responsibilities as recommended by this report, plus additional ones the State or **Council** might deem fit and necessary.

The Council should establish local Community Participation Committees (CPC's), which will be under its direction and guidance. The primary purpose of these committees is to act as liaison between local citizens affected by a proposed development, and **the Council**. Once **the Council** has been notified by a developer of a proposed development, **the Council** will appoint a CPC for the District within which the proposed development is located.

1. The CPC's function, just like **the Council's**, is to minimize time, costs and complexity, while at the same time act as a vehicle for communication between the local community and the rest of the parties involved in the proposed development and review process. Its primary concern should always be that of the welfare of the community that will potentially be affected by the development project.

2. The CPC's membership should reflect the local communities' social, cultural, and economic composition.
3. To the extent possible, CPC membership will be comprised of local residents or workers within districts affected by the development. The total number of members within each CPC will be determined by **the Council**.
4. **The Council** has responsibility for recruiting/appointing the local members into a CPC.

Purpose of the Council

The Council's function shall be to review all ADA's, and to minimize administrative red tape, costs, time and the overall complexity of the development review process. **The Council** shall:

1. Function as a "one-stop" agency/project approval system for anyone who plans to design or construct development projects within the State of Nayarit's jurisdictional boundaries, including its islands.
2. Review, assess, and recommend to the State, the approval or disapproval of all coastal zone and island development proposals.
3. Assure that all related federal, state, and local government regulations regarding development are addressed and complied with.
4. Assure that the recommendations in this report and other environmental and community concerns and issues are appropriately addressed and complied with.
5. Assure that the environmental and social/cultural impact assessment (EIA & S/CIA) studies and protocol requirements are fulfilled.
6. Assure that all development plans have demonstrated to be sustainable, as well as harmonious with the environment and its human, animal and vegetative components, before they are approved.
7. Determine appropriate quantity, type, and mechanisms for impact mitigation of proposed developments that affect the local community and its environment.

The Council, through its CPC's, shall inform the public at large of all projects proposed in their area. In this way, issues and concerns of local citizens can be addressed and clarified and heard by **the Council**. To accomplish this, **the Council** shall:

1. Announce, through the local and regional media and radio, all proposed projects. The announcement should provide the local CPC's address or a telephone number where the public can write or call to express their opinions and ideas.
2. Organize local town meetings where the plan can be presented (by the developer or his representative), discussed, debated, and where questions can be answered.
3. One of the CPC members and an alternate, should sit on **the Council** as an official voting member, in order to represent the interests of the local community.

Funding for the Council

The state shall initially be responsible for determining the amount and sources for funding **the Council** and its committees. It is recommended that a reasonable percentage should always come from at least the following sources:

1. The federal government: from its SEDESOL agency budget, corporate taxes collected, fines collected from environmental violations, etc.
2. The State: from its state SEDESOL budget, any surcharges imposed on developers, fines collected from environmental violations, etc.
3. A surcharge imposed on extractive industries (e.g., logging, mining, etc.), and others such as fisheries, mariculture and aquaculture, etc.

Once **the Council** is fully functional, it should establish a Finance Committee, which will be responsible for:

1. All the financial matters of **the Council**.
2. Drafting a yearly budget, and submitting it to the State for approval and subsequent funding.

APPLICATION FOR DEVELOPMENT APPROVAL

An Application for Development Approval (ADA) shall be prepared for all developments of a size greater than a threshold to be determined by **the Council**. The threshold may be different for different districts (or regions) of the coastal zone, depending on existing intensity of development and perceived environmental and cultural conditions and sensitivities. The ADA should include sufficient maps, quantitative data, and analysis of environmental and social/cultural impacts to judge the soundness of the development, and to judge its contributions and impacts on the local environment and social/cultural system. The ADA should include all relevant issues and concerns addressed in Sections 2 and 3 of Part 1 of this document.

Mitigation of Impacts

To insure that proposed developments contribute to a sustainable economy and the overall welfare of the local community, measures for the mitigation of growth-induced environmental and social/cultural impacts should be implemented. For simplicity, these measures can take the form of Impact Fees for the construction of schools, health care facilities, or other public facilities within the local community. Formulas for determining the required fees should be based on the growth-induced impacts of the development and needs of the local community.

SECTION 6: GENERATION OF THE PLAN

INTRODUCTION

The process of developing the land use management plan was a multi-faceted undertaking. Physical attributes of the landscape (vegetation, land use, soils, and geology) were mapped as constraints and opportunities for development. When combined, they yielded an Overall Development Potential Map. Sensitivities of marine and terrestrial ecological communities were explored, and regulations were developed to minimize impacts of development. Social/cultural constraints and opportunities were analyzed, and these formed the basis for developing impact fees and regulations for protection of local communities. Each of these separate facets were combined into an integrated whole, which spatially depicts developable lands and provides regulations and guidelines for their development.

A brief discussion of the process of developing these two elements (the written component and the maps) is given next.

REGULATIONS AND GUIDELINES

To generate the written component of the plan, management recommendations determined during analysis of constraints and opportunities were coalesced into development guidelines, and related to the various stages of the development process. Specific recommendations relating to design issues, construction practices, and site planning and development were grouped together. Recommendations were then written in the form of regulations based on the various development stages (design, site planning and development, and construction) using a formal language giving them a sense of legal force. The language and style were copied from regulations and legislation that are currently in use by governments of other countries with already successful coastal management plans. The regulations were written in this format to make their adoption as a legal and binding regulatory framework easier.

Suggestions and mere guidelines without the force of law are often ignored, at worst, or only selectively utilized, at best. While the language and style may seem overly restrictive, the level of regulation suggested in these documents is quite the contrary; they are relatively permissive. Only the simplest of requirements with a minimum of permitting is required of those seeking to develop within the **Nayarit Coastal Zone (NCZ)**. The intent was not to generate a complex regulatory framework that would baffle or confuse, but to provide a model framework that was not overly restrictive (especially for small-scale landowners and those wanting to build single family residences), but that adequately protects the environment and the health and safety of the public.

MAPS OF CONSTRAINTS, OPPORTUNITIES AND DEVELOPMENT POTENTIAL

Map coverages of land cover, slope, and geology/soils (Maps 1-3) were obtained from CETENAL (1973, 1974, 1975). The map coverages were encoded into a computer based Geographic Information System (GIS). Once encoded, they formed the basis for Constraints and Opportunities Maps. Constraint maps were generated for slope, agricultural lands, wetland ecosystems. In each of these maps, lands were classified as "constrained", or undevelopable based on their sensitivity, or economic/environmental importance. The resulting maps are called Constraints Maps (Maps 5-7). The maps for slope, agricultural uses, and wetlands were combined into Overall Development Constraints Maps (Maps 11-17).

Opportunity maps were generated from slope, vegetation and land cover, and geology/soils. In each case, the lands remaining after the constraints were determined were classified in varying degrees of suitability for development. The resulting maps (Maps 8-10) have varying shades of gray indicating their suitability for development: the darker the shade, the more suitable an area is for development, and thus the higher the allowable intensity of development.

A final Development Potential Map was generated from the combination of the 3 opportunities maps by overlaying and selecting the lowest opportunity for any areas that were shared by all 3 maps (Maps 19-25).

The Overall Development Potential Map (Map 18) gives detailed spatial zoning of the developable portions of the **NCZ**. Zones or Districts are organized as intensity districts where multiple uses are allowed within districts as long as intensities are compatible. In general, decisions of compatibility will rest with the **Nayarit Coastal Zone Environment Protection Council (the Council)**. Highest intensities of use are located on the least sensitive lands, while lowest intensities are located on those lands where environmental sensitivities limit the intensity of development. Precluded from development are wetlands, agricultural lands, and those areas where slopes, soil types, and/or other hazards exist such that development would seriously jeopardize structures and health and safety of the public.

Developable portions of the **NCZ** are shown on the Overall Development Potential Map in varying shades of gray. Areas that are intended for little or no development are those areas that remain as white background. They are indicated as undevelopable and should remain without development because of one of several factors that will limit their safe and environmentally benign conversion to some human use. Within the areas which are classified as undevelopable, there may be some areas of developable lands that are not restricted by land stability problems. The scale of mappable unit, and the quality of the original data from which the various Constraints and Opportunities Maps were made, may have precluded small areas that are developable. It may be equally valid to consider development proposals in many areas mapped as undevelopable on a case by case basis, where landowners or developers demonstrate to the satisfaction of the **Council** that they may be safely and sensitively developed.

LAND DEVELOPMENT INTENSITY DISTRICTS

It is intended that the **Nayarit Coastal Zone Management Plan** (see Part 2 of this volume), and the **Handbook of Development Guidelines and Considerations for the NCZ** (see Part 3 of this volume) foster a development pattern that is in keeping with the character and scale of other areas of Nayarit. Land Development Intensity (LDI) Districts (see Part 3, Section 5.2) that do not zone land uses, but rather indicate intensity of use, are utilized as a means of providing a great amount of flexibility to both developers in their plans, and to the **Council** in its ability to regulate development. The first two districts (LDI I and LDI II) are reserved for residential uses. The remaining districts (LDI III-VI) allow most land-use activities, with fewer restrictions as intensities increase. The flexibility that is allowed with such a system of land-use control is extensive. This pattern of development, with mixed uses based on appropriate constraints, has the potential of establishing a socially and economically integrated community, a goal that has been at the forefront of concern since the beginning of this planning exercise.

It is the expressed desire of the planning team to limit the size of hotel complexes within the districts allowing this use, as a means of accomplishing two very important goals: 1) the scale of development is in keeping with the urban scale prevalent in the **NCZ**; and 2) small-scale hotel development fosters involvement of local citizens, limits extensive development by multinational hotel chains, and ensures that a substantial portion of wages, expenses and profits are cycled through the local economy, instead of outside of Nayarit and Mexico.

Limits on the number of large hotel complexes seems entirely appropriate. If demand for hotel rooms is sufficient, four 50-room hotels can easily satisfy the needs of the same number of tourists as one 200-room hotel, only with more diversity of choice, a better sense of scale, and better ability to fit the social fabric of the **NCZ**. With sufficient creativity, several small hotels could easily band together to offer incentives and vacation packages that would rival those offered by the larger chains.

OVERLAY DISTRICTS

Overlay Districts should be generated by the **Council**, using site-specific data, as a means of further modifying LDI Districts, and to provide additional information to the public. A proposed Reserves and Protected Areas Map (Map 26) is included in this report as an example of an Overlay District that would affect land use and the spatial organization of permissible land uses. When overlaid on the Overall Development Potential Map, Overlay Districts have some added regulations that need to be observed.

These Overlay Districts allow greater flexibility than would otherwise be possible with only one map of land use zones. Their boundaries may be altered, they may be changed and updated at will, and their accompanying criteria may be altered without the need to alter the Overall Development Potential Map. In this way, the Overlay Districts act as modifiers that may be constantly updated and refined as new information is generated and development occurs. Yet the Overall Development Potential Map can remain intact and the confusion of altering the principal planning map is avoided.

A second advantage of the Overlay Districts is the simplicity that is created. The Overall Development Potential Map is relatively simple in comparison with other land use maps, and the primary reason is that fewer zones are needed to adequately address both questions of land-use compatibility and environmental protection. Environmental protection is addressed primarily by the overlay zones, freeing the Overall Development Potential Map and its zones for addressing questions of land-use compatibility.

SUMMARY: PLAN GENERATION

Accommodating intense development, while protecting unique treasures of marine and terrestrial resources in the NCZ, is a complex undertaking. It is a question of balance. The planning documents presented in this volume are the result of an attempt to organize the articulated goals and objectives of the government and people of Nayarit, and the information generated as the result of studies performed by scientist and planners over the past two years, into a balanced regulatory framework: a "Plan for the Future". These plans are models. They are a balance between development on the one hand and strict resource preservation on the other. If adopted, in whole or in part, they will help in the complex undertaking of managing the NCZ for future generations, as well as the thousands of visitors that will come to the NCZ to appreciate its beauty.

PART 2: PROPOSED LAND USE MANAGEMENT PLAN

INTRODUCTION

The development of the Nayarit Coastal Zone (NCZ) has broad and important environmental, social and economic benefits for both Mexico and Nayarit. Careful development can benefit from the great natural amenities of the NCZ. The development potential, however, is limited by several physical constraints, including the future water supply, the soils, topography and geologic formations. Excessive development intensity may cause environmental and visual degradation, resulting in loss of the attractiveness of the region as a tourist destination.

Given these considerations, this proposed **Nayarit Coastal Zone Management Plan (Management Plan)** and the **Handbook of Development Guidelines and Considerations for Nayarit Coastal Zone (the Handbook**--see Part 3 of this volume) attempt to accommodate an attainable level of development, while sustaining a healthy and sound environment and economy. Thus, the **Management Plan** and the **Handbook** are designed to guide development to the most suitable areas of the NCZ.

The **Management Plan** and the **Handbook** are companion documents, and shall be considered by the Nayarit Coastal Zone Environmental Protection Council (**the Council**) as having complementary provisions. The **Management Plan** sets forth goals and objectives designed to manage the development and protection of the land, natural resources and adjacent waters of the NCZ. The **Handbook** contains specific policies, standards and guidelines for the implementation of the **Management Plan**. It includes standards for development proposals, review procedures and development permitting by the **Council**. The purpose of the **Management Plan** and the **Handbook** is to provide the general and specific goals, objectives, policies and regulations for land-use management and environmental protection of the **NCZ**.

Background Information

The **Management Plan** and the **Handbook** are the result of analyses begun in 1989. These studies cover a full range of environmental aspects of the **NCZ** and the waters included within it. In addition, aesthetic, economic, political and social issues regarding the future of the **NCZ** were considered. The Government of Nayarit authorized and participated in these studies.

The project has been conducted by a team of scientists, resource planners and students, including two visiting Mexican students, at the Center for Wetlands and Water Resources, University of Florida in Gainesville. This team was brought together under the sponsorship of the Nayarit Government, through a contract with The Cousteau Society.

Handbook of Development Guidelines and Considerations for the NCZ

The **Handbook** establishes how the goals and objectives of the proposed **Management Plan** are to be achieved. The regulations contained in the **Handbook** cover development review and permitting procedures, complete with policies, guidelines, and standards controlling land development and protection and conservation of resources in the **NCZ**. The **Handbook** is thus part of the **Management Plan**, but is treated as a separate document for convenience. While the material it contains may have wider applicability to the development of Nayarit, its provisions have been expressly tailored to protect and enhance the natural and man-made environment of the **NCZ**.

Legal Authority

The State of Nayarit, in a move to protect the still pristine coastal zone of the State, is trying to promote ecologically and economically balanced development. Therefore, the government established the "Plan Maestro Turistico Ecologico de la Costa de Nayarit" or Nayarit Coastal Zone Management Plan. The legal authority for the adoption, amendment and administration of the **Management Plan** and the **Handbook** by the **Council**, is predicated upon the provisions of the National Development Plan 1989-1994. Related acts include the General Law on Ecological Balance and Environmental Protection, 1988 (**GLEBEP**); and any other National and State acts enacted by the Governments of Mexico and Nayarit.

PROPOSED NAYARIT COASTAL ZONE MANAGEMENT PLAN

1.0 **Nayarit Coastal Zone Management Plan Concept**

1.1 The **Management Plan** seeks to provide long-term benefits for the economy of the State of Nayarit, by managing development on the Coastal Zone to maintain the natural resources and aesthetic values that make it attractive as a tourist destination, as well as for its potential for productive activities such as agriculture, aquaculture and fisheries. It is designed to identify the suitability of the lands in the Coastal Zone for different types of development and conservation including: tourism and related facilities; aquaculture and fisheries and their related facilities; retail and marine related commerce; a full range of housing opportunities and the generalized location of streets and transport facilities; parks, public facilities and recreation areas; and natural areas to be protected from development for economic, public safety, ecological and aesthetic reasons.

1.2 Based on an analysis of environmental constraints, permissible land developement intensities that are compatible with sound development practice have been established for the **NCZ**. The land development intensities (LDI's) are intended to be a general guide to future land development. In addition to the LDI Districts, Overlay Districts have been established for the location of public facilities and resource protection.

1.3 In general, the **Management Plan** will be focused on three general regions, which are described fully in Part 1 of this volume. These regions are: **(1) North Pacific Coastal Plain Zone (NPCPZ); (2) Central Neovolcanic Axis Coastal Zone (CNVACZ); and (3) South Sierra Madre Coastal Zone (SSMCZ).** The greatest concentration of development will be focused in the **SSMCZ** and, to a lesser extent, in the **CNVACZ**.

2.0 Goals and Objectives

2.1 Goals

2.1.1 The **Council** recognizes that the Nayarit Coastal Zone has unique environmental resources, the conservation of which is essential to maintain the natural diversity of plant and animal species and habitat, including those of economic value such as commercial and sport fisheries.

2.1.2 The **Council** recognizes that to maximize tourism and related development opportunities, it is critical to: maintain diversity and aesthetic quality of the **NCZ**; create a secure, safe and aesthetically pleasing land management and community environment; and minimize damage to structures by natural events.

2.1.3 The **Council** adopts the following goals for the **Management Plan** and the **Handbook**.

1. It is the goal of the **Council** to adopt, amend as appropriate, and annually review the **Management Plan**, to monitor and evaluate the progress of land development and environmental protection of the **NCZ**, and to enforce the provisions of the **Management Plan** during the planning period of twenty (20) years following adoption of the **Management Plan**.

2. It is the goal of the **Council** to develop the **NCZ** in a manner that promotes the economic and social welfare of present and future residents and visitors of Nayarit by means of conservative and judicious utilization of the irreplaceable natural resources of the Coastal Zone.

3. It is the goal of the **Council** to guide development in a manner that preserves the environmental integrity, species diversity and scenic quality of the **NCZ**; promotes development patterns that avoid areas of natural hazard; and minimizes costs and maintenance of public facilities and infrastructure.

2.2 Objectives

2.2.1 In order to achieve the goals of the **Management Plan** as far as possible, the **Council** further adopts the following objectives for the **Management Plan** and the **Handbook**:

a) It is the objective of the **Council** to preserve and protect natural habitat areas adequately, in order to maintain the present diversity of plant and animal species in the **NCZ**, including migratory wildlife such as birds and sea turtles, by establishing districts for resource protection.

b) It is the objective of the **Council** to maintain the present high quality and cleanliness of coastal waters, thereby preserving the habitat necessary for such irreplaceable resources as reefs, islands, and commercial and sport fisheries, by establishing districts for resource protection.

c) It is the objective of the **Council** to create development patterns and land uses which contribute to: the preservation of scenic vistas, the aesthetic quality of development, and the efficiency and convenience of both public and private services and commerce; additionally, to encourage development that is coherent in design, complementary to existing and planned development, and of an architectural quality consistent with the historic traditions of Nayarit and the values of its natural setting.

d) It is the objective of the **Council** to plan for locations and, as appropriate, provide the proper level and timely provisions of public facilities and services for sewage collection and treatment, water supply, storm drainage, flood protection, solid waste management, culture and recreation, education, health care and governmental administration.

e) It is the objective of the **Council** to establish policies and regulations covering the location, design and construction of buildings and structures to minimize the potential for damage to property and life by events such as wave action and storm surge, flooding, land slippage, wind and fire. In the case of public facilities, the objective is also to minimize the need for costly repair and maintenance.

f) It is the objective of the **Council** to maximize the positive economic and social benefits of development to the State of Nayarit and the Nation, and integrate the development of the **NCZ** within the overall context of National socio-economic interests, as stated in the National Development Plan 1989-1994.

g) It is the objective of the **Council** to balance the need to protect the natural environment and to manage land development for the benefit of the Nation and State, with the need to accommodate the vested rights of landowners and citizens.

h) It is the objective of the **Council** to monitor and evaluate the implementation of the **Management Plan** and the **Handbook**, and to make appropriate changes over time in the substance and enforcement measures as needed to achieve these goals and objectives.

i) It is the objective of the **Council** to develop appropriate procedures to accomplish these goals and objectives, and to assist the Minister in the administration of other National Laws regarding land development and environmental protection of the **NCZ**.

3.0 Definitions

3.1 Nayarit Coastal Zone Management Plan (Management Plan)

3.1.1 The Nayarit Coastal Zone Environmental Protection Council (**the Council**) is proposed to be established under provisions of the National Development Plan 1988-1994 and other related legal authorities under the General Law for the Ecological Balance and Environmental Protection (**GLEBEP**).

3.1.2 The **Management Plan** is the legal document including parts **I, INTRODUCTION; II, LEGAL AUTHORITY; and III, PROPOSED COASTAL ZONE MANAGEMENT PLAN.** For purposes of interpretation of the **Management Plan**, the **Council** shall consider the parts in their entirety including maps, graphics or other materials specifically included in these parts.

3.1.3 "**Minister**" means the current Minister being charged with the subject of planning and development at SEDESOL-COPLADES.

3.1.4 "**Shall**", as used in the **Management Plan**, means imperative or as interpreted by the **Council** to further the goals and objectives of the **Management Plan.**

3.1.5 "**Should**", as used in the **Management Plan**, means the conditional of "Shall", implying duty and obligation and is not synonymous with "may".

3.1.6 "**NCZ**" or "**Nayarit Coastal Zone**" is the coastal area extending from the northern boundary of Nayarit with the state of Sinaloa at the Canas river mouth, to the southern boundary with the state of Jalisco at Bahia de Banderas on the Ameca river mouth, to the 100-meter depth contour in the Pacific Ocean, to 5 Kilometers inland from the "**ZFMT**".

3.1.7 **"ZFMT"** or **"Federal Maritime Terrestrial Zone"** is a strip of land including: a) in the case of beaches, all the intertidal zone plus the twenty adjacent meters inland; b) in the case of cliffs or rocky shores, these formations and the twenty meters inland adjacent to the first freely transitable point on the top of the cliffs or rocky formations; and c) in the case of water bodies and wetlands communicating with the sea or containing salt water, the twenty-meter strip adjacent to the highest annual water level. These cases are defined in Article 49 of the General Law on the National Welfare.

3.1.8 **"NPCPZ"** or **"North Pacific Coastal Plain Zone"** is the area delimited within the physiographic region known as Pacific Coastal Plain, with its boundary to the north at the Canas river and to the south at the southern end of the Matanchen's Bay.

3.1.9 **"CNVACZ"** or **"Central Neovolcanic Axis Coastal Zone"** is the area delimited within the physiographic region known as Neovolcanic Axis, with its boundary to the north at the southern end of the Matanchen's Bay and to the south at the southern end of the El Naranjo Beach.

3.1.10 **"SSMCZ"** or **"South Sierra Madre Coastal Zone"** is the area delimited within the physiographic region known as South Sierra Madre, with its boundary to the north at the southern end of the El Naranjo Beach and to the south at the Banderas Bay's Ameca river mouth.

3.2 Applicable Terms: National Law

3.2.1 **"GLEBEP"** is the General Law of Ecological Balance and Environmental Protection, or "Ley General del Equilibrio Ecologico y la Proteccion al Ambiente".

3.2.2 **"Wild Fauna"** are the terrestrial animal species, which subsist subject to the natural selection processes, whose populations inhabit temporarily or permanently within the National territory where they develop freely, including their minor populations which are under man control, as well as the abandoned domestic animals that have turned wild for which they may be susceptible to be captured or appropriated. As in Art. 3-XIV (GLEBEP).

3.2.3 **"Wild Flora"** are the terrestrial vegetation species, as well as mushrooms, which subsist subject to the natural selection processes, whose populations develop freely within the National territory, including those populations or specimens of these species which are under man's control. As in Art. 3-XV (GLEBEP).

3.2.4 **"Aquatic Flora and Fauna"** are the biological species and biogenic elements that inhabit the waters within the National Territory as a temporary, partial or permanent medium of life, as well as those within the zones where the Nation exercises sovereignty and jurisdictional rights. As in Art. 3-XVI (GLEBEP).

3.2.5 **"Biosphere Reserves"** are areas with an extent greater than 10,000 hectares, integrated by representative and relevant biogeographic areas of natural ecosystems not significantly altered by man, with at least one zone not altered, and inhabited by species considered endemic or endangered. It combines conservation, research, education, training policies and functions as a local population integrator. No new development may take place in a Biosphere Reserve. As in Art. 48 (GLEBEP).

3.2.6 **"Special Biosphere Reserves"** have the same characteristics as the biosphere reserves, but they are smaller in size or have less species diversity. As in Art. 49 (GLEBEP).

3.2.7 **"National Parks"** are constituted in forested land according to this and the Forestry Law; they represent one or more ecosystems which are important for their natural beauty, scientific, educational or recreational and historic value, for the existence of important flora and fauna, for its suitability for tourism development, or for other reasons of general interest. These areas will be for the use of the general public, and may have activities related to natural resources protection, increase of flora and fauna populations and, in general, to preserve the ecosystem and its elements, as well as for research, recreation, tourism and ecological education. Exploitation of the natural forestry resources may only be authorized by SEDUE. As in Art. 50 (GLEBEP).

3.2.8 **"Natural Monuments"** will be established according to this and the Forestry Law; they will represent areas that have one or various natural elements of national importance. The only activities allowed will be those related to their preservation, scientific research, recreation and education. As in Art. 51 (GLEBEP).

3.2.9 **"National Marine Parks"** will be established in marine zones within the national territory, and will include the beaches and the maritime-terrestrial federal zone contiguous to them. Only activities related to the preservation of aquatic ecosystems and their elements, research, recreation and ecological education, and exploitation of natural resources authorized by this law and the Federal Fisheries and Seas Law, and other related national and international laws and regulations will be allowed. As in Art. 52 (GLEBEP).

3.2.10 **"Natural Resources Protected Areas"** are areas designed for the preservation and restoration of terrestrial and aquatic areas. They are as follows:

I. Forestry reserves;
II. National forestry reserves;
III. Protected and forestry zones;

IV. Restoration and forestry propagation zones;

V. Zones for the protection of rivers, springs, deposits, and water reservoirs.

The establishment, organization and management of these areas will be according to this law, and the Federal Forestry and Waters Law, and other related regulations. As in Art. 53 (GLEBEP).

3.2.11 "**Flora and Fauna Protected Areas**" are areas established for the protection of wild and aquatic species, and will be constituted according to this law and the Federal Hunting and Fishing Law and related regulations. Activities related to preservation, propagation, acclimatization, refuge and research of species, as well as those related to education, will be allowed. As in Art. 54 (GLEBEP).

3.2.12 "**Urban Parks**" are areas of public use, constituted by the federal entities and municipalities within the towns and cities to obtain and preserve the balance of urban-industrial ecosystems. As in Art. 55 (GLEBEP).

3.2.13 "**Zones Subject to Ecological Conservation**" are areas constituted by federal entities and municipalities, in zones neighboring human settlements, in which there exists one or more ecosystems suitable for conservation, designed to preserve the natural elements of the area. As in Art. 56 (GLEBEP).

3.2.14 "**Ecological Ordinance**" is the planning process directed to evaluate and program land-use and natural resources management, in order to preserve and restore ecological balance and to protect the environment, within the National Territory and those zones where the Nation exercises sovereignty and jurisdiction. As in Art. 3-XX (GLEBEP).

3.2.15 "**Environment**" is the unit of natural or human-induced elements which interact in a determined space and time. As in Art. 3-I (GLEBEP).

3.2.16 "**Natural Protected Areas**" are National Territory Zones and those on which the Nation exercises sovereignty and jurisdiction, where original environments have not been significantly altered by human activity, and that have been subject to a protection regime. As in Art. 3-II (GLEBEP).

3.2.17 "**Pollution**" means the presence in the environment of one or more pollutants or any combination of them, which may cause harm or ecological imbalance. As in Art. 3-IV (GLEBEP).

3.2.18 "**Pollutant**" means all matter or energy in any of its physical states and forms which, when been incorporated or acting in the atmosphere, water, soil, flora, fauna, or any natural element, alters or modifies its composition and its natural condition. As in Art. 3-V (GLEBEP).

3.2.19 "**Natural Resources**" are the natural elements susceptible of being exploited for the benefit of humans. As in Art. 3-XXIV (GLEBEP).

3.2.20 "**Natural Elements**" are the physical, chemical and biological elements which are present in a determined space and time, without introduction by man. As in Art. 3-XII (GLEBEP).

3.2.21 "**Historic Site**" is a place or site which is historic by reason of an association with the past, and is part of the cultural or historical heritage of Nayarit and Mexico, and such a classification may include archaeological sites, historic landmarks, and areas of special historic or cultural interest.

3.2.22 "**Scenic site**" is an area containing a scenic feature of national or local importance.

3.2.23 "**Beach**" is the sloping area of unconsolidated material, typically sand, that extends landward from the mean high water mark to the area where there is a marked change in material or natural physiographic form or when there is no such marked change in the material or natural physiographic form, the beach shall be deemed to extend to a distance of twenty meters landward from the high water mark or such lesser area as may be determined by the Minister in consultation with the **Council**, and in all cases shall include the primary sand dune.

3.2.24 "**Development**", in relation to any land, includes any building or rebuilding operations and any use of the land or any building thereon for a purpose which is different from the purpose for which the land or building was last being used, or the sub-division of any land, and "develop" shall be construed accordingly.

3.2.25 "**Land**" includes land covered with water and also includes incorporeal as well as corporeal hereditament of every tenure or description, and any interest therein, and also an undivided share in land.

3.2.26 "**Owner**", in relation to any building or land, means a person other than a mortgagee not in possession, who is for the time being entitled to dispose of the right of ownership of the building or land, whether in possession or reversion, and includes also a person holding or entitled to the rents and profits of the building or land under a lease or agreement, the unexpired term whereof exceeds ten years.

3.2.27 "**Authorized officer**" means any police officer, forest officer or any other person appointed for purposes of this act.

4.0 Land Development Intensity Districts and Overlay Districts

4.1 Land Development Intensity Districts

Each Land Developement Intensity (**LDI**) District describes the types and intensities of land uses permitted in the District, and planning policies for the development of the District. **LDI** boundaries are shown on the **Overall Development Potential Map (Map #18)**, and shall be interpreted to be generalized, except where boundaries are coincident with center lines of road or right-of-ways, or with naturally occurring geographic boundaries. The **Council** shall be the interpreter of any boundary issues.

4.1.1 Land Development Intensity District I (**LDI-I**). The following uses shall be permitted in **LDI-I** districts: Single family detached residential and related uses. Such uses shall be located on individual lots or on aggregated sites, in which the density of dwelling units shall be equal to or less than 1 dwelling unit per hectare (DU/ha).

4.1.2 Land Development Intensity District II (**LDI-II**). The following uses shall be permitted in **LDI-II** districts: Single family detached or clustered detached residential and related uses. Such uses shall be located on individual lots or on aggregated sites in which the density of dwelling units shall be equal to or less than 5 DU/ha, but not less than 1 DU/ha.

4.1.3 Land Development Intensity District III (**LDI-III**). This district category is reserved for **Planned Unit Developments (PUD)**. **LDI-III** districts shall be permitted only on sites equal to or greater than 2 ha, and shall be subject to individual proposal review and approval as provided for in the **Handbook**. A **PUD** is a development of one or more uses that is planned by a developer as a single coherent and comprehensive land use and public facilities plan for a given site. In this District, innovative design and planning is encouraged. The **PUD** should embody mixed compatible uses to increase variety and aesthetic quality and to permit the integration of open spaces with buildings. Heights of buildings shall be limited to **10 meters**. Density shall not exceed **5 DU/ha**, and lot coverage shall not exceed **40%** of the land area. The following uses may be approved in the **LDI-III** district: primarily residential, with related commercial, marine, and tourist facilities, including hotels of **50 rooms** or less and any use that is compatible with uses in **LDI-I** and **LDI-II**.

4.1.4 Land Development Intensity District IV (**LDI-IV**). The following uses shall be permitted in **LDI-IV** districts: single hotel or tourist facilities, commercial retail related to tourist facilities, and multi-family residential uses. The floor area ratio shall not exceed **(0.75)**. Floor area ratio is the ratio of the floor area of all buildings to the total area of the site (floor area ratio = floor area/site area). The height of buildings shall be limited to **10 meters**.

4.1.5 Land Development Intensity District V (**LDI-V**). The following uses shall be permitted in **LDI-V** Districts, which shall be known as Marine Related Districts: water- and marine-related uses, commercial retail, attached and multi-family residential, and hotels of **25 rooms** or less. The floor area ratio shall not exceed **2.0**. Floor area ratio means the ratio of the floor area of all buildings, except open docks and quays, to the total area of the site (floor area ratio = floor area/ site area). Height of buildings shall be limited to **7.5 meters** with care to preserve vistas over the water for inland development, as may be approved by the **Council**.

4.1.6 Land Development Intensity District VI (**LDI-VI**). This District shall be known as the Town Center. The following uses shall be permitted in **LDI-VI** districts: mixed and multiple uses including hotels of **25 rooms** or less, commercial wholesale not exceeding **10 percent** of all commercial floor area, attached townhouses and multi-family residential, churches, professional and other personal services, automobile services limited to sites which minimize conflicts with residential uses, governmental services and other uses which, in the determination of the **Council**, would be compatible with the Town Center concept. The floor area ratio shall not exceed **3.0**. Floor area ratio means the ratio of the floor area of all buildings to the total area of the site (floor area ratio = floor area/site area). Height of buildings shall be limited to **10 meters**, with care to preserve vistas and open space, as may be approved by the **Council**.

4.2 Overlay Districts

The Overlay District identifies future public facilities services areas, recreation areas, or natural resource protection areas. The overlay indicates that special considerations for future land development are required to forward the goals and objectives of the **Management Plan** and the policies and standards of the **Handbook**. Boundary issues related to Overlay Districts will be resolved by the **Council**. The **Council** will be guided by the natural characteristics and sensitivity of environmental conditions in the resolution of boundary issues, and will be further guided by its judgement as to the consistency of its interpretation to the overall goals and objectives of the **Management Plan**.

4.2.1 Public Facilities District (**PFD**). The Public Facilities District shall include specific sites for police services, health facilities, library, school, solid waste management facility and sewage treatment facilities.

4.2.2 Natural Resource Protection Districts. The following districts shall be considered Overlay Districts requiring special attention and application of goals, objectives, policies and regulations found in the **Management Plan** and the **Handbook**.

a) Conservation District (**CD**). These areas are dominated by significant vegetation associations or species of special concern, or are districts where wildlife species of rare, endangered, or special concern status are known to breed, feed, or roost. All uses within the Conservation District shall conform to the policies and regulations of the **Handbook**.

b) Natural Hazard District (HD). These areas are characterized by natural hazards such as flooding and land slippage, which makes these areas unsafe and unsuitable for construction. Residential or commercial structures shall not be constructed in Hazard Districts, and public utilities and infrastructure shall cross through a Hazard District only when no alternative route is feasible.

c) Recreation District (RD). Recreation Districts are reserved for recreational purposes, based on existing or potential resource characteristics. Special areas such as beaches, golf courses and marine-related activities are included. In addition, a table is provided in the **Handbook** indicating the set-aside hectarage for public parks. These parks shall be designed in the project plans to be coherent, connected and appropriate for open space and park uses. Areas should be adequate for the intended use. All uses within Recreation Districts should conform to the policies and regulations of the **Handbook**.

d) Scenic District (SD). Scenic Districts are areas where visual intrusion of structures or utilities shall not detract from the natural scenic beauty of the area.

e) Reserves and Protected Areas (RP). Allowable uses and numbers of dwelling units, hotels or commercial uses are not precluded from Reserves and Protected Areas, however allowable development shall be encouraged to cluster such that at least **90 percent** of the District, parcel by parcel, remains in an unaltered state. In addition, roads and utility corridors shall be constructed so as to minimize disruption of the natural vegetative cover. Modifications of existing vegetation, land or water, and wildlife habitat shall be allowed only in conjunction with a permitted development activity. The boundaries of proposed Reserves and Protected Areas are shown on Map #26.

f) Marine Resource Districts (MD). Marine Resource Districts are areas of near-shore waters, estuaries, and adjacent lands that have special significance because of their productivity, nursery function, or are otherwise important because they are the habitat for marine species of special biological or economic significance.

4.3 Definition of Terms Used in Section 3.0 and 4.0

4.3.1 "**Attached residential uses**" means the use of common walls between or connecting dwelling units.

4.3.2 **"Cluster housing"** means assembling several detached dwelling units in close proximity to each other in a unified development plan on a single site, thereby preserving the density permitted in the particular LDI District and creating larger open spaces. The units may be connected by landscaping, walls or other unifying architectural elements.

4.3.3 **"Commercial retail"** means businesses established for retail sales of finished goods and products, including but not limited to food sales, restaurants and related goods, and services including fuel and automobile services.

4.3.4 **"Commercial wholesale"** means limited warehousing and distribution businesses established to serve the supply needs of the retail, hotel and tourist market. Light manufacturing may be permitted by the **Council.**

4.3.5 **"Wildlands"** means a portion of the landscape that is left undeveloped and set aside as wildlife habitat, and which remains a vestige of the previous unaltered landscape, where human interface is kept to a minimum.

4.3.6 **"Density"** means the count of residential dwelling units permitted on the land and is always in terms of dwelling units per hectare (DU/ha). For purposes of the **Management Plan** the land measure should include drive and road right-of-ways, automobile parking and service areas, building areas, open space and recreational areas internal to the site.

4.3.7 **"Detached residential uses"** means traditional single family dwelling units built as separate structures.

4.3.8 **"Floor area ratio"** means the ratio of the total floor area of all buildings' floors to the total area of the site or parcel **FAR (floor area ratio = floor area /site area)**. The same unit of area must be used, e.g., square meters.

4.3.9 **"Height of building"** or **"building height"** means the height measured from the mean grade between highest and lowest grade at the base of the building to the uppermost point of the roof or parapet wall. Excluded from the height shall be elevator rooms, solar collectors or other untenable roof structures.

4.3.10 **"Hotel"** means any building or group of buildings the business of which is letting rooms or suites to guests for short or long stays, and the related facilities to provide complete guest services.

4.3.11 **"Lot coverage"** means the area of land occupied by the building.

4.3.12 **"Multi-family"** means any building or group of buildings containing two or more residential dwelling units, including kitchen facilities, that is not a townhouse or cluster housing development.

4.3.13 "**Professional and personal services**" means the practice of law, medicine, pharmacy, architecture, engineering and other professional practices, and the provision of services such as barbering, cobbling, laundering and dry cleaning and other services to individuals.

4.3.14 "**Tourist facility**" means commercial retail and services such as, but not limited to, boat, automobile, diving gear rental and guide services, all of which are related to sales and services provided for tourists.

4.3.15 "**Townhouse residential**" means individual dwelling units, built with common walls separating units in a row, or similar connecting configuration.

4.3.16 "**Corridor**", or "**wildlife corridor**" is a strip of unaltered land that connects larger areas of wildlife habitat, the purpose of which is to allow the movement of wildlife from one area to another with minimum amount of disturbance or impediment to wildlife activity.

4.3.17 "**Wetlands**" are areas that are inundated by surface water with a frequency sufficient to support, and under normal circumstances do or would support, a prevalence of vegetative or aquatic life that require saturated or seasonally saturated soil conditions for growth and reproduction.

5.0 Nayarit Coastal Zone Management Plan Maps

The maps in this volume are an integral part of the **Management Plan** and the **Handbook** and shall be considered as complementary provisions, including map notes and descriptive material. Boundaries shown on the maps shall be considered to be generalized, since the scale is a limiting factor. Any specific interpretations will be resolved by the **Council** or the Minister.

5.1 List of Maps

MAP 1 Land Cover
MAP 2 Slope
MAP 3 Geology/Soils
MAP 4 Cultural Features
MAP 5 Slope Constraints
MAP 6 Agricultural Constraints
MAP 7 Wetland Constraints
MAP 8 Slope Opportunities
MAP 9 Vegetation Opportunities

MAP 10 Geology/Soils Opportunities

MAPS 11-17 Overall Development Constraints (Regions 1-7)

MAP 18 Overall Development Potential

MAPS 19-25 Overall Development Potential (Regions 1-7)

MAP 26 Proposed Reserves and Protected Areas

In addition to the planning maps listed above, the **Council** shall develop, as needed, the following maps, based on site-specific analysis:

1) Conservation Districts Map
2) Scenic Vista Districts Map
3) Reserves and Protected Areas Map
4) Natural Hazards Map
5) Recreation Area Map
6) Public Facilities Map
7) Marine Resource Districts Map

6.0 Procedural Requirements

6.1 Adoption

The **Management Plan** is hereby recommended for adoption by the **Council** pursuant to the provisions of the National Development Plan 1989-1994, and the **General Law of Ecological Balance and Environmental Protection**, particularly section 6.3.1 Ecological Ordinance and 6.3.2 Natural Resources from the **NDP 89-94**, and chapter IV and sections I and II from chapter V of the first title, and the only chapter from the fifth title of the **GLEBEP.**

The **Council** shall submit the **Management Plan** to the Minister in accordance with the provisions of the **GLEBEP**, and with the approval of the Minister, the **Council** shall regulate developmental activity in the Nayarit Coastal Zone. During the evaluation and review process and with the approval by the Minister, the **Council** may make the **Management Plan** available for public inspection and may receive written comments or recommendations.

6.2 Amendments

6.2.1 The **Management Plan** may be amended by the **Council** based on applications by a citizen or upon an action by the Minister or other appropriate government official or upon an action by the **Council**. The **Council** shall not act upon applications for amendment more frequently than annually, except in the event of an emergency that may affect the safety, health and welfare of the citizens of Nayarit and Mexico.

6.2.2 Any amendment application, or action, shall be supported by an application for **Management Plan** amendment showing specifically the nature of the request, the specific proposed amendment to the **Management Plan** and a written report setting out the reasons and justifications for the proposed amendment. The **Council** shall accept, modify, or reject the amendment in a timely fashion. The **Council** shall provide written findings and conclusions in support of its action. Any amendments to the **Management Plan** shall be subject to the adoption process as provided above.

6.2.3 Any amendments that are adopted in the **Management Plan** shall be reviewed for necessary changes in the **Handbook**, and the **Council** shall take appropriate steps to restore consistency between the provisions of the **Management Plan** and the **Handbook**.

6.3 Annual Review

An annual review of the **Management Plan** shall be prepared by the **Council** at the end of each calendar year. The review shall be written in a report to the Minister and shall contain an evaluation of the development of the **NCZ**, the effectiveness of the provisions in the **Management Plan**, changes in the **Management Plan**, changes in the **Handbook** made during the review period and practical experience with the enforcement of the regulations.

PART 3: HANDBOOK OF DEVELOPMENT GUIDELINES AND CONSIDERATIONS FOR THE NAYARIT COASTAL ZONE

1.0 INTRODUCTION

1.1 Purpose

The Handbook of Development Guidelines and Considerations for the Nayarit Coastal Zone **(Handbook)** contains the Nayarit Coastal Zone (NCZ) development policies and regulations. These policies and regulations are complementary to the goals and objectives of the Nayarit Coastal Zone Management Plan **(Management Plan)** and have been established to guide the development of the NCZ natural resources, to protect important amenities for enjoyment by local residents and tourists, and to permit development in a safe, economical, organized, and environmentally sound manner.

1.2 Relationship Between the Management Plan and the Handbook

These policies have been established to achieve the types of desired development patterns outlined in the **Management Plan**. It is the **Management Plan** that establishes the overall land management goals and objectives and the **Handbook** that provides specific policies and regulations to be followed to achieve the goals and objectives. Together, these documents should result in siting, design, and construction practices that are in harmony with both human and natural environmental needs, resulting in successful development. The maps in the **Management Plan** section are part of this **Handbook**.

1.3 Legal Authority

1.3.1. The Nayarit Coastal Zone Environmental Protection Council **(Council)** will be a government authority created under the National Development Plan Policies. Its main objective will be to provide for the rational development, conservation and management of the NCZ.

1.3.2. With the concurrence of the Minister of **SEDESOL-COPLADES**, the provisions of this **Handbook** are binding on all parties engaged in building, developing or otherwise altering the physical and biological attributes of the NCZ, unless and until overruled by higher authority or modified by the **Council** with regard to a specific request for variance, in accordance with provisions stipulated in Section 3.4.

1.4 Related Laws

1.4.1 Related acts include the Mexican Constitution (MC); General Law for Ecological Balance and Environmental Protection (GLEBEP); General Law for Human Settlements (GLHS); Housing Federal Law (HFL); Fisheries Federal Law (FFL); Waters Federal Law (WFL); Federal Tourism Law (FTL); Federal Forestry and Game Law (FFGL); Mining Law (ML); Roads Law (RL); Agrarian Reform Law (ARL); General Law for Health (GLH); and National Development Plan 89-94 (NDP).

1.4.2 Land developers are advised that these National Laws may have procedures and requirements that supersede the **Handbook** and the **Management Plan**.

1.5 Adoption

The **Handbook** should be adopted by the **Council** in accordance with the **NDP** and the **GLEBEP**. This will require the **Council** to review and advise the Minister of **SEDESOL-COPLADES** on all matters having to do with development within the **NCZ**, and specifically with regard to land-use management regulations, environmental protection, and land-use guidelines in accord with **NDP**, **GLEBEP** and related Laws.

1.6 Amendments

There shall be a regularly scheduled review and evaluations by the **Council** of the development guidelines, with the objective of continually updating the guidelines to keep pace with new situations as they arise and to incorporate any changes the **Council** may recommend to the **Management Plan**. In the event that such situations arise within a proposed development which is not fully dealt with in the guidelines, the **Council** reserves the right to present recommendations to deal with these situations. These recommendations will be binding.

1.7 Severalty

If for any lawful reason regarding conflict with National Law or adjudication any section or subsection is found to be in violation of such National Law or court order, it shall not affect the remainder of the provisions of the **Handbook**.

1.8 Policies of the Handbook

The policies of the **Handbook** are drawn from the goals and objectives of the **Management Plan**, and are considered minimum policies to forward the intent of **Management Plan**.

1.8.1 Create and Preserve a Quality Environment

1.8.1.1 Preserve the outstanding natural features and environmental attributes of the NCZ and the uniqueness of its physical setting in the Pacific Coastline of Mexico, making the area a showpiece of innovative development in the Mexican Republic.

1.8.1.2 Protect the fragility of the natural environment of the NCZ and its-near shore waters because of topographic features, microclimate considerations, and edaphic features.

1.8.1.3 Enable Nayarit to create a Mexican example of quality development, through the actions of a Government committed to exercising firm controls over development to ensure sustainable long-term benefits.

1.8.2 Promote Economic Growth

1.8.2.1 Develop the NCZ to create significantly higher levels of job and income generation for Nayarit, and improve stability of income and employment opportunity.

1.8.2.2 Develop the NCZ to create positive secondary impacts on the entire Nayarit economy.

1.8.2.3 Develop opportunities for training in order to upgrade labor force skills in the construction, services, and management sectors of the Nayarit economy.

1.8.3 Sustain Long-Term Development for the Future of Nayarit

1.8.3.1 Strike a balance between economic growth and environmental protection by following a disciplined and even-handed approach to the development of the NCZ.

1.8.3.2 Make development decisions, taking a long-view, incorporating a nation-building perspective that recognizes the NCZ as an irreplaceable natural asset which, if carefully managed, will accrue to the peoples of Nayarit and Mexico for generations to come.

1.8.4 Balance Public and Private Interests

1.8.4.1 The NCZ should be regarded as a public trust. Even though the land is privately owned, its commercial value is solely the result of Government investments and bilateral international assistance intended to benefit the Nation as a whole. Regulation is needed to protect the public interest. The guidelines incorporated in the **Handbook** are not intended to create a bureaucratic maze which discourages development. Its procedures stress the importance of even-handedness; of requiring high quality design and infrastructure from all developers; and of requiring the participation of qualified and objective professionals in reviewing development plans before they are presented to the **Council**.

1.8.4.2 Explore opportunities for innovation and creative design. The best developers will insist on--not resist--high standards in order to protect their own investments.

1.8.5 Protect Environmental Values

1.8.5.1 Removal of vegetation and trees within the **NCZ** shall be discouraged to prevent erosion and protect scarce vegetation resources, except as needed for permitted development activities.

1.8.5.2 Significant archaeological sites shall be identified and protected from destruction, or their destruction shall be mitigated by data recovery by a qualified archaeologist.

1.8.5.3 Habitats of endangered plants and animals shall be protected from encroachment by development.

1.8.5.4 Development occurring along the edges of Conservation, Recreation, Scenic Vista, and Reserves and Protected Areas shall be designed to protect and minimize the impact of development on the adjacent district.

1.8.5.5 The significance of topography, vegetation, soils, and wildlife resources for a particular site will be determined during the development review process, through an application for development approval submitted by the applicant for the development.

1.8.5.6 The spread of wildfires shall be discouraged by the effective incorporation of fire breaks in the design of roadways and other development. Vegetation shall be maintained to mitigate the potential of wildfire in areas where fire hazard is significant.

1.9 <u>Overlay Districts</u>

1.9.1 The **Council** shall establish two types of Overlay Districts as circumstances and development of the **NCZ** proceed: (1) Natural Resource Protection Districts, and (2) Public Facilities Districts. Overlay Districts provide additional information and a regulatory framework that is flexible and easily adaptable to the changing conditions of the **NCZ**.

1.9.2 **Natural Resource Protection Districts**

1.9.2.1 Areas that have natural limitations to development or sensitive environmental characteristics that deserve protection shall be developed only within the constraints of those natural limitations. Examples of these areas include mangroves, marshes, prime examples of tropical deciduous forest, wildlife resource areas, beaches and dunes, areas of significant scenic quality, and coral reefs. The following overlay districts (described in Sections 1.9.3 through 1.9.8) are created in the **Management Plan** to protect these resources:

a. Conservation District (**CD**);
b. Recreation District (**RD**);
c. Scenic Vista District (**SVD**);
d. Reserves and Protected Areas (**RPA**);
e. Natural Hazard District (**NHD**)
f. Marine Resource District (**MRD**)

1.9.3 **Conservation District (CD)**

1.9.3.1 Land is deemed to be a Conservation District if it possesses one or more of the following characteristics:

a. Vegetation: areas containing the following vegetation communities (see Part 1):
    1. mangroves
    2. mature tropical deciduous forests
    3. beach and dune vegetation
    4. halophytic vegetation
    5. palms
b. Soils: areas containing hydric soils (see Section 2.2.7)
c. Wild Animal Areas: areas of known significant use for breeding, nesting, or feeding by wild animals or birds

1.9.3.2 The following uses will be permitted in Conservation Districts:

a. Public and private recreation and open spaces uses that do not significantly alter natural vegetation and topography, except as otherwise provided for in Section 1.9.3.
b. Public and private wildlife preserves and refuge areas.

1.9.3.3 Developable land deemed to be a Conservation District within a proposed development or parcel of land shall be considered Land Development Intensity District I (see Section 5.2), even if not shown as such on the Overall Development Potential Map (Map 18). However, the protection of Conservation Districts shall be implemented through the transfer of density from the Conservation District to other portions of the parcel or development, or other contiguous property under the same ownership.

1.9.3.4 Where development is permitted, the following conservation policies shall apply:

a. All site alterations shall be confined to the area with the least environmental constraints;

b. Site alterations and/or coverage by access roads, foot or bridle paths, and minor structures shall be limited to 5% of the total area within the Conservation District;

c. Existing vegetation shall be incorporated within proposed developments to the greatest extent possible;

d. Storm water runoff from developed areas shall be detained and directed to prevent erosion.

1.9.3.5 The extraction of sand or rock for any purpose from a Conservation District shall be considered inconsistent with sound conservation practices and shall not be allowed.

1.9.4 Recreation Districts (RD)

1.9.4.1 Land is deemed to be a Recreation District if it possesses the following characteristics:

a. A measured portion of each beach (on a case-by-case basis) shall be allocated for recreational purposes which may conflict with sound conservation practices. The remaining portions of each beach shall be classified as a Conservation District and public access shall be prohibited;

b. Other areas as designated by the Council.

1.9.4.2 The following uses may be permitted within Recreation Districts:

Public and private recreational uses that significantly alter natural vegetation and topography such as: golf courses, tennis courts, ball playing fields, and intense use public beaches.

1.9.4.3 Where development is permitted, the following environmental policies shall apply:

a. All site alterations shall be confined to areas with the least environmental constraints;

b. Existing native vegetation shall be incorporated within proposed developments to the greatest extent possible; and

c. Stormwater runoff shall be directed so as to insure that erosion or sedimentation of nearby or downstream areas does not occur.

1.9.4.4 The development of private lands for public recreational purposes shall be encouraged.

1.9.5 Scenic Vista District (SVD)

1.9.5.1 The following areas and land features shall be considered visual amenities of special importance, and shall not be developed except as the **Council** may approve:

a. Bluffs;
b. Cliff faces;
c. Sea cliffs;
d. Ridge tops; and
e. Hill tops.

1.9.5.2 The scenic and visual qualities of coastal areas and identified hill sides, cliffs and bluffs shall be protected as a resource of public importance. Permitted development shall be sited and designed to protect views, to be visually compatible with the character of surrounding areas, and shall not obstruct or otherwise interfere with views of designated Scenic Vista Districts.

1.9.5.3 There shall be no development of the top 100 meters of all hills and ridges within Scenic Vista Districts, unless specifically approved by the **Council**.

1.9.6 Reserves and Protected Areas (RPA)

1.9.6.1 Lands designated as Reserves and Protected Areas are important environmental resources.

1.9.6.2 The construction of arterial roads and public facilities that cross Reserves and Protected Areas shall be discouraged to the maximum extent possible.

1.9.6.3 The removal of vegetation, cutting of trees, land clearing, or burning of vegetation shall be discouraged to the maximum extent possible, and shall be allowed only in conjunction with a permitted development activity.

1.9.7 Natural Hazards Districts (NHD)

1.9.7.1 Land is deemed to be a Natural Hazard District if it possesses one or more of the following characteristics:

a. Topography: slopes greater than 16° or 30%, and alluvial lands downslope of unstable guts;
b. Sea cliffs;
c. Storm-surge prone areas;
d. Flood-prone areas.

1.9.7.2 Development inconsistent with prudent construction standards relative to slope, topography, coastal flooding, and erosion shall be prohibited within Hazard Districts.

1.9.8 Marine Resource Districts (MRD)

1.9.8.1 Marine resources shall be maintained, enhanced, and, where feasible, restored. Special protection shall be given to areas and species of special biological or economic significance. Uses of the marine environment shall be carried out in a manner that will sustain the biological productivity of coastal waters, and that will maintain healthy populations of all species of marine organisms adequate for long-term commercial, recreational, scientific, and educational purposes.

1.9.8.2 The biological productivity and quality of the marine environment shall be maintained through, among other means, minimizing adverse effects of wastewater discharges, encouraging wastewater reclamation, controlling sedimentation from runoff, preventing substantial interference with surface water flows, maintaining natural vegetation buffer areas that protect riparian habitats, and minimizing alteration of near shore beaches, rocky shores and other habitats.

1.9.8.3 The diking, filling, or dredging of open coastal waters, wetlands, estuaries, and salt ponds shall be permitted in accordance with other applicable provisions, where there is no feasible, less environmentally-damaging alternative, and where feasible mitigation measures have been provided to minimize adverse environmental effects. These activities shall be limited to the following:

a. The construction of new marine-related facilities, designed and constructed in accordance with both the **Management Plan** and the **Handbook**, as approved by the **Council**.
b. Maintaining existing, or restoring previously dredged depths in existing navigational channels, turning basins, vessel berthing and mooring areas, and boat launching ramps.
c. In open coastal waters, the placement of structural pilings for public recreational piers.

d. Incidental public service purposes, including but not limited to, burying cables and pipes, inspection and maintenance of piers, and placement of navigational pilings or buoys.

1.9.8.4 Dredging and spoil disposal shall be planned and carried out to avoid significant disruption to marine and wildlife habitats and water circulation.

1.9.9 Public Facilities District (PFD)

1.9.9.1 Preceding development within the **NCZ**, the **Council** shall establish Public Facilities Districts where allowable intensities of development dictate that education, public health, and centralized water, sewage, waste collection and waste disposal facilities are necessary.

1.9.9.2 The following utility districts shall be created as part of Public Facilities Districts, where necessary:

a) Sewer Districts
b) Solid Waste Districts
c) Potable Water Districts

1.9.9.3 The **Council** shall provide specific sites for police services, health facilities, libraries, schools, solid waste management facilities, and sewage treatment facilities

1.9.9.4 The **Council** shall develop formulas for calculating monetary contributions by developers for the construction, operation and maintenance of public facilities, in proportion to the proposed use of the facilities, and in proportion to the population growth in the community induced by the development.

2.0 DEFINITIONS

2.1 Reference to the Nayarit Coastal Zone Management Plan

All of the definitions found in sub-sections 3.2 and 3.3 of the **Management Plan** are made a part of the **Handbook**, and are binding as if they were incorporated herein.

2.2 Handbook Definitions

2.2.1 "Applicant" means a property owner, or a representative authorized by the owner to speak or act on the owner's behalf.

2.2.2 "Application for Development Approval" means a written request for approval of a proposed use and development plan and for issuance of a development order.

2.2.3 "Application for Site Development Approval" means a written request for approval of a proposed development on a specific site and for a site development permit.

2.2.4 "Building Area" means an area within and bounded by the building lines (footprint) established by required yards and setbacks.

2.2.5 "Developer" is any land owner, agent for a land owner, person, or business entity, who proposes or causes any development to occur in the NCZ.

2.2.6 "Dwelling unit" means one accommodation of one or more rooms arranged in a single structure, housing a family or closely related persons, with provisions for preparing food, sleeping, and other life necessities.

2.2.7 "Hydric Soils" means soils that are saturated more than two months of the year in seven out of 10 years, and are generally found within and adjacent to water bodies and wetlands.

2.2.8 "Impact Area" means the spatial area surrounding a proposed development site that will be affected by development.

2.2.9 "Parcel" means a particularly surveyed land area under a single ownership.

2.2.10 "Parking space" means a portion of the vehicle accommodation area specifically and permanently set aside for the parking of one (1) vehicle.

2.2.11 "Setback" means the minimum horizontal distance between the street, rear or side line and the front, rear or side lines of the building, including steps, terraces, or any projection thereof. When two (2) or more lots under one (1) ownership are used, the exterior property lines so grouped shall be used in determining setbacks.

2.2.12 "Sewer System" means any plant, system, facility or property used or useful or having the present capacity for future use in connection with the collection, treatment, purification or disposal of sewage and sewage effluent and residue from more than one dwelling or from any commercial or industrial establishment; and without limiting the generality of the foregoing definition, embraces treatment plants, pumping stations, intercepting sewers, pressure lines, mains, laterals and all necessary appurtenances and equipment; and shall include all property, rights, easements and franchises relating to any such system and deemed necessary or convenient for the operation thereof.

2.2.13 "Signs" means any device, placard, or billboard used for advertising sales or services at point of sale. No other signs will be approved except road and public notices.

2.2.14 "Site" means a specific surveyed building or development parcel of land.

2.2.15 "Transfer of Density" means that allowable land development densities in Land Development Intensity Districts (see Section 5.2) may be transferred within the same parcel if an Overlay District is more restrictive to development.

2.3 Rules of Interpretation

2.3.1 General. All provisions, terms, phrases and expression contained in these regulations shall be liberally construed in order that the true intent and meaning of the **Council** may be fully carried out. Terms used in these regulations, unless otherwise specifically provided, shall have the meanings prescribed by the laws and regulations found in **GLEBEP** and other related laws for Mexico and Nayarit, as well as those in the regulations of **SEDESOL-COPLADES**.

2.3.2 Computation of time. The time within which an act is to be done shall be computed by excluding the first and including the last day; if the last day is a Saturday, Sunday or legal holiday, that day shall be excluded.

2.3.3 In Writing. The term "in writing" shall be construed to include any representation of words, letters or figures, whether by printing or otherwise.

2.3.4 Boundaries. Interpretation regarding boundaries of land-use districts shall be made in accordance with the following:

a. Boundaries shown as following or approximately following any street shall be construed as following the centerline of the street.

b. Boundaries shown as following or approximately following any platted lot line or other property line shall be construed as following such line.

3.0 PROCEDURAL REQUIREMENTS FOR DEVELOPERS

3.1 General Procedures and Requirements

The procedural requirements for the orderly development of the **NCZ** that will insure the timely and thorough review of development proposals involve a two step process. All development projects involving land parcels greater than 5 hectares, involving the subdivision of a parcel into more than 2 parcels, or the construction of 2 or more dwelling units on a single parcel are subject to the procedures as set forth in Section 3.2 of the **Handbook**. All development projects of a single land parcel or unity of parcels combined for purposes of development are subject to the Site Development Permit procedures as set forth in Section 3.3 of the **Handbook**. No Site Development Permit shall be reviewed or considered unless an approved Development Approval Permit is in order. The Site Development Permit Application may be considered simultaneously with the Development Approval Permit Application, if the **Council** approves of the simultaneous review, as provided in sub-section 3.1.3. of the **Handbook**.

3.1.1 Application for Development Approval. The Application for Development Approval (ADA) process consists of three steps. The first step is submission of a written Notice of Intent submitted to the **Council**. The second step is a meeting between the applicant and the **Council** to provide the applicant with the necessary information that must be submitted for development approval. The third step in the development approval is the submission of an ADA. The application shall contain pertinent information on the size and scope of the development and its environmental and social/cultural impacts, as well as any other information enabling the **Council** to evaluate the proposed development and insure that the development project is in keeping with the goals and objectives of the **Management Plan**, and the policies and regulations of the **Handbook**.

3.1.2 Application for Site Development Permit. The second permit required is the Site Development Permit. Once a Development Approval Permit is issued, the developer may submit an Application for Site Development Permit. The application shall contain more detailed information on land use, landscaping, roads and parking, public facilities, building uses, and construction techniques and engineering, among other things. The review process for a Site Development Permit insures that the development project is in keeping with the Development Approval Permit, and the regulations for subdivision of lands and the regulations for site development of the **Handbook**.

3.1.3 Combined Applications for Development Approval and Site Development Permit. Under some circumstances it may be advantageous to submit Applications for Development Approval and Site Development Permit simultaneously. Where the development project is small in scale it may be appropriate to combine the applications. The **Council** may review both applications simultaneously. However, the developer should be forewarned that combined applications require significant expenditures of time and money on detailed development design and engineering that may be rejected, or endorsed with conditions. The two step process is designed to facilitate review and approval of development schemes to insure that the development project adheres to the goals, objectives, policies and regulations of the **Management Plan**, the **Handbook**, and the **Council**, prior to undertaking detailed site design and engineering.

3.1.4 Each application received will be considered in relation to the **Management Plan** for the development of the **NCZ**.

3.1.5 All plans and descriptive development notes may be viewed by interested parties at the office of the **Council.**

3.2 Application for Development Approval

3.2.1 Procedure for Development Approval

3.2.1.1 All developers shall apply to the **Council** for development approval. The **Council** shall receive a "notice of intent" in writing from the applicant for a proposed project.

3.2.1.2 Within 14 days of submittal of the "notice of intent", the **Council** shall determine: (1) whether all provisions and submittals required in the **Handbook** are necessary, and (2) the impact area of the proposed development. The determinations shall be based on the size and location of the proposed development, and shall be made in writing to the developer.

3.2.1.3 A formal development application, based on the **Handbook**, including an Environmental Impact Assessment (EIA) and a Social/Cultural Impact Assessment (S/CIA), shall be submitted to the **Council** by the developer.

3.2.1.4 Within ten (10) working days after an Application for Development Approval has been received, the **Council** shall determine whether the application contains all required information.

a. If the **Council** determines that the application is not complete, a written notice shall be served on the applicant specifying the applications deficiencies. The **Council** shall take no further action on the application unless the deficiencies are remedied.

b. If the application is determined to be complete, the **Council** shall notify the applicant and review the project application. The evaluation focuses on the projected economic, social and environmental impacts of the proposed project; meetings might be held between **Council** members or advisory personnel and the developer to secure additional information or to explore alternative development options.

c. When deemed necessary and appropriate by the **Council**, the **Council** shall appoint a **Community Participation Committee (CPC)** from local citizens of the area of the proposed development. The responsibilities of the **CPC** are to review the social/cultural impacts of a proposed development, and to insure that local social concerns and issues are adequately and appropriately addressed in the design and implementation of all development projects. The **CPC** shall provide for local community participation, by organizing public meetings designed expressly for local input. Once all relevant community input has been obtained, it should be passed on to the **Council** with the **CPC**'s recommendations for final review.

3.2.1.5 Within 60 days, the **Council** shall forward its rejection, endorsement, or endorsement with conditions, of the proposal to the Minister, along with the recommendations of any advisory personnel or agency.

3.2.1.6 The Minister may issue a Development Approval Permit based upon the **Council** recommendations, or make a decision that is deemed lawfully appropriate.

3.2.2 Required Submissions for Application for Development Approval

3.2.2.1 Each application shall have seven (7) sets of plans, drawings, and reports accompanied by development and descriptive notes. These shall be deemed the Application.

3.2.2.2 All maps or site plans submitted to the **Council** must include a north arrow and scale bar, legend showing all symbols, name of designer, project name, and owner's or developer's name. The following maps shall be required:

a. <u>Location Map</u>

Survey scale not less than 1:1000, showing position of the parcel or parcels in relation to the surrounding area and adjacent land within 300 meters, showing the names of adjacent property owners and property boundaries.

b. <u>Topographical Map</u>

Scale not less than 1:1000, preferably at the same scale as the location map, showing at a minimum 1.5-meter contour intervals for the land and surrounding area and adjacent land within 30 meters. The topographic map shall indicate all hazard areas including but not limited to, flood zones, guts, cliffs, bluffs, and beaches. It shall also show any significant environmental features, such as hydric soils, sandy soils, trees and forest areas, and infrastructure such as roads, tracks and utilities.

c. Land Use Districts Map

Scale not less than 1:1000, preferably at the same scale as the previous maps, showing Land Development Intensity Districts and all Overlay Districts from the **Management Plan** Maps.

d. Development Plan

Scale not less than 1:1000, preferably at the same scale as the previous maps, showing:

(1) Property boundary and ownership lines.

(2) General areas to be developed and affected on earth movement.

(3) Areas that are not to be developed.

(4) Site ingress and egress.

(5) Locations of major infrastructure facilities such as access roads, internal roads, storm water system, sewage system, and other facilities including recreation areas.

3.2.2.3 Development or descriptive notes and reports shall include the following information:

a. Name of development.

b. Name, address and telephone number(s) of owner(s) and/or developer(s) or local agent.

c. Date of application.

d. Description of the development, to include:

(1) total land area;

(2) total existing and proposed development area;

(3) total proposed undeveloped area;

(4) total areas of various **Management Plan** designated land uses and proposed land uses;

(5) total number of proposed dwelling units and other buildings by type, use, and approximate floor area;

(6) calculation of floor area ratios;

(7) approximate cost of development;

(8) expected commencement date and completion date;

(9) project phasing and financial plan;

(10) other relevant information.

e. A completed Environmental Impact Assessment (EIA), which specifically addresses the following issues:

(1) Flooding and drainage.

* Have watersheds been delineated and drainageways been located?

* Has the peak 50-year runoff flow been computed for each drainageway assuming that the upstream tributary area is fully developed?

* Has the peak runoff been routed through the existing and proposed guts to determine the depth of flooding?

* Will any of the proposed structures be affected by this flooding?

* Will there be a significant potential for loss of life in the event of flash flooding?

* What assumption has been used for the water level at the point of discharge for computation of flood flows? (The water level in the receiving body should be assumed to be higher than normal, as is likely to be the case during a severe flood)

* Is the floor elevation of all living structures high enough to provide protection from flooding due to rainfall runoff or hurricane storm surge?

(2) Conformance with the Nayarit Coastal Zone Management Plan.

* Are the proposed use and density compatible with the land use intensities?

* Is the required public access to the beach provided?

* Do structures comply with the minimum setback requirements?

* Does the planned development confirm with the requirements of overlay districts?

(3) Environmental Protection: Wildlife

* Have adequate measures been taken to preserve wildlife? For instance, what shields and other lighting restrictions will apply on those beaches important for turtle nesting?

* Who will be responsible for compliance, and what monitoring procedures will be used to insure that the proposed environmental controls are complied with?

(4) Environmental Protection: Sediment Control.

Submit a plan for sediment control, outlining the procedures to be used to minimize erosion and sedimentation during the construction and operational phases of the project. All areas affected by earth movement must receive permanent erosion protection. Areas not covered by concrete or asphalt must be revegetated. In the portion of the EIA addressing the sediment control plan, identify the plant species to be planted and whose responsibility it will be to undertake site re-vegetation.

* Will stormwater discharges have any foreseeable adverse impact, such as sediment discharge to the reefs?

* Is runoff from parking areas handled so that the potential for erosion will be minimized?

* Does the grading plan minimize destruction in vegetation and changes in topography?

* Does it preserve sand dunes and the vegetation that protects the dunes?

* Is the design of roadways and gut crossings satisfactory in terms of drainage and erosion control?

(5) Traffic

* Has adequate parking area been provided for the projected number of guests, employees and visitors?

* Is there a parking area available for public beach areas?

* Is the design of roadways satisfactory in terms of safe and convenient transit?

(6) Solid Wastes

* Where will construction wastes be disposed of and who will be responsible for haulage to the disposal site?

* What will be the solid waste volume generated during project operations?

* Will waste containers be placed at convenient places on the beach and other public areas?

* How frequently will wastes be collected, who will collect and haul the wastes, and where will they be disposed?

A solid waste management plan, which includes plans for the recycle of organic wastes on-site and minimization of residential, commercial, and/or industrial waste, must be prepared by all developers.

(7) Water and Sewer

Compute daily water use and indicate the reserve cistern capacity that is to be provided on-site.

* Will pressure from the main water line be adequate, or will pumping and a storage tank be required to service high elevations?

* If a pump station and tank are provided, does the tank provide a two-day reserve?

* How will liquid wastes be disposed of?

If an on-site waste treatment plant is to be constructed, the financial, engineering, construction, and operational and development plans shall be submitted to the **Council**.

* Is the proposed system of adequate size?

For septic tank systems, present the results of percolation test and sizing computations.

* What will be the sanitary and environmental consequences if the system does not operate as efficiently as designed?

The treated effluent should be discharged via land application (golf courses, appropriate agriculture, or wetlands [either constructed or natural]), and not to surface water bodies or near-shore waters.

(8) Construction Material

* How much sand will be required for concrete and where will it come from?

* What other building materials (wood, palm, stone, etc.) will be obtained from local forests, quarries, etc., and from where will they be obtained?

f. A completed Social/Cultural Impact Assessment (S/CIA), which specifically addresses the following issues:

(1) Community Health

* What are the current health needs of the local population and what changes can be expected as a result of the development?

* How will the development affect existing endemic diseases, especially the communicable, host-parasitic, water and vector-borne diseases, and what will be done to combat and prevent the further spread of these diseases?

* What plans are being made to provide physical examinations and bi-monthly health education and disease prevention seminars for all employees?

Compute (using the formulas provided by the **Council**), monetary contributions for the construction, equipping, staffing, and operation and maintenance of a hospital capable of providing all the major preventive and primary medical care services for employees, their families, and the local community.

(2) Community Education

* What are the current educational needs of the local population and what are the future needs created from the changes imposed by the development?

Compute (using the formulas provided by the **Council**), monetary contributions for the construction, equipping, staffing, and operation and maintenance of education facilities capable of providing the necessary educational needs for employees, their families, and the local community.

(3) Housing Standards

* What are the current housing needs of the local population and what are the future needs created from the changes imposed by the development? Compute (using the formulas provided by the **Council**), monetary contributions for the construction of housing for employees and their families, and contributions toward improved housing within the local community. If the developer is providing housing for employees and their families, then compute (using the formulas provided by the **Council**), monetary contributions toward improved housing within the local community.

(4) Community and Cultural Organization

* What are the total labor force requirements, current labor pool, and the present and future impact of the development on supply and demand of labor?

* What are the projected demographic changes in the local population that will result from the development, relative to: numbers, age, sex, and social, economic, labor, and educational status?

* What problems arising from the social, economic, and cultural differences between the local residents, immigrants, and visitors will result from the development?

(5) Recreation and Parks

* What are the current park and recreational needs of the local population, and what are the future needs created from the changes imposed by the development?

Compute (using formulas prescribed by the **Council**), monetary contributions for the construction, equipping, staffing and for operation and maintenance of local parks and recreational activities capable of meeting the needs of employees, their families, and the local community.

(6) Public Services

*What are the current public service needs (water supply, sewage, solid waste disposal, communication, and transportation) of the local population, and what are the future needs created from the changes imposed by the development?

Compute (using formulas prescribed by the **Council**), monetary contributions for the construction, equipping, staffing, and for the operation and maintenance of necessary public services capable of meeting the needs of all employees, their families, and the local community.

(7) Cultural Sites, Traditions, and Activities

* Are there any past or presently used archeological sites and ruins on the development site?

* If so, what is being done to protect them or mitigate for unavoidable disturbance?

(8) Local Economy

* How will the development affect access to and prices of local commodities?

* How will the development affect the availability of imported goods and services?

* What will be the impact of temporary and permanent employment and wages?

(9) State and National Economy

* How much government revenue, by source, will be generated by the development each year?

* What will be the government costs incurred per year of development?

(10) Working Conditions and Standards

* Are there any special training programs required for temporary or permanent employees?

* What are the intended standards for working conditions and safety?

* What are the intended benefits for temporary and permanent employees?

* What is the wage scale for all temporary and permanent employees?

* What are the work schedules for all temporary and permanent employees?

3.3 Application for Site Development Permit

3.3.1 Procedure for Site Development Approval

All developers shall apply to the **Council** for site development approval.

3.3.1.1 Within 14 days a representative of the **Council**, at the option of the applicant, shall meet with the applicant to review the proposed project.

3.3.1.2 A formal site application, based on the **Handbook**, shall be submitted to the **Council** by the applicant.

3.3.1.3 The site development application shall be referred to the **Council** for study, evaluation and recommendations within 30 days according to procedural guidelines established by the **Council**.

3.3.1.4 The **Council** shall forward its endorsement, endorsement with conditions, or rejection for the site plan to the Minister, along with the recommendations of any advisory personnel or agency.

3.3.1.5 The Minister may issue a Site Development Approval Permit based upon the **Council** recommendations, or make a decision that is deemed lawfully appropriate.

3.3.2 Required Submissions for Site Development Approval

3.3.2.1 Seven (7) complete sets of drawings, or a number of sets as determined by the **Council**, and site specifications shall be submitted to the **Council** with descriptive development notes.

3.3.2.2 The applicant shall include evidence of the Development Approval Permit and all general and special conditions contained therein.

3.3.2.3 Drawings submitted to the **Council** must include a north arrow and scale bar, legend showing all symbols, name of designer, project name, and owner or developers name. The following maps shall be required:

a. Location Plan
Scale not less than 1:1000, showing position of the site or parcel in relation to the surrounding area and adjacent land within 150 meters. This plan shall include approved Land Development Intensity Districts, Overlay Districts and leasehold/ownership boundaries.

b. Stormwater Drainage Map
Scale not less than 1:1000, preferably at the same scale as site plan, showing natural drainageways, computed 50-year peak discharge, and the principal aspects of the storm drainage system.

c. Vegetation Map
Scale not less than 1:1000, preferably at the same scale as the site plan, showing major vegetation communities, including but not limited to: mangroves, deciduous

tropical forest, halophytic vegetation, Palm vegetation, sand dune vegetation, marshes and open water.

d. Site Plan

At a scale not less than 1:1000, show:

(1) Boundary lines and dimensions along with all pertinent data regarding the lot and legal description;

(2) Building(s) and other structure locations, required setbacks, clearing lines, floor elevations, general overall dimensions of building(s), floor areas and uses, any other important features, and in dotted lines the layout of any planned additions;

(3) All utility lines on the property and connections to street utilities for water, telephone service and electricity;

(4) All existing physical features whether to remain or to be removed;

(5) Fences, structural retaining walls, walkways and pools;

(6) Storm drainage on both paved and unpaved areas, water catchments and drains;

(7) Sewage disposal: location of proposed system;

(8) Existing and finished ground elevations;

(9) Access to building(s) from off-site roads or internal roads;

(10) Prevailing wind direction;

(11) Parking provisions;

(12) Legend showing all symbols and construction materials to be used on the site;

(13) Name of designer;

(14) North arrow and scale box;

(15) Proposed vegetation removals and landscaping plan;

(16) Topography; and

(17) All other relevant information.

3.3.2.4 Descriptive development notes shall include information on the following:

(1) Name of development;

(2) Name, address and telephone number(s) of owner(s) and/or developer(s) and/or local agent, and date;

(3) Total land area of the proposed development;

(4) Computation of the 50-year runoff on all drainageways that cross the developed areas of the site, and demonstration of how this volume of runoff will be retained and routed across areas to be developed;

(5) Breakdown of Land Development Intensity Districts and Overlay Districts, land area of the various districts uses, and leasehold/ownership map;

(6) Types and sizes of units and number of units including:

(a) floor area ratios

(b) number of stories (specifying height)

(c) density of dwelling units

(7) Approximate cost of building(s);

(8) Project phasing considerations;

(9) Expected commencement date;

(10) Statement of intended use of the site;

(11) Computation of water use and wastewater generation, including water use for irrigation of landscaping.

(12) Solid waste disposal plan;

(13) All other relevant information.

3.4 Appeals to Regulation

3.4.1 Variances based on legal hardship from these guidelines may be granted by the **Council** providing that the developer can satisfy the **Council**, based on an advisory opinion of its professional staff, that the purposes and intent of these guidelines can only be achieved by the use of measures, techniques or approaches that differ from those which are specified in the **Handbook** or the **Management Plan**, and that the application of these provisions is unique to the particular site and that the uniqueness is not self-imposed.

3.4.2 In cases where the **Council** does not approve of a developer's plan, the Minister may review the proposed project.

3.5 Enforcement

Any willful deviation from the policies and regulations in the **Handbook**, without the express permission of the Minister, will be considered a violation of the laws of Nayarit and Mexico, and will be subject to the administrative and/or judicial prosecution including, but not limited to, forfeiture of performance bonds or other such surety that may be required as a condition for proceeding with development. All developers applying for a Development Approval Permit or a Site Development Approval Permit shall be bound by all sections of the **Handbook**.

4.0 LAND DEVELOPMENT REGULATIONS

4.1 Land Subdivision

The subdivision of land into parcels shall be regulated in minimum sizes and dimensions of parcels as required in the detailed regulations for LDI Districts found in section 5.2 of the **Handbook**. For purposes of ownership and parcel identification, a parcel numbering system and subdivision identification system shall be approved by the **Council**. No subdivision of land into 2 or more parcels shall be permitted without conforming to all requirements of sections 4 and 5 of the **Handbook**, and without having an approved Development Permit.

4.2 Public Facilities Requirements

4.2.1 Access, Internal Development Roads, Foot Paths, and Bicycle Trails

4.2.1.1 Access, or curb cuts, to the main **NCZ** roads shall be no closer than 800 meters on one side and shall be located in such a manner as to be opposite any existing or proposed access point. If more access points are needed in a development, the developer shall be required to construct an internal development road.

4.2.1.2 All roads, except the already existent main roads of the **NCZ**, shall be considered internal development roads, whether major, minor, two lane, or one lane. The pattern of road layout shall provide for efficiency and safety, including access for emergency and service vehicles, and access to all private parcels of land. The pattern shall provide for cross-roads, where necessary, to be in alignment; no jogs are permitted. Cul-de-sacs are encouraged in residential LDI Districts.

4.2.1.3 Major internal development roads having two lanes shall have a road reserve of 10 meters, with a carriageway of 6 meters.

4.2.1.4 Minor internal development roads having two lanes shall have a road reserve of 8 meters, with a carriageway of 5 meters.

4.2.1.5 One lane internal development roads shall have a road reserve of 6 meters, with a carriageway of 3 meters.

4.2.1.6 Typical cross-sections shall be approved by the **Council**. Drawings shall be submitted for the different types of access roads showing relative elevations at centerline, edge of pavement or gutter line, top of curb or bottom of ditch, back of sidewalk or natural grade, as well as fallouts for surface course, base course, subsurfaces preparation or subgrade, curb and gutter and sidewalk material and thickness.

4.2.1.7 The **Council** may determine the points of access from the road to the development's lots. Buildings, fences, walls or hedges that are located close to or on road corners or road junctions must be aligned and constructed in a manner that would not restrict the view of vehicles on the roads, or emerging from the lots.

4.2.1.8 Access roads shall have trees planted in irregular groups, at least 10 trees per 30 meters on the high side, and groups of at least five trees in every low spot where water runs off. Trees on the high side should be ornamental or shade trees where practical, or cedar in dry or windy places. On the low side the trees should be cherry where grass is prevalent. Casuarina, Neem, flamboyant, cedar, leucaena, and other appropriate species may be used where grass is absent or controlled. Access roads should follow the natural contours of the site to avoid unnecessary cutting and filling.

4.2.1.9 Below the outfall of culverts and road dishes a pavement of rubble shall be laid or set so that a top rock overlaps and covers the inside half of the rock beneath. This rubble bed shall follow the diverted water course until it re-enters the old gut bed. If there is no old gut bed present, an apron or protective vegetation of grass and trees may be used to spread the water.

4.2.1.10 All road-fill slopes shall have appropriate grass planted with sprigs one foot apart in rows along the contour which are less than three feet apart.

4.2.1.11 The **Council** shall have road design and proposed subdivision layouts reviewed by a forester from **SARH**, a representative of **SEDESOL-COPLADES**, and an engineer selected by the **Council**.

4.2.1.12 Internal development roads shall be located so as to avoid cutting through areas of tropical deciduous forest where possible.

4.2.1.13 Roads shall be constructed to the widths shown in sub-sections 4.2.1.3 through 4.2.1.5 in the **Handbook**. Surface paving material shall be 5 cm thick asphaltic concrete, or 10 cm thick, reinforced Portland Cement concrete. Base shall be 20 cm loose to 15 cm rolled and compacted base material that is acceptable to the Minister. For the asphaltic concrete surface, a complete hot asphalt tack coat shall be used. Curbs, gutters and water control structures, where required to control stormwater, shall be made of reinforced Portland Cement concrete. The one lane access roads in residential districts are exempt from this paving provision if the **Council** is assured that excessive erosion will not result from the exemption. All roads shall have a minimum 1.2 meters-wide sidewalk. Where such extra width may cause additional damage to slopes or vegetation, the walk may be separated from the road paving and allowed to meander. All roads and sidewalks shall be lighted with acceptable standards, and signed and marked for safe vehicle and pedestrian movements. Lighting shall be modified or eliminated on beaches where sea turtles may nest.

4.2.1.14 Foot paths shall be constructed in a manner which avoids, or mitigates the effect of storm water runoff. Bicycle trails shall be constructed of materials which provide for the safe and efficient use of the vehicle.

4.2.2 Water and Sewer

4.2.2.1 Providing a water distribution system with connections to all lots shall be the responsibility of the developer. Pipe sizes and construction techniques shall conform to the specifications and requirements of **SOSP, CNA, SEDESOL-COPLADES, COEDUE**, and other related branches of the Nayarit Government.

4.2.2.2 Within Sewer Districts, and where an adequate sanitary sewer is reasonably accessible, each lot in a subdivided area shall be provided with a connection to the centralized system.

4.2.2.3 In all areas of the **NCZ**, the installation of low volume, water-conserving toilets shall be mandatory.

4.2.2.4 On shallow soils of sloping terrain, where septic tank systems are allowed, the following regulations shall apply:

(1) Septic tank systems shall consist of a two-chamber tank with appropriate drainfield, and sized using an average treatment capacity of 150 liters per day per person.

(2) Septic tanks shall not be constructed on slopes greater than 8° (15%).

(3) Hydraulic load shall not exceed 12 liters per day per linear meter of drain.

(4) Drainpipes shall be installed along hill contours, and shall be 10 cm (4") diameter PVC pipe with 1.27 cm (1/2") diameter holes on the bottom and sides at intervals of at least 10 cm (4"), or equivalent.

(5) A buffer zone of 90 meters of natural, undisturbed vegetation between the drainage field and adjacent downslope property shall be maintained.

4.2.2.5 In areas of deep, poorly-permeable soils where septic tanks are allowed, the following regulations shall apply:

(1) Drainfields shall be located in the highest percolation areas.

(2) Drainfield trenches shall be sized based on 150 liters of waste water per person per day, using the application rate from the table below:

Percolation Test Rate (min/inch)	Wastewater Application Rate (gpd/ft² trench)
<1	not suitable
1-5	1.5
6-15	1.0
16-30	0.75
31-60	0.55
60-120	0.33
>120	not suitable

(3) When both water conserving toilets (less than 9.5 liters per flush) and water conserving shower heads are installed, wastewater generation may be based on 95 liters per person per day.

4.2.3 Electric and Telephone Services

Wherever possible, electric and telephone distribution lines and cables shall be located underground.

4.2.4 Drainage

4.2.4.1 Rainfall on a developement site must be permitted to enter the natural drainage system as if the site were not developed. This water should not be led to the end of the site and discharged, on or in front of a site that is owned by another, excepting discharge to a natural drainageway.

4.2.4.2 Watershed boundaries for all drainageways that cross a development site shall be delineated, and peak 50-year runoff shall be calculated for each. The peak runoff calculations shall assume full development of all upslope portions of watersheds.

4.2.4.3 Detailed stormwater management plans shall be submitted by the project engineer certifying that the storm drainage system will adequately handle runoff entering the site from upslope, will dispose of runoff generated on-site, and will not cause damage to downstream areas due to excess water or erosion.

4.2.4.4 In coastal and marine areas, hydraulic calculation for drainageways affected by the level of the sea shall be made by assuming a sea level one (1) meter higher than its present normal level.

4.2.5 On-Site Solid Waste Storage

4.2.5.1 Provision shall be made for concealed-bin storage of adequate capacity in an appropriate area or areas, and for adequate access for removal.

4.2.5.2 The developer shall be responsible for providing garbage bins with suitable covers, which must be suitably protected against damage, spillage, and wildlife.

4.2.5.3 The developer shall make operational provisions for solid waste collection and disposal as approved by the **Council**.

4.2.6 Uniform Building Code

All construction of buildings shall conform to standards and methods adopted by the Uniform Building Code for the Coastal Zone, if one exists.

5.0 SITE DEVELOPEMENT REGULATIONS

5.1 General Regulations for Site Development

The following section gives site standards and development information concerning Land Development Intensity (LDI) District. LDI Districts are given on **Management Plan** Map 18--Overall Development Potential.

5.1.1 Buildings and Sites

5.1.1.1 Building Use. An application to the **Council** is necessary for changing the use of a building.

5.1.1.2 Setbacks. Dwelling houses in LDI I and LDI II (see Section 5.2) will be restricted as to the distance that will be allowed between the building and the boundaries containing the site. In all cases, buildings must be set back enough to prevent a loss in the amount of daylight or view, or to prevent harm to adjacent buildings. Cluster plans approved by the **Council** may be exempt.

Front Setback: 3 m minimum
Side Setbacks: 3 m minimum
Rear Setback: 9 m minimum

5.1.1.3 Minimum Floor Area. The minimum net floor space for individual residential units shall be 50 square meters. This should not include garage spaces, patios, balconies, porches, or terraces. The **Council** will introduce flexibility when dealing with minimum size for hotel room units or condominium units. The **Council** reserves the right to reject a proposal based on inadequate room sizes.

5.1.2 Parking Requirements - General

5.1.2.1 Parking spaces shall be clustered in maximum counts of 20 vehicles, and shall be screened with a minimum 3-meter planted buffer on all sides.

5.1.2.2 All stormwater runoff from parking areas shall be contained in drainage structures to prevent erosion.

5.1.2.3 Parking areas shall be lighted, utilizing fixtures similar to roadway lighting, as may be required by the **Council**.

5.1.2.4 In multi-family development there shall be one parking space for each unit, to be provided on the development site in close proximity to the units.

5.1.2.5 In hotel development there shall be one parking space for every two hotel units. Parking spaces shall be at least 2.8 meters wide, except that a parking space adjoining a walkway shall be at least 3 meters wide.

5.1.2.6 Restaurant development shall require one parking space for every 9 square meters of public floor space or part thereof. Parking spaces should be on a properly prepared surface that has been well compacted, or on a porous or grassed area.

5.1.2.7 Provisions shall be made for parking rental, bus and service vehicles on roads, or public or private parking areas in LDI Districts IV-VI.

5.1.2.8 Surfaces of all required parking lots and areas shall be of materials that will avoid erosion, prevent dust and permit safe usage. It is recommended that porous surfaces be considered as an alternative to paving.

5.1.2.9 Automobile parking spaces, where required, shall be a minimum of 2.8 meters wide by 5.6 meters deep, except where adjacent to a walkway; then the width shall be 3 meters.

5.1.3 Landscaping Regulations

5.1.3.1 No excavation and/or filling that involves greater than 7.5 cubic meters of material shall be permitted without a detailed analysis of the impacts on the site and subsequent approval by the **Council**.

5.1.3.2 Every building shall have shade trees established as part of the landscaping immediately upon completion of construction. These trees must be maintained and replaced if they die. Cleared building sites should be revegetated with appropriate native plant species as soon as possible to avoid erosion.

5.1.3.3 Landscaping shall utilize plants which are known to be fast growing and drought resistant. Salt tolerant plants should be used in appropriate places.

5.1.3.4 On hillsides, the clearing of trees and bushes should be minimized to reduce the likelihood of soil erosion and landslides. Site Development Permits shall be required for the cutting of trees with a diameter at breast height (DBH--1.3 meters above ground) greater than 20 cm, or a stature greater than 4 meters, and in no case shall such trees be cut for the purpose of landscaping. All trees greater than 30 cm DBH shall be strictly preserved, even to the point of relocating proposed development. Areas with 80% crown closure for every 18 square meters, and trunks greater than 12.5 cm DBH, shall be preserved.

5.1.3.5 Guinea grass may not be used for erosion control or landscaping unless other considerations outweigh or minimize the fire hazard.

5.1.3.6 Primary dunes shall be absolutely protected. The use of raised wooden walkways shall be used to concentrate traffic and allow sand to move and accumulate, and prevent erosion of the dune and destruction of the dune revegetation.

5.1.3.7 No construction or land clearing shall be done within 4 meters of any gut with a bare rock bed or clearly discernable bed 12 cm or more in width, except that an access road may cross such a gut at right angle to it on a concrete road dish or with an adequate culvert or bridge.

5.1.3.8 To minimize soil erosion, vegetation and soil should only be removed in a manner to correspond with phasing of development, whether it be a single building or a group of buildings. The sequence of land clearing should be submitted in detailed note form or presented in drawing form.

5.1.4 Fire Fighting Provision

5.1.4.1 Buildings must be 30 meters or less from a street, road or driveway to provide access for fire fighting equipment.

5.1.4.2 Where possible, fire hydrants shall be provided at distances not more than 90 meters along roads internal to developments. Internal fire hydrants may be incorporated as standpipes as part of buildings. The main size shall not be less than 10 cm inside-diameter.

5.1.4.3 The burning of natural grass shall be strictly controlled. Natural grass must be removed from within 8 meters of any building.

5.1.4.4 Fire-breaks of fire-resistant trees shall be planted on the upwind border of any developed property adjacent to natural grasslands. Fire-breaks and windbreaks shall be planted in an irregular or clumped line rather than a straight line, using several species of plants in any particular planting, where feasible. Windbreaks may utilize casuarina, coconut, eucalyptus, almond, or other, preferably native, species at the discretion of the developer.

5.1.5 Slopes

Natural hazards related to slope and geomorphic instability dictate that the degree of slope and underlying geology restrict development as follows:

Percent Slope	Description	Uses
0-8%	Developable with little or no modifications to slopes; minor danger of instability	All LDI's
8-15%	Developable with moderate modification of slopes; moderate danger of instability	LDI I, LDI II, LDI III (low density), LDI IV (low density)
15-30%	Developable only in areas composed of stable igneous rock; high danger of instability	LDI I, LDI II
30-70%	Undevelopable unless bedrock exists within 20 feet of surface; very high danger of instability	LDI I
>70%	Undevelopable; extremely high danger of instability	Wildlands/open space

5.2 Land Development Intensity Districts

5.2.1 General Description. Each Land Development Intensity (LDI) District description gives the types and intensities of land uses permitted in the District, and planning policies for the development of the District. LDI District boundaries are shown on the Overall Development Potential Map (Map #18), and shall be interpreted to be generalized except where boundaries are coincident with center lines of road or rights-of-way, or with naturally occurring geographic boundaries. The **Council** shall be the interpreter of any boundary issues.

5.2.1.1 Land Development Intensity District I (LDI I). The following uses shall be permitted in LDI I Districts: single family detached residential and related uses. Such uses shall be located on individual lots or aggregated sites in which the density of dwelling units per hectare shall be equal to or less than 1 dwelling unit per hectare (1 DU/ha).

5.2.1.2 Land Development Intensity District II (LDI II). The following uses shall be permitted in LDI II Districts: single family detached or clustered detached residential and related uses. Such uses shall be located on individual lots or aggregated sites in which the density of dwelling units shall be equal to or less than 5 DU/ha, but not less than 1 DU/ha).

5.2.1.3 Land Development Intensity District III (LDI III). This District category is reserved for planned unit developments. LDI III Districts shall be permitted only on sites equal to or greater than 2.5 hectares, and shall be subject to individual proposal review and approval as provided for in the **Handbook**. The following uses may be approved in the LDI III District: primarily residential, with commercial, marine-related, tourist facilities, including hotels of 50 rooms or less and any use and density that is compatible with uses in LDI I and LDI II.

5.2.1.4 Land Development Intensity District IV (LDI IV). The following uses shall be permitted in LDI IV Districts: single hotel or tourist facilities; commercial retail related to tourist facilities; and multi-family residential uses. The floor area ratio shall not exceed 0.75. Height of buildings shall be limited to 10 meters.

5.2.1.5 Land Development Intensity District V (LDI V). The following uses shall be permitted in an LDI V District, which shall be known as the Marine District: water- and marine-related uses, commercial retail, attached and multi-family residential, and hotels of 25 rooms or less. The floor area ratio shall not exceed 2.0. Heights of buildings shall be limited to 8 meters, with care to preserve vistas over the water for inland development as may be approved by the **Council**.

5.2.1.6 Land Development Intensity District VI (LDI VI). This District shall be known as the Town Center District. The following uses shall be permitted in LDI VI: mixed and multiple uses, including hotels of 25 rooms or less, commercial retail, commercial wholesale not exceeding 10% of all commercial floor area, attached townhouses and multi-family residential, churches, professional and other personal services, automobile services limited to sites which minimize conflicts with residential uses, governmental services and other uses which, in the determination of the **Council**, would be compatible with the Town Center concept. The floor area ratio shall not exceed 3.0. Heights of buildings shall be limited to 10 meters with care to preserve vistas and open space, as may be approved by the **Council**. The LDI VI district requires very special care in site planning, architectural, and aesthetic quality, according to standards and procedures that shall be developed by the **Council**.

5.3 Public Facilities Districts

5.3.1 Sewer Districts (SD)

5.3.1.1 The use of septic tanks within Sewer Districts is not compatible with the proposed high development densities, and is prohibited. All wastewater generated within Sewer Districts shall be conveyed to a centralized wastewater treatment system for treatment and disposal.

5.3.1.2 Areas located outside, but adjacent to Sewer Districts, have the option of constructing septic tanks with drain fields, or to discharge to a Sewer District.

5.3.1.3 If adequate capacity is not available in existing waste treatment facilities, the **Council** may decide to allow the developer to either construct an on-site treatment facility, or expand the existing facility.

5.3.1.4 All developers shall submit to the **Council** the financial, engineering, construction, operational and development plans for wastewater treatment facilities within Sewer Districts. The **Council** will review these plans with the Application for Development Approval for adequacy and conformance with the **Management Plan** and the **Handbook**.

5.3.1.5 All wastewater shall be treated to secondary standards, and shall not be discharged directly to near-shore waters. Wherever possible, combined systems of treatment and land application (to golf courses, appropriate agriculture, or wetlands [either constructed or natural]) shall be used, rather than discharge to surface water bodies.

5.3.2 Solid Waste Disposal Districts (SWD)

5.3.2.1 All developments within SWD's shall have a plan for minimization and disposal of construction rubbish and landscaping wastes outside of the established solid waste facility.

5.3.2.2 To minimize solid waste generation, all developments shall establish a solid waste management plan that will include plans to recycle organic wastes on-site, and minimize other residential, commercial, or industrial wastes.

5.3.3 Water Distribution Districts (WD)

All developers shall submit to the **Council** complete financial, engineering, construction, operational and development plans for water supply distribution proposed for any development. The **Council** will review these plans with the Development Approval Application for adequacy and conformance with the **Management Plan** and the **Handbook**.

5.3.3.1 If adequate capacity is not available in existing public water supply systems, the **Council** may decide to allow the developer to either construct an on-site potable water supply facility, or expand the existing public supply system.

5.3.3.2 If the development will not use existing public water supplies, the developer shall submit to the **Council** complete financial, engineering, construction, operational and development plans for potable water supply.

5.3.3.3 All developments shall establish a potable water management plan, with provision to minimize use of potable water, including plans for recycling gray water and minimizing liquid waste generation, through the use of water conservation practices and fixtures.

5.4 <u>Natural Resources Protection and Recreation Districts</u> (Conservation, Recreation, Scenic Vista, Reserves and Protected Areas, Natural Hazard, and Marine Resource Districts)

5.4.1 Tree cutting and vegetation removal shall be regulated when these activities are carried out within the **NCZ**. At no time shall the aerial extent of permitted removal of vegetation be greater than 75% of a building site or development, except in LDI Districts.

5.4.2 Land deemed to be a Recreation District within a proposed development or parcel of land shall be considered as having an LDI equal to 1/2 of the allowable LDI. Said density may be transferred from the Recreation District to other portions of the parcel or development, or other contiguous property under the same ownership, provided that the densities in the receiving areas do not exceed the allowable density by 20%.

5.4.3 The following percentages of land are to be set aside for public parks and recreation areas by LDI Districts:

District	% Set Aside	Use
LDI I	0	Parks
LDI II	10	Parks
LDI III	10	Parks
LDI IV	10	Parks
LDI V	10	Parks
LDI VI	10	Parks

5.4.4 The following scenic vista protection standards shall apply to permitted development within Scenic Vista Districts:

5.4.4.1 Hills and bluffs should be used, where feasible, to buffer habitat areas. Where otherwise permitted, development should be located on the sides of hills away from views and scenic vistas.

5.4.4.2 Structures shall not exceed 8 meters in height from the averaged finished grade at the perimeter of the base of the building envelope.

5.4.4.3 The roof lines of buildings shall not project above any ridge line by more than one story.

5.4.4.4 Natural and planted vegetation screens or visual buffers shall be incorporated into landscaping plans to buffer habitat areas, wherever feasible.

5.4.4.5 The use of natural wood and masonry painted in pastel colors should be encouraged. Roof covering materials should be light in color to minimize heat gain, and to add to visual quality. The use of bright, dark, or obtrusive exterior finishes shall be prohibited.

5.4.4.6 Cuts and fills on hill slopes shall be minimized. There shall be no wasting of cut soil materials onto downslope areas. All clear-cuts and disturbed areas shall be revegetated with appropriate plant species within one growing season.

5.4.4.7 Wherever possible, access roads shall run parallel to hillside contours.

5.4.5 The following resource protection standards shall apply to permitted development within **Reserves and Protected Areas**:

5.4.5.1 Permitted development shall occur in clusters such that allowable densities overall are not exceeded, but cluster density may exceed LDI of any site within the development or parcel, provided that 90% of the development site or property remains in an unaltered condition.

5.4.5.2 Access roads and utility corridors shall be minimized. Clustered development shall be located so as to minimize the length and extent of the access roads and utility corridors.

5.4.5.3 Public park and recreation area set-asides, as provided for in section 5.4.3, shall not apply within Reserves and Protected Areas.

5.4.5.4 Where allowable development would cause a break in the natural vegetative cover such that a contiguous Reserves and Protected Areas District would be severed into two districts, the land owner shall designate a connecting strip of land at least 30 meters wide as a wildlife corridor connecting the Reserves and Protected Areas that have been severed. The wildlife corridor shall be maintained in an unaltered, natural vegetative cover.

5.4.5.5 Owners of lands within Reserves and Protected Areas shall be encouraged to develop systems of natural trails throughout areas not disturbed by developed uses.

5.4.6 No development shall be allowed within **Natural Hazard Districts**.

PART 4: NAYARIT COASTAL ZONE RESERVES AND PROTECTED AREAS PLAN

INTRODUCTION

As part of the larger effort to provide guidelines and planning documents for the State of Nayarit, the research team developed a framework for a system of reserves and protected areas. Called the **Nayarit Coastal Zone Reserves and Protected Areas Plan (RPA Plan)** it lays the groundwork for a comprehensive system of protected areas. A map of areas that were considered important candidates for protection status is included as MAP 26. The areas included as potential reserves are shown on the map in schematic fashion. Actual boundaries and designations of reserve status should be considered by the **Council**. This proposed RPA plan provides guidelines for selecting reserves, provides a map of potential reserves, and gives details for the operation and management of a reserve system, including management infrastructure.

THE PRESENT SITUATION

Inland parks and reserves have been created in Mexico since the 1930's, but protection of coastal lands and waters is very recent. The existing coastal reserves and parks have been established within the last decade (Merino, 1987). For example, the State of Nayarit, in an effort to protect areas of importance within its jurisdiction, supported the efforts of environmentalists and ecologists to have Isla Isabela decreed a National Park on December 8th, 1980.

The groundwork had been laid for the beginnings of a **Protected Areas System (PAS)** when, in 1988, the President of Mexico decreed the General Law for Ecological Balance and Environmental Protection (**GLEBEP**). This law provides descriptions of Natural Protected Areas, resource categories, and a National Park System network.

As part of a comprehensive plan to develop a unified **PAS** that includes the marine resources of the **NCZ**, it is recommended that a **PAS Authority** be appointed by the government of Nayarit, in conjunction with **SEDESOL**, **SARH**, **SEPESCA** and other related authorities, which will be responsible for its administration, management and planning. This document contains suggestions for components of legislation that would establish a **PAS**, and gives its authority.

DEVELOPMENT OF THE SYSTEM

Justification

The Nayarit Coastal Zone is a diverse landscape of terrestrial communities and marine resources that is now under development pressure. An important goal is the designation of protected areas within the **NCZ** that will preserve the most important resources, and provide for effective education of visitors and local citizens. Recent trends in tourism suggest that future expansion will depend heavily upon the environmental quality of chosen destinations. Increasingly, tourists are seeking destinations that offer a wide variety of marine- and land-based natural environmental values. The **NCZ** can easily offer significant amenities such as scenic vistas, wildlife, marine resources and interesting vegetation communities.

By designating a system of protected areas prior to development, the government may move forward in negotiations with landowners to achieve implementation of the plan. In conjunction with the park system, it is suggested that a series of trails on both public and private lands be developed and maintained by the government. This will require some legal agreements with landowners whose lands these trails may transgress. Landowners and potential landowners should be made aware as soon as possible that the protected areas and trail systems are considered important parts of tourism development in the **NCZ**. In this way, as planning for individual developments proceeds, planners and architects may take into account the right-of-ways that are required for **RPA's** and the integrated trail system.

Goals and Objectives

The overall goals and objectives of the **Council** have been articulated in the Nayarit Coastal Zone Management Plan (**Management Plan**; see Part 2 of this volume); those goals that are of particular relevance to the **RPA Plan** are:

1. The **NCZ** has unique environmental resources, the conservation of which is essential to maintain the natural diversity of plant and animal species and habitat, including those of economic value such as commercial and sport fisheries.

2. In order to maximize tourism and related development opportunities, it is critical to create a secure, safe and aesthetically pleasing land management and community environment; and it is critical to minimize damage to structures by natural events such as hurricanes.

In addition to these goals, several objectives are recognized that are important to achieve sustainable and environmentally compatible development of the **NCZ**, and that are considered pertinent to the **RPA Plan** as follows:

a. Establish terrestrial and marine resource protection districts

b. Create development patterns that protect scenic vistas and aesthetic quality, and that are consistent with historic architectural traditions

c. Balance land management and environmental protection with accommodation of vested rights of landowners and citizens

d. Develop procedures and assist the Minister in administration of laws regarding land development and environmental protection of the **NCZ**

These goals and objectives were the driving force behind the development of the overall resource protection strategy that led to the **RPA Plan**. They were further refined into a single goal and two objectives for a protected areas system which, if implemented, will insure the vitality of the environment and economy of the **NCZ** and which, if extended to the remainder of the State, will act to unify the recreational and resource protection efforts of Nayarit's government.

Goal of the Reserves and Protected Areas Plan

It is recognized that the vegetation communities, wildlife, beaches, and scenic qualities of the **NCZ** are a unique regional and National treasure that are of special importance to the economic development of the State of Nayarit. It is the overall goal of the government of Nayarit to develop a system of protected areas and trails that will protect and enhance these resources, and help to educate citizens and visitors alike of their importance and unique character.

Further, the following two objectives are recognized as important to achieve an integrated approach to the management of a **Protected Areas System** in the **NCZ**:

Objective 1. Manage important natural resource areas in ways that will contribute to their quality, and to the quality of life of inhabitants and visitors to the **NCZ**. Management of the **PAS** in the Coastal Zone in particular is vital for:

a. the productivity of commercial marine species that depend to some degree on a high quality terrestrial environment for breeding and feeding activities, and/or juvenile life stages;

b. the protection of endangered species and life patterns of other wildlife species;

c. retaining unaltered examples of the natural heritage of the Coastal Zone;

d. continued economic development, particularly tourism and fisheries; and

e. the study and interpretation of Nayarit's natural and cultural heritage.

Objective 2. Encourage, through educational and interpretative programs, an understanding and awareness of conservation issues and needs, as well as the enjoyment of the natural environment.

Site Selection

There are two aspects to site selection in the **RPA**. The first is the establishment of suggested boundaries of natural protected areas; and the second is a proposal for the establishment of an integrated system of hiking and horseback trails that will connect scenic overlooks and protected and conservation areas as well as the best examples of natural, vegetative communities.

Reserves and Protected Areas

Management Plan Map #26 shows the various **RPA's** that have been proposed for the **NCZ**. In addition, those areas which are in need of special attention because of their unique character or some other special feature, were identified and are included as Natural Monuments. There are 9 proposed categories of land management in the **PAS** that are found in the **NCZ**. These are:

1. Biosphere Reserves (**BR**)
2. Special Biosphere Reserves (**SBR**)
3. National Parks (**NP**)
4. Marine National Parks (**MNP**)
5. Natural Monuments (**NM**)
6. Zones Subject to Ecological Conservation (**ZSEC**)
7. Flora and Fauna Protected Areas (**FFPA**)
8. Natural Resources Protected Areas (**NRPA**)
9. Urban Parks (**UP**)

These categories are defined in a later section of this chapter, according to the **GLEBEP**. Recommendations for lands that should be included in each of these categories, and the boundaries necessary for their establishment, are discussed in the following paragraphs.

Biosphere Reserves (BR). The Teacapan-Agua Brava-Marismas Nacionales Coastal Lagoon system, with its important area of mangrove forests, salt marshes, and estuarine lagoons, comprises one of the most extensive mangrove areas on the Pacific coast of North America. These mangroves are ecologically important to both resident and migratory waterfowl and shore birds. The area supports a very important high-diversity fish community (Flores-Verdugo, 1990), also supports a declining number of highly valuable mammals and reptiles threatened by hunters, poachers, and development. The Teacapan-Agua Brava-Marismas Nacionales Coastal Lagoon System should be incorporated into the **PAS**.

Sierra Vallejo has been proposed as a Biosphere Reserve in the Comprehensive Plan for the Municipality of Bahia de Banderas. This area is an important tropical deciduous forest area, which should be preserved and controlled.

Special Biosphere Reserves (SBR). The Mexcaltitan-Boca de Camichin Coastal Lagoon system, which has characteristics very similar to the Teacapan-Agua Brava-Marismas Nacionales system, is proposed as a **SBR**. It also contains within its area an important cultural human settlement in Mexcaltitan Island.

National Parks (NP). Islas Marietas has been proposed as a National Park in the Comprehensive Plan for the Municipality of Bahia de Banderas. This area is considered to be very important in the development of the PAS.

The San Blas-La Tobara estuarine system is another area which should be considered as a National Park, due to its vegetation and wildlife characteristics. This area has supported populations of alligators which are threatened by development and tourism. It is therefore important to preserve and protect this area.

Marine National Parks (MNP). Proposed areas for MNP's include:

1. The coral communities of the reefs surrounding the Islas Marietas.
2. The coral communities of the Isla de Jaltemba at ensenada de Jaltemba.
3. The Playa Platanitos, which supports an important nesting area for sea turtles.

Natural Monuments (NM). The Strand Plain Barrier at the Marismas Nacionales, located in the northern portion of the NCZ, contains about 280 subparallel ridges formed by accretion of the shoreline (see Part 1, Section 1 of this volume). This is an exceptional geological and archaeological area, due to the presence of kitchen midden mounds (Curray et al., 1969).

La Tobara Spring, located west of San Blas, is an area of winding estuarine channels leading to a fresh-water spring. The channels are surrounded by a scenic mangrove forest, which has been used as a tourist attraction for "jungle trips". This is an exceptional vegetation and wildlife area of mangrove community associations that should be preserved as a Natural Monument.

Zones Subject to Ecological Conservation (ZSEC). Within the NCZ there are many areas that may be included as ZSEC's, including nearly all of the ecological communities surrounding human settlements. Specific analysis on particular areas should be made in order to assess the potential environmental impact of any development plans on such areas.

Flora and Fauna Protected Areas (FFPA). There are several areas that should be protected because of the importance of their flora and fauna, but overall they are more important because of their characteristic ecosystems. Some of these areas have already been mentioned, including: (a) Teacapan-Agua Brava-Marismas Nacionales; (b) Mexcaltitan-Boca de Camichin; (c) San Blas-La Tobara; (d) Islas Marietas; and (e) Isla Jaltemba. Another area that should be protected is the Chacala-Santa Cruz corridor, where a new road has recently been paved. It contains a pristine tropical deciduous forest with beautiful vistas and aesthetic landscapes.

Natural Resources Protected Areas (NRPA). La Tobara Springs is one of the areas that should be considered within this category, as a Springs and Rivers Protection Zone. There is increasing concern among ecologists and conservationists, due to an interest in developing the area intensively for tourism. This area has long been a popular tourist attraction. Increasing the intensity of use could lead to a disruption of the ecosystem by damaging and polluting it which will, in turn, decrease its value for tourism, with repercussions for the economy of the area depending on it. Low intensity tourism, as well as low impact eco-tourism activities (e.g., bird watching, canoe trips, wildlife trails) are best suited for this area.

Urban Parks (UP). The **Management Plan** suggests that lands be set aside for public parks and recreation areas, ranging from five to ten percent of the total developed area. These park set-asides will require that an agency operates and maintains them, and makes decisions concerning location and facilities. In some instances, it may be appropriate to request that park set-asides be clustered to form larger recreational amenities or central open-space commons areas. Once lands are set aside, ownership title should revert to the government as part of the **PAS**. This management category will include those areas that are designated as park and recreational set-asides.

MANAGEMENT REQUIREMENTS

Implementation

Implementation of a **Protected Areas System** will require an active partnership between the **Council** and **COPLADES, SEDESOL, SARH,** or other authorized natural resources agencies. The **Council** will be responsible for implementing the system in the **NCZ,** while the government will be responsible for acting on the Council's recommendation.

Legislation establishing a **PAS** should be drafted with the assistance of an environmental law specialist. The new legislation should spell out the management categories proposed above, provide the **Council** and/or other resource management agencies with enforcement authority, and establish procedures. New legislation should establish procedures for commercial activities operating in parks, including the levying of user's fees, and establishment of concession procedures. Regulations applicable to all protected areas should be established under this ordinance.

The following guidelines may be used by **SEDESOL-COPLADES** and the Nayarit government in developing an **PAS**:

1. Legislation should be enacted or modified to create the **PAS** and clearly defined set of land-management categories. Recommended management categories are described below, according to **GLEBEP.** Overall management and policy formulation for the **PAS** should be through a semi-autonomous Authority of appointed public officials and private citizens. Organizational structure below the authority that will be responsible for delivery of services and system management can follow the pattern of other departments of government.

2. Funding sources should be sought through applications to private foundations, bilateral organizations and other world conservation organization.

3. Studies of the **NCZ** should be implemented to determine appropriate candidate historic and ecological areas for inclusion into the **PAS**. The following process should be used:

   a. Consideration of new areas should be brought to the **Council**, with evaluation and ranking based on the criteria established in the **RPA Plan**. Priority should be given to areas already identified, and which have the greatest urgency for management.

   b. The **Council** should direct studies of management alternatives for the proposed area, indicating the range of ways in which the area could be managed and determining a preferred alternative.

   c. The Council should present the preferred alternative to resource users, local inhabitants, relevant government departments, and the public at large.

   d. Based on the input received, the appropriate management category should be selected and a single management strategy produced and recommended to **SEDESOL-COPLADES**.

   e. **SEDESOL-COPLADES** should then study the proposal and legally establish the area, or reject the proposal.

4. Once established, areas should be managed according to the objectives stated for their creation. Management should be guided by a plan prepared by the **Council** and approved by **SEDESOL-COPLADES**.

Management Categories

The objectives for management of the proposed areas will vary. Certain objectives will stress conservation of endangered species, some will stress recreation or research and education, while others will aim to protect important habitat. It is, therefore, necessary to establish categories of protected areas that will reflect the diversity of objectives.

The categories used in the present study correspond to those established in **GLEBEP**. The categories, and the articles where they are found, are as follows:

Article 46 considers the natural protected areas as follows:

1. Biosphere reserves;
2. Special biosphere reserves;
3. National Parks;
4. Natural monuments;
5. National marine parks;
6. Natural resources protected areas;
7. Flora and fauna protected areas;
8. Urban parks;
9. Zones subject to ecological conservation.

1. Article 48: **BIOSPHERE RESERVES** are areas with an extent greater than 10,000 hectares, integrated by representative and relevant biogeographic areas of natural ecosystems not significantly altered by humans, with at least one zone not altered, and inhabited by species considered endemic or endangered. It combines conservation, research, education, and training policies and functions as a local population integrator. No new population development can take place.

2. Article 49: **SPECIAL BIOSPHERE RESERVES** have the same characteristics as the biosphere reserves, but they are smaller in size or have less species diversity.

3. Article 50: **NATIONAL PARKS** will be constituted in forested land according to this and the Federal Forestry and Game Law. They will represent one or more ecosystems which are important for their natural beauty; scientific, educational, recreational or historic value; for the existence of nationally important flora and fauna; for their suitability for tourist development; or for other reasons of general interest.

4. Article 51: **NATURAL MONUMENTS** will be established according to this and the Federal Forestry and Game Law. They will represent areas that have one or various natural elements of national importance, which will be protected for their exceptional or unique characteristics, or for aesthetic, historic, and scientific purposes. The only activities allowed will be those related to its preservation, scientific research, recreation and educational.

5. Article 52: **NATIONAL MARINE PARKS** will be established in marine zones within the national territory, and may include the beaches and the maritime-terrestrial federal zone contiguous to them. Activities related to the preservation of aquatic ecosystems, research, recreation, and ecological education are allowed in these areas, as well as the exploitation of natural resources authorized by this law and the Federal Fisheries and Seas Law, and other related national and international laws and regulations.

6. Article 53: **NATURAL RESOURCES PROTECTED AREAS** are areas designed for the preservation and restoration of terrestrial and aquatic areas. The establishment, organization and management of this areas will be according to this law, and the federal forestry and waters law and other related regulations. These areas are:

    I. Forestry reserves;
    II. National forestry reserves;
    III. Protected and forestry zones;
    IV. Restoration and forestry propagation zones;
    V. Zones for the protection of rivers, springs, deposits, and water reservoirs.

7. Article 54: **FLORA AND FAUNA PROTECTED AREAS** are established for the protection of wild terrestrial and aquatic species, and will be constituted according to this law and the Federal Hunting and Fishing Law and related regulations. Activities related to preservation, propagation, refuge, and research are allowed in these areas.

8. Article 55: **URBAN PARKS** are areas of public use, constituted by the federal entities and municipalities within the towns and cities to obtain and preserve the balance of urban-industrial ecosystems.

9. Article 56: **ZONES SUBJECT TO ECOLOGICAL CONSERVATION** are areas constituted by federal entities and municipalities, in zones neighboring human settlements, in which there exist one or more ecosystems appropriate for conservation.

Management Infrastructure

Staffing

The **PAS** should be maintained at a minimum staffing level, with an overall **PAS Authority** to organize and supervise management activities. Research, planning, and implementation activities should be carried out through cooperative agreements with other government departments, non-governmental organizations and international organizations and resource-user groups. The full staff required to manage the expanded system will be phased in, as funding allows. The final staff suggestions to manage the **PAS** are as follows:

Administrative Staff

1. One Director (professional): overall supervision
2. One Resource Manager (professional): coordination of research, supervision of resource management projects
3. One Senior Executive Officer (technical): accounting, office management, logistics
4. One to two Clerks (basic)

Park Staff (per Reserve)

5. Park Wardens: coordination of infrastructure construction and maintenance (number depends on number of parks within the system)
6. One to two Interpreters (professional): oversight of research and public awareness and training
7. Maintenance Personnel (number depends upon the size of the reserve)

This core staff should be supplemented by collaborative agreements with other governmental departments. Agreements might be established with:

SEPESCA (marine resource assessment, monitoring, planning)

SARH (resource assessment, monitoring, planning)

POLICE DEPARTMENT/SEDESOL (law enforcement)

COPLADES/SEDESOL/COEDUE (planning)

SEP (education and participation)

SOSP (infrastructure and maintenance)

CNA (infrastructure and service)

Physical Plant

Requirements for physical plant for the entire **PAS** are difficult to determine at the outset, since the number and scope of parks and protection areas are not yet known. The following is a generalized list:

1. Headquarters/information center
2. Park warden office/information center at each major park
3. Transport vehicles and launches (Four-Wheel drives)
4. Information panels and trails as required by individual parks
5. Fencing

Revenue and Budget

The finances of the **PAS** should be met through government subvention, donations, technical assistance projects, international bilateral agencies, and revenues raised through concessions. Fund raising must be a major and permanent aspect of the Authority's program, and all the above sources of revenue and any new sources that become available in the future, direct-user fees for example, should be pursued to the fullest extent possible. It is unreasonable to expect that any one source can or should be relied on to provide the revenues required.

The **PAS** might be funded through allocation of a portion of annual land tax collected. Additional funds for specific management programs should be sought from local sources, private foundations, and international agencies.

Cooperative Agreements and Concessions

As a matter of policy, resource users and government departments should be encouraged to participate in the planning and management of the areas in the system. Cooperation should be actively sought with the appropriate government departments and non-government groups. Cooperative activities must be structured within the framework of the overall **PAS** approach. These should be managed by a committee from the **Council** comprised of relevant government departments, resource users and members of the local community. Users cannot be given direct and formal law enforcement authority; however, areas of cooperation in exchange for a waiver or reduction of concessions fees may include assistance from concessionaires in maintaining moorings or removing garbage, assistance in research, studies of management alternatives, management planning, monitoring, evaluation and interpretation, and education.

Concessions from commercial users of park areas could provide a major source of revenue for park management activities. The major commercial users involved would be charter and dive boat operators, aquatic sports operators, nature tour operators and restaurants and shops within park areas.

Liability

The **PAS Authority** should be considered a corporate body, which has the ability to sue and/or the responsibility of being sued. Although the legal owner of park lands, the **Authority** by common law is the legal occupier and, thus, responsible for activities within park areas. The **Authority** has a common law duty to take "reasonable care" to ensure that visitors are "reasonably safe", using parks for the purposes for which they are intended. As long as the **Authority** exerts such reasonable care, it cannot be liable for accidents or injury to visitors. Reasonable care includes the issuance of warnings of dangers, signs and, in some cases, closure of dangerous areas. In order to further limit its liability, the **Authority** should secure insurance coverage.

Contributions from Government Agencies

The **Authority** should not duplicate the duties of government ministries. Specifically, cooperative agreements should be made between the **Authority** and relevant ministries for sanitation, certain types of maintenance, and law enforcement. For example, SARH could provide personnel and administrative assistance for management of forested parks, SEPESCA could provide personnel and administrative assistance for management of marine-related research, and the Coast Guard could provide enforcement personnel for marine-related activities.

Inclusion of Private Lands

Private lands and whole communities may, in some areas, be included within the boundaries of parks and other **RPA** categories. Under these circumstances, land owners and/or local community residents should be adequately represented. The **Council** can fulfill the functions of the **PAS Authority**, and its duties will be to evaluate suggested lands and management categories, negotiate with landowners on behalf of the **Authority**, and set overall management policy for the **NCZ**.

It may be valuable to include private lands as part of park or protected areas. Since it is unrealistic to expect government to purchase all private lands within the boundaries of protected areas, other means of obtaining lands for public purposes should be explored. Such methods as tax incentives, transfer of development rights, and outright gifts may be considered when privately held lands appear to be critical for habitat or species preservation.

Any new legislation relative to a **PAS** should provide for the right of landowners to appeal; inclusion of private land in **RPA's** should occur only after landowners and the **Authority** have reached consensus on management of these lands. The **Authority's** position on these negotiations must be based on a respect for the rights of the landowners, but should also consider the environmental integrity of the area in question. If consensus cannot be reached, the private lands will not be included in the park's boundaries. Once consensus is reached, the **Authority**, SEDESOL, COEDUE, COPLADES and the landowners involved will work together to establish covenants that ensure the integrity of the protected area.

MANAGEMENT PROGRAM

The following is a suggested management program for the **PAS**, which can easily be expanded according to the extent of the approved plan. Categories of management tasks are given, followed by those responsible for conducting the work and, finally, specific suggestions related to managing the resources of the NCZ.

Research and Planning

Responsibility

Senior Executive Officer.

Resource Manager.

General Statement

The **Authority's** research program should concentrate on applied research, primarily on existing management problems. Research needs for established **RPA's** should take priority over those for proposed areas, except in cases in which the establishment of an area is, in itself, a priority.

NCZ Recommendations

The limited staff available to carry out research and planning on the NCZ will limit the amount of research in which the staff can be directly involved. The most needed research in the early phases of the program is related to detailed documentation of the existing resources and the planning and design of specific management programs. There are three areas of research and planning that should be carried out as soon as possible during these early establishment phases:

1. Develop a detailed inventory of the floral and faunal composition of the **NCZ**, focusing, at first, on those areas that are included in the **PAS**.
2. Refine the boundaries of the **RPA's**, and the alignment of hiking, canoe and bridle trails.
3. Begin research, and implement a management program for the protection of threatened and endangered species, to balance their populations, and help prevent their deterioration.

Information

Responsibility

Resource Interpreter.

General Statement

Information should be readily available to the public and visitors. Topics covered at both the whole system and individual **RPA** levels should include logistics (how to get there, what to see, costs involved, etc.), background information (importance of resources to human welfare and problems associated with misuse), and regulations for visiting the areas (permitted and restricted activities, and why).

NCZ Recommendations

The information needs of residents and visitors are great. Of primary importance is the generation of information about the **PAS**. This information should be organized and written in such a way that it may be used as a means of securing funding from external sources for development and enrichment of the program. Of equal importance is the development of information and interpretive materials for the public. Such material should detail the **PAS** and the system of hiking and canoe trails available, and be in the form of pamphlets for distribution at an Information Center and through tour operators. Graphic maps of the **NCZ**, showing locations and ecological information about **RPA's** and trails should be displayed in the Information Center, and at hotels throughout the Coastal Zone.

Education and Awareness

Responsibility

Senior Executive Officer.

Resource Manager.

Resource Interpreter.

General Statement

Elements of the program will include regular presentations to Nayarit's schools, workshops for interested civil servants, and workshops for commercial users such as tour guides and charter boat and dive tour operators. Probably of greatest importance are presentations and dialogue with landowners and developers of lands within and adjacent to RPA's.

The thrust of the program should be on the contribution of RPA's to development and resource management, and the location and value of individual RPA's. Target groups by priority should be communities in or near there areas, resource users, relevant Government officials, school children, and the general public.

NCZ Recommendations

The development of materials for presentations to landowners and developers of the NCZ is of primary concern. Materials should include general presentations on the scope and value of the PAS and the trail system, the values of natural vegetation on lands other than RPA's, wildlife values and management concerns, and information concerning the need for cooperative agreements where the trail system crosses private lands. The Resource Manager and, to a lesser degree, the Resource Interpreter should be involved as much as possible in the planning and design of all development projects in the NCZ, so that the welfare of the PAS is a part of the development process. Early dialogue may avoid conflicts in the planning and design process.

Fund Raising

Responsibility

Council.

Senior Executive Officer.

General Statement

Emphasis should be placed on sources of assistance, such as USAID, CIDA, UNESCO, WWF, and other major private foundations. As projects are identified by the PAS staff, proposals for funding assistance should be drawn up and submitted. Appeals for general support of the PAS should be aimed at communities, businesses, and the general public.

NCZ Recommendations

The successful development of the PAS will depend in great measure on the ability of the Council to garner the support (both financial and philosophical) of the Government of Nayarit, business, and the public. Immediate funding should be sought to hire the necessary staff and to fund initial expenses. Once hired, the Resource Manager and Resource Interpreter can then begin to develop information and appeals/proposals to outside funding agencies that may make it possible to quickly expand the PAS into its final stage. Working with developers, business interests and the public, the staff may be able to secure funding and contributions of time, materials, and labor to significantly enhance both the Information Center and the trail system, since both of these amenities are extremely important to most tourism development in the Coastal Zone.

Infrastructure

Responsibility

Nayarit Coastal Zone Environmental Protection Council.

Senior Executive Officer.

General Statement

Infrastructure needs should be addressed, 1) at the system level; 2) at the specific **RPA** level; 3) at the level of site plans for a development within a protected area; and 4) at facility design.

NCZ Recommendations

Immediate needs for infrastructure are permanent interpretive signs and displays at roadway scenic overlooks, improvements along the trail system (steps, erosion control, handrails, etc.) and signs and trail markings. The largest expense will be the construction of a staff headquarters and several information/interpretive centers. The centers should be located at some important, easily accessible location that will serve as the focal point of the **PAS** and trail systems of each of the three regions of the **NCZ**.

MARINE PARK/RESERVE RECREATION PLAN

The creation of a Marine Park/Reserve is an immediate need, to manage the nearshore waters and shoreline for the conservation the marine resources of the **NCZ**. Special management rules such as those listed above, along with an overall fisheries and recreational management program, could help to insure long-term use of the renewable marine resources of the **NCZ**. Special **RPA's** could be best administered within the overall umbrella of a Marine Park/Reserve in the **NCZ**. This concept is compatible with the **GLEBEP**, and is also compatible with the desire of the government of Nayarit to attract tourism, and thereby stimulate the economy.

The plan presented here is a guide to action. Once the concept has been approved, the plan will need to be tailored more specifically to the development decisions of the **Council** and other government authorities directly involved with the exploitation of marine resources.

1.0 Objectives

The objectives of the Marine Park/Reserve will be:

1. To provide passive, marine-oriented recreation and environmental education to tourists.
2. To generate income for marine management.
3. To protect reef fish and coral communities from incompatible uses, and damage from anchoring and fishing.
4. To provide a research area for better knowledge and management of marine resources.

2.0 Actions for Implementation

The following are some of the actions that should be taken to establish a Marine Park/Reserve:

1. Designed as a multiple-use area, fishermen would serve on a steering committee for the park and would fish in the park, according to adopted fisheries management guidelines and regulations. Their knowledge and experience in the marine environment would be invaluable to the development of a management plan for the Park/Reserve.
2. Working committee for the park might consist of the following:
   a) A representative of the Coastal Zone Hotel Association or SECTUR.
   b) A representative from Nayarit's Government Fisheries Division or SEPESCA.
   c) A representative of the fishermen.
   d) A representative of **Council** and SEDESOL.
   e) A representative of the diving community or FMAS.
   f) A representative of the marinas.
   g) A representative of the land owners/developers of the coastal zone.
3. Proposed boundaries would be approved and delineated by the working committee.
4. A full-time manager would be hired and based at the development area near the proposed parks. A small Visitor's Center could be set up and provide environmental and other information about the park. The manager would be hired by the park committee with the approval of the government, and also serve as staff to collect fees.

3.0 Park/Reserve Guidelines and Use

3.1 <u>Guidelines for Recreational Use</u>

1. Strictly control use of the beaches known to be nesting grounds for sea turtles; e.g., Platanitos Beach.
2. Regulate use of all beaches to prevent damage to vegetation and habitat of shoreline species.
3. Allow only passive use of the marine resources within the park (i.e. **NO** taking of coral, sea shells, soft corals).
4. Establish guidelines for recreational boating (to help keep boats out of shallow fragile reef areas and prevent dumping of wastes in the nearshore waters of the parks).

3.2 Guidelines for Land Developers

1. Prohibit all beach and berm sand extraction.
2. Prohibit the removal of strand vegetation from dune systems.
3. Encourage the use of wooden walkways or boardwalks for foot passage to the beach.
4. Designate anchoring areas for recreational boats in high-use areas.
5. Site development with sufficient setbacks from beaches and dunes.
6. Minimize development of areas which, due to the slope, soil, or vegetative characteristics, could cause major coastal erosion and siltation of marine areas.
7. Retain, as much as possible, the mangroves of the NCZ which act as natural retention ponds of sediment from natural and human-induced runoff.
8. Avoid damage to coral communities
9. Prevent introduction of pollutants and sewage into coastal waters by installing efficient package treatment plants and on-site retention and treatment of liquid wastes.

3.3 Guidelines for Fisheries Use

1. Sustainable use of the fisheries resource is not an incompatible use in a Marine Park/Reserve. A Marine Park/Reserve is often the traditional fishing grounds of a community. Working with the community to establish sustainable fishing practices, within the context of a Park/Reserve, can benefit conservation of marine resources more effectively than banning fishing from the area.

4.0 Institute a Fisheries Management Program as Part of the Park/Reserve

Fisheries management to conserve the fisheries resources and their habitats can only be achieved with the cooperation of the fishermen. Working with the fishing community to establish simple ground rules and regulations that can be enforced seems to be the only way to protect the resource over the long term.

4.1 Fisheries Conservation Measures

4.1.1 Finfish

1. Catch limits by species and size class shall be established for all commercial fin fish
2. No person shall use spearfishing gear in the taking of fin fish
3. No person shall harvest fin fish using gill nets or other methods that result in significant bicatch

4.1.2 Lobsters

1. Lobster "undersize" means:
   (a) a carapace length of less than 95 mm, measured from immediately behind the rostral horns to the maximum concavity of the rear edge of the carapace; or
   (b) less than 680 grams in weight; or
   (c) having a tail weighing less than 200 grams
2. No person shall harm, take, have in his possession, sell or purchase:
   (a) any lobster carrying eggs
   (b) any lobster which is undersize
   (c) any lobster which is molting
3. No person shall capture any lobster other than by hand, loop, pot, or trap
4. No person shall have in his/her possession or sell any lobster that has been speared, hooked, or otherwise impaled.
5. No person shall remove the eggs from a lobster, or have in his/her possession, sell or purchase a lobster from which the eggs have been removed.
6. The SEPESCA Minister may declare any season as a closed season for lobster by giving notice in The "Diario Official de la Federacion", or any other official publication.
7. No person shall fish for lobster during the period of a closed season for lobster.

4.1.3 Sea Turtles

1. No person shall:
   (a) fish for, take, sell, purchase or have in his/her possession any sea turtle or part thereof
   (b) disturb, take, sell, purchase or have in his/her possession any turtle eggs
   (c) interfere with any turtle nest

2. Beach environments should not be used as waste disposal sites
3. Beach cleaning, when necessary, should be accomplished using hand tools and not heavy machinery, which may deeply incise or compact the sand
4. All site development activities should be carried out in a manner designed to minimize potential impacts upon sea turtles or their nesting or feeding habitats
5. Artificial light sources shall be positioned so that the source of light is not directly visible from the beach, does not directly illuminate areas of the beach, or emit wavelengths (560-620 nm) which do not disorient hatchlings
6. Low pressure sodium lights should be used to the maximum extent possible
7. Nighttime and security lighting shall be mounted not more than 5 meters above the ground, and shall not directly illuminate areas seaward of the primary dune or line of permanent vegetation
8. Low intensity, ground-level lighting is encouraged, both for aesthetic reasons and to minimize beach illumination
9. No lighting, regardless of wavelength, should be placed between sea turtle nests and the sea
10. All lights on balconies should be shielded from the beach
11. Lighting for decorative and accent purposes within line-of-sight of the beach shall be prohibited, and the use of lights for safety and security purposes shall be limited to the minimum number required to achieve their functional roles
12. In nesting season, interior lights from buildings shall be prevented by the use of: blackout draperies, shade-screens, and/or window tint/film with a shading coefficient of 0.37 to 0.45
13. Site inspection shall be conducted after completion of construction activities (and periodically thereafter), to verify that beach illumination is minimized, and is in accordance with regulations designed to protect nesting or hatching sea turtles
14. Parking lots and roadways should be designed and positioned such that vehicular headlights do not cast light toward the beach. Vehicular lighting should be shielded from the beach through the use of hedges, dune vegetation or other ground-level barriers
15. The operation of all motorized vehicles (with the exception of emergency and law enforcement vehicles) should be prohibited on all beaches
16. Sand mining should be prohibited on all beaches of the NCZ, and the prohibition strongly enforced
17. Vegetation above mean high tide should not be removed from the beach
18. Beach fires should be restricted to designated grill facilities

19. Shoreline stabilizing structures, such as the placement of riprap (loose rock) or the construction of cement walls parallel or perpendicular to the sea, should be discouraged. Cycles of erosion are naturally followed by cycles of accretion. Disruption of these natural cycles should be avoided
20. Recreational equipment should be removed from the beach early each evening during the nesting and hatching seasons, to avoid obstructing nesting or hatching sea turtles
21. The dumping of solid waste, such as plastics, into the sea shall be prohibited
22. Research on sea turtles should be encouraged, in order to improve conservation areas and techniques within the NCZ

4.1.4 Corals

1. No person shall take or collect coral from fisheries waters, except with the written permission of SEPESCA, in accordance with such conditions as may be specified

4.1.5 Aquarium Fish

1. No person shall import, sell, or export any aquarium fish, except with the permission of SEPESCA, in accordance with such conditions as may be specified

4.1.6 Fisheries Research

1. These regulations shall not apply to fishing operations which are conducted solely for the purpose of fisheries research, provided that 1) permission has been granted in respect of such operations by SEPESCA, under the Fisheries Law, and 2) the operations are carried out in accordance with the conditions of such permission

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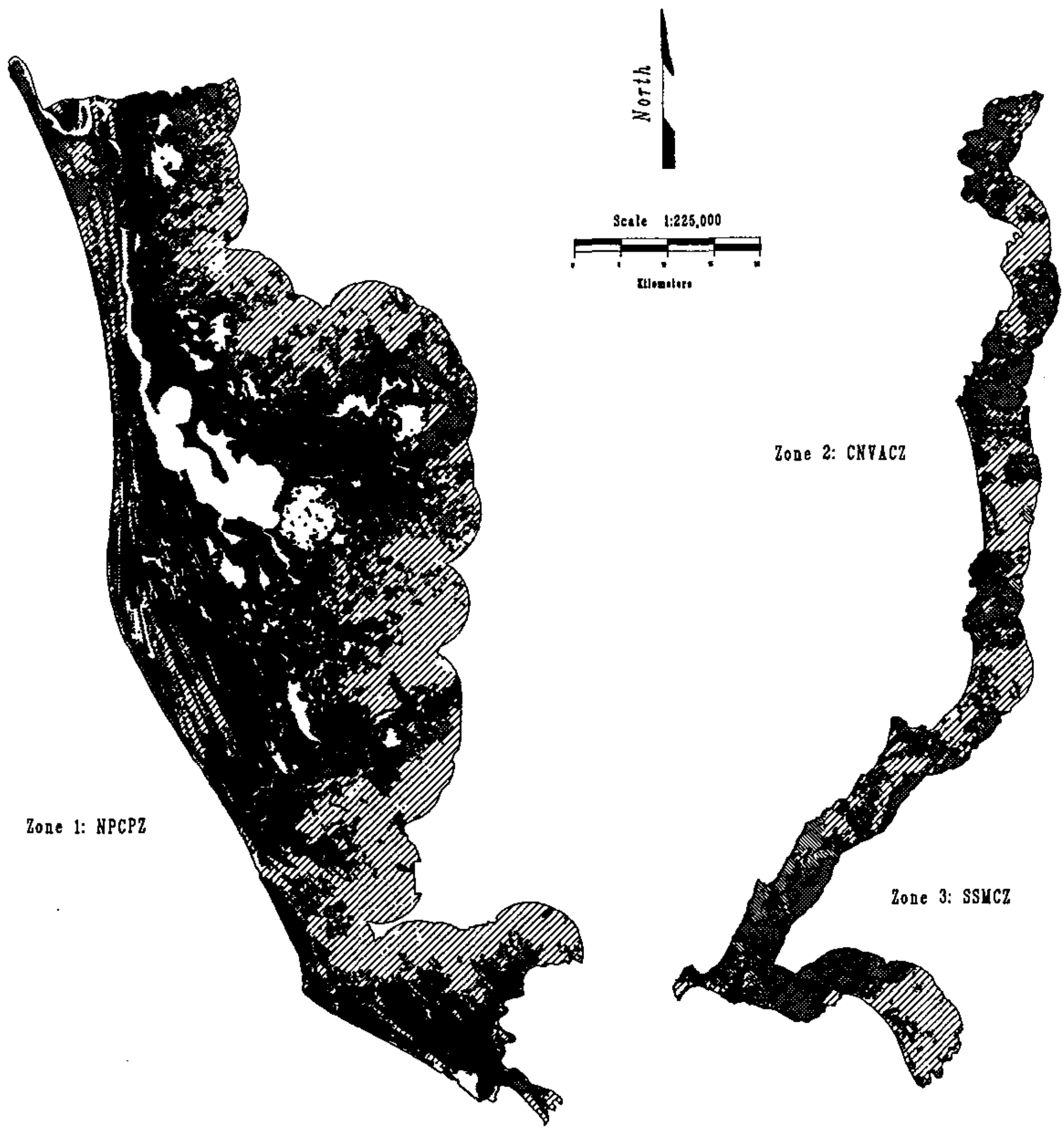


Coastal Zone of
Nayarit, Mexico

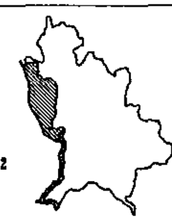
Land Cover

Emergy Analysis Perspectives, Public Policy Options, and Development Guidelines for the Coastal Zone of Nayarit, Mexico

A Research Project Funded by
the State of Nayarit, Mexico

Map Legend

- Wetlands
- Jungle
- Forest
- Agriculture
- Open Water



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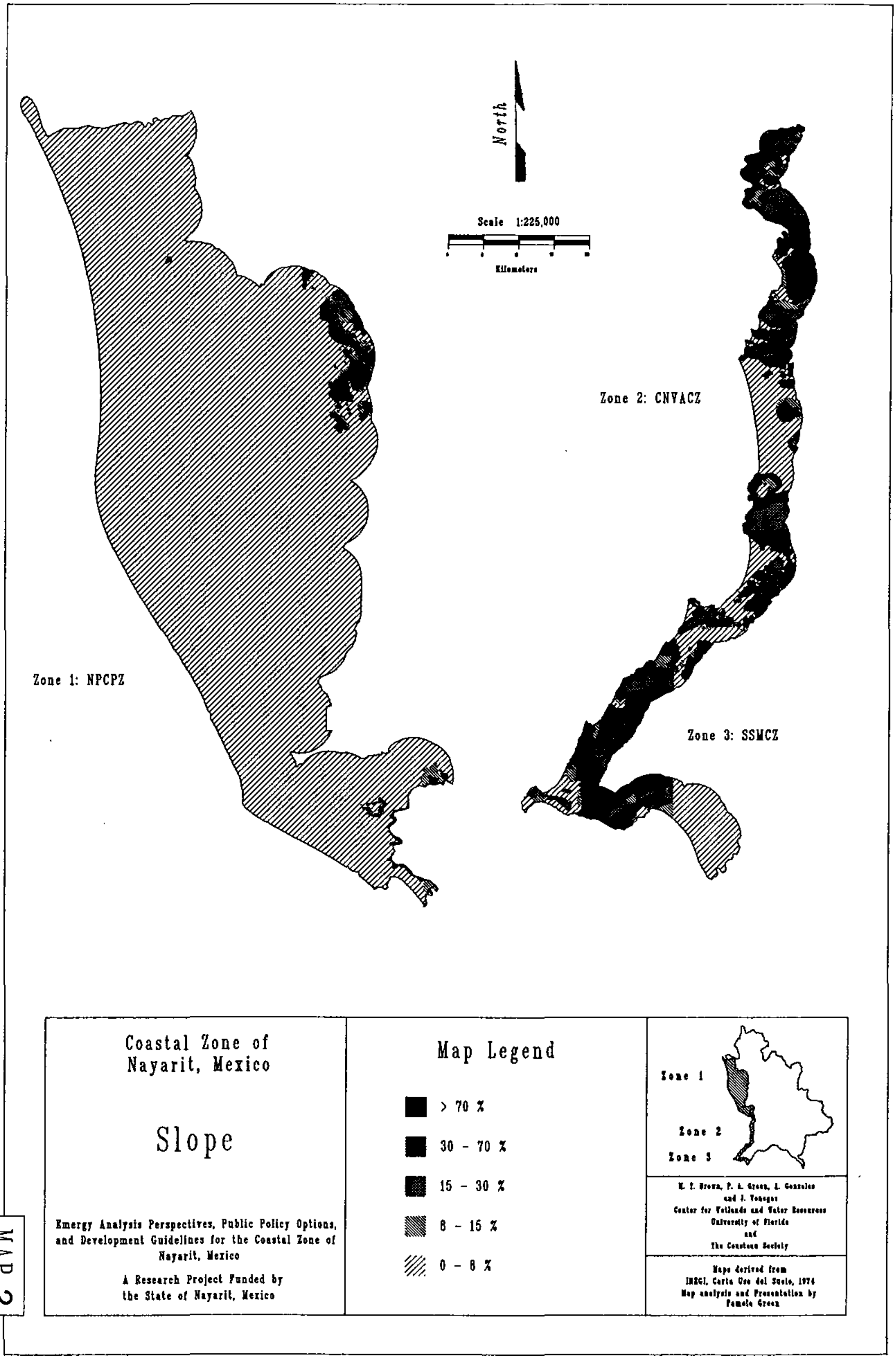
University of Florida
and
The Cousteau Society

Maps derived from
INEGI, Carta Uso del Suelo, 1974
Map analysis and Presentation by
Pamela Green

MAP 1


North
Scale 1:225,000
Kilometers
Zone 1: NPCPZ
Zone 2: CNVACZ
Zone 3: SSMCZ
Coastal Zone of
Nayarit, Mexico
Slope
Emergy Analysis Perspectives, Public Policy Options, and Development Guidelines for the Coastal Zone of Nayarit, Mexico
A Research Project Funded by
the State of Nayarit, Mexico
Map Legend
> 70 %
30 - 70 %
15 - 30 %
8 - 15 %
0 - 8 %
Zone 1
Zone 2
Zone 3
Center for Wetlands and Water Resources
University of Florida
and
The Cousteau Society
Maps derived from
Map analysis and Presentation by
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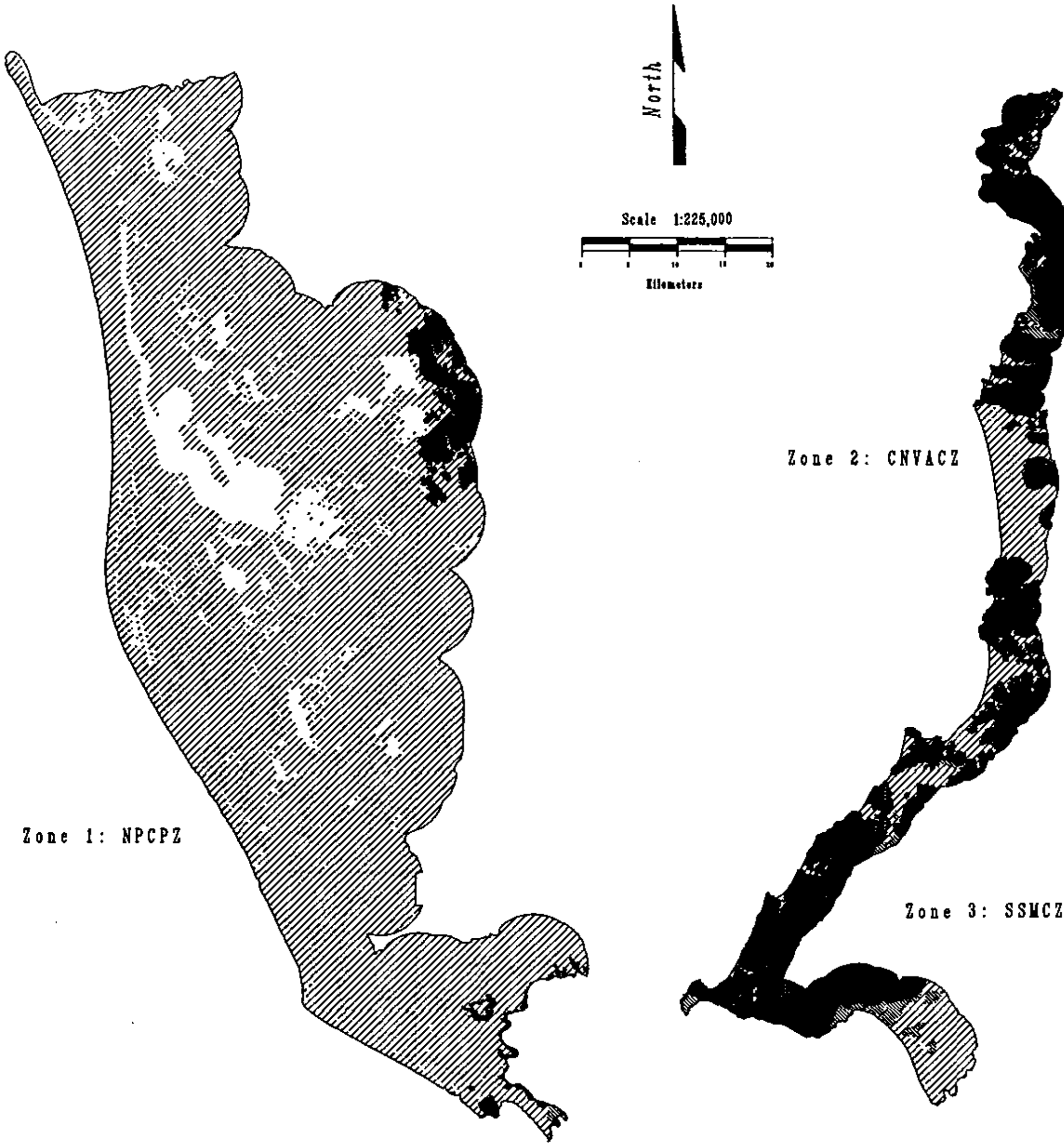
MAP 2



Coastal Zone of Nayarit, Mexico

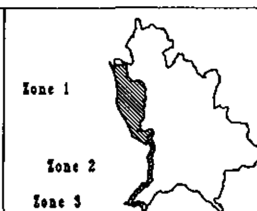
Geology/Soils

Emergy Analysis Perspectives, Public Policy Options, and Development Guidelines for the Coastal Zone of Nayarit, Mexico

A Research Project Funded by the State of Nayarit, Mexico

Map Legend

- Igneous Rock
- Metamorphic Rock
- Sedimentary Rock
- Soil



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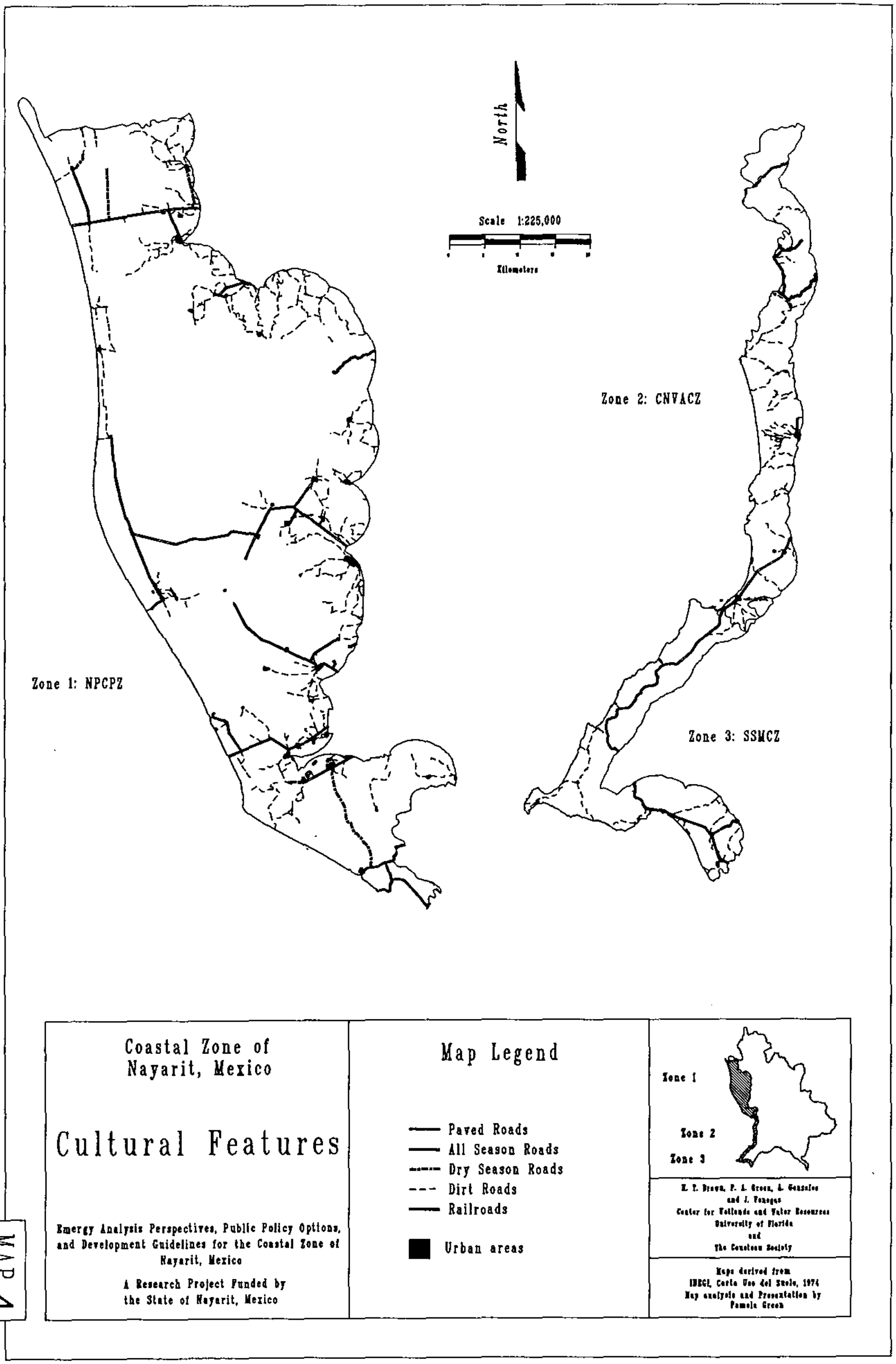
MAP 3


North
Scale 1:225,000
Kilometers
Zone 1: NPCPZ
Zone 2: CNVACZ
Zone 3: SSMCZ
Coastal Zone of
Nayarit, Mexico
Cultural Features
Emergy Analysis Perspectives, Public Policy Options, and Development Guidelines for the Coastal Zone of Nayarit, Mexico
A Research Project Funded by
the State of Nayarit, Mexico
Map Legend
Paved Roads
All Season Roads
Dry Season Roads
Dirt Roads
Railroads
Urban areas
Zone 1
Zone 2
Zone 3
Center for Wetlands and Water Resources
University of Florida
and
Maps derived from
Map analysis and Presentation by
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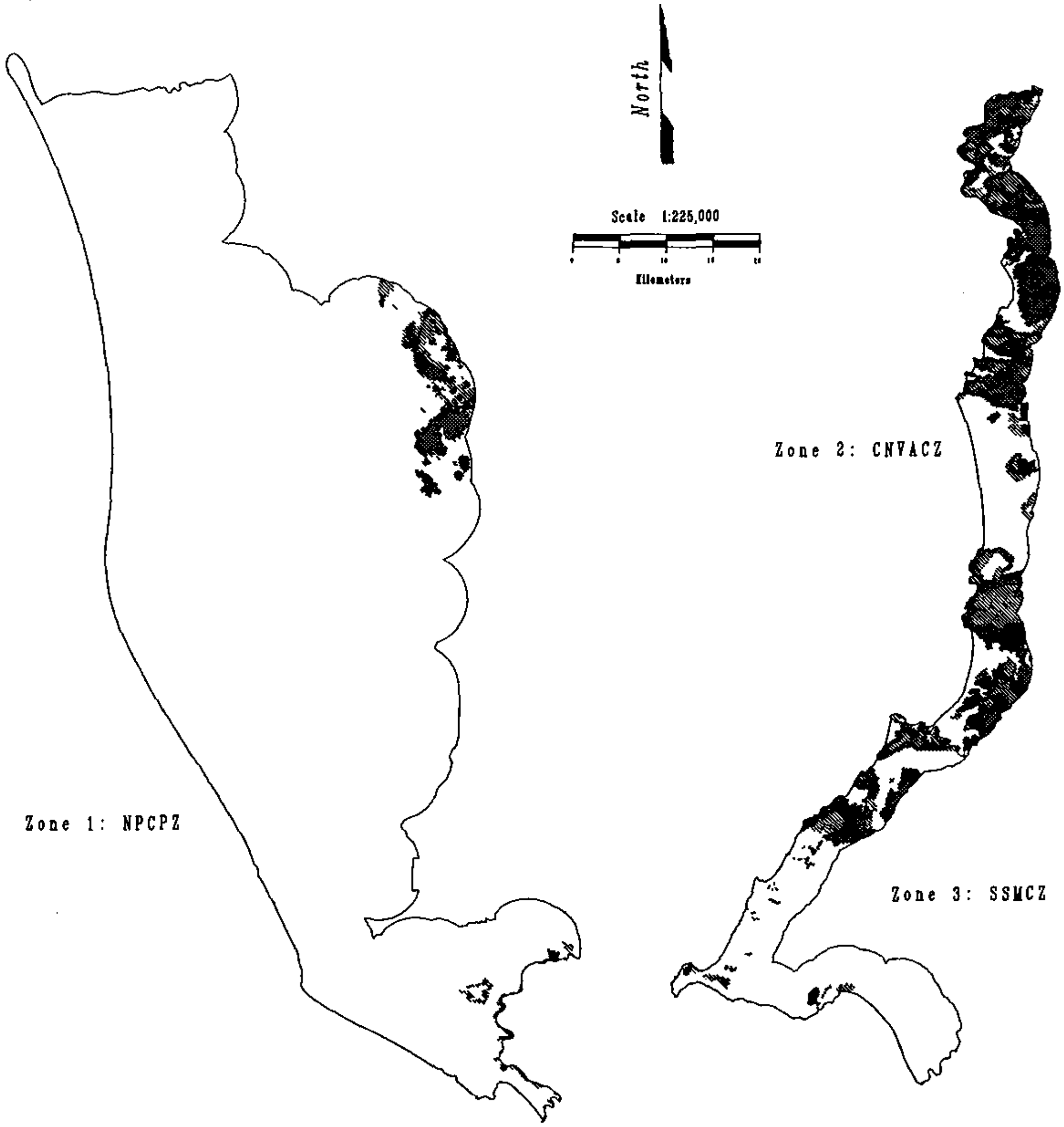
MAP 4



Coastal Zone of
Nayarit, Mexico

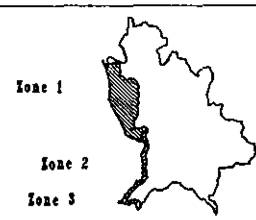
Slope Constraints

Emergy Analysis Perspectives, Public Policy Options, and Development Guidelines for the Coastal Zone of Nayarit, Mexico

A Research Project Funded by
the State of Nayarit, Mexico

Map Legend

- Slope > 70 %
- Slope 30 - 70 % with Soil, Sedimentary Rock or Metamorphic Rock
- Slope 15 - 30 % with Soil or Sedimentary Rock



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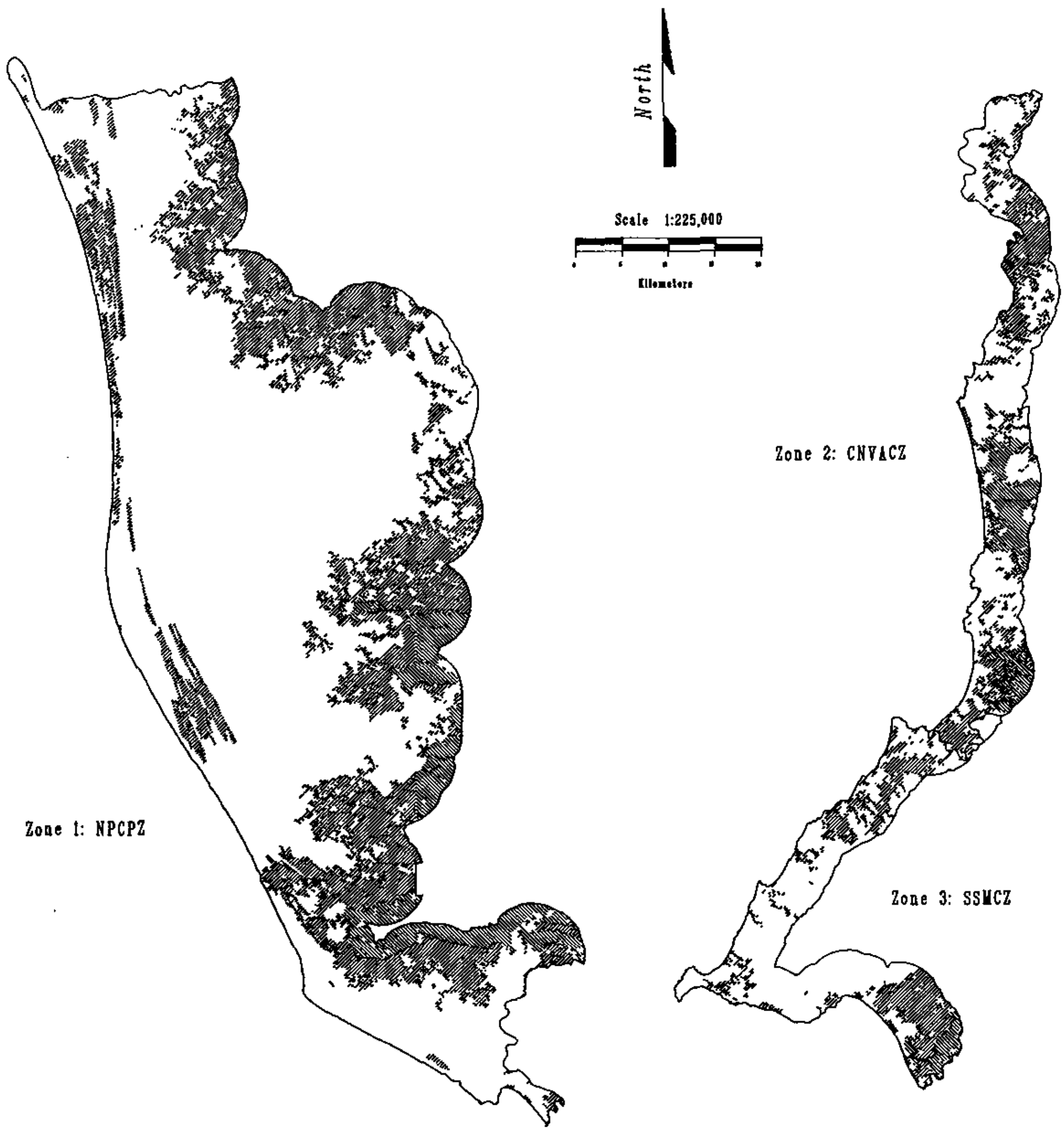
MAP 5



Coastal Zone of Nayarit, Mexico

Agricultural Constraints

Emergy Analysis Perspectives, Public Policy Options, and Development Guidelines for the Coastal Zone of Nayarit, Mexico

A Research Project Funded by the State of Nayarit, Mexico

Map Legend

- Irrigated Agriculture
- Temporal Agriculture
- Cultivated Pasture

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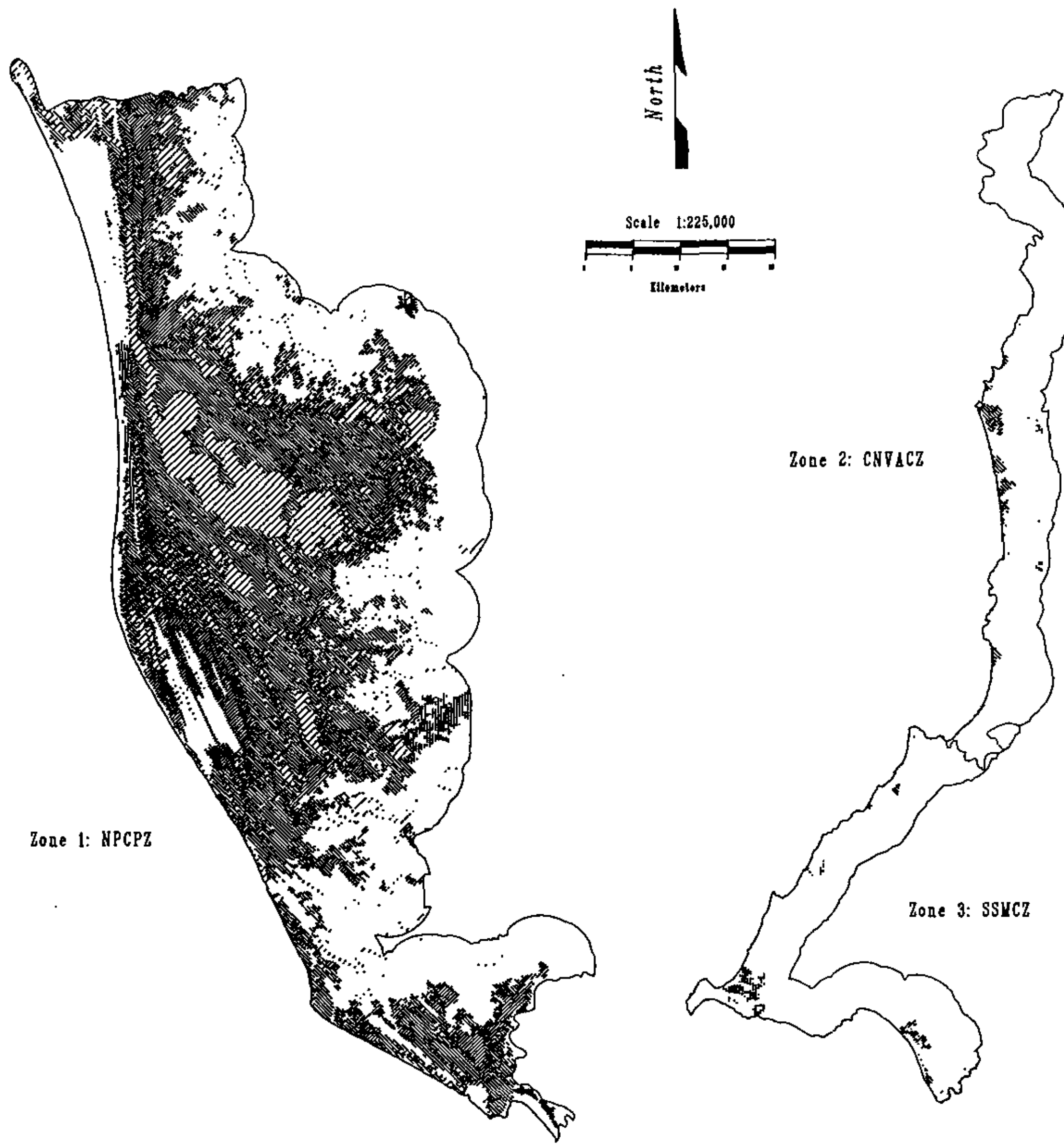
MAP 6



Coastal Zone of
Nayarit, Mexico

Wetland Constraints

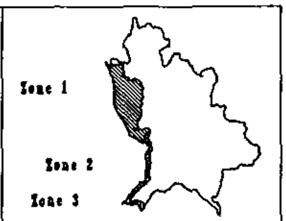
Emergy Analysis Perspectives, Public Policy Options, and Development Guidelines for the Coastal Zone of Nayarit, Mexico

A Research Project Funded by
the State of Nayarit, Mexico

MAP 7

Map Legend

- Open Water
- Mangrove
- Salt Marsh
- Hydric Palms
- Fresh Marsh



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Map analysis and Presentation by
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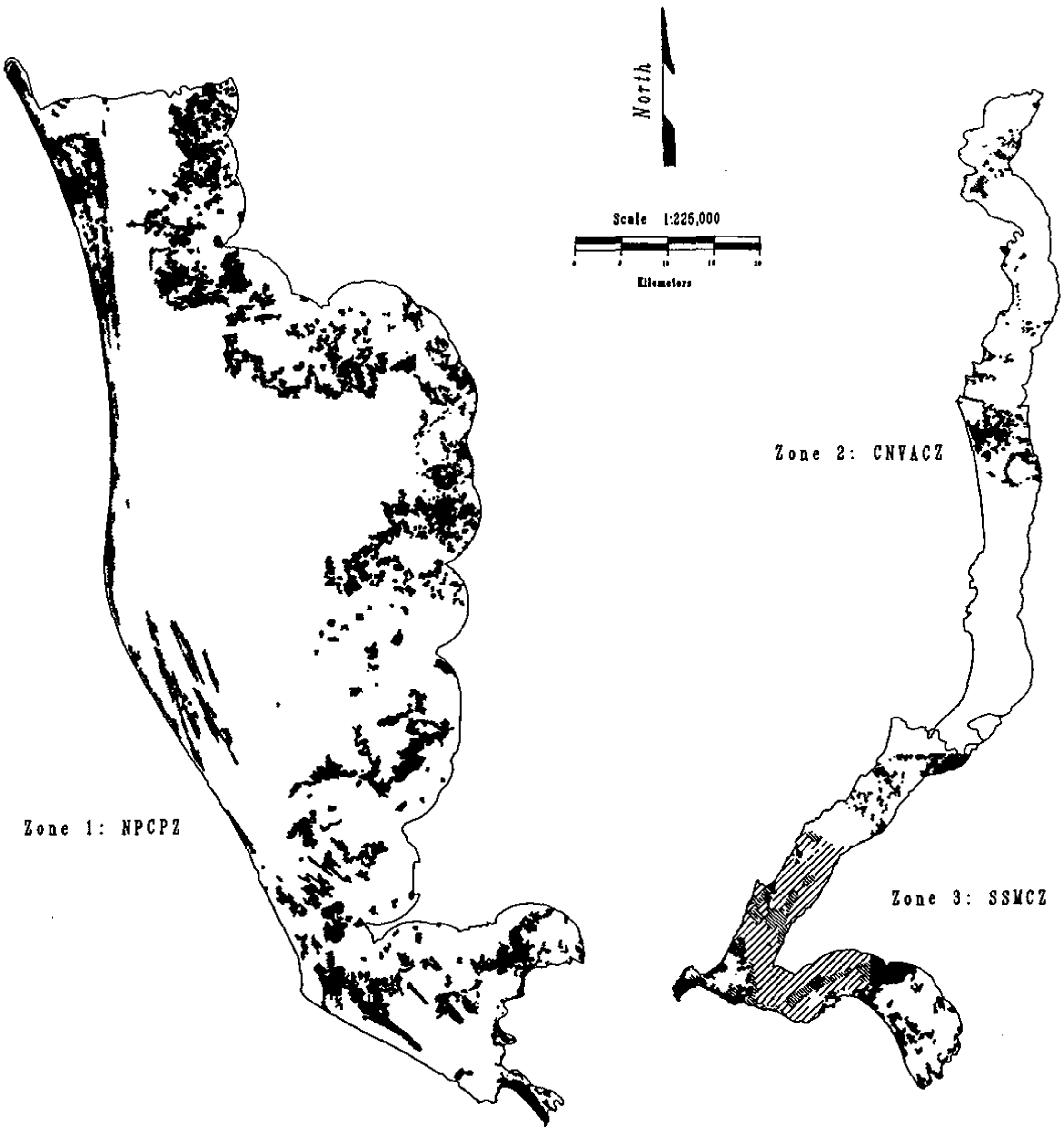

Coastal Zone of Nayarit, Mexico

Slope Opportunities

Emergy Analysis Perspectives, Public Policy Options, and Development Guidelines for the Coastal Zone of Nayarit, Mexico

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Map Legend

- 0 - 8 %
- 8 - 15 %
- 15 - 30 %
- 30 - 70 %

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INEGI, Carta Geologica, [illegible]
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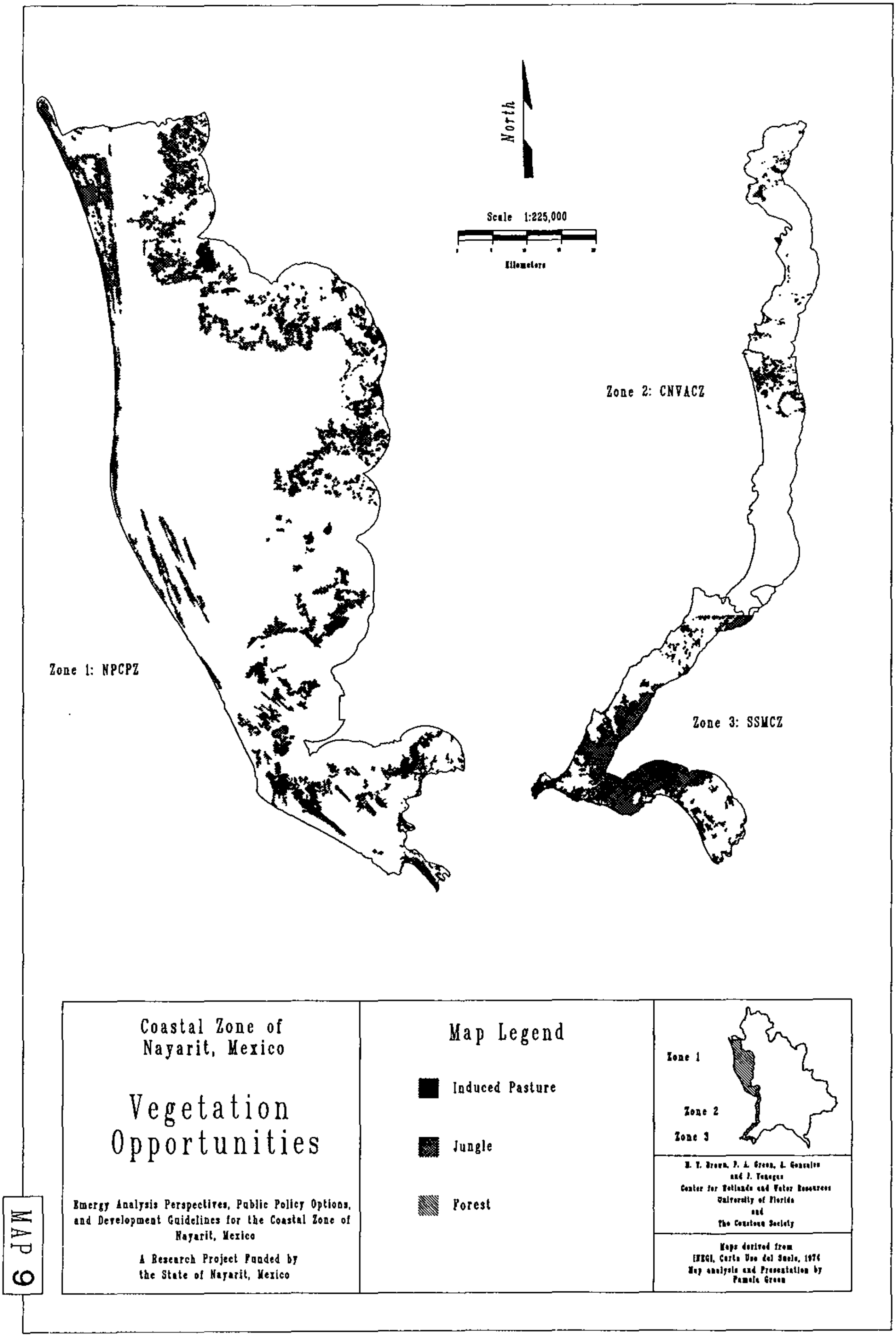
MAP 8


North
Scale 1:225,000
Kilometers
Zone 1: NPCPZ
Zone 2: CNVACZ
Zone 3: SSMCZ
Coastal Zone of
Nayarit, Mexico
Vegetation
Opportunities
Emergy Analysis Perspectives, Public Policy Options, and Development Guidelines for the Coastal Zone of Nayarit, Mexico
A Research Project Funded by
the State of Nayarit, Mexico
Map Legend
Induced Pasture
Jungle
Forest
Zone 1
Zone 2
Zone 3
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and
The Cousteau Society
Maps derived from
INEGI, Carta Uso del Suelo, 1976
Map analysis and Presentation by
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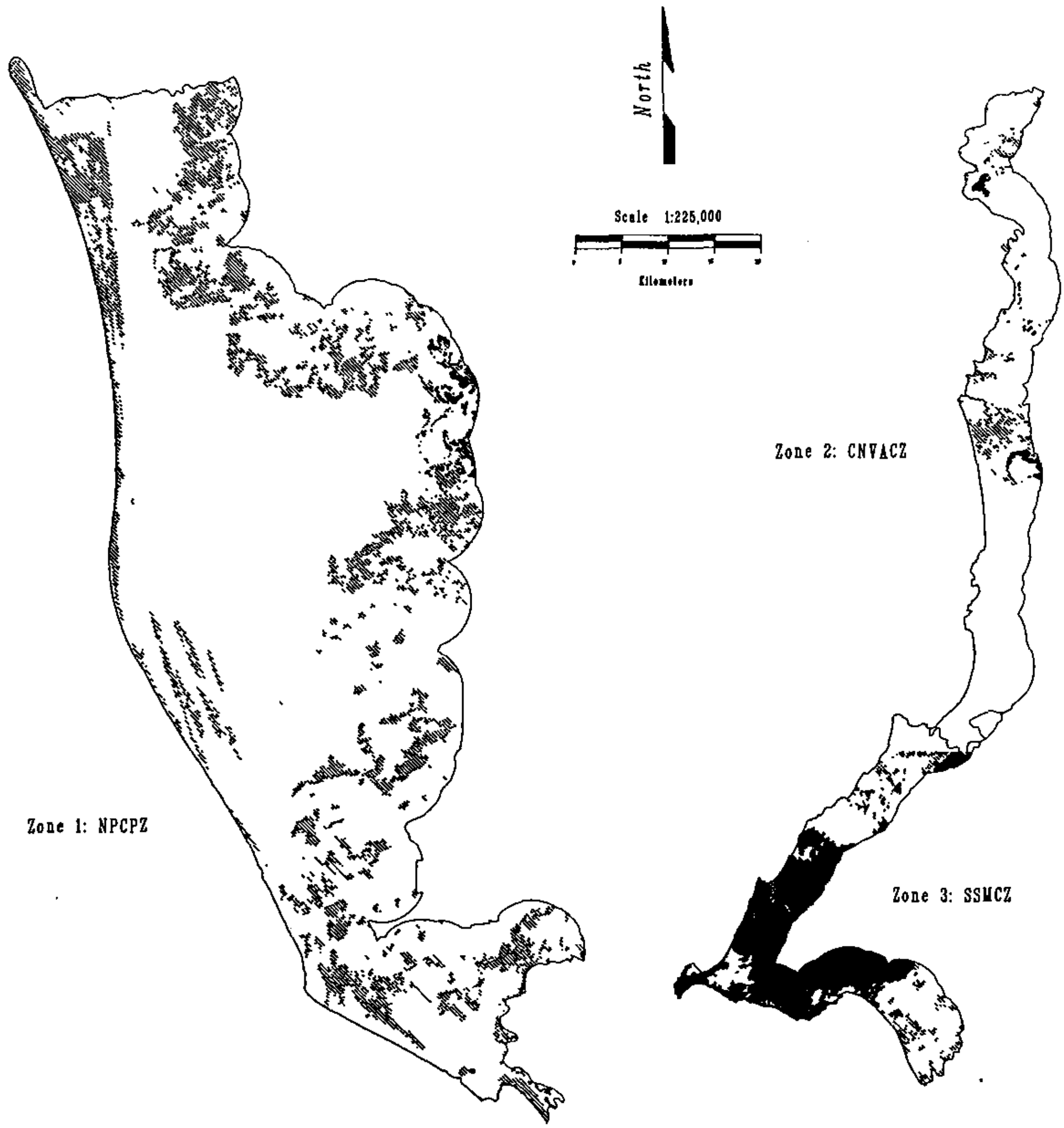
MAP 9



Coastal Zone of Nayarit, Mexico

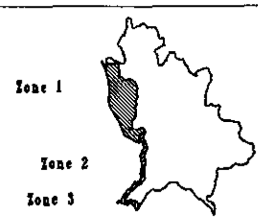
Geology/Soils Opportunities

Emergy Analysis Perspectives, Public Policy Options, and Development Guidelines for the Coastal Zone of Nayarit, Mexico

A Research Project Funded by the State of Nayarit, Mexico

Map Legend

- Igneous & Sedimentary Rock
- Metamorphic Rock
- Soil



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Maps derived from
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Map analysis and Presentation by
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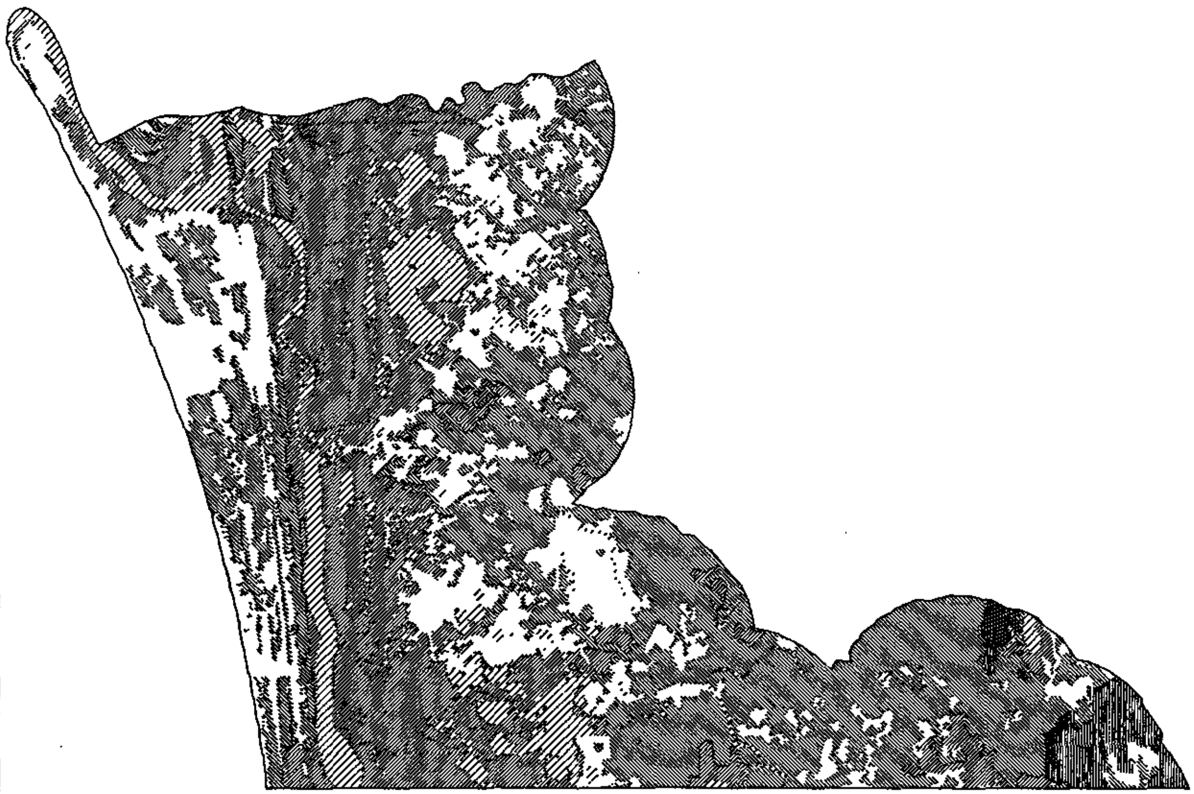
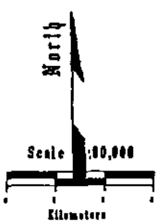
MAP10





Coastal Zone of
Nayarit, Mexico

Overall Development Constraints

Region 1

Emergy Analysis Perspectives, Public Policy Options, and Development Guidelines for the Coastal Zone of Nayarit, Mexico

A Research Project Funded by
the State of Nayarit, Mexico

Map Legend

- Open Water
- Slope Constraints
- Agricultural Constraints
- Wetland Constraints

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Maps derived from
INEGI, Carta Uso del Suelo, 1974
Map analysis and Presentation by
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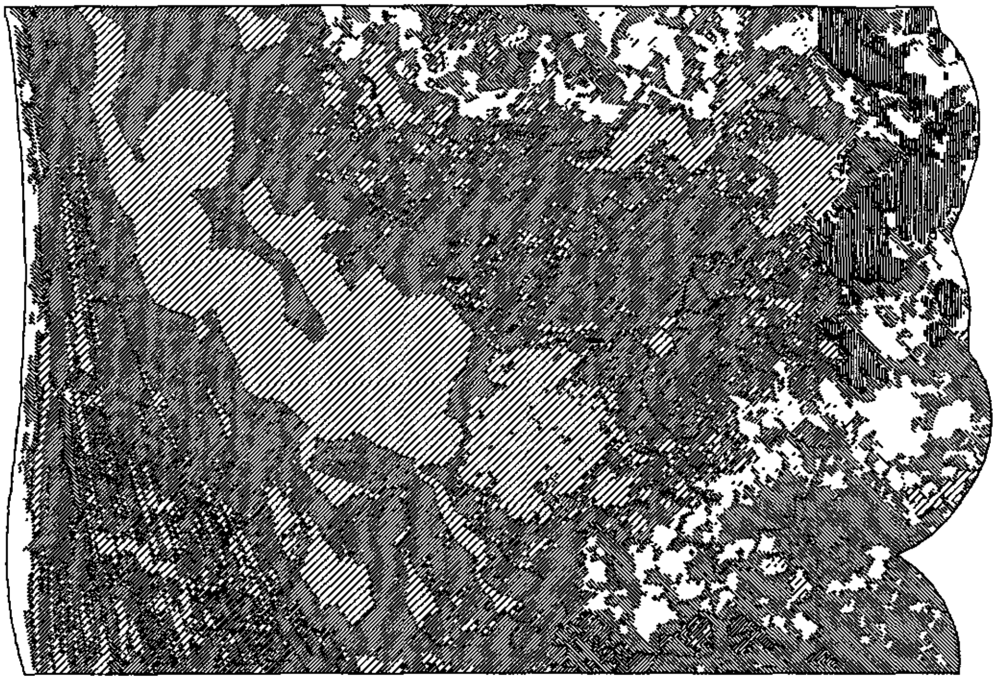
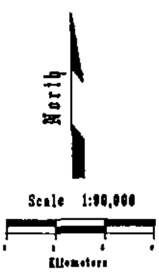
MAP11





Coastal Zone of Nayarit, Mexico

Overall Development Constraints

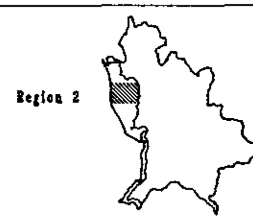
Region 2

Emergy Analysis Perspectives, Public Policy Options, and Development Guidelines for the Coastal Zone of Nayarit, Mexico

A Research Project Funded by the State of Nayarit, Mexico

Map Legend

- Open Water
- Slope Constraints
- Agricultural Constraints
- Wetland Constraints



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INEGI, Carta Uso del Suelo, 1974
Map analysis and Presentation by
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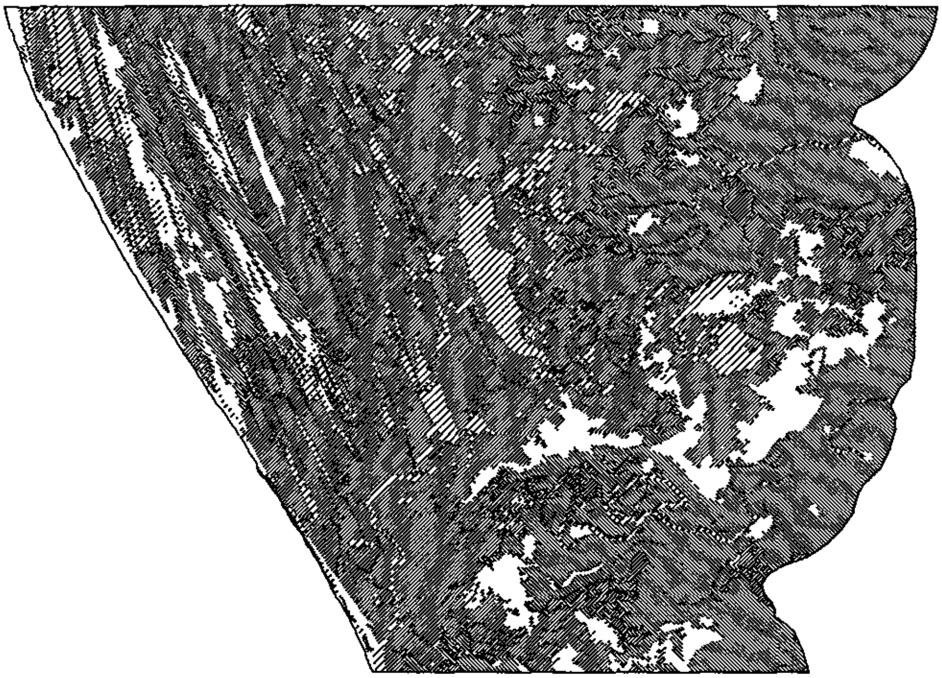
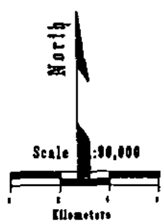
MAP12





Coastal Zone of Nayarit, Mexico

Overall Development Constraints

Region 3

Emergy Analysis Perspectives, Public Policy Options, and Development Guidelines for the Coastal Zone of Nayarit, Mexico

A Research Project Funded by the State of Nayarit, Mexico

Map Legend

- Open Water
- Slope Constraints
- Agricultural Constraints
- Wetland Constraints

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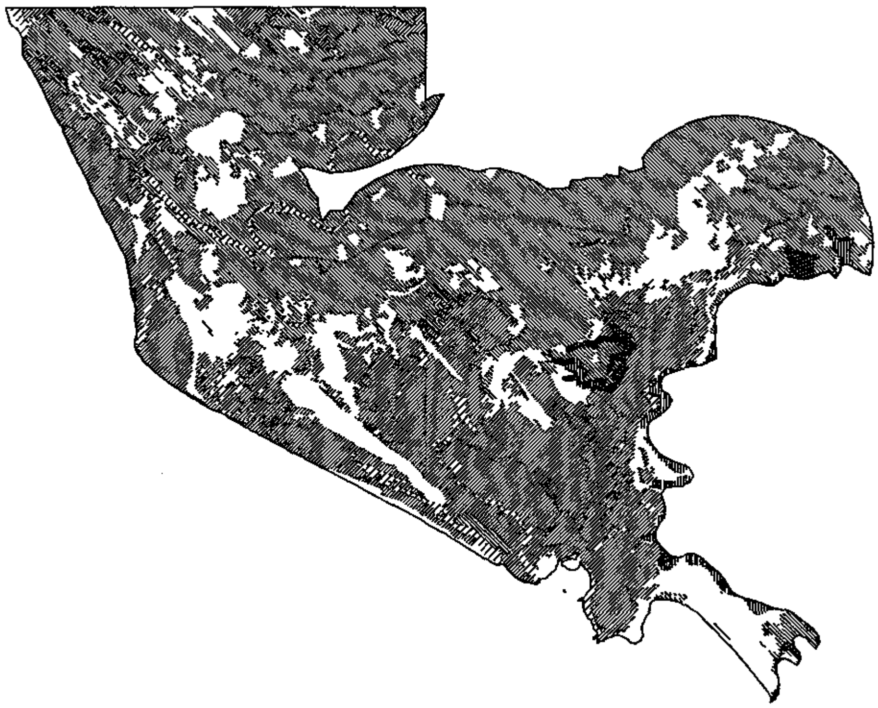
MAP13



Coastal Zone of
Nayarit, Mexico

Overall Development Constraints

Region 4

Emergy Analysis Perspectives, Public Policy Options, and Development Guidelines for the Coastal Zone of Nayarit, Mexico

A Research Project Funded by the State of Nayarit, Mexico

Map Legend

- Open Water
- Slope Constraints
- Agricultural Constraints
- Wetland Constraints

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Maps derived from
INEGI, Carta Uso del Suelo, 1974
Map analysis and Presentation by
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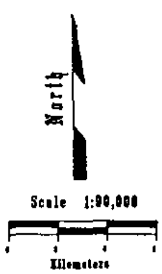
MAP 14



Coastal Zone of
Nayarit, Mexico

Overall Development Constraints

Region 5

Emergy Analysis Perspectives, Public Policy Options, and Development Guidelines for the Coastal Zone of Nayarit, Mexico

A Research Project Funded by
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Map Legend

- Open Water
- Slope Constraints
- Agricultural Constraints
- Wetland Constraints

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INEGI, Carta Uso del Suelo, 1974
Map analysis and Presentation by
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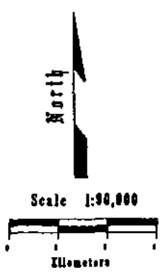
MAP 15



Coastal Zone of
Nayarit, Mexico

Overall Development Constraints

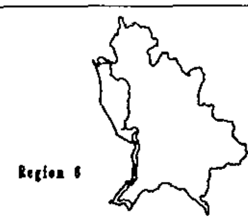
Region 6

Emergy Analysis Perspectives, Public Policy Options, and Development Guidelines for the Coastal Zone of Nayarit, Mexico

A Research Project Funded by
the State of Nayarit, Mexico

Map Legend

- Open Water
- Slope Constraints
- Agricultural Constraints
- Wetland Constraints



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Maps derived from
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Map analysis and Presentation by
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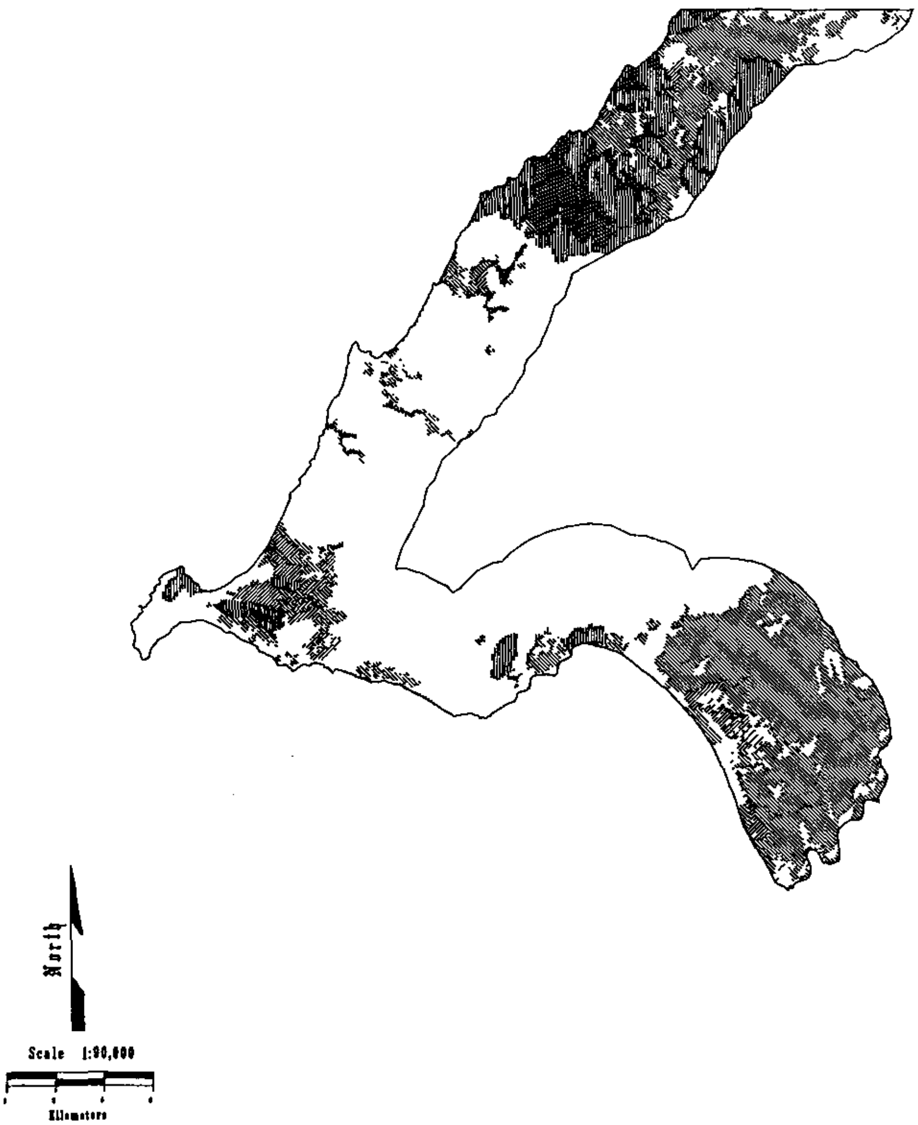
MAP16



Coastal Zone of
Nayarit, Mexico

Overall Development Constraints

Region 7

Emergy Analysis Perspectives, Public Policy Options, and Development Guidelines for the Coastal Zone of Nayarit, Mexico

A Research Project Funded by
the State of Nayarit, Mexico

Map Legend

- Open Water
- Slope Constraints
- Agricultural Constraints
- Wetland Constraints

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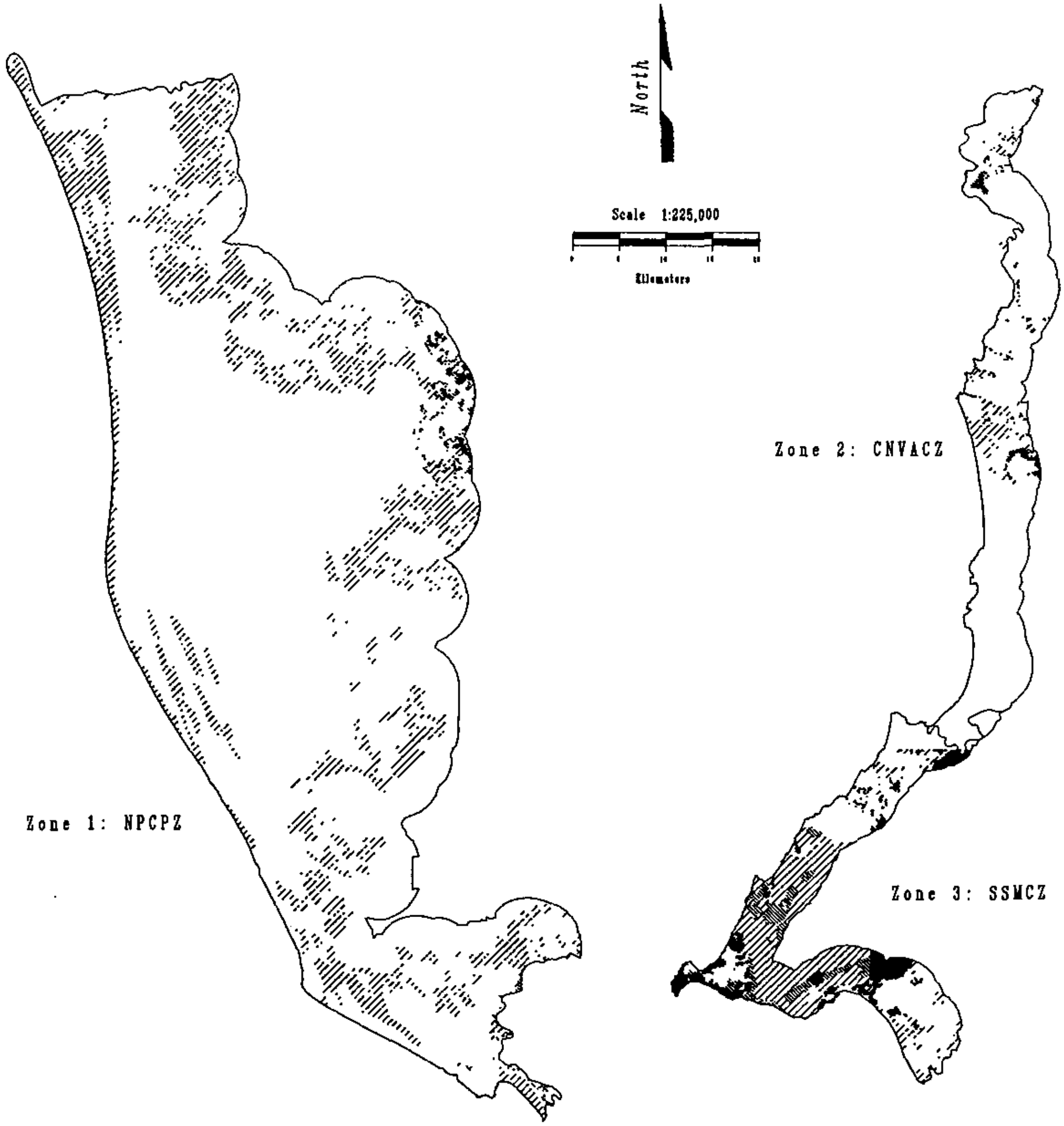
Map analysis and Presentation by
Pamela Green

MAP17



Coastal Zone of Nayarit, Mexico

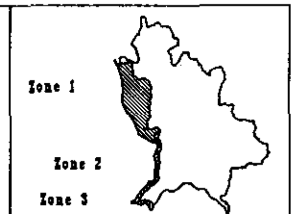
Overall Development Potential

Emergy Analysis Perspectives, Public Policy Options, and Development Guidelines for the Coastal Zone of Nayarit, Mexico

A Research Project Funded by the State of Nayarit, Mexico

Map Legend

- LDI District 6
- LDI District 3 & 4
- LDI District 2
- LDI District 1
- No Development



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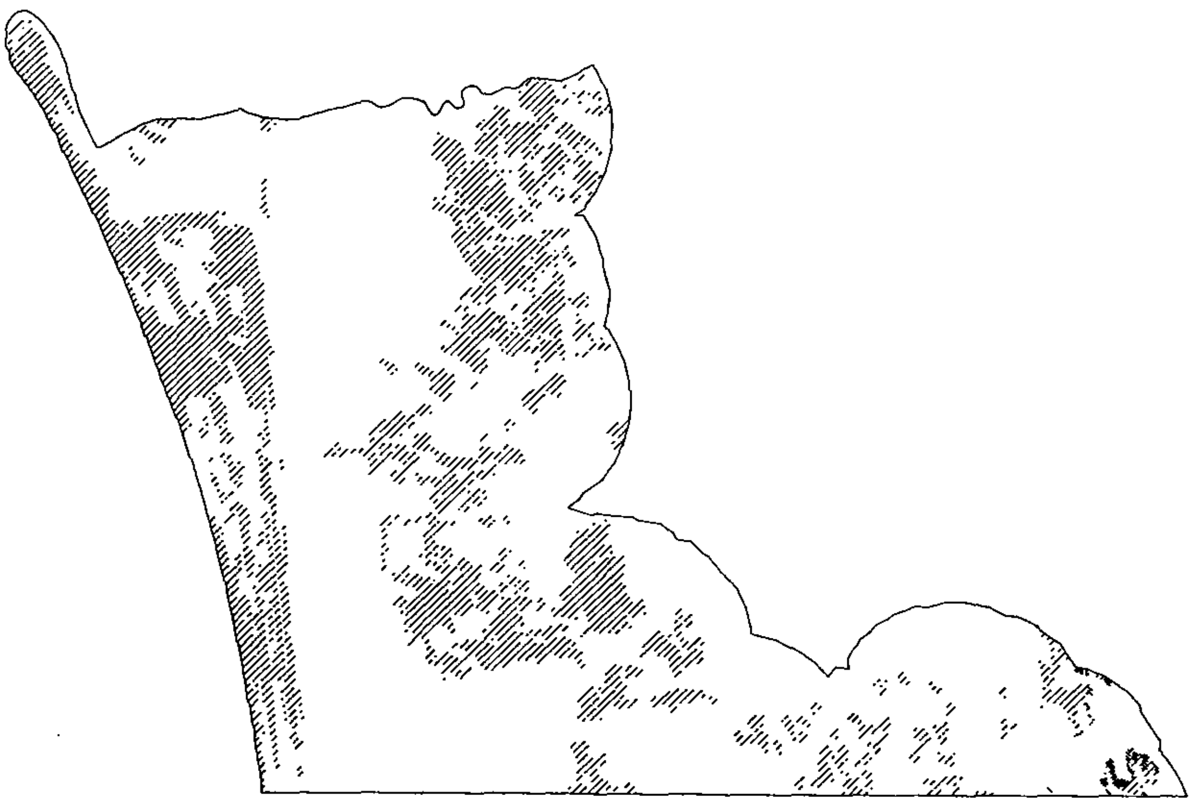
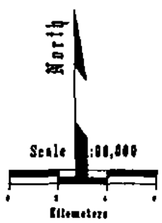
Map analysis and Presentation by Pamela Green

MAP18





Coastal Zone of
Nayarit, Mexico

Overall Development Potential

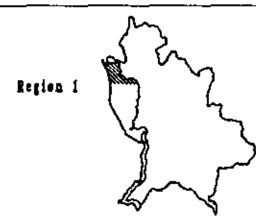
Region 1

Emergy Analysis Perspectives, Public Policy Options, and Development Guidelines for the Coastal Zone of Nayarit, Mexico

A Research Project Funded by the State of Nayarit, Mexico

Map Legend

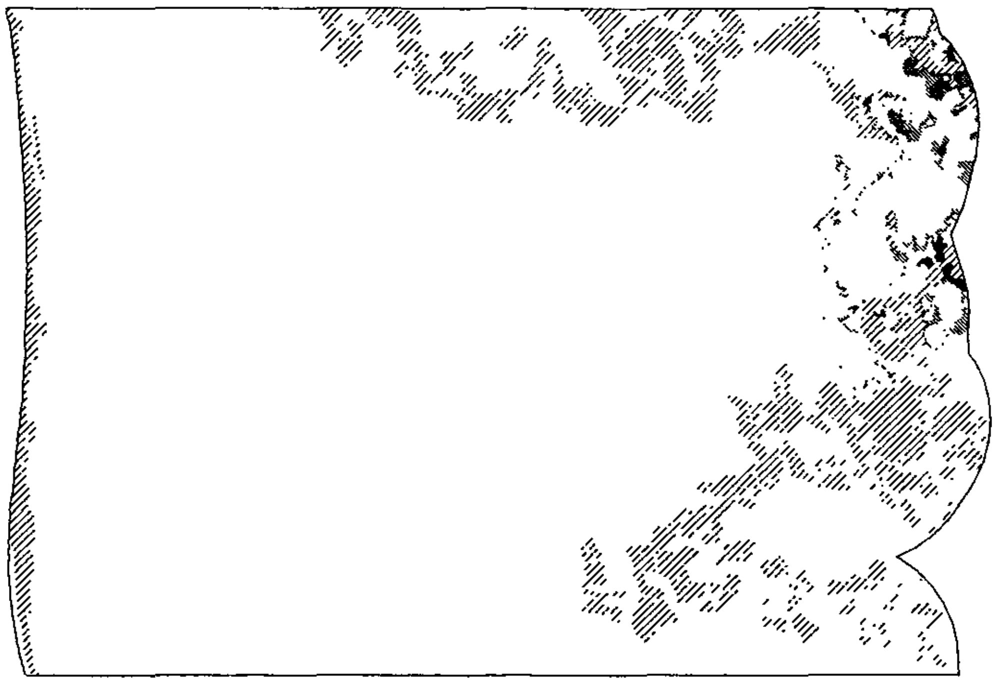
- LDI District 6
- LDI District 3 & 4
- LDI District 2
- LDI District 1
- No Development

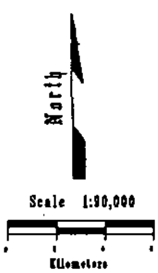


M. T. Brown, P. A. Green, A. Gonzalez
and J. Venegas
Center for Wetlands and Water Resources
University of Florida
and
The Cousteau Society

Maps derived from
INEGI, Carta Uso del Suelo, 1976
Map analysis and Presentation by
Pamela Green

MAP19





Coastal Zone of Nayarit, Mexico

Overall Development Potential

Region 2

Emergy Analysis Perspectives, Public Policy Options, and Development Guidelines for the Coastal Zone of Nayarit, Mexico

A Research Project Funded by the State of Nayarit, Mexico

Map Legend

- LDI District 6
- LDI District 3 & 4
- LDI District 2
- LDI District 1
- No Development

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MAP 20

Coastal Zone of
Nayarit, Mexico

Overall Development Potential

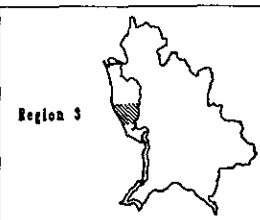
Region 3

Emergy Analysis Perspectives, Public Policy Options, and Development Guidelines for the Coastal Zone of Nayarit, Mexico

A Research Project Funded by the State of Nayarit, Mexico

Map Legend

- LDI District 6
- LDI District 3 & 4
- LDI District 2
- LDI District 1
- No Development



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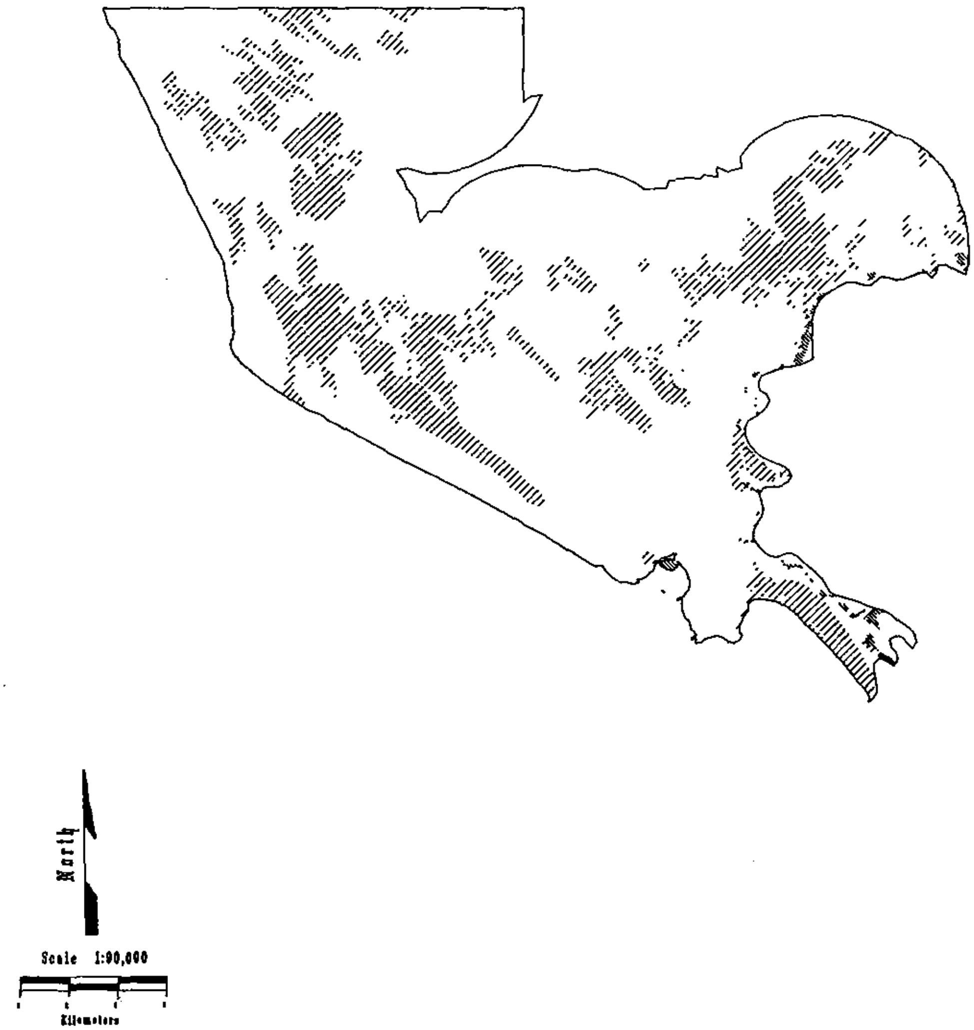
MAP21



Coastal Zone of
Nayarit, Mexico

Overall Development Potential

Region 4

Emergy Analysis Perspectives, Public Policy Options, and Development Guidelines for the Coastal Zone of Nayarit, Mexico

A Research Project Funded by
the State of Nayarit, Mexico

Map Legend

- LDI District 6
- LDI District 3 & 4
- LDI District 2
- LDI District 1
- No Development

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MAP22

Coastal Zone of Nayarit, Mexico

Overall Development Potential

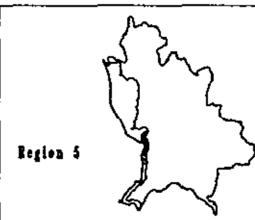
Region 5

Emergy Analysis Perspectives, Public Policy Options, and Development Guidelines for the Coastal Zone of Nayarit, Mexico

A Research Project Funded by the State of Nayarit, Mexico

Map Legend

- LDI District 6
- LDI District 3 & 4
- LDI District 2
- LDI District 1
- No Development



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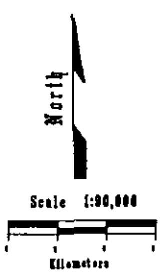
MAP 23



Coastal Zone of Nayarit, Mexico

Overall Development Potential

Region 6

Emergy Analysis Perspectives, Public Policy Options, and Development Guidelines for the Coastal Zone of Nayarit, Mexico

A Research Project Funded by the State of Nayarit, Mexico

Map Legend

- LDI District 6
- LDI District 3 & 4
- LDI District 2
- LDI District 1
- No Development

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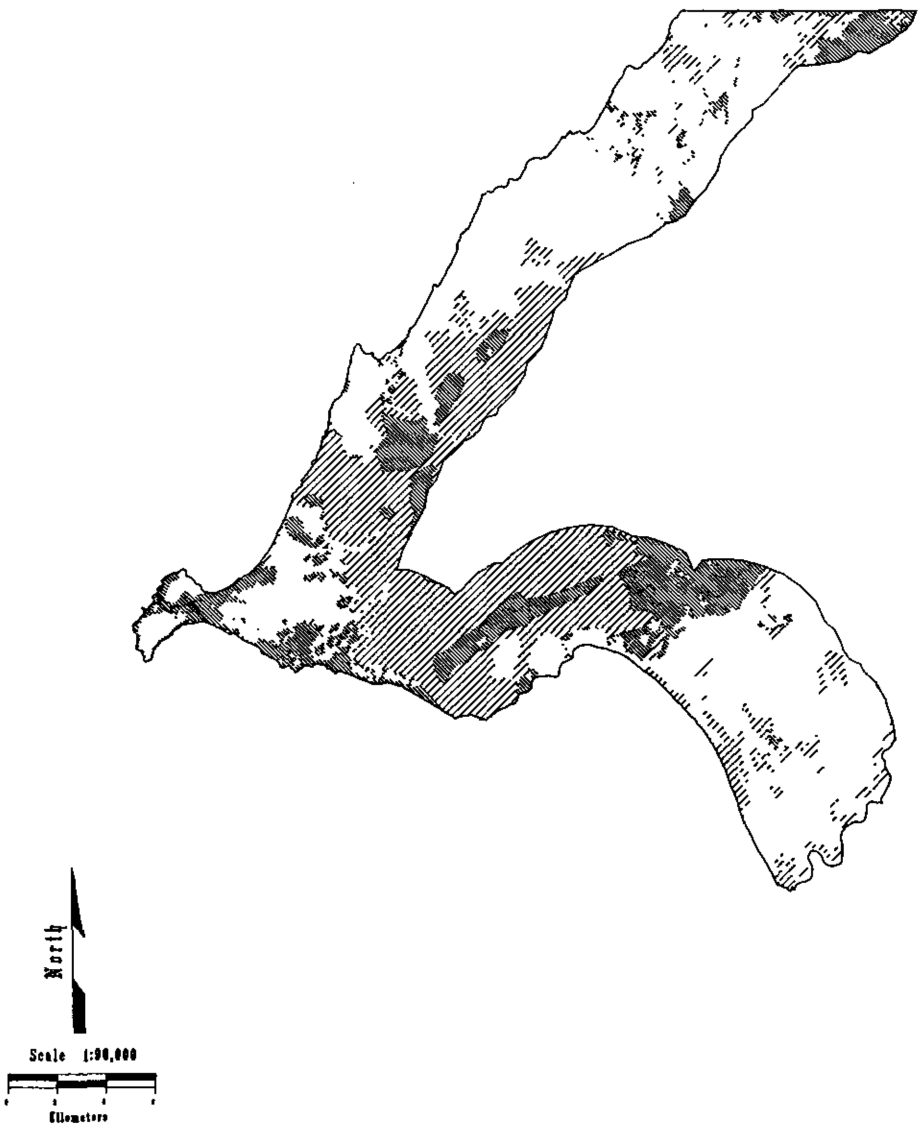
MAP 24



Coastal Zone of
Nayarit, Mexico

Overall Development Potential

Region 7

Emergy Analysis Perspectives, Public Policy Options, and Development Guidelines for the Coastal Zone of Nayarit, Mexico

A Research Project Funded by the State of Nayarit, Mexico

Map Legend

- LDI District 6
- LDI District 3 & 4
- LDI District 2
- LDI District 1
- No Development

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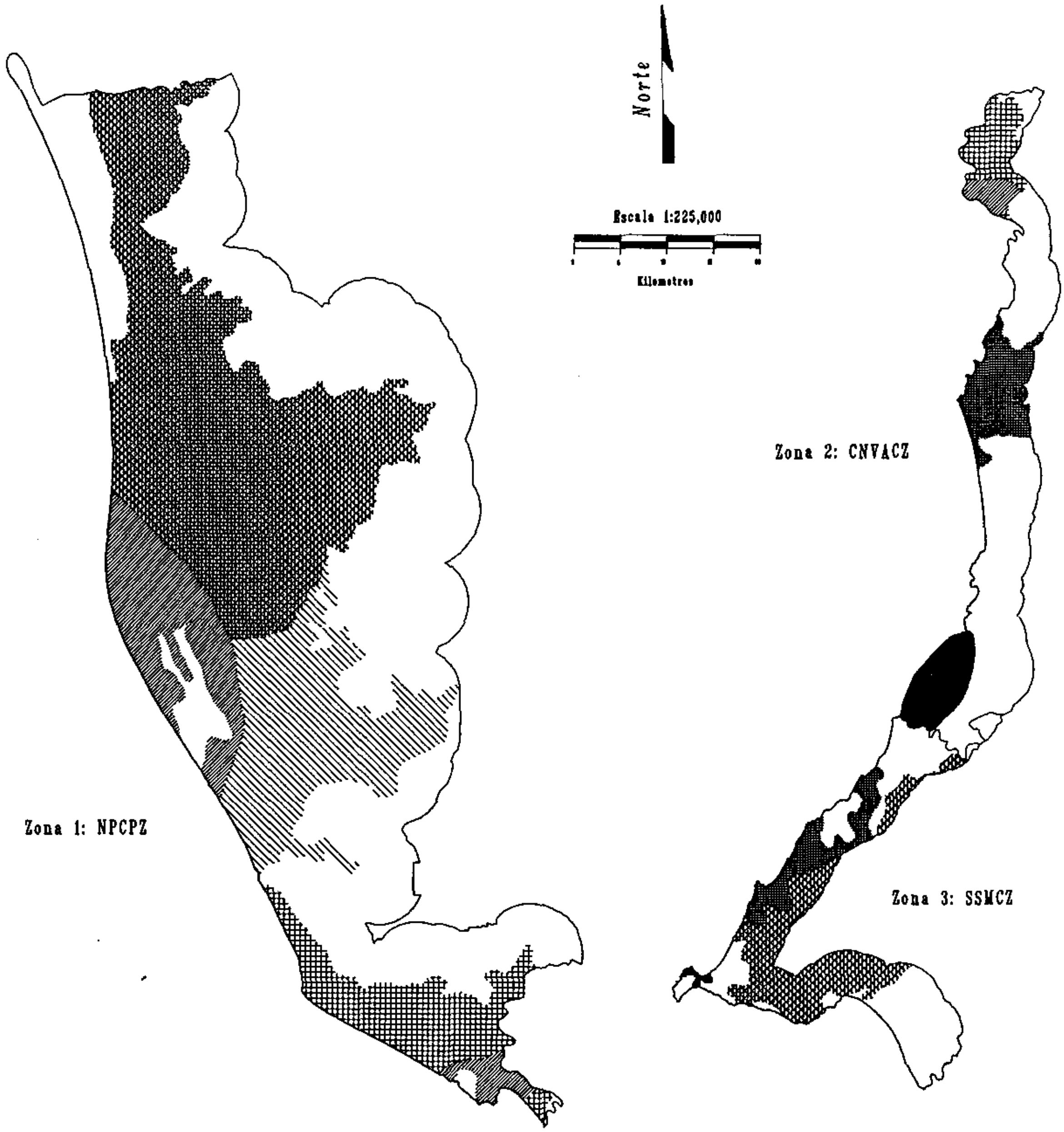
MAP25



Zona Costera de Nayarit, Mexico

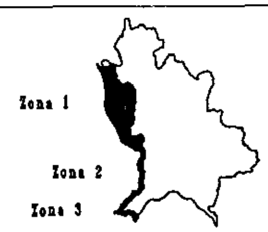
Reservas Propuestas y Areas Protejidas

Perspectivas del Analysis de Emergia, Opciones de Politica Publica Reglamentos de Desarrollo para la Zona Costera de Nayarit, Mexico

Projecto de Investigation Patrocinado por el Gobierno del Estado de Nayarit, Mexico

Leyenda de Mapa

- Reservas de la Biosfera
- Reservas Especial de la Biosfera
- Monumento Natural
- Parque Nacional
- Flora y Fauna Areas Protejidas
- Parque National de la Marina



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Universidad de Florida
y
La Sociedad Cousteau

Mapas Derivados del
INEGI, Carta Usos, [illegible]
Analysis y Presentacion por
Pamela Green

MAP 26

EMERGY ANALYSIS PERSPECTIVES, PUBLIC POLICY OPTIONS, AND DEVELOPMENT GUIDELINES FOR THE COASTAL ZONE OF NAYARIT, MEXICO

Report to
The Cousteau Society
and the
Government of Nayarit, Mexico

VOLUME 2:
EmergyAnalysis and Public Policy Options

By

Mark T. Brown
Pamela Green, Agustin Gonzalez, and Javier Venegas

September, 1992

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EMERGY ANALYSIS PERSPECTIVES, PUBLIC POLICY OPTIONS, AND DEVELOPMENT GUIDELINES FOR THE COASTAL ZONE OF NAYARIT, MEXICO

Report to
The Cousteau Society
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Volume 2: ***EMergy Analysis and Public Policy Options***

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Research Studies Conducted Under Contract No. 90071109

September, 1992

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EMERGY ANALYSIS PERSPECTIVES, PUBLIC POLICY OPTIONS, AND DEVELOPMENT GUIDELINES FOR THE COASTAL ZONE OF NAYARIT, MEXICO.

Volume 2: EMergy Analysis and Public Policy Options

TABLE OF CONTENTS

EMERGY ANALYSIS PERSPECTIVES, PUBLIC POLICY OPTIONS, AND DEVELOPMENT GUIDELINES FOR THE COASTAL ZONE OF NAYARIT, MEXICO

Volume 2: ***EMergy Analysis and Public Policy Options***

Mark T. Brown, Pamela Green, Agustin Gonzalez, and Javier Venegas

INTRODUCTION

This document is the second of a two volume report to The Cousteau Society and the Government of the State of Nayarit, Mexico (see Figure 1). It is an outgrowth of a 2-year study to develop a master plan for the coastal zone of Nayarit. As part of our effort, we developed a recommended Master Plan, comprised of a complete set of planning documents that included a map of Overall Development Potential, a regulatory framework, and the necessary legislation for implementation (given in Volume 1). In addition to the planning documents, the research team conducted EMergy analysis studies of fisheries, tourism, water use, and health care within the coastal zone. These studies provided the necessary background information for public policy decisions regarding the best use of resources and for determining carrying capacity of the coastal zone for future development. As part of our efforts, two Mexican students were trained in the methods of EMergy analysis and environmental planning.

This volume is composed of the results of our studies. While there are many aspects of the coastal zone and its environment and cultural systems that should be studied, time and resources dictated that only a few of the most important resource questions be addressed. In addition to the analysis of the Mexican economy and that of the State of Nayarit (that were necessary for background data), we selected the four areas listed above, which we felt would provide needed information for developing a strong and coherent proposed Master Plan.

Background

In July of 1990, The Cousteau Society received funds from the Governor of the State of Nayarit, Mexico for studies of the coastal resources of the State, with the ultimate goal of developing a proposed Master Development Plan. Nayarit was beginning to experience growth of populations and tourist facilities within its coastal zone, and wisely felt the need to protect and enhance its resources and foster environmentally compatible development. The Cousteau Society and a team of researches from the Center For Wetlands and Water Resources at the University of Florida embarked on a two-year effort to develop a proposed Master Development Plan for the coastal zone that would protect the cultural and environmental resources of Nayarit. The work effort was composed of two aspects: a research effort to apply techniques of EMergy analysis to questions of resource use, and a parallel

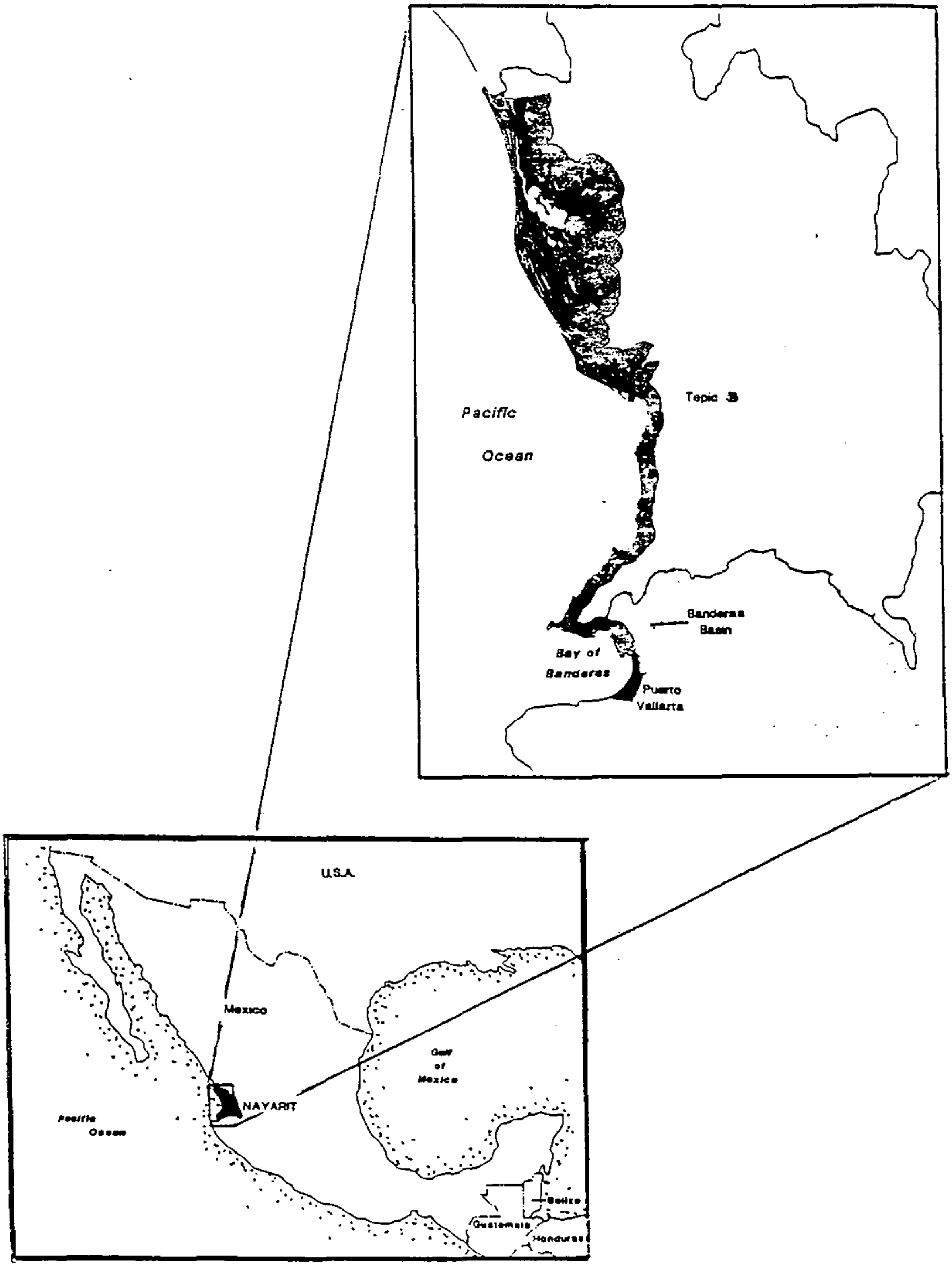


Figure 1. Location map of the State of Nayarit, Mexico and its coastal zone (shaded area).

effort to develop a proposed Master Plan. The results of the EMergy analysis formed a basis for recommending wise resource use and, ultimately, for determining carrying capacity for human populations and tourism within the coastal zone.

Ecological Economics

Among the most important problems facing humanity today are the sound management of natural resources and development of procedures for the integrated study of human and non-human processes. Increasingly, there is a need to understand both of these domains, each in the context of the other, and to develop management strategies which acknowledge and promote the vital interconnections between the two. Neither economics nor ecology alone adequately address the problems world society presently faces. Questions regarding optimizing resource use, managing equitable international trade, over-exploitation of resources, loss of biotic diversity, or global climate change cannot be solved by focusing on isolated aspects of a larger problem. A wider view is necessary: one that combines the systems of humanity and nature and that does not treat the affairs of humans and the productive processes of the biosphere as distinct entities; the one having domain over the other. A new paradigm for such an analysis is emerging. Just as the separate and distinct economies of individual nations are becoming increasingly interwoven into a worldwide economic system, it is becoming quite apparent that economic well-being and ecologic stability depend upon developing an interface between ecology and economics. We call this interface "ecological economics" and the tool we use to quantitatively evaluate the interface is "EMergy Analysis"

This study uses techniques of EMergy analysis to evaluate both traditional economic variables and ecologic systems (Odum 1978, 1988). This method evaluates--on a common basis--the main driving energies of the economy, and the requirements and contributions of individual development projects. Included are economic goods and services, fuels, and the fluxes of renewable energies, as well as environmental changes that occur, such as the loss of terrestrial production. EMergy analysis allows comparison and incorporation of environmental costs and benefits with variables of traditional economic costs and benefits to provide a more comprehensive perspective for policy decisions.

Public Policy and Issues of Resource Use

The interface of ecology and economics is most often found in the marketplace. Resources are exploited and sold, and in the process the environment sustains some transformations. Questions of how best to manage a nation's resources, how to develop them, extract them, and whether they should be exported in exchange for other needed resources are public policy questions. Until very recently, public policy was most often determined almost wholly within an economic framework, most commonly within the limited context of market transformations. Yet economic considerations often do not reflect ecologic realities, societal needs, environmental impacts, or sustainability of natural resources because these things are generally outside the realm of individual human preferences or the ability of markets to provide adequate information.

Theory of Maximum EMergy Designs

A new public policy value system is required -- one that can recognize the differences between short-term individual human preference and long-term macroscopic economic well-being, and that can quantitatively determine value at the macroscopic scale of society and environment. Decisions regarding use of resources ultimately impact on the well-being of the entire citizenry, and as a result, the process of decision making should focus on determining which alternatives and options will have the greatest positive impact on well-being. We believe that public policy decisions should be based on the principle that the alternative that maximizes EMergy is the preferred choice.

Theory suggests (Odum 1971, 1983; Odum and Odum 1983) that economies of nature and humans organize so as to develop the maximum EMergy possible; and that in so doing they prevail and are sustained over alternatives. The theoretical basis is found in the Maximum Power Principle (Lotka 1922a,b, and 1945). To maximize power, an economy develops an organization of useful processes that increases total production through positive feedback and by overcoming limiting factors. Economies, in the long run, cannot prevail in competition with others if EMergy is wasted in nonproductive processes; yet in the short run, one can observe apparent contradictions. However, since observations of any system are time dependent, the real issue is not that processes exist that seem to "waste" EMergy (i.e., do not reinforce productive processes) and thus violate the maximum power principle, but whether they can do so indefinitely in a competitive environment where selective processes are geared to eliminate them. This view is in contradiction to some economic theories that suggest any expenditure of money and resources leads to economic vitality, whether or not it is for unnecessary products or services.

Many scientists are used to thinking of systems as organizations of processes that are sustained by their driving energies and resources, and that competition and competitive exclusion are the means by which systems self-organize and develop sustainable patterns. Yet few believe that the criterion for survival, or sustainability, is maximum EMergy or that competition and competitive exclusion are selective processes that operate to maximize EMergy. Other criteria for survival that have been suggested include: minimum cost, minimum risk, maximum stability, maximum efficiency, maximum production, least work, and maximum diversity, among others. The viewpoint used in the present study is that economies, and processes within economies, organize and operate so as to increase real wealth and prevail according to the maximum EMergy principle; and that a measure of real wealth is EMergy.

EMergy, Wealth and Value

EMergy is a quantitative measure of the resources required to develop a product (whether a mineral resource that results from bio-geologic processes, a biologic resource such as wood, or an economic product that results from industrial processes) and express the required resources in units of one type of energy (usually solar). We suggest that evaluations using EMergy may help to clarify policy options, because the use of EMergy as a measure of value overcomes four important limitations of previous attempts to quantify environmental impacts, development cost/benefits, and alternative technologies. These limitations are as follows: (1) Mixing units of measure such as weight, volume, heat capacity, or economic market price cannot lead to comparative analysis. The relative contribution to a nation's economic vitality derived from fossil fuels (measured in barrels), sunlight (measured in ergs), and phosphorus in fertilizers (measured in kilograms) is difficult to determine. (2) Evaluations that use the heat value of resources for quantification assume that the only value of a resource is the heat that is derived from its combustion. In this way, for example, human services are evaluated as the calories expended doing work, and when compared to other inputs to a given process are several orders of magnitude smaller and often considered irrelevant. (3) Unmonied resources and processes (i.e., those outside the monied economy) are often considered externalities and are thus not quantified. Most processes, and all economies, are driven by a combination of renewable and nonrenewable energies. Renewable energies (sunlight, rain, wind, tides, etc.) are outside the monied economy and therefore are generally not accounted for in economic evaluations. Yet they are absolutely necessary in all economies and make up a large portion of most products. Economic vitality depends on the successful use of available resources, both renewable and nonrenewable (fuels, mineral resources, and the goods derived from them); thus, evaluations that leave out renewable energies because they are externalities consistently "undervalue" the total production in economies and environmental processes. (4) Price determines value. The price of a product or service reflects human preferences often called "willingness-to-pay." It can also reflect the amount of human services "embodied" in a product. A valuing system based on human preference assigns either relatively arbitrary values or no value to necessary resources or environmental services.

EMergy is a measure of the real wealth of an economy (Odum 1984; Odum and Arding 1991). Since wealth is ultimately tied to resources, it is necessary to express wealth in units that reflect the resource base. Conditioned as we are that price reflects value, we often believe that money is the measure of wealth and that price determines value. Price suggests what humans are willing to pay for something; but value to the public is determined by the effect a resource has in stimulating an economy. For instance, a gallon of gas will power a car the same distance no matter what its price; its value to the driver is the number of miles (work) that can be driven. Its price reflects the scarcity of gasoline and how important it is to do the work. Price is often inverse to a resource's contribution to an economy. When a resource is plentiful, its price is low, yet it contributes much to the economy. When a resource is scarce its total contribution to the economy is small yet its price is high.

EMergy may be a measure of the equivalence when one resource is substituted for another. Sunlight and fossil fuels are very different energies; yet when their heat values are used the difference is not elucidated. A joule of sunlight is not equivalent to a joule of fossil fuel in any system other than a heat engine. In the realm of the combined system of humanity and nature, sunlight and fuels are not equally substitutable, joule for joule. However, when a given amount of fuel energy is expressed as solar EMergy, its equivalence to sunlight energy is defined. Since EMergy is a measure of the work that goes into a product, expressed in units of one type of energy (sunlight), it is also a measure of what the product should contribute in useful work in relation to sunlight.

We recognize the difficulty that these concepts present since they use new terminology and a different measure of value from those in common usage. However, the concept of value and national wealth stemming from resources is not new, but is as old as economics itself. The history of economic thought is replete with considerable discussion and analysis of national wealth as measured by resources and by attempts to measure value as it stems from resource use. Only recently has economic theory been dominated by the determination of value based on price and national wealth measured by currency. During times of resource scarcity, economic values were related most often to resources (land, labor or energy) and resource use; but during times of resource abundance, economic values were related most often to currency and price.

The failing of previous theories of resource-based value, and most current ones as well, has been that they did not account for different types of energy, but assumed that the heat value of energy was a common denominator by which quantification and comparisons could be made. We believe this to be incorrect. All energy types are not equivalent in their ability to do work; and, without accounting for the differences in what has been termed the quality of different types of energy, erroneous conclusions can result. Use of EMergy to represent all the contributions to any given product or process accounts for differences in resource quality and expresses different resources in equivalent capacity to do work.

Plan of Study

The studies contained in this volume are part of a larger study to develop a proposed Master Plan for the state of Nayarit, Mexico. Since a Master Plan focuses on the physical use of lands and waters, we felt it necessary to provide additional studies of important aspects of the economy that are not normally addressed in a Master Plan. These studies, then, were undertaken to provide background information from which public policy related to resource use and sustainable development might be better focused. They provide a quantitative framework from which policy can be decided. While there are numerous issues and environmental concerns that could be studied, we focused on four areas:

1. Tourism and its impacts on local economies, environments and social systems
2. Water use, and potentials for reuse
3. Coastal fisheries, mariculture, and options for protein production
4. The current public health system

Everything is part of a system, and systems are composed of interrelated units. Each of these four areas were studied as a whole and as a subsystem of the next larger system in order to understand how they fit together. To accomplish this, it was necessary to also conduct EMergy evaluations of the economy of Mexico, the State of nayarit, and the Banderas Basin. This "top-down" approach facilitates a better understanding of subsystems and the public policy issues that surround them. Decisions regarding the exploitation of natural resources almost invariably require the integration of both economic and ecologic concerns. All too often policy decisions on the local level are made without sufficient information concerning the implications to the next larger system level. The reverse is also true; decisions made at the regional or national level have serious impacts on local economies and resource systems. The hierarchical systems approach presented in these studies lends insight and allows for the public policy decision process to integrate both the economic and ecologic implications of management alternatives.

METHODS

This section gives general methods of EMergy analysis for the evaluations that follow in the Results sections. The general methodology for EMergy analysis is a "top-down" systems approach. The first step is to construct systems diagrams that are a means of organizing thinking and relationships between components and pathways of exchange and resource flow (systems symbols and brief definitions are given in Figure 2). The second step is to construct EMergy analysis tables directly from the diagrams. And the final step involves calculating several EMergy indices that relate EMergy flows of the economy with those of the environment, and allow the prediction of economic viability and carrying capacity. Additionally, using the results of the EMergy analysis tables, comparisons between the EMergy costs and benefits of proposed developments as well as insights related to international flows of money and resources are made. Before presenting detailed descriptions of each step in the methodology, definitions are given for several key words and concepts.

Definitions

Energy. Sometimes referred to as the ability to do work, energy is a property of all things which can be turned into heat, and is measured in heat units (BTUs, calories, or joules).

EMergy. EMergy is an expression of all the energy used in the work processes that generate a product or service, in units of one type of energy. Solar EMergy of a product is the EMergy of the product expressed in equivalent solar energy required to generate it. Sometimes it is convenient to think of EMergy as Energy Memory.

EMjoule. The unit of measure of EMergy ("EMergy joule"), it is expressed in the units of energy previously used to generate the product. For instance, the solar EMergy of wood is expressed as joules of solar energy that were required to produce the wood. Solar EMjoules is abbreviated "sej".

EMpower. The flow of EMergy per unit time; expressed as sej/time.

EMpower density. EMpower per unit area; units are sej/time/area.

Macroeconomic dollar. This is a measure of the money that circulates in an economy as the result of some process. In practice, to obtain the macroeconomic dollar value of an EMergy flow or storage, the EMergy is multiplied by the ratio of total EMergy to Gross National Product for the national economy.

Nonrenewable Energy. Energy and material storages like fossil fuels, mineral ores, and soils that are consumed at rates that far exceed the rates at which they are produced by geologic processes, are nonrenewable energies.

Renewable Energy. Energy flows of the biosphere that are more or less constant and reoccurring, and which ultimately drive the biological and chemical processes of the earth and contribute to geologic processes, are renewable energies.

Resident Energy. Resident energies are the renewable energies that are characteristic of a region.

Transformity. The ratio obtained by dividing the total EMergy that was used in a process by the energy yielded by the process, transformity has the dimensions of EMergy/energy (sej/J). A transformity for a product is calculated by summing all the EMergy inflows to the process and dividing by the energy of the product. Transformities are used to convert energies of different types to EMergy of the same type. Given next is further elaboration on the methods used for EMergy analysis.

Step 1: Overview System Diagrams

A system diagram in "overview" is drawn first to put in perspective the system of interest, combine information about the system from various sources, and to organize data gathering efforts. The process of diagramming the system of interest in overview ensures that all driving energies and interactions are included. Since the diagram includes both the economy and environment of the system, it is like an impact diagram which shows all relevant interactions.

Next, a second simplified (or aggregated) diagram, which retains the most important essence of the more complex version is drawn. This final, aggregated diagram of the system of interest is used to construct a table of data requirements for the EMergy analysis. Each pathway that crosses the system boundary is evaluated.

Step 2: EMergy Analysis Tables

EMergy analysis of a system of interest is usually conducted at two scales. First, the system within which the system of interest is embedded is analyzed and indices necessary for evaluation and comparative purposes are generated. Second, the system of interest is analyzed. Both analyses are conducted using an EMergy Analysis Table organized with the following headings:

1	2	3	4	5	6
Note	Item	Raw Units	Transformity	Solar EMergy	Macro-economic $

Each row in the table is an inflow or outflow pathway in the aggregated systems diagram; pathways are evaluated as fluxes in units per year. An explanation of each column in an EMergy Analysis Table is given next.

Column 1	The line number and footnote number that contains sources and calculations for the item.
Column 2	The item name that corresponds to the name of the pathway in the aggregated systems diagram.
Column 3	The actual units of the flow, usually evaluated as flux per year. Most often the units are energy (joules/year), but sometimes are given in grams/year or dollars/year.
Column 4	Transformity of the item, usually derived from previous studies.
Column 5	Solar EMergy (sej), which is the product of the raw units in Column 3 with the transformity in Column 4.
Column 6	The result of dividing solar EMergy in Column 5 by the EMergy to money ratio (calculated independently) for the economy of the nation within which the system of interest is embedded.

Step 3: Calculation of EMergy Indices

Once the EMergy analysis tables are completed, several indices using data from the tables are calculated to gain perspective and aid in public policy decision-making. The principles used in judging development alternatives are as follows: (1) When alternative investments are compared, the investment that contributes the most EMergy value to the public economy in the long run is most likely to be successful; and (2) when a single system is analyzed, the EMergy intensity of the development should match that of the local economy. Two ratios are calculated: EMergy Investment Ratio (IR), and the Environmental Loading Ratio (ELR). Several other indices help in gaining perspective about processes and are necessary precursors to the IR and ELR; they are: EMergy/Money Ratio, EMergy Per Capita, EMergy Density, EMergy Exchange Ratio, Net EMergy Yield Ratio, and Solar Transformity. These are defined as follows:

EMergy/money ratio is the ratio of total EMergy flow in the economy of a region or nation to the GNP of the region or nation. The EMergy/money ratio is a relative measure of purchasing power when the ratios of two or more nations or regions are compared.

EMergy per capita is the ratio of total EMergy use in the economy of a region or nation to the total population. EMergy per capita can be used as a measure of average standard of living of the population.

EMergy density is the ratio of total EMergy use in the economy of a region or nation to the total area of the region or nation. Renewable and nonrenewable EMergy densities are also calculated separately by dividing the total renewable EMergy by area and the total nonrenewable EMergy by area, respectively.

EMergy exchange ratio is the ratio of EMergy exchanged in a trade or purchase (what is received to what is given). The ratio is always expressed relative to one or the other trading partners and is a measure of the relative trade advantage of one partner over the other. Figure 3a shows the relationship and calculation of the EMergy exchange ratio.

Net EMergy yield ratio is the ratio of the EMergy yield from a process to the EMergy costs. The ratio is a measure of how much a process will contribute to the economy. Primary energy sources have yield ratios in the range of 3:1 to as high as 11:1; thus, they contribute much to the wealth of the economy. Figure 3b shows the method of calculating the net EMergy yield ratio.

Solar transformity is the ratio of the actual energy in a product or service to the solar EMergy that is required to generate it; its units are sej/J. The transformity is a measure of the "value" of a service or product, with the assumption that systems operating under the constraints of the maximum EMergy principle (Odum and Arding 1991) generate products that stimulate productive processes which generate at least as much as value as they cost. Figure 3c shows the method of calculating a transformity.

Determining the Intensity of Development and Economic Competitiveness: EMergy INVESTMENT RATIO

Given in Figure 4 is a diagram illustrating the use of nonrenewable and renewable EMergies in a regional economy. The interaction of indigenous EMergies (both renewable [I] and nonrenewable [N] with purchased resources from outside [F]) is the primary process by which humans interface with their environment. The Investment Ratio (IR) is the ratio of purchased inputs (F) to free EMergies derived from local sources (the sum of I and N) as follows:

$$IR = F/(I+N) \quad (1)$$

The name is derived from the fact that it is a ratio of "invested" EMergy to resident EMergy. The Investment Ratio is a dimensionless number; the bigger the number the greater the amount of purchased EMergy per unit of resident EMergy. Comparison between a regional IR and the ratio for a proposed development may be used as an indicator of the intensiveness of the development within the local economy. When the ratios of two developments of the same kind are compared, an indication of their economic competitiveness is derived. The Investment Ratio can also be used to indicate if a process is economical in its utilization of purchased inputs in comparison with other alternative investments within the same economy.

Determining Environmental Impact: ENVIRONMENTAL LOADING RATIO

Nearly all productive processes of humanity involve the interaction of nonrenewable EMergies with renewable EMergies of the environment, and in so doing the environment is "loaded" (meaning to strain, stress, or pressure). Figure 4 shows environmental loading as the interaction of purchased EMergy and nonrenewable storages of EMergy from within the system with the renewable EMergy pathway, through environmental work. An index of environmental loading, the Environmental Loading Ratio (ELR) is the ratio of nonrenewable EMergy (N+F) to renewable EMergy (I) as follows:

$$ELR = (N+F)/ I \tag{2}$$

Low ELRs reflect relatively small environmental loading, while high ELRs suggest greater loading. The ELR reflects the potential environmental strain or stress of a development when compared to the same ratio for the region, and can be used to calculate carrying capacity.

Evaluating Regional and Local IRs and ELRs

Figure 5 is a simplified diagram of a regional economy and a sector of the economy. The sector uses of renewable EMergy (I_s) and purchased EMergy from both the local (F_m) and world economy (F_i). The sector is actually a part of the regional economy, but is shown separately to highlight the comparison between it and the region in which it is embedded. The Investment Ratio in the regional economy is derived using the ratio of purchased EMergy (F) to resident EMergy inputs (I_m + N_m) as follows:

$$IR_m = F/ (I_m + N_m) \tag{3}$$

The Investment Ratio of the sector (IR_s) is calculated in a similar manner, accounting for all sources of renewable and purchased EMergy as follows:

$$IR_s = (F_m + F_i)/(I_s + N_s) \tag{4}$$

The Environmental Loading Ratio for the region and sector within the regional economy are calculated somewhat differently from each other. The regional ELR is calculated as the ratio of nonrenewable (F + N_m) to renewable EMergy (I_m) as before. However, calculation of the ELR for the economic sector has to take into account the portion of F_m that comes from I_m, since that area of environment is not adding to the "load" on the environment of the sector but, in effect, is part of the environmental support for the sector. Thus the ELR for the sector is calculated by subtracting the portion of F_m that is from I_m. This is done by first calculating the total EMergy budget of the main economy (Total EMergy = $F_m+F_i+N_m+N_s+I_m+I_s$), then dividing by I_m to determine the percent of the total that is derived from I_m. Then the ELR for the sector is determined as follows:

$$ELRs = [F_i+(F_m-kF_m) + N_s] / (I_s+kF_m) \tag{5}$$

where:

k = percent of total EMergy budget that is from I (refer to Figure 5)

Determining Carrying Capacity for Economic Investments

Once the ELR for a region is known and the total annual nonrenewable EMergy use by a development is determined, the area of land necessary to balance the development can be calculated using the average annual flux of renewable EMergy per year per unit area of landscape (renewable EMpower density). Renewable EMpower density is derived from the analysis of the regional or national economy. To determine the area of support necessary for a proposed development and thus the carrying capacity (i.e., the area of landscape required for the development), the ELR for the region is calculated (as above), and then the following equivalent proportion is constructed:

$$ELR_{(region)} = ELR_{(development)} \tag{6}$$

where:

$ELR_{(region)}$ = known

$ELR_{(development)}$ = $[F_i+(F_m-kF_m) + N_s] / (I_s+kF_m)$

and the equation is solved as follows:

$$(I_s+kF_m) = [F_i+(F_m-kF_m) + N_s] / ELR_{(region)} \tag{7}$$

Once the quantity (I_s+kF_m) is known, the area of landscape required to balance the proposed development can be calculated as follows:

$$\text{Support Area} = (I_s+kF_m)/ I_{(region)}$$

where:

$I_{(region)}$ = known regional EMpower density of renewable inputs (sej/unit area)

Criteria for Alternative Public Policies

Public policy alternatives that involve decisions regarding a development and use of resources are guided by two criteria in this study: (1) the alternative should increase the total EMergy inflow to the economy, and (2) the alternative should be sustainable in the long run.

Development alternatives that result in higher EMergy inputs to an economy increase its vitality and competitive position. A principle that is useful in understanding why this is so is the Maximum EMergy Principle (which follows from the work of Lotka [1922a], who named it the "maximum power principle"). In essence, the Maximum EMergy Principle states that the system (or development alternative, in this case) that will prevail in competition with others is the one that develops the most useful work with inflowing EMergy sources. Useful work is related to using inflowing EMergy in reinforcement actions that insure and, if possible, increase the inflowing EMergy. The principle is somewhat circular. That is, processes that are successful maximize useful work, and useful work is that work which increases inflowing EMergy. It is important that the term "useful" is used here. Energy dissipation without useful contribution to increasing inflowing EMergy is not reinforcing, and thus cannot compete with systems that use inflowing EMergy in self-reinforcing ways. Thus, drilling oil wells and then burning off the oil may use oil faster (in the short run) than refining and using it to run machines, but it will not compete in the long run with a system that uses oil to develop and run machines that increase drilling capacity and, ultimately, the supply of oil.

Development alternatives that do not maximize EMergy cannot compete in the long run and are "selected against". In the trial and error processes of open markets and individual human choices, the patterns that generate more EMergy will tend to be copied and will prevail. Recommendations for future plans and policies that are likely to be successful are those that go in the natural direction toward maximum EMergy production.

The second guiding criterion is that development alternatives be sustainable in the long run. To be sure, sustainability is an elusive concept. Ultimately, sustainable developments are activities that use no nonrenewable energy, for once supplies have dwindled, developments that depend on them must also dwindle. However, the criteria for maximum EMergy would suggest that energy be used effectively in the competitive struggle for existence. Thus, when energy is available, its use in actions that reinforce overall performance is a prerequisite for sustainability. To do otherwise would suggest that the development would not be competitive, and in the short run would not be sustainable. This alternative (no use of nonrenewable energy) provides the lower bound for sustainability. The upper bound is determined by the Maximum EMergy Principle as well. Sustainable developments are those that operate at maximum power, neither too slow (efficient) nor too fast (inefficient). The question of defining sustainability becomes one of defining maximum power. In this analysis, we use the Investment Ratio and the Environmental Loading Ratio as the criteria for sustainability. By matching the ratios of a development with those of the economy in which it is imbedded, a proposed development is neither more nor less sustainable than the economy as a whole.

Analysis of Public Policy Options

The EMergy analysis procedure is designed to evaluate the flows of energy and materials of systems in common units that enables one to compare environmental and economic aspects of systems. Usually questions of development policy and uses of resources involve environmental impacts that must be weighed against economic gains. Most often impacts and benefits are quantified in different units resulting in a paralysis of the decision-making process because there is not a common means of evaluating the trade-offs between environment and development. EMergy provides a common basis, the energy of one type that is required by all productive processes.

While "Ecological Economics" and the methods of EMergy Analysis are comparatively new and still evolving, and often difficult to understand, we believe they offer an important step in developing a quantitative basis for public policy decision making.

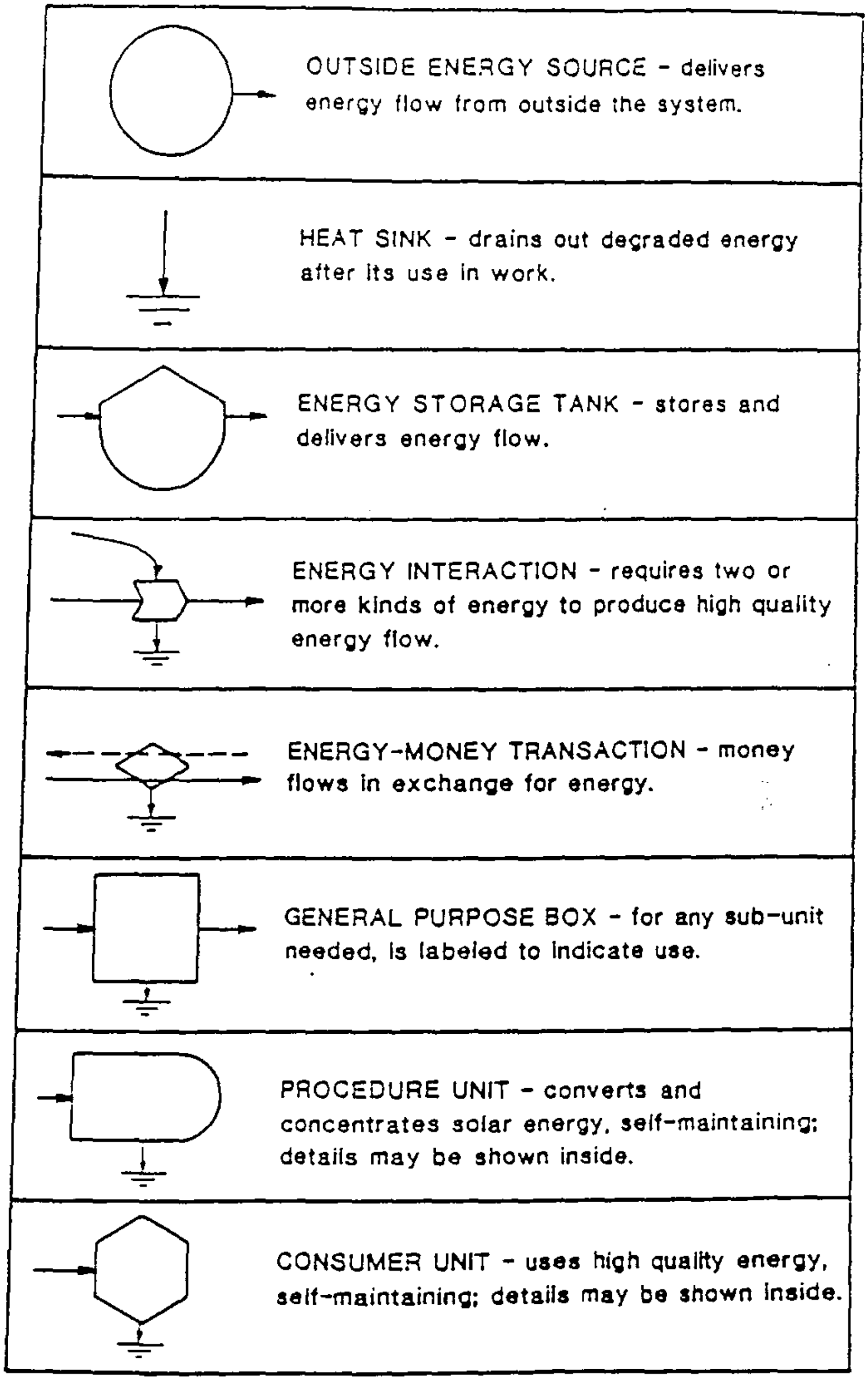


Figure 2. Energy language symbols.

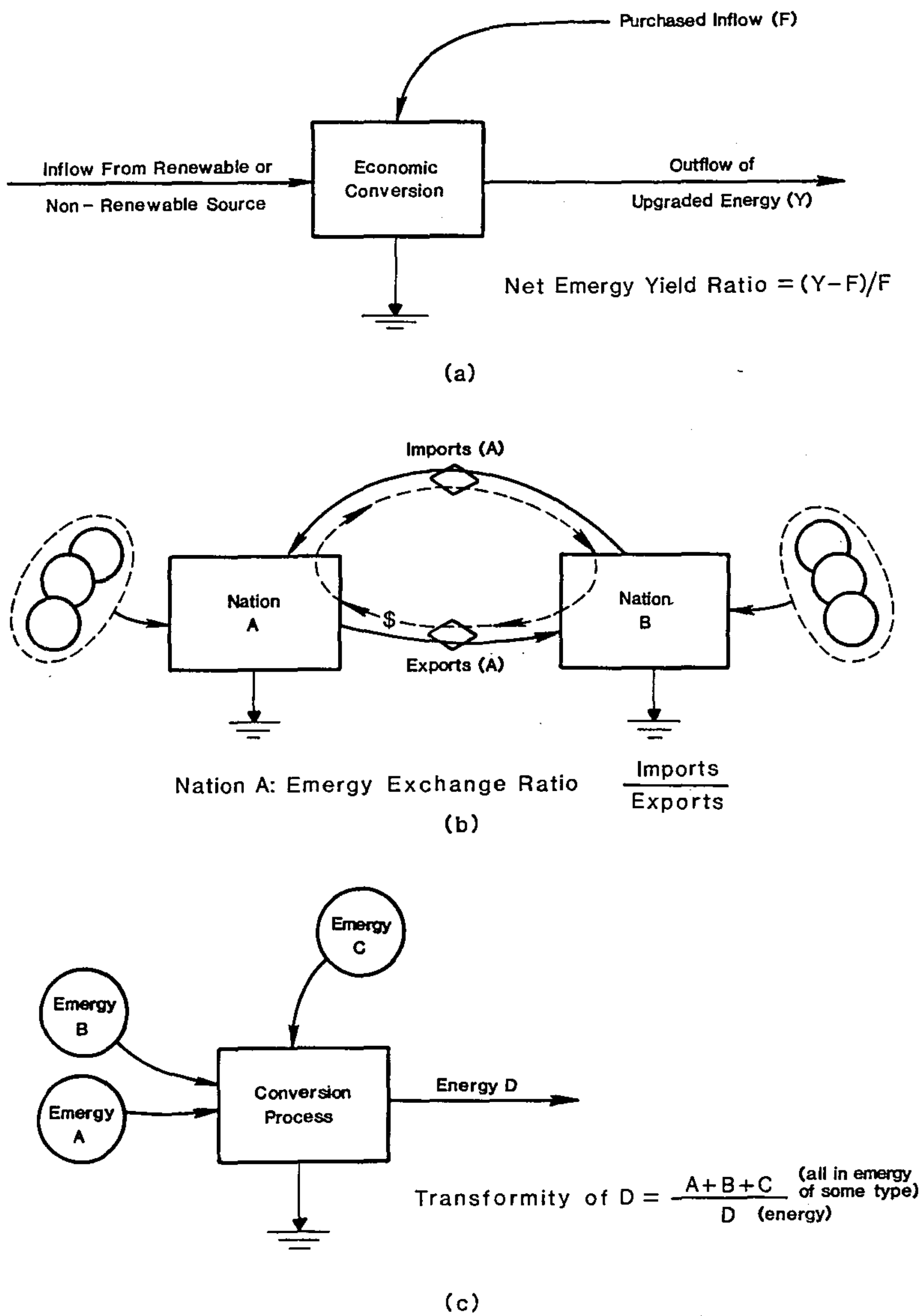
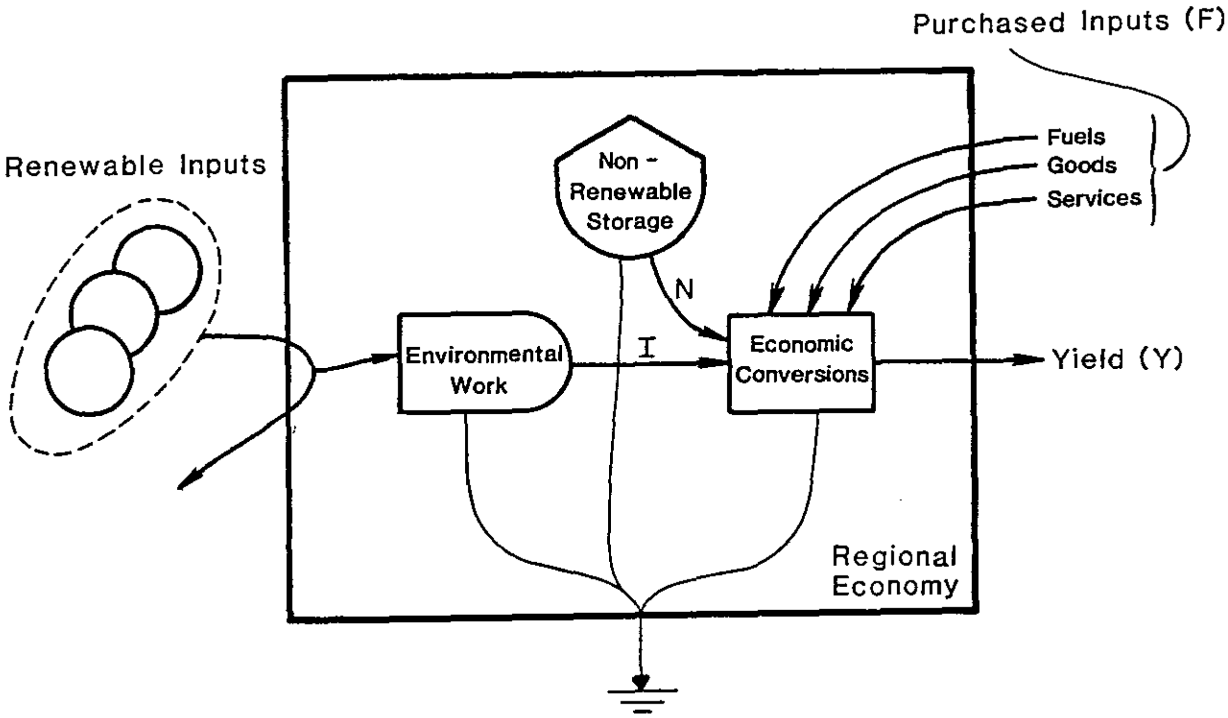


Figure 3. Simplified diagrams illustrating (a) the calculation of Net EMergy Yield Ratio for economic conversion where purchased energy is used to upgrade a lower grade resource, (b) the calculation of EMergy Exchange Ratio for trade between tow nations, and (c) the calculation of a Transformity for the flow "D" that is a product of the process that requires the input of three different sources of EMergy.

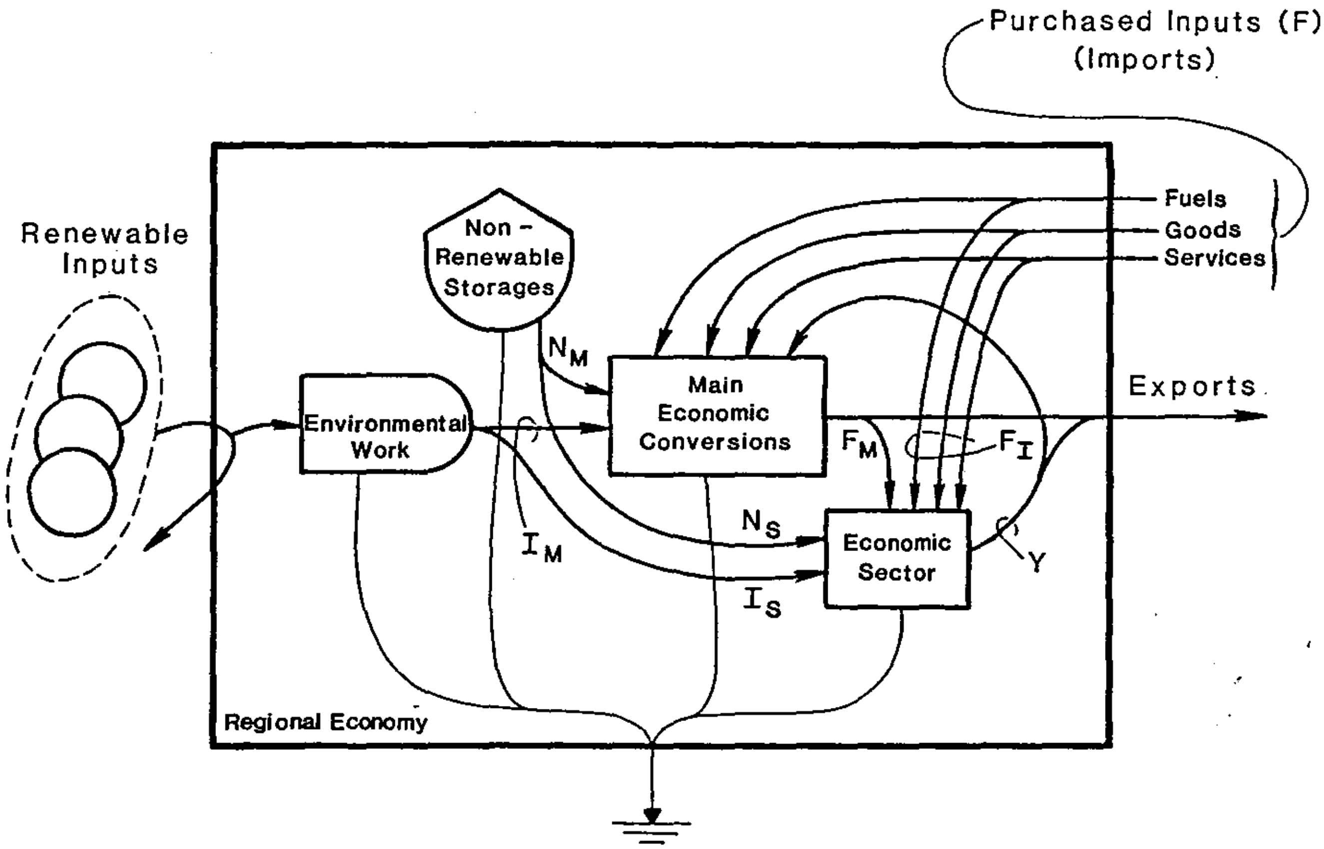


Investment Ratio of Regional Economy: $IR = F/(I + N)$

Environmental Loading Ratio of Regional Economy: $ELR = (F + N)/I$

Yield Ratio of Regional Economy: $YR = Y/F$

Figure 4. Diagram illustrating a regional economy that imports purchased inputs (F) and uses resident renewable inputs (I) and nonrenewable storages (N). Several ratios used for comparison between systems are given below the diagram and are explained in the text. The letters on pathways refer to flows of EMergy per unit time, thus ratios of flows are dynamic and changing over time.



Investment Ratio for Economic Sector: $IR = \dfrac{F_I + F_M}{I_S + N_S}$

Environmental Loading Ratio for Economic Sector: $ELR = \dfrac{F_I + (F_M - KF_M) + N_S}{I_S + KF_M}$

where K = percent of F_M that is from I_M

Yield Ratio for Economic Sector: $YR = \dfrac{Y}{F_M + F_I}$

Figure 5. Diagram of a regional economy showing the flows of energy from external sources and within the economy. One sector of the economy is shown separated from the main economy in the lower left. The sector receives flows of energy from imports (F_I), from the main economy (FM), from nonrenewable storages (N_S), and from the environment (I_S). The ratios given below the diagram are explained in the text.

SECTION 3A: EMergy Analysis of Mexico

by Agustin Gonzalez

OVERVIEW

Given in Figure A-1 is a map of the physiographic features of Mexico. The total land area of Mexico is 1,958,201 km^2, which includes 5,073 km^2 of insular land. Its land borders are comprised of the United States on the north, and Guatemala and Belize to the south. The eastern coastline includes 2,070 km along the Gulf of Mexico and 735 km along the Caribbean Sea. The western coastline encompasses 7,338 km on the Pacific Ocean and the Sea of Cortez. Mexico's Economic Exclusive Zone extends the total sovereign land area to 2,715,012 km^2 (INEGI, 1990). The area of the continental shelf is 442,100 km^2, at a depth of 200 m (World Resources, 1990).

The topography of Mexico ranges from low desert plains and jungle-like coastal strips to high plateaus and rugged mountains. Beginning at the Isthmus of Tehuantepec in southern Mexico, an extension of a South American mountain range runs north almost to Mexico City, where it divides to form the coastal Occidental (west) and Oriental (east) Ranges of the Sierra Madre. Between these ranges lies the great central plateau, a rugged tableland 2,400 km (1,500 mi) long, and as much as 800 km (500 mi) wide. From a low desert plain in the north, the plateau rises to 2,400 meters (8,000 ft) above sea level near Mexico City.

Mexico's climate is generally more closely related to altitude and rainfall than to latitude. Most of Mexico is dry; only about 12% of the total area receives adequate rainfall in all seasons, while about one-half is deficient in moisture throughout the year. Temperatures range from tropical in the coastal lowlands to cool in the higher elevations. Mexico is the most populous Spanish-speaking country in the world and the second most populous (81 million) country in Latin America (after Brazil). More than one-half of the people live in the central portion of the country.

Mexico is rich in mineral and energy resources. A leading producer of silver, sulfur, lead, and zinc, it also produces gold, copper, manganese, coal, and iron ore. The discovery of extensive oil fields in the coastal regions along the Gulf of Mexico in 1974 enabled the country to become self-sufficient in crude oil and to export significant amounts of petroleum. The Mexican economy remains heavily dependent on petroleum production and exports. Mexico ranks as the world's fifth largest oil producer, with an average production of 2.5 million barrels per day. About half of the oil is refined and consumed domestically, leaving an average of 1.29 million barrels per day for export.

Mexico's manufacturing sector's main products are cement, aluminum, artificial fibers, chemicals, fertilizers, petrochemicals, and paper. A growing automobile industry has become one of Mexico's most important industrial and export sectors. 1989 agricultural production showed no growth, as a series of natural events and economic realities have all limited output. Mexico's tourist attractions, from coastal resorts to archeological sites, bring approximately 6 million tourists per year, some 90% of them U.S. citizens (USDS, 1990). One of the coastal resorts, Puerto Vallarta, shares half of the Bahia de Banderas, where the first steps of the study of Nayarit will take place.

The plan of study consisted in evaluating the resource base of the national economy of Mexico in order to further evaluate the resource base of the state of Nayarit, and of the Bahia and Valle de Banderas region; to evaluate the environmental impacts on the development of the coastline of Nayarit; and, using EMergy analysis, to evaluate tourism, sewage disposal, impacts on fisheries, and to develop a terrestrial resources management plan for Nayarit's coastal zone.

RESULTS

Mexico EMergy Analysis

The overview energy circuit diagram of Mexico is shown in Figure A-2. An evaluation of the overall resource basis of the Mexican economy in 1989 is given in Table A-1. The main components of the economy of the country are listed, including exports and imports. In terms of renewable resources, those with higher solar EMergy are the most important for the economy, as reflected in terms of macroeconomic value. For Mexico these are: rain (1324 E+20 solar EMjoules [sej]), Earth cycle (1085 E+20 sej), and waves (415 E+20 sej). The most important indigenous renewable energy resources are livestock production (3210 E+20 sej), agriculture production (1962 E+20 sej), and fisheries (508 E+20 sej). The most important nonrenewable sources within Mexico were found to be oil (1490 E+20 sej), silver (1200 E+20 sej), thermoelectricity (626 E+20 sej) and steel/Iron (519 E+20 sej).

Exports with the highest solar EMergy values were silver (5723 E+20 sej), oil (1538 E+20 sej), copper (156 E+20 sej), zinc (115 E+20 sej) and cash crops (73 E+20 sej). Imports with the highest values were machinery (398 E+20 sej), agriculture and forestry products (254 E+20 sej), and oil-derived products (172 E+20 sej).

Summary of EMergy Indices

Tables A-2 and A-3 and Figure A-3 summarize solar EMergy flow in Mexico for 1989. The flow of nonrenewable resources is 11364.4 E+20 sej/yr, with 67.8% of the total flow (7707.7 E+20 sej/yr) being exported unused. The rest of the nonrenewable resource flow is mostly used in the urban and industrial sectors, with a value of 3594 E+20 sej/yr. This accounts for 31.6% of the total EMergy flow, leaving only 63 E+20 sej/yr, or about 0.6%, for use in rural areas.

Comparisons of socio-economic and EMergy indices are given in Table A-4. The Mexico EMergy/$ ratio of 3.32 E+12 sej/$ is higher than that of the USA, but lower than those of Papua New Guinea, Brazil, Australia, and the World average. This corroborates earlier findings of an EMergy analysis of the State of Texas, USA (Odum et al., 1987). The EMergy/$ ratio for Mexico is thus not high enough to classify it as an undeveloped country. In fact, 72.6% of its population is considered to be urban.

DISCUSSION

The Economy of Mexico

The economy of Mexico is driven, in part, by renewable energies like rainfall, tidal energy, and geologic uplift. When expressed in solar EMergy, the renewable energy basis for Mexico's economy amounts to about 24% of its total yearly flux. To avoid double counting of renewable energy, since the various renewable energies driving an economy are derived from the same source (solar energy), only the largest from each of the separate global energy inputs are included as driving forces. In Mexico, the renewable energies are rainfall, river inflows, and tidal energy. Rainfall is the single most important input (about 95% of the total yearly flux). The ebb and flow of tidal energy that continually flushes and mixes the extensive marine ecosystems increasing Mexico's fishery potential amount to about 3% of the total renewable EMergy flux. And the energy inflow of rivers that cross the Mexico-U.S. border account for about 2% of the renewable EMergy flux. The geologic process of earth uplift, while not included in the accounting procedure to avoid double-counting, is none-the-less extremely important. The geologic process that lifts and buckles the earth's crust and makes available sources of mineral wealth and the materials from which fertile soils are made, is important to the economy, comprising about 40% of the flux of renewable EMergy if it were included.

Nonrenewable energy sources, when expressed as solar EMergy, make up about 76% of the total yearly EMergy flux. Of the total EMergy flux, about 68% is from sources of nonrenewable EMergy derived from within Mexico, and about 24% is from renewable sources, giving a total of 82% that is derived from within Mexico. The single largest nonrenewable source from within Mexico is silver, of which nearly 83% is exported. Crude oil is the second largest nonrenewable energy flow, and about 51% is exported.

Mexico's EMergy balance of payments (imports minus exports) is negative. In other words, more EMergy is exported annually than is imported. Expressed as a ratio (exports/imports), Mexico exports about 7.5 times the EMergy it imports.

Comparisons of indices of Mexico's economy with other nations (Table A-4) is striking because of the differences related to population and EMergy use. Its population density is the highest of all countries listed and its EMergy use per unit area is second only to the U.S. Yet because of the high population density, Mexico ranks last in per capita EMergy use. In addition to this relatively low per capita EMergy consumption, the relative buying power of the Mexican monetary system (measured by the ratio of EMergy/$) is indicative of a more developed economy. The net result is that, because of the low buying power, the population has much lower EMergy available for personal consumption.

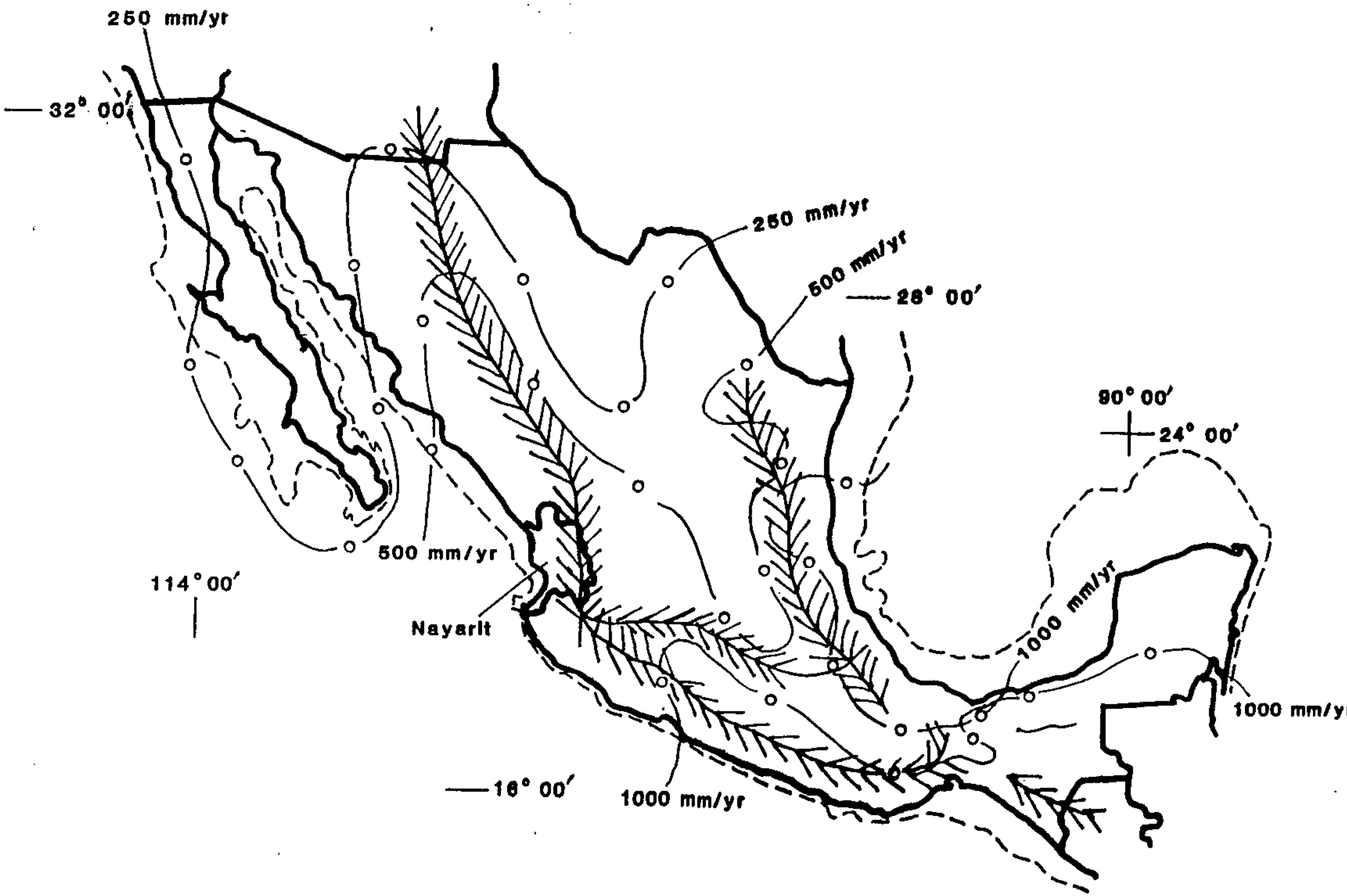


Figure A-1. Generalized map of Mexico showing mountain regions and isobars of rainfall.

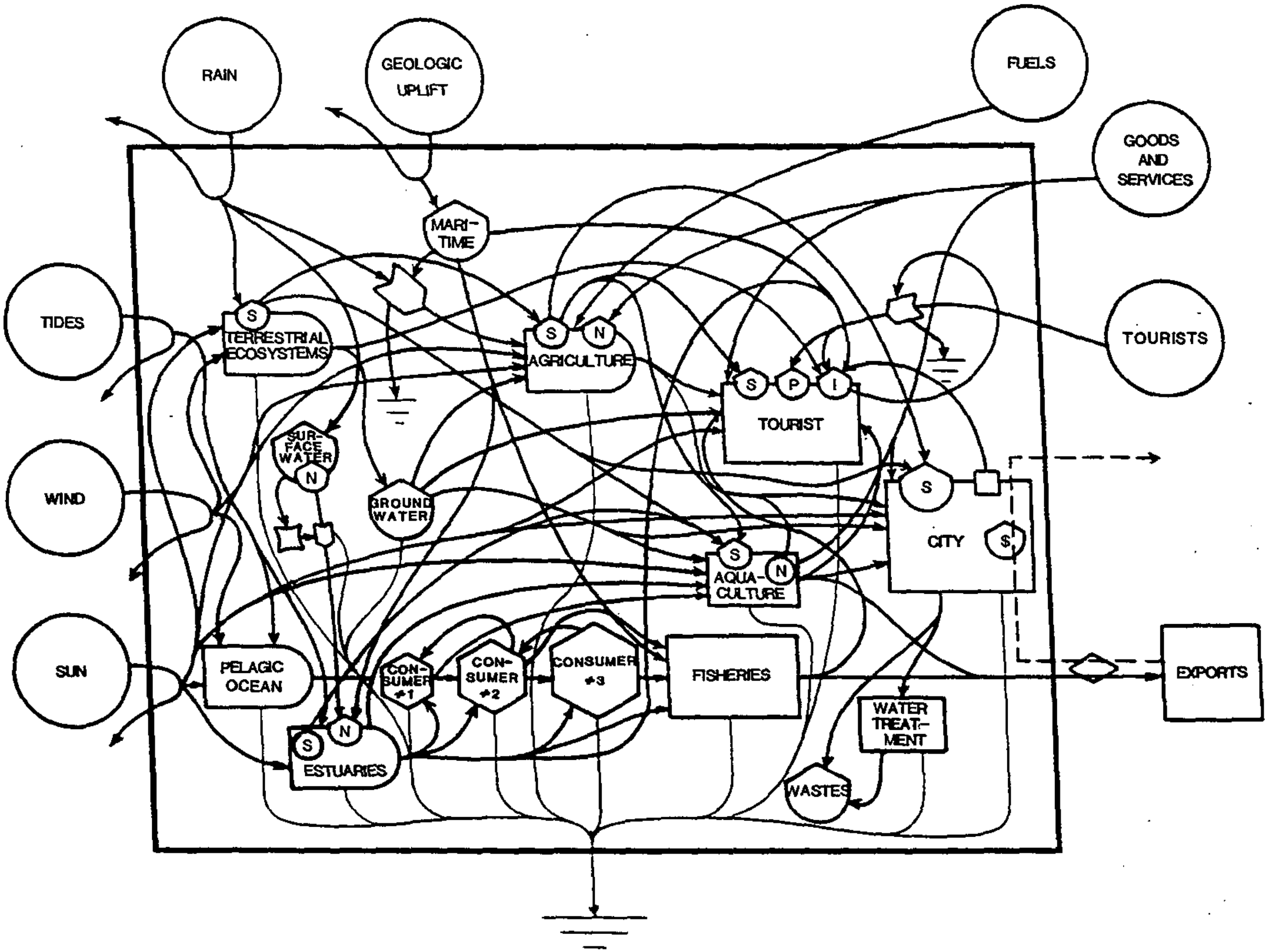


Figure A-2. Energy systems diagram of Mexico showing the interplay of renewable and nonrenewable and purchased energy sources that drive the economy.

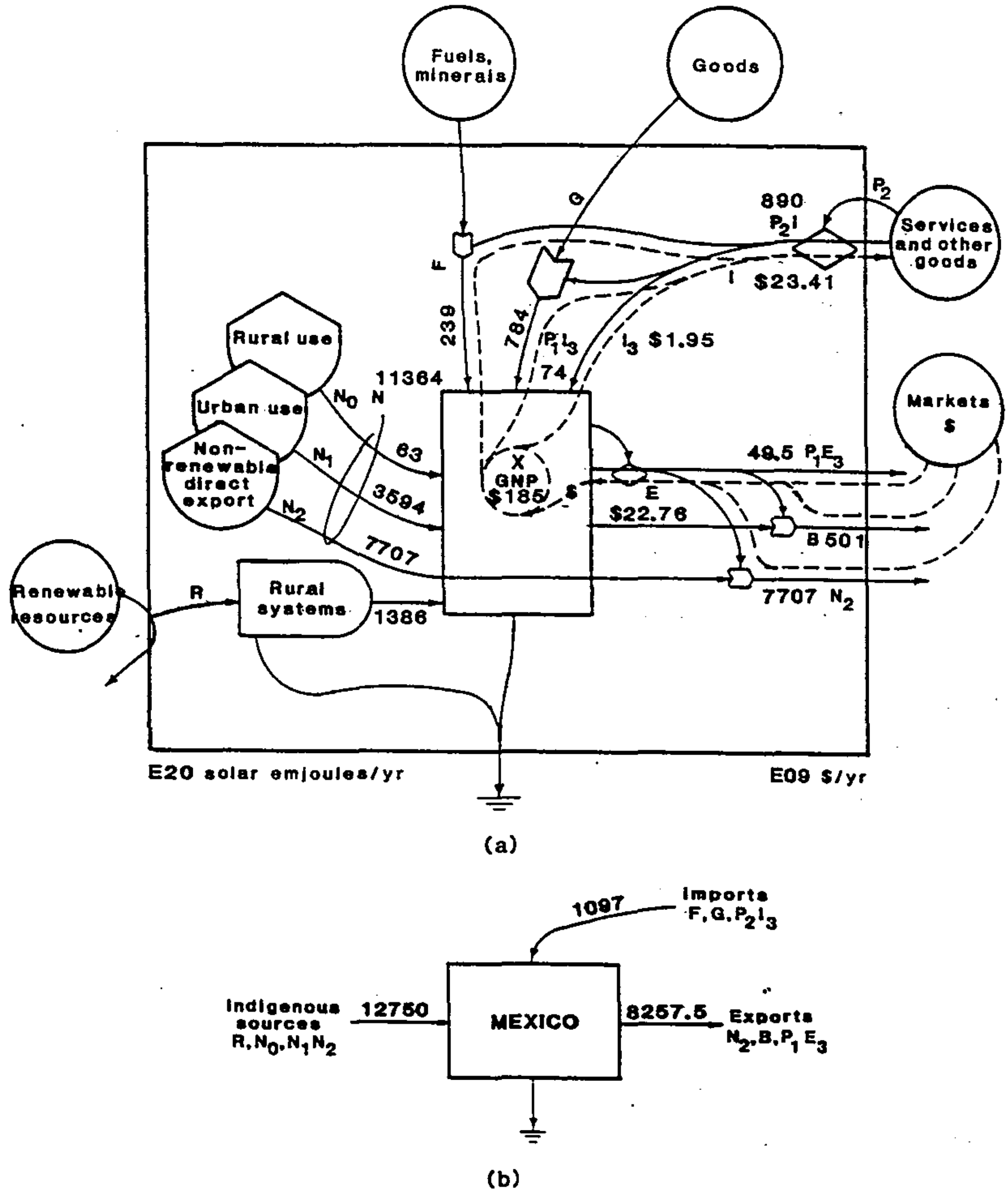


Figure A-3. Summary diagrams of the economy of Mexico in 1989. The top diagram shows the flows of energy from renewable and nonrenewable sources and from purchased resources. The circle of money within the central box is GDP. The bottom diagram is a further simplification of the economy, showing the main driving energies and balance of imports and exports.

Table A1. EMergy evaluation of resource basis for Mexico, 1989.

Note	Item	Raw Units	Trans-formity (sej/unit)	Solar EMergy (E20 sej)	Macroeconomic Value (E9 1984 US$)
RENEWABLE RESOURCES:					
1	Sunlight	1.26E+22 J	1	126.42	3.81
2	Rain, chemical	7.81E+18 J	15423	1205.19	36.31
3	Rain, geopotential	1.49E+19 J	8888	1324.54	39.91
4	Wind, kinetic	1.40E+19 J	623	87.44	2.63
5	Waves	1.60E+18 J	25889	415.35	12.51
6	Tide	1.34E+17 J	23564	31.63	0.95
7	River Geopotential	1.26E+17 J	23564	29.72	0.90
8	Earth Cycle	3.74E+18 J	29000	1085.11	32.70
INDIGENOUS RENEWABLE ENERGY:					
9	Hydroelectricity	8.66E+16 J	1.59E+05	137.65	4.15
10	Agriculture prod	9.81E+17 J	200000	1962.37	59.13
11	Livestock prod	1.61E+17 J	2000000	3210.82	96.74
12	Fisheries	2.54E+16 J	2000000	508.13	15.31
13	Fuelwood prod	4.51E+15 J	18700	0.84	0.03
14	Forest extraction	8.59E+16 J	34900	29.99	0.90
NONRENEWABLE SOURCES FROM WITHIN SYSTEM:					
15	Natural Gas	4.92E+17 J	4.80E+04	235.99	7.11
16	Oil	2.76E+18 J	5.40E+04	1490.21	44.90
17	Thermoelectricity	3.13E+17 J	2.00E+05	626.24	18.87
18	Fertilizer	4.29E+12 g	5.17E+09	221.32	6.67
19	Gold	8.65E+06 g	4.40E+14	38.07	1.15
20	Silver	4.00E+08 g	3.00E+14	1200.96	36.19
21	Copper	1.98E+10 g	6.80E+10	13.49	0.41
22	Zinc	1.12E+11 g	6.80E+10	76.26	2.30
23	Iron ore	5.37E+12 g	1.00E+09	53.73	1.62
24	Coal	1.22E+17 J	4.00E+04	48.97	1.48
25	Gypsum	2.87E+11 g	1.00E+09	2.87	0.09
26	Salt	1.87E+12 g	9.20E+08	17.18	0.52
27	Minerals	6.22E+12 g	9.20E+08	57.19	1.72
28	Steel/Iron Prod.	1.97E+13 g	2.64E+09	519.84	15.66
29	Steel/Iron Cons.	1.32E+13 g	2.64E+09	349.19	10.52
30	Cement	1.83E+13 g	7.48E+08	136.88	4.12
31	Plastics	1.24E+12 g	3.80E+08	4.71	0.14
32	Top Soil	4.57E+16 J	7.37E+04	33.69	1.02
IMPORTS AND OUTSIDE SOURCES:					
33	Oil derivatives	2.61E+17 J	6.60E+04	172.17	5.19
34	Steel/Iron	1.64E+12 g	2.64E+09	43.38	1.31
35	Minerals	2.53E+12 g	9.20E+08	23.25	0.70
36	Agri. & Forestry	1.27E+17 J	2.00E+05	254.43	7.67
37	Livestock	4.03E+14 J	2.00E+06	8.05	0.24
38	Foods	3.55E+16 J	8.50E+04	30.21	0.91
39	Plastics	6.37E+10 g	3.80E+08	0.24	0.01
40	Chemicals	7.83E+11 g	3.80E+08	2.98	0.09
41	Wood	2.55E+15 J	3.49E+04	0.89	0.03
42	Paper	2.78E+16 J	2.15E+05	59.75	1.80
43	Textiles	7.81E+14 J	3.80E+06	29.67	0.89
44	Machinery	1.05E+10 $	3.80E+12	398.11	12.00
45	Service in imports	2.34E+10 $	3.80E+12	889.57	26.80
46	Tourism	1.54E+09 $	3.80E+12	58.70	1.77

Table A1. Continued.

Note	Item	Raw Units	Trans-formity (sej/unit)	Solar EMergy (E20 sej)	Macroeconomic Value (E9 1984 US$)
EXPORTS:					
47	Crude Oil	2.85E+18 J	5.40E+04	1538.74	46.36
48	Oil derivatives	1.62E+17 J	6.60E+04	106.87	3.22
49	Fertilizer	2.35E+11 g	5.17E+09	12.15	0.37
50	Steel/Iron	1.38E+12 g	2.64E+09	36.51	1.10
51	Silver	1.91E+09 g	3.00E+14	5723.04	172.44
52	Copper	2.29E+11 g	6.80E+10	156.04	4.70
53	Zinc	1.69E+11 g	6.80E+10	115.02	3.47
54	Gypsum	2.60E+12 g	1.00E+09	26.04	0.78
55	Salt	5.53E+12 g	9.20E+08	50.84	1.53
56	Minerals	1.90E+12 g	9.20E+08	17.51	0.53
57	Cement	4.37E+12 g	7.48E+08	32.68	0.98
58	Agri. & Forestry	3.65E+16 J	2.00E+05	73.00	2.20
59	Fishery Products	6.51E+13 J	2.00E+06	1.30	0.04
60	Livestock	3.07E+14 J	2.00E+06	6.13	0.18
61	Foods	2.04E+16 J	8.50E+04	17.31	0.52
62	Plastics	6.40E+10 g	3.80E+08	0.24	0.01
63	Chemicals	9.41E+11 g	3.80E+08	3.58	0.11
64	Wood	1.46E+15 J	3.49E+04	0.51	0.02
65	Paper	1.60E+14 J	2.15E+05	0.34	0.01
66	Textiles	2.50E+15 J	3.80E+06	95.15	2.87
67	Machinery	5.89E+09 $	3.32E+12	195.49	5.89
68	Service in exports	2.28E+10 $	3.32E+12	755.53	22.76
69	Tourist Service	2.98E+09 $	3.32E+12	98.97	2.98

Footnotes to Table A1

1 SOLAR ENERGY:

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  Cont Shelf Area = 4.42 E+11 m² at 200 m depth (World Resources 90-91)
        Land Area = 1.96 E+12 m² (INEGI, 1989)
       Insolation = 1.80 E+02 Kcal/cm²/yr   (World Energy Data Sheet)
           Albedo = 0.30 (%, given as decimal)  * estimate

        Energy(J) = (area incl shelf)*(avg insolation)*(1-albedo)
                  = (____m²)*(____Cal/cm²/y)*(E+04cm²/m²)*
                       (1-0.30)*(4186 J/kcal)
              (J) = 1.26 E+22
```

2 RAIN, CHEMICAL POTENTIAL ENERGY:

```
        Land Area = 1.96 E+12 m²  (INEGI, 1989)
   Cont Shlf Area = 4.42 E+11 m²  @ 200 m depth  (World Resources 90-91)
    Rain @ (land) = 0.73 m/yr avg. for 1966-1987 (CNA, SARH, 1991)
   Rain @ (shelf) = 0.33 m/yr (est. as 45% of tot. rain)
              Etr = 0.90 m/yr (% given as decimal)   (IAM, UG) (SRH, 1976)
                        @ E-T of 0.662782 m/yr  calc. by turc method @ mean Temp (21 C)

    Energy (land) = (area)*(ET)*(rainfall)*(Gibbs #)
                  = (____m²)*(____m)*(1000 kg/m³)*(4.94 E+03 J/kg)
              (J) = 6.38 E+18 or 7.09 E+18 (J) using method as for USA (HTO, 1992)

   Energy (shelf) = (area of shelf)*(rainfall)*(Gibbs #)
              (J) = 7.21 E+17

 Total energy (J) = 7.10 E+18 or 7.81 E+18 (J) using method as for USA (HTO, 1992)
```

3 RAIN, GEOPOTENTIAL ENERGY:

```
             Area = 1.96E+12 m² INEGI, 1989
         Rainfall = 0.73 m/yr avg. for 1966-1987 (CNA, SARH, 1991)
        Avg. Elev = 1059.00 m   (avg. from WATER ATLAS, SRH, 1976)
              Etr = 0.90 m/yr (% given as decimal)   (IAM, UG) (SRH, 1976)
                         @ E-T of 0.662782 m/yr  calc. by turc method @ mean Temp (21 C)
      Runoff rate = 0.10 @(1-Etr) as a % in decimal point

       Energy (J) = (area)*(% runoff)*(rainfall)*(avg elevation)*(gravity)
                  = (____m²)*(____m)*(1000 kg/m³)*(____m)*(9.8 m/s²)

              (J) = 1.49 E+18 or 1.49 E+19 (J) using method as for USA (HTO, 1992)
```

4 WIND ENERGY:

```
   @ ground level = 3.90 E+12 kwh/yr (World Energy Data Sheet, 1980)
                        @ 860.5 kcal/kwh
                        @ 4186 J/kcal

       Energy (J) = 1.40 E+19 J/yr
```

5 WAVE ENERGY:

```
     @ coast line = 4.45 E+11 kwh/yr (World Energy Data Sheet, 1980)
                        @ 860.5 kcal/kwh
                        @ 4186 J/kcal

       Energy (J) = 1.60 E+18 J/yr
```

6 TIDAL ENERGY:

Cont Shlf Area = 4.42E+11 m^2 (globe resources 90-91)
Avg Tide Range = 0.91 m (avge. from 35 stations) (IG-F, UNAM, 1990)
Density = 1.03E+03 kg/m^3 (Odum et al. 1983)
Tides/year = 7.30E+02 (estm. of 2 tides/day in 365 days)

Energy (J) = (shelf)(0.5)(tides/y)(mean tidal range)^2
(density of seawater)(gravity)
=(___m^2)*(0.5)*(___/yr)*(___m)^2*(____kg/m^3)
*(9.8m/s^2)

(J) = 1.34E+18 or 1.34E+17 (J) using method as for USA (HTO, 1992)

7 RIVER GEOPOTENTIAL

Energy (J) = (flow)(elevation change)(gravity)(sec/yr)
(water weight)(0.5 energy available to Mexico)

Energy (J) = (m^3/s)(m)(9.8m/s^2)(1000kg/m^3)(3.1E7s/yr)(0.5)

River	Flow (m^3/s)	Elevation change (m)		Energy (J)
Colorado	65.55	200.00	*	2.84E+15
Bravo	11.80	1123.00		2.05E+15
Suchiate	23.26	800.00		2.88E+15
Usumacinta	1751.00	350.00	**	1.18E+17

* (0.7 enegy avail. to Mex.)
** (0.625 energy avail. to Mex.)

Flow data from (WATER ATLAS, SRH, 1976)
Elev change data (Mex. topographic maps, INEGI)

Total energy (J) = 1.26E+17

8 EARTH CYCLE:

Land Area = 1.96E+12 m^2 (INEGI, 1989)
* Heath Flow/Area = 1.91E+06 J/m^2/yr

* @ 60.6 mW/m^2 avge. for N-America Continent (Jessop, 1990).
@ 1 W/m^2 = 2.388E-05 cal/cm^2 sec

Energy (J) = (land area)(Heat flow per unit area)

(J) = 3.74E+18

INDIGENOUS RENEWABLE ENERGY

9 HYDROELECTRICITY:
Kilowatt Hrs/yr = 2.40E+10 KwH/yr @ 1989 (II I.G.,CSG,SPP, 1990)
@ 3.60E+06 J/KwH
Energy(J) =(____KwH/yr)*(____J/KwH)

(J) = 8.66E+16

10 AGRICULTURAL PRODUCTION:
Ag. Prod = 6.70E+07 MT at 1989 (II I.G.,CSG.,SPP,1990)

Energy(J) = (3.74E+07 MT)*(1E06 g/MT)*(3.5 Kcal/g)*(4186 J/Cal)

= 9.81E+17

```
11 LIVESTOCK PRODUCTION:
     L'stock Prod    = 9.59E+06 MT  at 1989 (II I.G.,CSG.,SPP, 1990)

          Energy(J) = (1.13E+07 MT)*(1E+06 g/MT)*(4 Cal/g)*(4186 J/Cal)
                    = 1.61E+17

12 FISHERIES PRODUCTION:
     Fish Catch      = 1.52E+06 MT  at 1989 (II I.G.,CSG.,SPP, 1990)

          Energy(J) = (1.28E+06 MT)*(1E+06 g/MT)*(4 Cal/g)*(4186 J/Cal)
                    = 2.54E+16

13 FUELWOOD PRODUCTION:
     Fuelwood Prod  = 4.43E+05 m^3 (m^3 R, 1989) (II I.G.,CSG.,SPP, 1990)

        Energy (J) =  (__ m^3)(1E6 cm^3/m^3)(10176 J/cm^3)
               (J) =  4.51E+15

14 FOREST EXTRACTION
     Harvest        = 8.45E+06 m^3 (m^3 R, 1989) (II I.G.,CSG.,SPP, 1990)

          Energy(J) = (__ m^3)(1E6 cm^3/m^3)(10176 J/cm^3)
                    = 8.59E+16

NONRENEWABLE RESOURCE USE FROM WITHIN MEXICO


15 NATURAL GAS        Consumption = (internal sales + imports)

   Internal sales    = 1.23E+10 m^3 @ 1989 (IMP, 1990)(II I.G.,CSG.,SPP., 1990)
                   @  3.53E+01 ft^3/m^3
        imported    = 1.66E+10 ft^3/yr @ 1989 (IMP,1990)

          Energy(J) = (((__m^3)*(__ft^3/m^3))+(__ft^3))*(1031 BTU/ft^3)*(1055 J/BTU)

                (J) = 4.92E+17

16 OIL                Consumption = (production - exports)

        production =  9.17E+08 barrels/yr @ 1989 (IMP, 1990)
           exports =  4.66E+08 barrels/yr @ 1989 (IMP, 1990)

          Energy(J) =(Prod. - export. in b/yr)*(5800000 BTU/barrel)*(1055 J/BTU)
                    = 2.76E+18

17 THERMOELECTRICITY      Consumption = (production - exports + imports)

        production =  8.83E+04 Gwh/yr @ 1989 (II I.G.,CSG, SPPP, 1990)
           exports =  1.93E+03 Gwh/yr @ 1989 (II I.G.,CSG, SPPP, 1990)
           imports =  6.12E+02 Gwh/yr @ 1989 (II I.G.,CSG, SPPP, 1990)

          Energy(J) =(Consumed__ GwH/yr)*(1.0E+06 KwH/GwH)*(3.6E+06 J/KwH)
                    = 3.13E+17

18 FERTILIZER         Consumption = Internal sales

    Internal sales  = 4.29E+06 MT/yr  @1989 (II I.G.,CSG, SPP, 1990)
          Energy(g) = (__ MT/yr)*(1E6 g/MT)
                (g) = 4.29E+12

19 GOLD               Consumption = production
        Production =  8.65E+03 Kg/yr @ 1989 (INEGI,1990)(The Economist,91-92)
    Energy (grams) = (__Kg)*(1000 g/Kg)
               (g) =  8.65E+06

20 SILVER             Consumption = (Production - Exports)

        Production =  2.31E+03 MT/yr @ 1989 (INEGI,1990)(The Economist,91-92)
           Exports =  1.91E+03 MT/yr @ 1989 (INEGI,1990)(II I.G.,CSG,SPP, 1990)

    Energy (grams) = (Prod.-Exp.___MT)*(1000000 g/MT)
               (g) =  4.00E+08
```

```
21 COPPER            Consumption = (Production - Exports)

       Production =  2.49E+05 MT/yr @ 1989 (INEGI,1990)(The Economist,91-92)
          Exports =  2.29E+05 MT/yr @ 1989 (INEGI,1990)(Mexico Data Bank, 1990)

   Energy (grams) = (Prod - Exp__MT)*(1000000 g/MT)
              (g) =  1.98E+10

22 ZINC              Consumption = (Production - Exports)

       Production =  2.81E+05 MT/yr @ 1989 (INEGI,1990)(The Economist,91-92)
          Exports =  1.69E+05 MT/yr @ 1989 (INEGI,1990)(Mexico Data Bank, 1990)

   Energy (grams) = (Prod - Exp__MT)*(1000000 g/MT)
              (g) =  1.12E+11

23 IRON ORE          Consumption = (Production - Exports)

       Production =  5.37E+06 MT/yr @ 1989 (INEGI,1990)(The Economist,91-92)
          Exports =  0.00E+00 MT/yr @ 1989 (INEGI,1990)(Mexico Data Bank, 1990)

   Energy (grams) = (Prod - Exp__MT)*(1000000 g/MT)
              (g) =  5.37E+12

24 COAL              Consumption = production

       Production =  4.24E+06 MT/yr @ 1989 (INEGI,1990)(The Economist,91-92)
  Energy (Joules) = (__MT)*(0.9072 sht. Ton/MT)*(3.18E10 J/sht. Ton)
              (J) =  1.22E+17

25 GYPSUM            Consumption = (Production - Exports)

       Production =  2.89E+06 MT/yr @ 1989 (INEGI,1990)(The Economist,91-92)
          Exports =  2.60E+06 MT/yr @ 1989 (INEGI,1990)

   Energy (grams) = (Prod - Exp__MT)*(1000000 g/MT)
              (g) =  2.87E+11

26 SALT              Consumption = (production - Exports)

       Production =  6.97E+06 MT/yr @ 1988 (Mexico Data Bank, 1990)
          Exports =  5.10E+06 MT/yr @ 1988 (BANCOMEX,1990)

   Energy (grams) = (Prod - Exp__MT)*(1000000 g/MT)
              (g) =  1.87E+12

27 MINERALS          (Pb,non-ferrous metals,Coke, Mn,non-metalic)
                     Consumption = (production - exports)
       Production =  8.12E+06 MT/yr @ 1989 (INEGI, 1990)
          Exports =  1.90E+06

        Energy(g) =(Prod - Exp__MT)*(1000000 g/MT)
              (g) = 6.22E+12

28 STEEL & IRON      (Steel, Pig & Sponge iron, Rolled products)

            Steel =  7.92E+06 MT/yr @ 1989 (Mexico Data Bank, 1990)
         Pig iron =  3.25E+06 MT/yr @ 1989 (Mexico Data Bank, 1990)
      Sponge iron =  2.23E+06 MT/yr @ 1989 (Mexico Data Bank, 1990)
  Rolled prodcts. =  6.30E+06 MT/yr @ 1989 (Mexico Data Bank, 1990)
                    ----------
  Total Productn. =  1.97E+07 MT/yr @ 1989 (Mexico Data Bank, 1990)
       Energy (g) = (__MT/yr)(1000000 g/MT)
              (g) =  1.97E+13

29 STEEL & IRON      Consumption

      consumption =  1.32E+07 MT/yr @ 1989 (II I.G., CSG, SPP, 1990)
       Energy (g) = (__MT/yr)(1000000 g/MT)
              (g) =  1.32E+13
```

30 CEMENT Consumption = (production - Exports)

```
        Production =  2.25E+07 MT @ 1988 (Mexico Data Bank, 1990)
           Exports =  4.20E+06 MT @ 1988 (Mexico Data Bank, 1990)
    Energy (grams) = (Prod - Exp__MT)*(1000000 g/MT)
               (g) =  1.83E+13
```

31 PLASTICS Consumption

```
       Consumption =  1.24E+06 MT/yr @ 1989 (Plastics yearbook,IMPI, 1990)
        Energy (g) = (__MT/yr)(1000000 g/MT)
               (g) =  1.24E+12
```

32 TOPSOIL:

```
         Land Area =  1.96E+12 m^2 (INEGI, 1990)
       Arable land =  2.55E+11 m^2 @ 1986 as 13 % of Land area (FAO,1989)
       Forest land =  4.50E+11 m^2 @ 1986 as 23 % of Land area (FAO,1989)
soil loss arbl land =  8.50E+02 g/m^2/yr (estimated from Odum et al 1983)
     new soil form. =  1.26E+03 g/m^2/yr (assume for half of forest area)
          soil loss = ((Forest__m^2)*(0.5))*(new soil form.__g/m^2/yr)
                    =  2.84E+14 g/yr
        soil eroded = (Arable__m^2)*(soil loss Arabl. land__g/m^2/yr)
                    =  2.16E+14 g/yr

                      (soil loss)-(soil eroded) =
                    =  6.74E+13 g/yr

        Energy (J) = (__g/y)(0.03 organic)(5.4 Kcal/g)(4186 J/Kcal)
               (J) =  4.57E+16
```

IMPORTS OF OUTSIDE ENERGY SOURCES:

33 OIL DERIVATIVES

```
           Imports =  4.35E+07 bls/yr @ 1989 (BANCOMEX,1990)
        Energy (J) = (__bls/yr)(5.7E6 BTU/bls)(1055 J/BTU)
               (J) =  2.61E+17      value US ($)=  8.13E+08
```

34 STEEL:

```
           Imports =  1.64E+06 MT/yr @ 1989 (BANCOMEX, 1990)
        Energy (g) = (__ MT/yr)*(1E6 g/MT)
               (g) =  1.64E+12      value US ($)=  1.31E+09
```

35 MINERALS (metal, non-metal)

```
           Imports =  2.53E+06 MT/yr @ 1989 (BANCOMEX, 1990)
        Energy (g) = (__ MT/yr)*(1E+6 g/MT)
               (g) =  2.53E+12      value US ($)=  3.88E+08
```

36 AGRIC. & FOREST. PRODS.

```
           Imports =  8.68E+06 MT/yr @ 1989 (BANCOMEX, 1990)
        Energy (J) = (__ MT/yr)*(1E6g/MT)*(3.5 Kcal/g)*(4186 J/Kcal)
               (J) =  1.27E+17      value US ($)=  1.75E+09
```

37 LIVESTOCK

```
           Imports =  1.09E+05 MT/yr @ 1989 (II I.G.,CSG,SPP,1990)(BANCOMEX, 1990)
        Energy (J) = (1E5 MT/yr)*(1E6 g/MT)*(4 Kcal/g)*(4186 J/Kcal)*(.22 protein)
               (J) =  4.03E+14      value US ($)=  2.48E+08
```

38 FOOD & BEVRGE.

```
           Imports =  2.35E+06 MT/yr @ 1989 (BANCOMEX, 1990)
        Energy (J) =  (__ MT)*(1E6g/MT)*(15.1E3 J/g)
               (J) =  3.55E+16      value US ($)=  2.01E+09
```

39 PLASTICS

Imports = 6.37E+04 MT/yr @ 1989 (BANCOMEX, 1990)
Energy (g) = (__ MT/yr)*(1000000 g/MT)
(g) = 6.37E+10 value US ($)= 2.59E+08

40 CHEMICALS

Imports = 7.83E+05 MT/yr @ 1989 (BANCOMEX, 1990)
Energy (g) = (7.8 E5 MT/ yr)*(1E6g/MT)
(g) = 7.83E+11 value US ($)= 2.46E+09

41 WOOD

Imports = 1.45E+05 MT/yr @ 1989 (BANCOMEX, 1990)
Energy (J) = (__ MT/yr)*(1E6 g/MT)*(1.72733 cm^3/g)*(10176 J/cm^3)
(J) = 2.55E+15 value US ($)= 1.11E+08

42 PAPER

Imports = 1.58E+06 MT/yr @ 1989 (BANCOMEX, 1990)
Energy (J) = (__ MT/yr)*(1E6 g/MT)*(1.72733 cm^3/g)*(10176 J/cm^3)
(J) = 2.78E+16 value US ($)= 9.34E+08

43 TEXTILES

Imports = 5.21E+04 MT/yr @ 1989 (BANCOMEX, 1990)
Energy (J) = (__ MT/yr)*(1E6 g/MT)*(15E3 J/g)
(J) = 7.81E+14 value US ($)= 7.00E+08

44 MACHINERY (transportation & industry)

Imports = 1.05E+10 US ($) @ 1989 (BANCOMEX, 1990)

Value US ($) = 1.05E+10

45 SERVICES:

Dollar value = 2.34E+10 $US @1988 (BANCOMEX, 1991)

US ($) = 2.34E+10

46 TOURISM :

Dollar Value = 1.54E+09 $US @ 1989 (II I.G.,CSG, SPP, 1990)

US ($) = 1.54E+09

EXPORTS OF ENERGY, MATERIALS AND SERVICES

47 CRUDE OIL :

Exports = 4.67E+08 Barrels/yr @ 1989 (BANCOMEX, 1990)
Energy (J) = (4.67E8 B/yr)*(6.1E9 J/Barrel)
(J) = 2.85E+18 value US($) = 7.29E+09

48 OIL DERIVATIVES

Exports = 2.70E+07 bls/yr @ 1989 (BANCOMEX,1990)
Energy (J) = (__bls/yr)(5.7E6 BTU/bls)(1055 J/BTU)
(J) = 1.62E+17 value US ($)= 4.24E+08

49 FERTILIZER

Exports = 2.35E+05 MT @ 1989 (II IGCSG,SPP,1990)
Energy (g) = (2.35E5 MT)*(1E6 g/MT)
(g) = 2.35E+11 value US($) = 2.98E+07

50 STEEL:

```
       Exports =  1.38E+06 MT/yr @ 1989 (BANCOMEX, 1990)
    Energy (g) = (1.6E6 MT/yr)*(1E6 g/MT)
           (g) =  1.38E+12      value US($) =  8.67E+08
```

51 SILVER

```
       Exports =  1.91E+03 MT/yr @ 1989 (INEGI,1990)(II I.G.,CSG,SPP, 1990)
Energy (grams) = (__MT)*(1000000 g/MT)
           (g) =  1.91E+09      value US($) =  3.47E+08
```

52 COPPER

```
       Exports =  2.29E+05 MT/yr @ 1989 (INEGI,1990)(Mexico Data Bank, 1990)
    Energy (g) = (__MT)*(1000000 g/MT)
           (g) =  2.29E+11      value US($) =  1.48E+08
```

53 ZINC

```
       Exports =  1.69E+05 MT/yr @ 1989 (INEGI,1990)(Mexico Data Bank, 1990)
    Energy (g) = (__MT)*(1000000 g/MT)
           (g) =  1.69E+11      value US($) =  7.91E+07
```

54 GYPSUM

```
       Exports =  2.60E+06 MT/yr @ 1989 (INEGI,1990)
Energy (grams) = (__MT)*(1000000 g/MT)
           (g) =  2.60E+12      value US($) =  3.70E+07
```

55 SALT

```
       Exports =  5.53E+06 MT/yr @ 1988 (BANCOMEX,1990)
    Energy (g) = (__MT)*(1000000 g/MT)
           (g) =  5.53E+12      value US($) =  6.59E+07
```

56 MINERALS :   (metal, non-metal)

```
       Exports =  1.90E+06 MT  @ 1989 (BANCOMEX, 1990)
    Energy (g) = (__ MT)*(1E6 g/MT)
           (g) =  1.90E+12      value US($) =  2.75E+08
```

57 CEMENT

```
       Exports =  4.37E+06 MT @ 1988 (Mexico Data Bank, 1990)(BANCOMEX,1990)
    Energy (g) = (__MT)*(1000000 g/MT)
           (g) =  4.37E+12      value US($) =  1.56E+08
```

58 AGRI. & FORESTRY   (cash crops)

```
  Exports:                      @1989 (BANCOMEX, 1990)
    Coffe         2.45E+05 MT
    Tomatoe       4.39E+05 MT
    Vegetables    8.62E+05 MT
    Watermelon    4.07E+05 MT
    Fresh Fruit   3.06E+05 MT
    Cotton        8.93E+04 MT
    Others        1.43E+05 MT
        TOTAL     2.49E+06 MT

    Energy (J) =  (__ MT)*(1E+06 g/MT)*(3.5 Cal/g)*(4186 J/Cal)
           (J) =  3.65E+16      value US($) =  1.46E+09
```

59 FISHERY PRODUCTS

```
       Exports =  1.77E+04 MT  @ 1989 (BANCOMEX, 1990)
    Energy (J) = (1.77E4 MT)(1E+06 g/MT)(4 Cal/g)(4187 J/Cal)(.22 prot)
           (J) =  6.51E+13      value US($) =  4.70E+07
```

60 LIVESTOCK :

```
        Exports =  8.33E+04 MT  @ 1989 (II Inf. de Gob. 1990, SPP)(SARH,1991)(BANCOMEX,1990)
     Energy (J) =  (8.33E4 MT/yr)(1E6 g/MT)(4 Kcal/g)(4186 J/Cal)(.22 protein)
            (J) =  3.07E+14      value US($) =  2.46E+08
```

61 FOOD & BEVRGE.

```
        Exports =  1.35E+06 MT/yr @ 1989 (BANCOMEX, 1990)
     Energy (J) =  (__ MT)*(1E6g/MT)*(15.1E3 J/g)
            (J) =  2.04E+16      value US($) =  1.27E+09
```

62 PLASTICS

```
        Exports =  6.40E+04 MT/yr @ 1989 (BANCOMEX, 1990)
     Energy (J) = (__ MT/yr)*(1000000 g/MT)
            (J) =  6.40E+10      value US($) =  1.59E+08
```

63 CHEMICALS :

```
        Exports =  9.41E+05 MT  @ 1989 (BANCOMEX, 1990)
     Energy (g) = (__ MT)*(1E6 g/MT)
            (g) =  9.41E+11      value US($) =  1.51E+09
```

64 WOOD

```
        Exports =  8.31E+04 MT/yr @ 1989 (BANCOMEX, 1990)
     Energy (J) = (__ MT/yr)*(1E6 g/MT)*(1.72733 cm^3/g)*(10176 J/cm^3)
            (J) =  1.46E+15      value US($) =  1.97E+08
```

65 PAPER

```
        Exports =  9.12E+03 MT/yr @ 1989 (BANCOMEX, 1990)
     Energy (J) = (__ MT/yr)*(1E6 g/MT)*(1.72733 cm^3/g)*(10176 J/cm^3)
            (J) =  1.60E+14      value US($) =  2.69E+08
```

66 TEXTILES

```
        Exports =  1.67E+05 MT/yr @ 1989 (BANCOMEX, 1990)
     Energy (J) = (__ MT/yr)*(1E6 g/MT)*(15E3 J/g)
            (J) =  2.50E+15      value US($) =  5.06E+08
```

67 MACHINERY   (transportation & Industry)

```
        Exports =  5.89E+09 US ($)  @ 1989 (BANCOMEX, 1990)

  Value US ($) =  5.89E+09
```

68 SERVICES IN EXPORTS:

```
  Dollar Value =  2.28E+10 $US  @ 1989 (BANCOMEX, 1991)

       US ($) =  2.28E+10
```

69 TOURISM SERVICES:

```
  Dollar Value =  2.98E+09 $US @ 1989 (II I.G.,CSG, SPP,1990)

       US ($) =  2.98E+09
```

Table A2. Summary of flows in Mexico, 1989

Variable	Item	Solar EMergy (E+20 Sej/yr)	Dollars (E+9 $/yr)
R	Renewable sources (rain,tide,river)	1385.89	
N	Nonrenewable source flows within Mexico	11364.37	
N_0	Dispersed rural source	62.84	
N_1	Concentrated use	3593.88	
N_2	Exported without use	7707.66	10.00
F	Imported fuels and minerals	238.80	2.51
G	Imported goods	784.33	18.95
I	Dollars paid for imports		23.41
P_2I	Emergy value of goods and service imports	889.57	
I_3	Dollars paid for imports minus dollars in F+G		1.95
P_2I_3	Imported services	74.14	
E	Dollars received for exports		22.76
P_1E	EMergy value of goods and service exports	755.53	
B	Exported products transformed within Mexico	500.84	11.28
E_3	Dollars received for exports, minus $ in (B+N2)		1.49
P_1E_3	Exported services	49.46	
x	Gross National Product		185.00
P_2	World EMergy/$ ratio, used in imports	3.80 E+12 Sej/$	
P_1	Mexico EMergy/$ ratio	3.32 E+12 Sej/$	

Table A3. Indices using EMergy for overview of Mexico, 1989.

Item	Name of Index	Expression	Quantity (sej/yr)
1	Renewable EMergy flow	R	1.39 E+23
2	Flow from indigenous non-renewable reserves	N	1.14 E+24
3	Flow of imported EMergy	$F+G+P_2I_3$	1.10 E+23
4	Total EMergy inflows	$R+N+F+G+P_2I_3$	1.38 E+24
5	Total EMergy used, U	$N_0+N_1+R+F+G+P_2I_3$	6.14 E+23
6	Total exported EMergy	$B+P_1E_3$	5.50 E+22
7	Fraction of EMergy used derived from home sources	$(N_0+N_1+R)/U$	0.82
8	Imports minus exports	$(F+G+P_2I_3)-(N_2+B+P_1E_3)$	-7.16 E+23
9	Ratio of export to imports	$(N_2+B+P_1E_3)/(F+G+P_2I_3)$	7.53
10	Fraction used, locally renewable	R/U	0.23
11	Fraction of use purchased	$(F+G+P_2I_3)/U$	0.18
12	Fraction used, imported service	P_2I/U	0.14
13	Fraction of use that is free	$(R+N_0)/U$	0.24
14	Ratio of concentrated to rural	$(F+G+P_2I_3+N_1)/(R+N_0)$	3.24
15	Use per unit area (1.96 E+12 m^2)	U/area (in sej/m^2)	3.13 E+11
16	Use per person (81.14 E+6 people)	U/population	7.57 E+15
17	Renewable carrying capacity at present living standard	(R/U)*(population)	1.83 E+07
18	Developed carrying capacity at same living standard	8*(R/U)*(population)	1.47 E+08
19	Ratio of use to GNP, EMergy/dollar ratio	P_1=U/GNP (in sej/$)	3.32 E+12
20	Ratio of electricity to use (Elec: 494.94 E+20 Sej/yr)	(elec)/U	0.10
21	Fuel use per person (Fuel: 1553 E+20 Sej/yr)	(fuel)/(population)	2.13 E+15

Table A4. Summary of EMergy indices of Mexico compared with other countries and the world.

Index	Mexico	U.S.A.	Papua New Guinea	Brazil	Australia	New Zealand	WORLD
EMergy use (E+20 sej/yr)	6140	66400	1205	17820	8850	791	188000
GNP (E+9 $/yr)	185	2600	2.3	214	139	26	5000
EMergy/$ (E+12 sej/$)	3.32	2.6	51.79	8.4	6.4	3.0	3.8
Population (E+6 people)	81.14	227	3.2	121	15	3.1	5044
EMergy use/person (E+15 sej/per/yr)	7.57	29	37.7	15	59	26	1.6
Environmental component of EMergy (E+20 sej/yr)	1386	8240	997	10200	4590	438	80000
Economic component of EMergy (E+20 sej/yr)	4754	58160	208	7600	3960	353	188000
Economic/Environment	3.43	7.1	0.21	0.74	1.1	0.8	2.35
Area (E+10 m^2)	196	940	46.2	918	768	26.9	-
Population density (people/km^2)	41.4	24.2	6.9	13.2	1.9	11.5	-
EMergy use/area (E+11 sej/m^2/yr)	3.13	7.0	2.61	2.8	1.42	2.49	-

SECTION 3B: EMergy Analysis of Nayarit

by Javier Venegas

INTRODUCTION

The physiographic characteristics of Nayarit are described in Volume I, Part 1 of this report. Those of Mexico as a whole are given in Section 3A of this volume. A brief description of the physical, population and economic characteristics of Nayarit is given below.

The State

The State of Nayarit is located midway along Mexico's Pacific coastline (see Figure B-1). It is oriented northwest to southeast, approximately 277 km long and averaging 180 km in width. The shoreline is approximately 295 km. The eastern boundary is delimited by the western (Occidental) ridge of the Sierra Madre mountain range, which rises to approximately 2,740 m.

Approximately two-thirds of Nayarit is comprised of rugged mountains: the Sierra Madre del Sur to the extreme south; the Sierra Madre Occidental comprising about one-half of the state along the eastern boundary; and, in the south central region, the westernmost portion of the neovolcanic range that transects Mexico from east to west. The remaining third of the state (northwest) is a coastal valley expansion, approximately 100 km long by 50 km wide (INEGI, 1986).

The Population

The estimated population of Nayarit for 1990 was 870,000. Its overall density was around 31.2/km^2, with the highest concentrations (50.1 or more/km^2) located in the state's mid coastal regions, surrounding the city of Santiago Ixcuintla and extending inland to the area surrounding Tepic, the State capitol. The lowest density regions are located in the mountainous areas of the eastern half and southernmost parts of the state. Thus, approximately one fourth of the area is considered high density, one fourth medium, and the remaining half low density. The growth rate, which has been declining in recent years, is calculated to be between 1.0% and 1.2%.

Approximately 67% of the population is concentrated in six of its urban centers, with Tepic being the most populous and making up around 24.4% (212,280 inhabitants) of the total. The birth and death rates are projected to continue at 22 and 5 per thousand, respectively. A net negative migration (-0.22%) has been reported (INEGI, 1990; SSA, 1991).

The Economy

The latest figures available on Nayarit's Gross Domestic Production (GDP) of goods and services (1980) represented about 0.8% of the nation's total. Of this, 26.1% came from primary production (agriculture, livestock, hunting and fishing, silviculture and mining), 24.4% from secondary production (transformation industry, electricity and construction) and 49.6% from tertiary production (commerce and services). Of these three, the primary sector continues to be the predominant one, even though it ranks second in the state's GDP. Agriculture, which makes up about 76% of the primary production and 18.4% of the state's total, is the most important. Livestock is 18.1%, fisheries about 3.3%, silviculture 2.5%, and the remainder 0.1% is taken up by mining. The top three have products which are exported to other parts of the country as well as abroad. (INEGI, 1990; SSA, 1991).

EMERGY ANALYSIS OF NAYARIT

Table B-1 provides a summary of Nayarit's 1985 economic resource base, which may be compared to that of Mexico (Table A-1). Renewable and nonrenewable resources, as well as imports and exports are given. For the renewable resources, riverine inputs, waves and wind, respectively, had the highest EMergy contributions. For the indigenous renewable inputs, livestock production followed by agriculture and then fisheries were the most significant. Electricity, followed by topsoil, was the highest in terms of nonrenewable sources.

For imports of EMergy sources, services (item 29) were first, followed by oil and then tourism. However, because of the transient nature of tourism, some clarification needs to be made. It is an outside source of EMergy input, but only temporarily. As such, this item is not counted in the summation under this section. For exports of EMergy, services in exports (i.e., money received in exchange for a product or service), tourist services, and livestock were the highest. It is important to recall that, in EMergy terms, the products which yield the highest raw units will not necessarily produce the highest EMergy yields nor result in the highest macroeconomic value. This will ultimately depend on the transformity value of each item. In Nayarit it was observed that those sources with the highest EMergy value provided the highest macroeconomic contribution. The results for Nayarit seem to closely parallel those of the whole country.

Figure B-2 is a schematic representation of Nayarit's main energy sources, flows (input and output), and storages (see also Table B-2). It is organized in hierarchical fashion from left to right, according to the EMergy quality (or transformity) of each item. This means that those to the left have a lower EMergy content per unit, are more abundant and diffused, and took less effort or work to produce. Moving to the right on the diagram, things become more concentrated, the quality per unit of each item is increased, the quantity decreased, and more resources and energy are required for their production. It is at this high EMergy level that the development of the interface between the economy and the ecosystems the economy draws from occurs.

The diagram in Figure B-2 shows how the main production forces driving Nayarit's economy are derived from its coastal ecosystems (mangroves, lagoons, marshes and estuaries), forests, and agriculture. Deep heat and uplift is probably an important contributor as well, but no reliable data regarding this has been found. Tourism is included on the lower right hand side of the diagram. The storage symbol for "Image", located above the tourist box, is closely associated with tourism and is a very powerful tool. The image of a resort and its natural surroundings is advertised in commercials and other promotional activities, and is actually the driving force behind the tourist industry.

Other aspects which might also be included in image are such things as culture. Such is the case for Nayarit. The indigenous Huichole and Cora tribes of the Sierra Madre Occidental have maintained much of their cultural traditions and, as such, have been an attractive force for tourism as well. If the tourists' experiences were overall positive as to their expectations of what the image had portrayed, this positive image will be taken home and shared with others. This acts as a feedback mechanism, reinforcing the tourist industry. This is why the line showing the flow of tourists has no arrows--meaning that the flow is bidirectional, and is reinforced by the image through the interaction symbol (shown flowing in both directions).

Image controls a switch (box with concave edges), which is turned on if the image is positive or off when its negative. When it is positive, usually more foreign investment money flows in to build more assets. While this growth is in progress, the local economy benefits because of the jobs it creates. Unfortunately, once the resort has been built, there is not much else left to do, so workers are laid off. In addition, because the investors are foreigners, the profits made thereafter are exported and the local economy is unable to benefit from it.

On the left in Figure B-3a are the total renewable inflows, the non-renewable EMergy used within the state, and the non-renewable EMergy exported to other areas and markets. At the top are the high EMergy imports which include the fuels and minerals, and goods and services. The dashed lines represent money flows in dollars per year.

The results of this diagram demonstrate that the highest percentage (71.5%) of imported high-quality EMergy came from fuels and minerals (F), followed by goods (G) with 26%, and a minimum of 2.4% from services (P_2I_3). From the environmental sources, renewable resources (R) had the highest input of 98.7% while non-renewables (N) accounted for 1.3%. In terms of EMergy exports, exported services (P_1E_3) made up 98.8%, while transformed products (B) comprised the remaining 1.2%.

Figure B-3b portrays the simplest way of illustrating the relationships in question. It is called a three-arm diagram, and includes the sum of the environmental inputs (from the left), the sum of the purchased imports (from the top), and the sum of the exports (to the right). Annual solar EMergy flows (EMpower) are written on each pathway. The total annual EMergy use (sum of the inputs from indigenous plus import sources) for Nayarit was about 5.5 E+21 sej/yr. Approximately 70.7% (3.9 E+21 sej/yr) of this is derived from imports, and 29.3% (1.6 E+21 sej/yr) from the regional renewable and non-renewable sources (environmental sources). Of this total EMergy used and transformed within the economy, approximately 2.3% is exported abroad and to other parts of the country.

EMergy Indices

Net EMergy Yield Ratio (NEYR)

This is the ratio of the EMergy yield (5.6 E+21 sej/yr) divided by the EMergy imported (or feedback EMergy of 3.9 E+21 sej/yr) used for processing (items 6 and 3, respectively, in Table B-3). The higher the yield ratio of an economy's primary energy source, the more will be available for other uses besides processing its energy. A good policy would therefore be one that utilizes those sources with the highest NEYR, even if they have to be purchased abroad (Odum, 1992). So the higher this ratio is compared to other external competing systems, the more of a competitive advantage it will have. For Nayarit, this ratio resulted in 1.45.

EMergy-to-Dollar Ratio (EMergy/$)

Nayarit's EMergy/$ ratio of 7.4 E+12 sej/US$ was derived by dividing the total EMergy used (5.5 E+21 sej/yr) by the Gross Domestic Product ($73.6 E+7 US$) for 1985 (Table B-3, item 19). The total EMergy used within a system is a measure of its wealth or EMergy contribution in goods and services. The (EMergy/$ ratio) represents the amount of real wealth which the circulating money can buy. Thus, it is a measure of the buying power of that currency.

According to Odum (1992), a low EMergy/$ ratio suggests a high position in the economic hierarchy. The EMergy/$ ratio is thus inversely related to economic development. As a country increases its EMergy imports and resource utilization, EMergy production increases but money circulation does so even faster, while the resources become limiting. As a result, the EMergy/$ ratio will continue to decrease with time, as long as these conditions persist. Since the same money is circulating faster and less real wealth becomes available, the purchasing power of money decreases (inflation).

Rural countries tend to have higher EMergy/$ ratios because more of the wealth goes directly from the environment to the consumer without money being paid. People living in rural areas have less need for money because they can obtain more of their living necessities directly from nature. This seems to be the case with Nayarit since 67% of its population is concentrated in only 6 urban centers while the remainder is dispersed throughout the rural regions of the state.

EMergy Per Capita Ratio

This ratio can be used as a measure of standard of living. A high value signifies a high standard. This index provides a more realistic view of the living conditions than the income index, because it includes the unpaid direct wealth to people from the environment. For Nayarit, the 1985 EMergy per capita ratio was found to be 6.8 E+15 sej/yr (Table B-3, item 16), which was low compared to several other nations previously studied, but higher than the world average of 4.0 E+15 sej/yr (Odum 1992).

EMpower Density (total EMergy used/area)

This index reflects the solar EMergy being used per unit area. It is useful for measuring both the intensity of economic development of a system plus its spatial location within the hierarchy of the economic organizations of the region. This hierarchy has a range which goes from the lower ratios of rural areas, to the higher ones of the cities. For Nayarit, this index was determined to be 1.95 E+14 sej/m^2, which was 1 to 2 orders of magnitude higher than that of urban nations (Odum, 1992).

EMergy Import to EMergy Export Ratio (Emergy received/EMergy Exported)

A high ratio suggests a rich economy based on external resources which come from the outside, such as from other countries. Since much more EMergy is embedded in raw materials than in money, the disadvantage in their exchange goes to the seller. The buying power of the money received in its sale is usually many times less than the EMergy contribution to the economy of that raw material sold. Therefore, a good policy for any nation or state is to limit the export of their raw materials except where a reasonable balance of EMergy is directly or indirectly obtained in return. The idea is to make them more available to the local economy, keeping their prices to a minimum. This creates an incentive for their use towards the manufacturing of finished products locally. Jobs are created, and the economy at home is stimulated, rather than that of the urban and industrial nations elsewhere. So the more exports of EMergy in finished products, the lower the ratio and thus the better off the local economy will be. Nayarit's Import/Export ratio was found to be 0.69 (Table 3B-3, item 3/item 6).

Other useful EMergy Ratios

Table B-3 provides some other indices valuable in analyzing potentials for economic development in relation to available resources (Odum 1992). These "investment ratios", as they are called, help identify which activities may be feasible for the local economy; especially if safeguarding the environment and the survival of the indigenous population's cultures are to be a priority.

The Purchased-to-Free Index (Purchased/Free = (M+S)/(R+N) = 38.66/15.94 = 2.43). This index is useful in determining how much investment (purchased EMergy) is appropriate for a given amount of free environmental resources, in order to be economically viable. Those systems which have sources that yield lower ratios than their competitors will be able to sell their products at lower prices because they rely on less purchased EMergy. A good ratio is one in which the purchased inputs do not go beyond what the environmental ones are providing. But at the same time, in order to be competitive, it will have to at least match the surrounding regions' ratio value.

Ideally, the EMergy that the environmental flows are supplying should be the limiting factor for the production processes. In this way, sustainable yields may be achieved. Odum (1992) states that interactions maximize their production when they act with equal output per unit input (equal marginal utility). A design that maximizes a unit's output delivers its effort as well and thus they all become equally limiting. This may occur when the total available EMergy is divided equally amongst all the interactions (inputs, outputs, and feedbacks).

For Nayarit, there are apparently more purchased inputs coming in than the environment is able to provide. It therefore needs to either seek out other environmental resources so that the load on the ones being used can be diluted, while at the same time free inputs are increased. The other alternative is to decrease the purchased inputs. However, in order to be economically competitive, Nayarit needs to match its ratio (2.43) to those of Mexico and its neighboring economies such as the United States. At this time, Mexico's ratio is 0.09 while the U.S.'s is 0.04.

The Non-renewable-to-Renewable Index (Non-renewable/Renewable = (N+M)/R = 37.93/15.74 = 2.41). This index gives an idea of how sustainable an economic system will be with regards to its resources, providing the resources are derived from within its boundaries or economy. The higher the ratio, the less sustainable is the economy. Nayarit's index of 2.41 signifies that it is using up non-renewable goods and resources (M+N) at a rate of 2.4 times that of the renewable ones (R). As population and industry grow, the need for more resources will increase, especially those for non-renewables. This will cause an increase in the index, and the carrying capacity (or sustainability) for economies will decrease as the non-renewable resources are used up. Since Nayarit imports practically all of its non-renewable resources (M), at this time it does not have to worry about this. But since access to non-renewable resources (oil, minerals, etc.) are diminishing globally, this figure demonstrates that it would be prudent to limit the use and/or reliance on them. The index will also help to set future policies if exploitation and utilization of its own non-renewable resources are being considered.

Developed-to-Environmental Ratio [or Environmental Loading Ratio] (Developed/Environmental [ELR] = (N+M+S)/R = 38.86/15.74 = 2.47). This index helps evaluate the impact that development has or will have on the environment. It is similar to the Non-renewable-to-Renewable Ratio except that the added impact that the imported services (S) will have is factored in. This is important for Nayarit's coastal zone, especially since development of a tourist industry is occurring.

The resultant ELR was only a 0.06 point increase compared to the Non-renewable-to-Renewable Ratio. This slight increase reflects the change caused by electricity, which was the only import of services that was added. So in terms of preventing overloading or exceeding the carrying capacity of the environment, similar policies like those of the previous index should be established. It should be kept in mind, however, that future increases in imports of services will cause the ELR to rise. Since this will have a negative effect on sustainability, precautionary measures should be taken to minimize this factor.

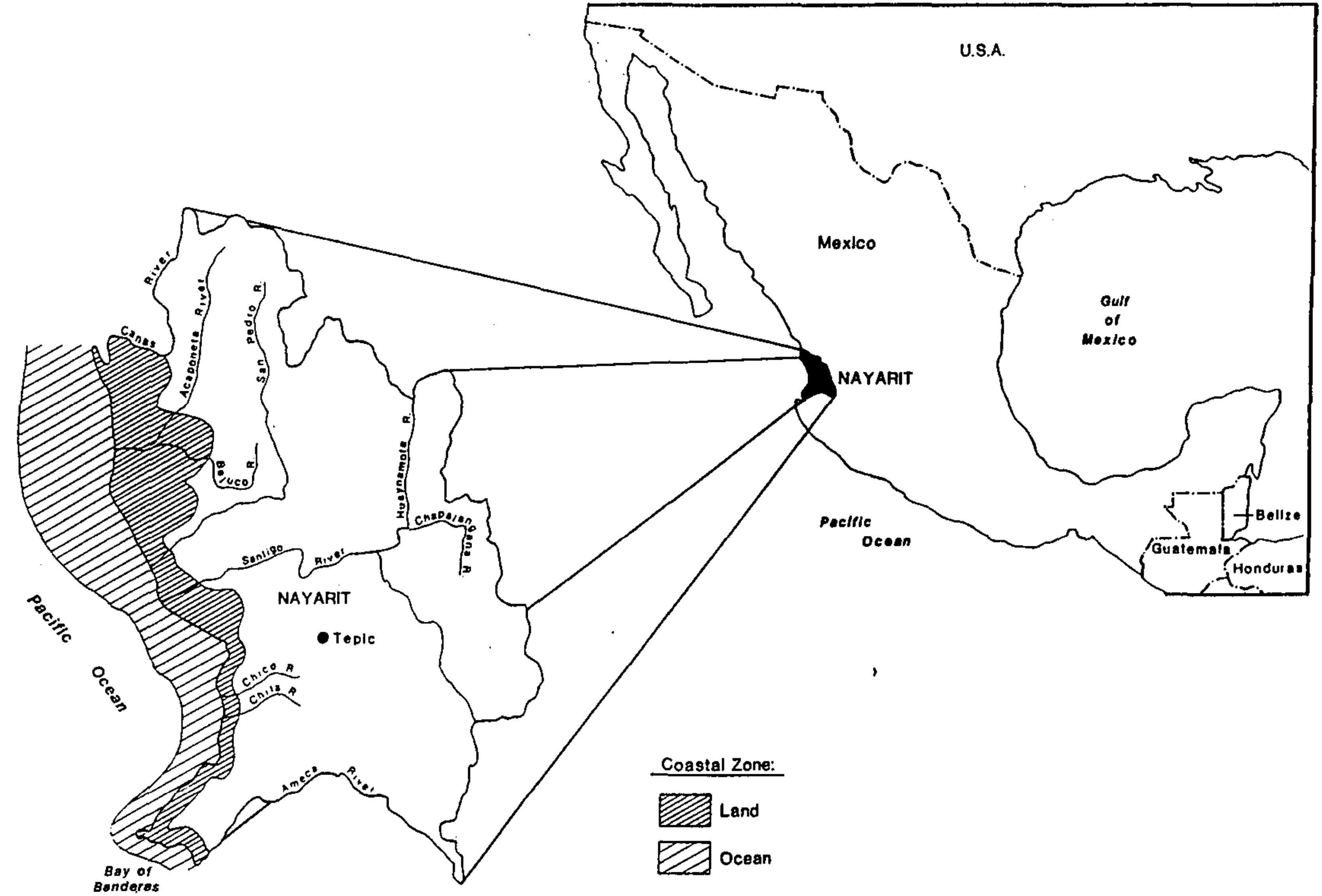


Figure B-1. Location map of the State of Nayarit Mexico showing the coastal zone and major rivers.

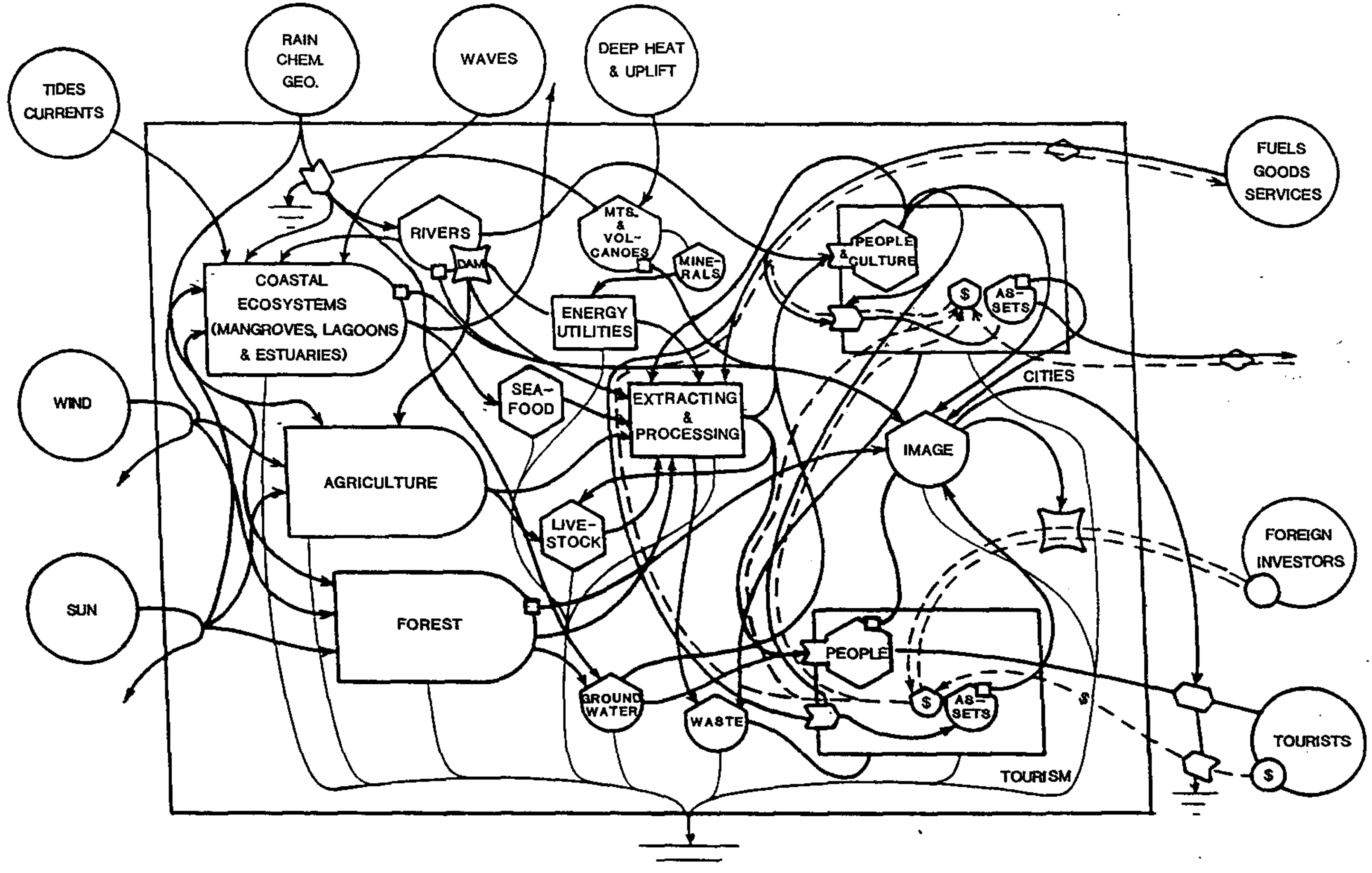


Figure B-2. Energy systems diagram of Nayarit showing the interplay of renewable and nonrenewable and purchased energy sources that drive the economy.

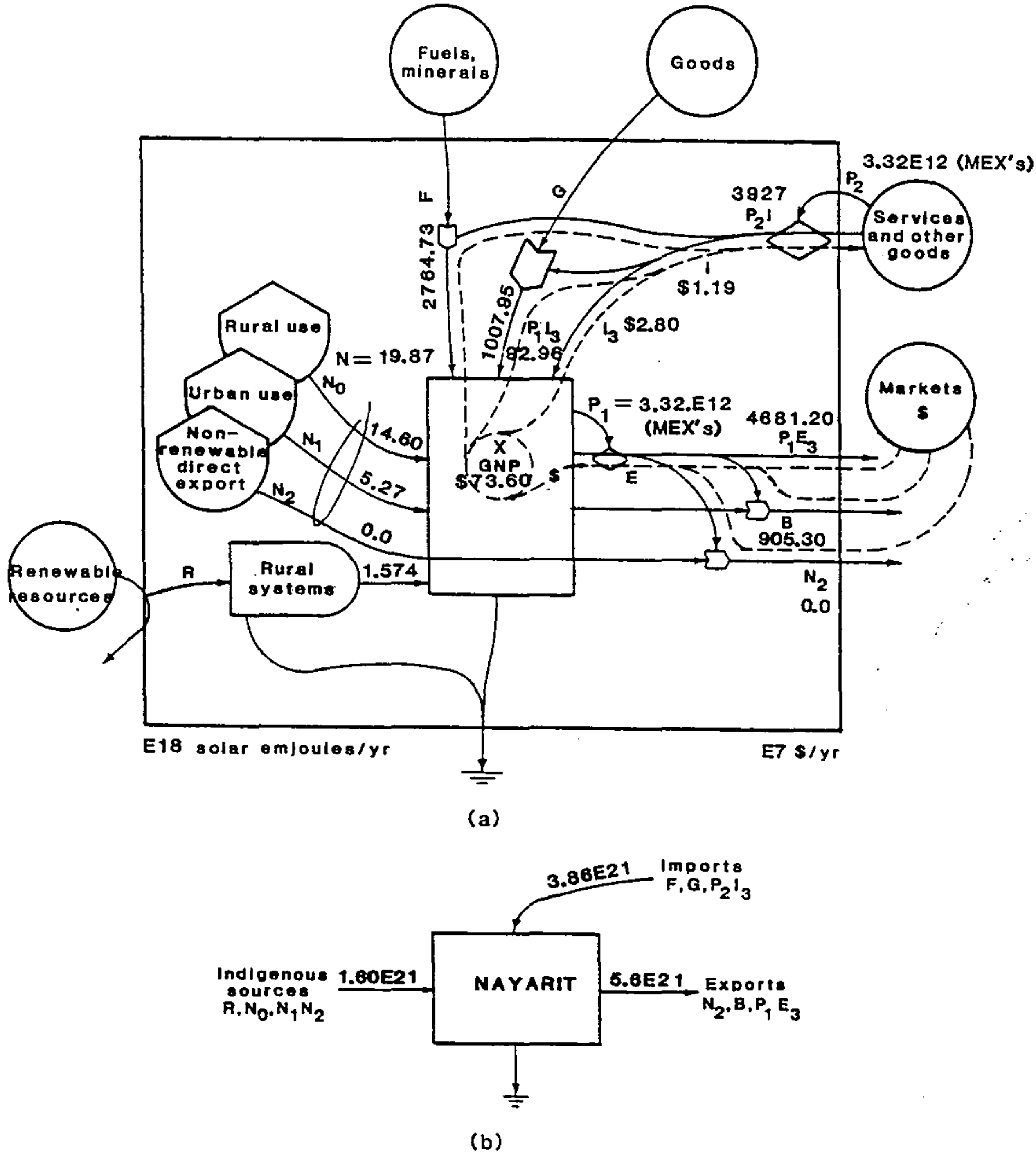


Figure B-3. Summary diagrams of the economy of Nayarit in 1989. The top diagram shows the flows of energy from renewable and nonrenewable sources and from purchased resources that drive the economy. The circle of money within the central box is GDP. The bottom diagram is a further simplification of the economy, showing the main driving energies and balance of imports and exports.

Table B-1. EMergy evaluation of resource basis for Nayarit, 1985.

Note	Item	Raw Units (J, g, $)	Transformity (sej/unit)	Solar EMergy (E16 sej)	Macroeconomic Value (E3 1984 US$)
RENEWABLE RESOURCES:					
1	Sunlight	1.75 E+17 J	1.00 E+00	17.47	5.26 E+01
2	Rain, chemical	1.25 E+14 J	1.82 E+04	227.86	6.86 E+02
3	Rain, geopotential	4.78 E+13 J	1.05 E+04	50.19	1.51 E+02
4	Wind, kinetic	2.00 E+15 J	1.50 E+03	299.50	9.02 E+02
5	Waves	5.15 E+16 J	3.06 E+04	157332.50	4.74 E+05
6	Tide	3.89 E+13 J	1.68 E+04	65.57	1.98 E+02
7	River geopotential	7.40 E+16 J	2.78 E+04	205764.40	6.20 E+05
INDIGENOUS RENEWABLE ENERGY:					
8	Electricity	2.72 E+13 J	2.00 E+05	544.00	1.64 E+03
9	Agriculture prod	7.90 E+15 J	6.80 E+04	53721.36	1.62 E+05
10	Livestock prod	3.85 E+14 J	2.00 E+06	77022.40	2.32 E+05
11	Fisheries	5.46 E+13 J	2.00 E+06	10920.00	3.29 E+04
12	Fuelwood prod	3.37 E+13 J	1.87 E+04	62.98	1.90 E+02
13	Forest extraction	2.55 E+14 J	4.10 E+04	1047.26	3.15 E+03
NONRENEWABLE SOURCES FROM WITHIN SYSTEM:					
14	Electricity	2.70 E+13 J	2.00 E+05	540.00	1.63 E+03
15	Minerals	2.97 E+08 g	9.20 E+08	27.32	8.23 E+01
16	Topsoil	6.54 E+13 J	6.30 E+04	411.84	1.24 E+03
IMPORTS AND OUTSIDE SOURCES:					
17	Electricity	3.10 E+14 J	2.00 E+05	6200.00	1.87 E+04
18	Oil deriv. Prods.	3.09 E+15 J	6.60 E+04	20415.12	6.15 E+04
19	Natural gas	1.41 E+16 J	4.80 E+04	67680.00	2.04 E+05
20	Oil	2.92 E+16 J	6.60 E+04	192720.00	5.80 E+05
21	Steel	1.64 E+10 g	1.97 E+07	32.31	9.73 E+01
22	Minerals	1.75 E+11 g	9.20 E+08	16072.68	4.84 E+04
23	Agr.& Forst. Prod.	2.54 E+14 J	2.00 E+05	5086.83	1.53 E+04
24	Foods	7.73 E+13 J	8.50 E+05	6571.52	1.98 E+04
25	Plastics & Rubber	7.54 E+12 J	7.50 E+07	56541.00	1.70 E+05
26	Fertilizers	6.95 E+10 g	1.75 E+06	12.16	3.66 E+01
27	Wood,Papr.,Text.	2.72 E+14 J	2.15 E+05	5837.25	1.76 E+04
28	Mach.& Trans Eqp.	9.40 E+09 g	6.70 E+09	6298.00	1.90 E+04
29	Service in imports	1.19 E+09 $	3.32 E+12	395080.00	1.19 E+06
30	Tourism	4.26 E+08 $	3.80 E+12	161965.39	4.88 E+05
EXPORTS:					
31	Livestock	4.20 E+14 J	2.00 E+06	83914.23	2.53 E+05
32	Cash Crops	5.98 E+13 J	2.00 E+05	1195.52	3.60 E+03
33	Fishery Products	9.32 E+12 J	2.00 E+06	1863.94	5.61 E+03
34	Sugar	4.17 E+14 J	8.50 E+04	3546.29	1.07 E+04
35	Service in exports	1.67 E+09 $	3.32 E+12	554440.00	1.67 E+06
36	Tourist service	4.26 E+08 $	3.32 E+12	141432.00	4.26 E+05

Footnotes to Table B-1

1 SOLAR ENERGY:

Cont Shlf Area = 1.06 E+07 m^2, @ 200 m depth (F.P., INEGI, 1985)
Land Area = 2.79 E+07 m^2 (INEGI-I, 1985)
Insolation = 1.55 E+02 kcal/cm^2/yr (IAM, U de G, circa 1988)
Albedo = 3.00 E-01 (% given as decimal)
Energy (J) = (area incl shelf)*(avg insolation)*(1-albedo)
= (3.85 E+07 m^2)(1.5 E+02 kcal/cm^2/y)(E+04cm^2/m^2)
(1-0.30)(4186 J/kcal)
= 1.75 E+17 J/yr

2 RAIN, CHEMICAL POTENTIAL ENERGY:

Land Area = 2.79 E+07 m^2 (INEGI-I, 1985)
Cont Shlf Area = 1.06 E+07 m^2 @ 200 m depth (F.P., INEGI, 1985)
Rain (land) = 9.44 E-01 m/yr (IAM, U de G, circa 1988)
Rain (shelf) = 4.20 E-01 m/yr (est. as 45% of tot. rain)
Evapotrans rate= 7.50 E-01 m/yr (est. as 80% of rain)
Energy (land) (J) = (area)(Evapotrans)(rain density)(Gibbs no.)
= (2.79 E+07 m^2)*(7.50 E-01 m/yr)*(1000 kg/m^3)
*(4.94 E+03 J/kg)
= 1.03 E+14 J/yr
Energy (shlf) (J) = (area of shelf)*(Rainfall)*(Gibbs no.)
= 2.20 E+13 J/yr
Total energy (J) = 1.25 E+14 J/yr

3 RAIN, GEOPOTENTIAL ENERGY:

Area = 2.79 E+07 m^2 INEGI, 1989
Rainfall = 9.40 E-01 m IAM, UdeG, circa 1988
Avg Elev = 7.00 E+02 m (estimate)
Runoff rate = 0.25 (1.0 - ET) (estimate)
Energy (J) = (area)*(% runoff)*(rain density)*(avg elevation)*(gravity)
= (2.79 E+07 m^2)*(0.25)*(1000 kg/m^3)*(7.0 E+02 m)*(9.8 m/s^2)
= 4.78 E+13 J/yr

4 WIND ENERGY:

Energy (J) = 2.00 E+15 J/yr (est. as 1.43% of Mex's total)

5 WAVE ENERGY (straight shoreline of 295 km, average wave heightt of 1 m, and average shoaling depth of 2 m):

Ew = (0.125 pgh^2)*C*(2.38 E+11) [where C = $(gd)^{0.5}$] = 1.48 E+8 m/yr
Ew = (0.125)*(1.025 g/cm^2)*(980 cm/s^2)*(100 cm)^2(100^2 cm^2/m^2)
*(2.38 E-11 cal/erg) = 0.298 cal/m^2
(0.298 cal/m^2)*(1.48 E+8 m/yr)*(295 E+3 m)(4186 J/Cal) =
Wave Energy (J) = 5.15 E+16 J/yr

6 TIDAL ENERGY:

Cont Shlf Area = 1.06 E+07 m^2 (F.P.,Abst.Inf,INEGI,1985)
Avg Tide Range = 1.00 E+00 m (estimate, N.D.A.)
Density = 1.03 E+03 kg/m^3 (Odum et al., 1983)
Tides/year = 7.30 E+02 (estm. of 2 tides/day in 365 days)
Energy(J) = (shelf)*(0.5)*(tides/y)*(mean tidal range)^2
(density of seawater)(gravity)
=(____m^2)*(0.5)*(____/yr)*(____m)^2*(_____kg/m^3)
*(9.8m/s^2)
= 3.89 E+13 J/yr

7 RIVER GEOPOTENTIAL:

Flow = 5.25 E+02 m^3/s (avg. flow/sec from all rivers; SPP, 1981)
Elevation Change = 4.64 E+02 m (INEGI Topo Maps, circa 1985)
Energy (J) = (flow)*(elev. change)*(grav.)*(water wt.)*(sec/yr)
= (5.25 E+02 m^3/s)*(4.64 E+02 m)*(9.8m/s^2)
(1000 kg/m^3)(3.1 E+07 s/yr)
= 7.40 E+16 J/yr

INDIGENOUS RENEWABLE ENERGY

8 ELECTRICITY:

Hydroelect. = 6.94 E+06 KwH/yr (INEGI-II, 1985)
Int. Combust. = 6.14 E+05 KwH/yr (INEGI-II, 1985)
Total = 7.55 E+06 KwH/yr (total produced in the state)
Energy(J) = 7.55 E+06 KwH/yr * 3.6 E+06 J/KwH
= 2.72 E+13 J/yr

9 AGRICULTURAL PRODUCTION:

Ag. Prod = 2.70 E+06 MT in 1985 (INEGI, 1990)
Energy(J) = (2.7 E+06 MT)*(20% dry wt.)*(1 E+06 g/MT)*(3.5 kcal/g)
*(4.18 E+03 J/kcal)
= 7.90 E+15 J/yr

10 LIVESTOCK PRODUCTION:

Livestock Prod. = 1.15 E+05 MT in 1989 (Plan Nayarit, 1990)
Energy(J) = (1.15 E+05 MT)*(20% dry wt.)*(1 E+06 g/MT)
(4 cal/g)(4186 J/Cal)
= 3.85 E+14 J/yr

11 FISHERIES PRODUCTION:

Fish Catch = 1.63 E+04 MT for 1988 (F.P., Extr Inf, INEGI, 1989)
Energy (J) = (1.63 E+04 MT)*(20% dry wt.)*(1 E+06 g/MT)
(4 cal/g)(4186 J/Cal)
= 5.46 E+13 J/yr

12 FUELWOOD PRODUCTION:

Fuelwood Prod = 4.47 E+03 m^3 for 1988 (INEGI, 1990)
Energy (J) = (4.47 E+03 m^3)*(0.5 E+06 g/m^3)*(3.6 cal/g)
*(4186 J/Cal)
= 3.37 E+13 J/yr

13 FOREST EXTRACTION:

Harvest = 3.39 E+04 m^3 for 1988 (INEGI, 1990)
Energy(J) = (3.39 E+06 m^3)*(0.5 E+06 g/m^3)*(3.6 cal/g)*(4186 J/cal)
= 2.55 E+14 J/yr

NONRENEWABLE RESOURCE USE FROM WITHIN NAYARIT

14 ELECTRICITY (no exports reported):

Hydroelect. = 6.94 E+06 KwH/yr (production for 1984, INEGI-II, 1985)
Int. Combust. = 6.14 E+05 KwH/yr (production for 1984, INEGI-II, 1985)
Total = 7.55 E+06 KwH/yr (production within state)
*(3.6 E+06 J/KwH)
= 2.70 E+13 J/yr

Consumption = 8.65 E+08 KWH/yr = 3.11 E+15 J/yr (per cap est. for the state in 1987; World Resources 90-91)
8.65 E+8 - 7.55 E+6 = 8.57 E+08 KwH/yr (what's probably imported)

15 MINERALS (no exports reported; includes Au, Ag, Pb & Cu):

Production = 2.97 E+02 MT/yr for 1985 (INEGI, 1990)
Consumption = 1.75 E+05 MT/yr (per cap est. for the state in 1989; INEGI, 1990)

16 TOPSOIL:

Soil loss = 9.64 E+10 g/yr (est. as 1.43% of Mex's. for 1986. FAO, State of Agric & Food, 1989)
Energy(J) = (9.6 E+10 g/yr)*(0.03 organic)*(5.4 kcal/g)*(4186 J/Cal)
= 6.54 E+13 J/yr

IMPORTS OF OUTSIDE ENERGY SOURCES:

17 ELECTRICITY (refer to item number 14 for details):

Imports = 8.57 E+08 kwh/yr
Energy (J) = (8.57 E+08 kwh/yr)*(3.6 E+06 J/kwh)
= 3.10 E+14 J/yr

18 OIL DERIV. PRODUCTS:

Imports = 7.03 E+07 l/yr (for the state based on per capita est. from Mex EMergy anal. for 1989 & BANCOMEX, 1990)
Energy(J) = (7.03 E+07 l/yr)*(4.4 E+07 J/l) (@ 44 E+06 J/kg & if 1kg = 1l)
= 3.09 E+15 J/yr

19 NATURAL GAS:

Consumption = 1.304 E+10 ft^3/y (for the state based on per cap. est. from Mex EMergy analysis for 1989)
= (1.304 E+10 ft^3/yr)*(1030 BTU/ft^3)*(1054 J/BTU)
= 1.41 E+16 J/yr

20 OIL:

Consumption = 1.31 E+04 B/day (for the state based on per capita est. for 1989; INEGI, 1990)
= (1.31 E+04 B/day)*(365 days/yr)*(6.1 E+09 J/B)
= 2.92 E+16 J/yr

21 STEEL:

```
Imports    =  1.64 E+04 MT/yr (for the state based on per capita
                  est. from Mex EMergy anal. for 1989 & BANCOMEX, 1990)
Energy(g) =  (1.64 E+04 MT/yr)*(1 E+06 g/MT)
           =  1.64 E+10 g/yr
```

22 MINERALS (Au,Ag,Pb,Cu):

```
Consumption       =  1.75 E+05 MT/yr (for the state based on per capita
                        est. from Mex EMergy anal. for 1989 & INEGI, 1990)
Production        =  2.97 E+02 MT/yr for 1985 (INEGI, 1990)
Assumed import.   =  1.75 E+05 MT/yr
In grams          =  (1.75 E+05 MT/yr)*(1 E+06 g/MT)
                  =  1.75 E+11 g/yr
```

23 AGRIC. & FOREST. PRODUCTS:

```
Imports     =  8.68 E+04 MT/yr (for the state based on per capita
                  est. from Mex EMergy anal for 1989 & BANCOMEX, 1990)
Energy (J)  =  (8.68 E+04 MT/yr)*(20% DW)*(1 E+06 g/MT)*(3.5 Cal/g)
                  *(4186 J/Cal)
            =  2.54 E+14 J/yr
```

24 FOODS:

```
Imports        =  2.56 E+04 MT/yr (for the state based on per capita
                     est. from Mex EMergy anal for 1989 & BANCOMEX, 1990)
Energy (J)      =  (2.56 E+04 MT/yr)*(20% DW)*(1E+06 g/MT)*(15.1E+03 J/g)
               =  7.73 E+13 J/yr
```

25 PLASTICS & RUBBER:

```
Imports        =   8.02 E+02 MT/yr (for the state based on per capita
                     est. from Mex EMergy anal for 1989 & BANCOMEX, 1990)
Energy (J)      =  (8.02 E+02 MT/yr)*(1000 Kg/MT)*(9.4 E+06 J/Kg)
               =   7.54 E+12 J/yr
```

26 FERTILIZERS:

```
Imports        =  6.95 E+04 MT/yr for 1989 (Plan Nayarit, 1990)
Energy (g)     =  (6.95 E+04 MT/yr)*(1 E+06 g/MT)
               =  6.95 E+10 g/yr
```

27 WOOD, PAPER, TEXTILES,LEATHER:

```
Imports     =  1.81 E+04 MT/yr (for the state based on per capita
                 est. from Mex EMergy anal for 1989 & BANCOMEX, 1990)
Energy (J) = (1.81 E+04 MT/yr)*(1 E+06 g/MT)*(15 E+03 J/g)
            =  2.72 E+14 J/yr
```

28 MACHINERY & TRANSPORTATION EQUIPMENT:

```
Imports        =  9.40 E+03 MT/yr (for the state based on per capita
                     est. from Mex EMergy anal. for 1989 & BANCOMEX,1990)
Total wt. (g) =  (9.40 E+03 MT/yr)*(1 E+06 g/MT)
               =  9.40 E+09 g/yr
```

29 SERVICES:

```
Dollar value =  1.19 E+09 $US   (for the state based on per capita
                   est. from Mex EMergy anal.& Sum. Estad., 1989)
EMergy (sej) =  1.19 E+09 $US)*(3.32 E+12 sej/$ = Mex's EMergy/$ ratio)
              =  3.95 E+21 sej
```

30 TOURISM (900,000 visited in 1990 (IV Inf.de G.del Estado, Ag, 1991):

Avg. daily expend. = 41.91 US$ 1990 (avg. stay of 11.3 days & expenditures of 473.60 US$ per II Inf. de G. de Mex., 1990)
= (900,000)*($41.91/day)*(11.3 days)
= 4.26 E+08 US$

EXPORTS OF ENERGY, MATERIALS AND SERVICES

31 LIVESTOCK PRODUCTION:

Production: 1.15 E+05 MT for 1989 (Plan Nayarit, 1990)
Consumption: -1.10 E+03 MT for state (based on per cap. natl avg)

1.14 E+05 MT assumed exported in 1989.

Energy (J) = (1.14 E+05 MT/yr)*(1 E+06 g/MT)*(4 cal/g)
(4186 J/Cal)(0.22 protein)
= 4.20 E+14 J/yr

32 CASH CROPS (Agriculture & Forestry):

Exports (for 1989, Plan Nay., 1990):
Mango
Melon
Watermelon
Tobacco
TOTAL 4.08 E+04 MT for 1989 (Plan Nay, 1990)
Energy (J) = (4.08 E+04 MT)*(1 E+06 g/MT)*(3.5 Cal/g)
(.1 dry wt)(4186 J/Cal)
= 5.98 E+13 J/yr

33 FISHERY PRODUCTION:

Exports = 2.53 E+03 MT for 1989 (Plan Nayarit, 1990)
Energy (J) = (2.53 E+03 MT/yr)*(1 E+06 g/MT)*(4 kcal/g)
(4186 J/kcal)(0.22 protein)
= 9.32 E+12 J/yr

34 SUGAR:

Exports = 2.49 E+04 MT/yr for 1985 (INEGI, 1990)
Energy (J) = (2.49 E+04 MT/yr)*(1 E+06 g/MT)*(4.0 kcal/g)
*(4186 J/kcal)
= 4.17 E+14 J/yr

35 SERVICES IN EXPORTS:

Value (Pesos) = 4.48 E+12
Dollar Value = 1.67 E+09 $US (at 1989 parity of $2,686 pesos/US$)
EMergy (sej) = (1.67 E+09 $US)*(3.32 E+12 sej/$)
= 5.54 E+21 sej

36 TOURISM SERVICES:

Dollar Value = 4.26 E+08 $US for 1990 (IV Inf.de G. del Estado, Ag, 1991; based on $473.60 as avg. amount spent by each tourist as per II Inf de G. de Mex 1990)
EMergy (Sej) = (4.26 E+08 $US)*(3.32 E+12 sej/$)
= 1.41 E+21 sej

Table B-2. Summary of flows in Nayarit, 1985.

Variable	Item	Solar EMergy (E18 sej/y)	Dollars (E7 $/yr)
R	Renewable sources (waves & tides)	1573.99	
N	Nonrenewable sources flow within Nayarit	19.87	
N_0	Dispersed rural source	14.60	
N_1	Concentrated use	5.27	
N_2	Exported without use	0.00	
F	Imported fuels and minerals	2764.73	
G	Imported goods	1007.95	
I	Dollars paid for imports		119.00
P_2I	EMergy value of goods and service imports	3927.00	
I_3	Dollars paid for imports minus goods		2.80
P_2I_3	Imported services	92.96	
E	Dollars received for exports		167.00
P_1E	EMergy value of goods and service exports	5511.00	
B	Exported products transformed within Nayarit	905.30	
E_3	Dollars received for exports minus goods		141.00
P_1E_3	Exported services	4681.20	
x	Nayarit's Gross Domestic Product		73.60
P_2	World EMergy/$ ratio, used in imports	3.80 E+12 sej/$	
P_1	Mexico's EMergy/$ ratio	3.32 E+12 sej/$	
U	Total EMergy used within Nayarit	5.46 E+21 sej/yr	

Table B-3. Indices using EMergy for overview of Nayarit, 1985.

Item	Name of Index	Expression	Quantity
1	Renewable EMergy flow	R	1.57 E+21 sej/yr
2	Flow from indigenous non-renewable reserves	N	1.99 E+19 sej/yr
3	Flow of imported EMergy	$F+G+P_2I_3$	3.87 E+21 sej/yr
4	Total EMergy inflows	$R+N+F+G+P_2I_3$	5.46 E+21 sej/yr
5	Total EMergy used, U	$N_0+N_1+R+F+G+P_2I_3$	5.46 E+21 sej/yr
6	Total exported EMergy	$N_2+B+P_1E_3$	5.59 E+21 sej/yr
7	Fraction EMergy use derived from home sources	$(N_0+N_1+R)/U$	0.29
8	Imports minus exports	$(F+G+P_2I_3)-(N_2+B+P_1E_3)$	-1.72 E+21 sej/yr
9	Export to imports	$(N_2+P_1E)/(F+G+P_2I)$	0.72
10	Fraction used, locally renewable	R/U	0.29
11	Fraction of use purchased	$(F+G+P_2I_3)/U$	0.71
12	Fraction used, imported service	P_2I/U	0.72
13	Fraction of use that is free	$(R+N_0)/U$	0.29
14	Ratio, concentrated to rural	$(F+G+P_2I_3+N_1)/(R+N_0)$	2.44
15	Use/unit area (2.8 E7 m^2)	U/(area of Nayarit)	1.95 E+14 sej/m^2
16	Use per person (8.0 E5 pop.)	U/population	6.82 E+15 sej/per
17	Renewable carrying capacity at present living standard	(R/U)*(population)	2.31 E+05 people
18	Developed carrying capacity at same living standard	8*(R/U)*(population)	1.85 E+06 people
19	Ratio of use to GDP, EMergy/dollar ratio:		
	(GDP: 73.6 E7 US$/yr)	P_1 = U/GDP	7.42 E+12 sej/US$
	(GDP: 3.32 E11 Pesos/yr)	PP_1 = U/GDP	1.64 E+10 sej/p$
20	Ratio of electricity to use	(elec.)/U	0.11
21	Fuel use per person	fuel/population	3.50 E+15

SECTION 3C: Water Resources Planning in the Bay of Banderas Basin

by Pamela Green

INTRODUCTION

Statement of the Problem

Economic vitality and carrying capacity of developing regional watersheds are often influenced by the interactions between agriculture, industry, and urbanization, and the need of each of these sectors for water. This is particularly true in areas with arid climates. As each of the economic sectors increases in size, the demand for water increases and a competition for water between sectors often results. Carrying capacity and economic vitality of a region may be diminished as competition and decreasing water supplies result in increased costs of water extraction, treatment and delivery. In addition to this increased demand for water there is often a concurrent increase in the generation of wastes. The costs, both in technology and environmental deterioration, of treating and disposing of wastes can place an added drain on the economy. Practices of improper disposal of wastes can reduce environmental quality and further drain the local economy. Quantitative criteria are needed to choose between alternative uses of water and decide which public policy options for water management will maximize economic vitality. Public policy regarding water use and reuse that maximizes local economic vitality may be fostered using techniques of energy analysis to gain perspective on the value of water in different applications. A water policy which generates the greatest energy flux and dollar flow in the local economy may lead to the greatest economic vitality. In this study, the role of water in the regional economy of Puerto Vallarta, Mexico was evaluated using EMergy analysis to help determine policy options and future water use/reuse patterns.

Plan of Study

The carrying capacity of an area will be limited as water supplies and water quality are reduced due to exploitation and misuse of regional water resources. Diminished availability of suitable water supplies can be particularly debilitating in arid regions, where water is most limiting. The main objective of this project was to evaluate the role of water in a regional system and the influence of a growing economy on water use and reuse and allocation between sectors of the system. EMergy evaluation was used to determine the macroeconomic dollar values of water to the economy for agriculture, urban, tourist and fishery sectors. Using the Bahia de Banderas watershed basin as a case study, the specific goals of this project were: 1) to determine the value of water that results from use in main sectors of the economy; and 2) to develop water policy options based on maximizing regional productivity and minimizing economic and environmental costs.

The value of water and its contributions to an economy were analyzed in overview by first diagramming the regional hydrologic system and sectors of the economy and evaluating all EMergy inputs to provide water as an input to each sector. The value of water in its economic interaction was evaluated based on the economic investments that its use attracted. EMergy contributions of water were expressed in macroeconomic dollar values. Results of the EMergy analysis were compared to economic values for water derived from the literature, including market value, the costs of energy required to provide water, and the marginal value of commodities produced from water.

Water policy options were formulated based on the results of the EMergy analysis and macroeconomic water values calculated. EMergy analysis of the various options for water use and reuse required both economic costs of alternatives and the environmental costs and benefits. Combined, these costs and benefits were compared for the various alternatives and policy options. The choice of the Banderas Basin as a study site was driven by the availability of data and the fact that it is under considerable development pressure. While only approximately one half of the basin is within the state of Nayarit, and the majority of urban infrastructure is within the neighboring state of Jalisco, the understanding gained concerning water-related policy in the basin will have applicability throughout the coastal zone of Nayarit.

Site Description

The Banderas Bay watershed basin (Figure C-1) is located on the Pacific coast of Mexico at the extreme southeast of the Gulf of California, between the parallels 20° 25" north and meridians 105° 08" and 106° 42". The geographic limits are: Punta Litigu to the north, Valle de Banderas to the east, and Cabo Corrientes to the south. The northern coast is situated in the state of Nayarit, stretching from Punta Litigu to the mouth of the Ameca River and extending inward along the river valley on the north side of the Ameca. The areas to the south of the Ameca and along the southern coast are located in the state of Jalisco.

The area can be divided into two types of terrestrial ecosystems, coastal mountains of the north and south regions and the alluvial plain associated with the Ameca River valley extending inland. The coastal mountain regions are an extension of the Sierra Vallejo and can be categorized as either high mountains (>250 m altitude) with steep slopes or low mountains (<250 m altitude) with milder or staggered slopes.

The climate of the basin can be described as dry, subhumid and warm with summer rains. Average annual precipitation in Valle Banderas is 1.12 m/yr, and average annual temperature is 26°C. The typical season consists of 4 to 5 months of rain (June to Sept) with 29% of this occurring in the month of August. The dry season lasts 7 to 8 months. Puerto Vallarta tends to have higher annual precipitation (1.4 m/yr), with maximum precipitation occurring in the month of September. Higher precipitation values are most likely a result of orographic effects due to the city's position relative to the adjacent mountains.

Hydrologic systems of the basin can be subdivided into the rivers of the Sierra Vallejo and the tributaries of the Ameca River. Groundwater recharge is generally greatest in the river valley and least in the higher reaches of the mountains. As a result, a number of important aquifers are located in the region of the valley. There are approximately 120 deep wells and 250 draw wells in the area that have an average depth of 59 m and an average pumping depth of 13 m (SEDUE, 1990; SEAPAL, 1991). Annual recharge is estimated as 1.6 E+08 m^3/yr in the valley, calculated as 10% of total rainfall over the region (SEDUE, 1990; Roose, 1989). Extraction of water from the aquifer mainly for urban or tourist consumption is 23.3 E+06 m^3/yr for the valley and coastal areas of the basin (SEDUE, 1990). The structure of drainage streams is very dense in the mountain areas draining directly into the ocean, while drainage in the valley generally occurs through convergence to the Ameca. A total of six major river basins drain the area, as shown in Figure C-1.

The coastal region is characterized by sandy beaches, bluffs and estuaries. The coastal area in the north from Punta Litigu to Punta Negra is dominated by sandy beaches of marine origin. Extending from Cerro Careyeros to Punta Las Cuevas are a series of bluffs and cliffs descending to the ocean. From Punta Plumeros to Punta Destiladeras there extends a succession of sandy beaches interrupted by rocky formations with coral reefs offshore. Between Destiladeras and Cruz de Huanacaxtle a natural corridor between the Sierra Vallejo and the ocean exists where the lower mountains abruptly meet the sea forming steep cliff and limiting access to the coast. To the south and east past Bucerias is the mouth of the Ameca river. Sandy beaches of terrestrial origin with the highest recreational value in the area comprise the coastal area with a string of tourist developments along the length of the beach on either side of the river mouth. On the southern side of the Ameca there exists an international airport and the main marina which was transformed from the El Chino estuary. The remaining coastal area to the south is comprised of sandy beach interrupted by tourist developments and the city of Puerto Vallarta. The beaches generally diminish south of Mismaloya where the lower mountains abruptly meet the sea.

Land use in the region can be broadly classified as natural, agriculture and urban. Natural systems in the area have been divided into the following categories (SEDUE, 1990): subperennial medium jungle, caducifolia low jungle, subperennial medium jungle with palms, inundated jungle, mangroves, riparian wetlands, savanna vegetation, beach vegetation, and secondary vegetation. Subperennial medium jungles are located in the Sierra Vallejo mountains along principal streams with some traces occurring in the alluvial plain of the valley. Caducifolia low jungles are located on the hills along the lower fringes of the Sierra Vallejo, generally in rocky or shallow soils, and play an important role in preventing erosion of the soil. Palm-dominated subperennial medium jungles are located in lower altitude humid and subhumid zones, generally in dry clayey soils, and are primarily found surrounding the city of Puerto Vallarta. These systems are interspersed with agricultural areas between Punta Pantoque and Punta Litigu and along the southern coast of the bay.

Inundated jungle and mangrove systems are found generally surrounding the lagoons north of the mouth of the Ameca river. Riparian wetland vegetation includes all flora associated with the river and stream systems including vegetation along the fringe, and submerged and floating aquatics. Savanna vegetation is found in dry, low-altitude areas such as Punta Mita, and is characterized by sparse tree cover and well-drained soils. Secondary vegetation is found throughout the region where natural vegetation has been disturbed by agriculture and forestry practices.

Agricultural and pasture lands are found throughout the river valley. There are both temporal and irrigated crop lands; the latter located adjacent to the Ameca River and the former towards the outer valley. In many cases temporal cultivation is alternated with foraging pastures to provide maximum use of the land. Urban areas in the region consist of the centers of population and the tourist developments. The towns in the valley originated as centers for agricultural and livestock industries. Although they still serve these industries today they are also centers of commerce and service in addition to housing the population. The average population of the towns in the valley is approximately 40,000.

The city of Puerto Vallarta and a number of small towns are situated along the coastal fringe, and were originally established as fishing villages. Although some of the towns in the northern area of the bay are still heavily involved with fishing activities, the larger cities are primarily geared towards tourist activities and services. The population of Puerto Vallarta is approximately 150,000 permanent residents. A variety of tourist developments including hotels, motels and bungalows are also found throughout the coastal areas and service over one million tourists each year. The equivalent yearly population including tourists and permanent residents is approximately 170,000, with tourists comprising 8% of the population.

The largest industry in the area is tourism, bringing in 600 million dollars per year. Agriculture, livestock and fishery industries also contribute to the economy but to a much lesser extent. All fuels, electricity and many raw materials (concrete, plastics, etc.) are imported to the region from larger metropolitan areas such as Tepic and Guadalajara.

Approaches To Valuing Water Resources

Resource Economics Approach

Traditionally, resource economics has determined the value of water in terms of the marginal value of the commodity. Marginal value is defined as the benefits received for an increase in water supply minus any marginal costs for treatment and delivery of the water. Marginal values are often estimated from water demand curves as the willingness to pay for the last unit of water delivered or the last increment of supply needed to meet consumer demand. Marginal values are also derived from water production functions as the increase in marginal physical productivity supported by an increment in water input to the process. Market demand curves and water production functions for waters consumed in agricultural, municipal and industrial processes can be determined directly from market-clearing prices for varying levels of water demand and use. For public goods not directly represented in the marketplace (such as recreation, aesthetics and waste assimilation) marginal values and demand curves must be simulated by other means such as travel costs or questionnaires.

Agriculture and urban value. According to traditional economic theory, the marginal value of irrigation water is equal to the amount of money paid for the last unit of water delivered for a given water supply level. The U.S. Bureau of Reclamation (1985) estimated the marginal value of irrigation water in the John Day Basin of north central Oregon to be between $10 and $24 per acre-foot. A higher estimate of $95.09/ac-ft was determined by Kulshreshtha (1991) for the south Saskatchewan irrigation district. Thus, although agricultural water values may vary they tend to be low, generally less than $100 per acre-foot. Gibbons (1986) states that these marginal values for irrigation are unique for different crops and may vary according to site location, which may contribute to the wide range of water values seen in the literature.

Marginal values for municipal water consumption are likewise determined as the cost of delivering the last unit of water to the municipality. Gibbons (1986) estimated marginal water values for municipal use to range between $4 and $225/ac-ft for Tucson, Arizona, and between $6 and $358/ac-ft for Raleigh, North Carolina. She contends that these marginal values vary both seasonally and according to location. Marginal values for water supply augmentation were calculated by Griffin (1990) for 221 Texas communities, and varied between $0 and $4000/ac-ft. He contended that value was a function of the economic and physical conditions faced by each community and varied with the season, the water source (surface or ground water) and the population growth rate. Typically, approaches to economic valuation of water have concentrated on off-stream uses, dictating that water be removed from the system and put to beneficial use (usually with tangible, financial returns) in order to gain priority rights. This approach does not account for the very real values of in-stream uses associated with recreation, waste assimilation, and ecological processes.

Recreation and aesthetics. Several methodologies have been developed to simulate market values for public goods not directly represented in the market such as water-based recreation, aesthetics and wastewater assimilation. In these methods, marginal values can be estimated either by indirectly assigning a price to the water through an associated variable such as travel costs and admission fees, or by directly questioning the consumers as to their willingness to pay for recreational gains resulting from changing water levels (contingent valuation method). A number of approaches have been taken to estimate the value of water for recreation and aesthetic purposes (Gibbons, 1986; Howe, 1971; Johnson, 1988; Lant, 1991). The end uses of recreational waters have a value derived from the provision of utility to the consumer. These uses include swimming, boating, fishing, picnicking, bird watching, beach walking, sightseeing, etc. Howe (1971) states there are also values of water which exists independent of use such as the value of the natural resource left in a pristine state for future use, for the benefit of future generations, or simply for the knowledge of its existence.

With increased urbanization and development the demand for recreational waters has increased while the supply has decreased or been altered, resulting in higher values for the water. Considering that market prices for this commodity are not readily available, the value for recreational waters must be estimated using other means outside of the market. Some traditional approaches to estimating recreational water value have been based on entrance and participation fees, travel costs, questionnaires and consumer surveys, or taking the water value as a portion of the total value of the recreational site (Gibbons, 1986; Howe, 1971; Johnson, 1988; Lant, 1991).

Marginal values can be determined from travel costs as the change in visitation as a result of flow levels. Marginal values can alternatively be derived from consumer surveys through responses to questions of how much a person would be willing to pay over changing water levels. In streams, for example, Gibbons (1986) estimated maximum marginal values for fishing, shoreline recreation and rafting along the Colorado River to be $16/ac-ft, $11/ac-ft and $6/ac-ft, respectively, occuring at low flows. In addition, she estimated maximum marginal values for water for recreational fishing for a number of areas in the United States based on dollars per visitor-day. Values ranged from $4 to $29 per user day depending on the site (stream vs. reservoir) and the type of species sought. Johnson (1988) determined the value of an additional acre-foot of water in the production of recreational steelhead fishing to be $2.36. However, the value of this water increases if it is used for other purposes such as irrigation at a point downstream, in which case the value of the water will be equal to the sum of the marginal values for recreation and irrigation.

Gibbons (1986) estimated values for fish hatchery water ($23/ac-ft in the Trinity River of California), as well as water for spawning ($40/ac-ft for the Toulumne River in California). In addition, values of wetland waters for fishing, waterfowl, hunting and recreation have been estimated by Gibbons (1986) for Michigan coastal regions ($590/ac-ft), Virginia fish production ($190/ac-ft), and recreational fish and wildlife in the Charles River, Massachusetts ($27/ac-ft).

Lant (1991) suggests that water value alone does not accurately reflect the intrinsic value of lakes and rivers for recreational uses. Rather, the geomorphologic, ecological and aesthetic characteristics of the site represent the real value for recreators. The degree to which water quality and hydrologic regime (water level, flow rates) contribute to these characteristics determines the value of the water to the recreation site. In addition, water quality as perceived by the recreator was found to be much less important than aesthetics of the site and the quality of fishing. Water quality and flow regimes were found to be more important in terms of their contributions to the ecology and aesthetic qualities of the site. Since different approaches have been used to reach common values, problems arise in comparing average values such as admission fees or fishing license fees to marginal values based on willingness to pay for the recreation, and comparing values having differently derived denominators (e.g., $/flow volume, $/visitor day).

Waste assimilation. Water also has a value associated with the dilution and assimilation of industrial and municipal wastewaters. Typically, the value of water for waste assimilation is based on either waste treatment costs forgone or downstream damage avoided (Gibbons, 1986). This value is often a function of the treatment level required and is unique to each type of pollutant removed or diluted. Gibbons (1986) gives marginal values for dilution and simulation of biochemical oxygen demand (BOD) in river basins, calculated by dividing the marginal cost of increasing treatment from 35% removal to 70% removal for municipal effluent and 50% for industrial effluent, by the amount of water needed to dilute the remaining BOD. Values range from $0.2/ac-ft for river basins in the Pacific Northwest to $6.81/ac-ft for river basins in the lower Missouri region. Gibbons (1986) also determined marginal values for the least-cost contribution of treatment and dilution, where cost minimization treatment levels were based on the initial assimilative capacity of the water, the amount of waste discharged and the potential for flow augmentation. Estimated values range from $0.48/ac-ft for the Pacific Northwest to $6.98/ac-ft in the upper Arkansas-White-Red River basin region. Typically, the largest dilution values were found in river basins with high waste loads and low flows, where high levels of treatment are required.

In addition to BOD, marginal values can also be estimated for treatment and dilution of a number of pollutants including nitrogen, phosphorous, bacteria, viruses, heavy metals and toxic organics. Brown (1990) estimated the value of water for dilution of total dissolved solids in the Colorado River Basin to be $11/ac-ft, based on the cost savings to water users.

The distribution costs of alternative effluent application systems is a contributing factor in predicting the value of water for waste assimilation. Boyle (1976) determined a cost estimating procedure for the various land and wetland effluent application systems based on the following parameters: construction costs, land costs, power costs, operation and maintenance, design flow in mgd, and amortization costs. Total cost for various application systems were calculated as the sum of all component costs per 1000 gallons of effluent. In Waldo, Florida, costs were estimated to be $0.42/1000 gallons for wetland discharge, $1.07/1000 gallons for advanced physical/chemical treatment, and $0.63/1000 gallons for spray irrigation. Boyle (1976) also compared the costs of disposal into a cypress dome ($0.71/1000 gallons) to disposal into a wetland strand ($0.22/1000 gallons) for the Orlando Naval Training Center.

Marginal value of a commodity varies in the short term as inputs become scarce or abundant causing prices to vary. Therefore value is a function of the perceived utility of the commodity among the users. Lynne (1974) states that maximum economic efficiency of water use is reached when the marginal values of water in all sectors are equal. According to this view, water will have the highest dollar value where it is perceived to be the most needed or scarce, and have a lower value where it is abundant and not a limiting resource. Since people tend to view services provided by the environment as "free of charge", it is likely that market values for water and other natural resources not requiring a large amount of processing will be characteristically underpriced. In addition, this belief fails to take into consideration market values that are not reflected in the market prices, such as recreation and aesthetic values, contributions to fisheries, pollution costs, benefits to labor that would otherwise be unemployed, and market prices that have been manipulated to misrepresent real values in order to be more competitive on the world market. Also not represented in the market value of a commodity are the secondary benefits and costs to other parts of the economy that are influenced by its production; for example, greater employment opportunities as a result of increased crop production due to irrigation practices.

An EMergy Theory of Value

As defined previously, EMergy is a scientific-based measure of wealth which places raw materials, commodities, goods and services on a common basis of the amount of energy required to produce each item (Odum, 1991). An EMergy theory of value is a "donor"-based system, where the value of the resource is a function of the outside inputs used to support the network that ultimately produces the resource. Since this approach bases value of the product on the energy inputs to the system, including natural, un-monied inputs, it contrasts with typical economic approaches which determine value according to market prices (Gibbons, 1986; Howe, 1971; Lynne, 1986; Grubstrom, 1988). The EMergy value of an item is measured by what is required from the donor sources to generate that item, where all inputs to the process are expressed in a common energy basis (energy of the same type). When expressed in common units of source energy, the units are called EMergy, and given the name of the source. In this study, solar EMergy was used as the common energy basis.

Odum (1986) states that the EMergy value of water is dependent on its place in the hierarchy of the water cycle. The lowest EMergy value for water is found in precipitation. As water converges in rivers, groundwater or lake storages its EMergy value increases. The energy of water can be characterized as geopotential, chemical potential, wave and tide energies, geothermal potential, and the energy in suspended sediments in the water. The degree to which each contributes is dependent on the way in which water contributes to the economy. For example, Odum et al. (1987a) used the geopotential energy of water as a measure of a river's contribution to hydropower activities. In an analysis of the coastal zone of Texas, Odum et al. (1987b) based the energy contribution of water sources for irrigation and municipal use on the chemical potential of the water.

The chemical potential of water has also been employed to measure the energy input of water to fisheries (Odum et al., 1987b; Odum and Arding, 1991; Brown et al., 1991). Tidal and wave energies of nearshore, waters as well as the energy of suspended sediments in discharging rivers have also been demonstrated to contribute to fisheries production but often to a lesser extent (Brown et al., 1991). Odum et al. (1987a) valued a river's contribution to coastal wetlands in terms of the energy of suspended sediments and organic matter carried by the river and deposited in the wetland, building structure. In each case, the EMergy inherent in the water is combined with the EMergy of human inputs (fuels, goods and services) utilized in processing the resource, to calculate the EMergy value of the water commodity.

The value of water for waste assimilation may be measured by the amount of production the nutrient rich effluent supports relative to the amount of outside EMergy required for treating the wastewater. Mitsch (1976) evaluated nutrient disposal alternatives, comparing the changes in EMergy flows caused by disposal of secondarily-treated effluent. Energy flows were given in fossil fuel equivalents and were determined for disposal in a lake system, a cypress dome and a tertiary treatment facility. The change in sunlight-based energy flow representing natural energy supporting the systems was found to be 2 E+08 and 7 E+08 (fossil fuel equivalents/yr) for the lake and cypress dome disposal methods, respectively. The change in fossil fuel work representing human fuels, goods and services supporting the treatment operations were calculated as 11.6 E+08, 14.7 E+08 and 25 E+08 (fossil fuel equivalents/yr) for the lake, cypress and tertiary treatment disposal systems, respectively. The cypress and lake systems utilize natural low-quality energies such as primary production to assimilate and treat the effluent, and amplify these energies with purchased high-quality energies to augment treatment and enhance production of wood products and aquatic biomass. The tertiary treatment method, on the other hand, is supported primarily by purchased high-quality energies that do not interact with lower quality natural energies. Since natural systems rely mostly on "free" natural inputs and less on purchased high quality energies, this would suggest that these natural systems may yield a higher realized work service per purchased energy invested.

Odum (1990) suggested that the availability of an environmental product such as water also contributes to the economy by attracting imported human resources such as fuels, to facilitate development in the area and promote economic growth. Abundant sources of water having characteristically low market prices attract developments to use the water, which in turn brings in additional goods and services to build the economy. When water is scarce, however, more outside energy is needed to retrieve the resource and its contribution to the economy decreases. The economic viability of an area may be predicted by the ratio of attracted EMergy to environmental EMergy, which can be used as an index for potential intensity of development.

Environmental resources are often viewed as being "free of charge", where the money paid for resource acquisition reflects the human work carried out to obtain and process the raw materials and not for the work of the environmental systems that produced them. Since there is no exchange of money between the economy and the environment, prices in the market place will not accurately reflect the value of environmental inputs to the economy, which also serves to further reinforce society's perception of the resources having low value. Odum et al. (1987b) found that macroeconomic EMergy values for water inputs to the different sectors of the Texas coastal zone economy were characteristically much higher than the actual money paid for the water itself. Macroeconomic values were determined for rain, river and groundwater ($0.035/m^3, $0.09/m^3, $0.25/m^3, respectively), which are not represented in the marketplace. The macroeconomic values determined for agricultural ($0.44/m^3) and domestic ($1.16/m^3) waters were found to be 11 and 1.5 times greater than the market values for these commodities.

According to EMergy theory, those systems which will succeed and be sustainable over the long-term increase and maximize their use of available energy (Odum, 1992). Systems maximize use of energy by drawing more resources, increasing efficiency, and reinforcing processes through feedback mechanisms and outside imports. Both ecologic and human systems self-organize through trial and error to select for those patterns which out-compete and survive by securing the most EMergy, and allocating it to uses that reinforce production. Human systems use creativity and choice to discover the optimum patterns for maximizing EMergy for the long-term, macroscopic well-being of the economy and environment. Basing policy decisions on EMergy evaluations which predict maximum wealth founded on scientific principles can result in better public policy choices with far less trial and error.

The results of an EMergy analysis can be used to compare the contributions of items to an economy and propose policy suggestions based on those patterns which are the most efficient and sustainable over time. In the case of an environmental commodity, such as water, its contribution to the economy can be measured in three ways: (1) EMergy cost, (2) the amount of outside energy the item attracts to the area, and (3) the degree to which the use of the commodity maximizes economic efficiency.

RESULTS

An energy systems overview of the role of water was developed for the Bay of Banderas watershed basin, including a comparison of water use between main economic sectors and an analysis of both temporal and spatial water resource availability and use in the basin. Energy systems diagrams were constructed for the entire region as well as for each main sector. Using these diagrams, EMergy analysis tables were assembled to document the main energy flows supporting the systems. From these tables appropriate EMergy indices were compiled to compare EMergy contributions between sectors.

Regional EMergy Analysis of the Banderas Basin

Overview Systems Diagram

Figure C-2 shows a systems diagram of the Banderas Bay watershed basin. The major subsystems in the basin can be broken down into four groups, each having a unique contribution to the system: natural lands, agricultural lands, nearshore zone, and urban areas. Natural lands include uplands, forests and pastures, which support fuelwood production, forest extraction and livestock production. These natural lands also contribute to the aesthetic and scenic qualities of the basin (represented by the image tank) which draws tourists to the area. Agricultural lands consist of those areas in the valley supporting agricultural production. Crop production supports local farm workers and distributors in the urban areas, as well as providing a needed food supply. Irrigation water is derived from both surface water (Ameca River) and groundwater sources. The nearshore zone is comprised of the pelagic ocean, beaches and estuaries which support fishery production as well as contribute to tourism. The bay receives an influx of fresh water containing nutrients and organic matter, in the form of suspended sediments from the six major rivers which discharge into the bay. These nutrient-laden waters sustain productivity of the bay ecosystem supporting the fishing industry upon which local fishermen depend for their livelihood. The bay, beaches and estuaries are also a major element in attracting tourists who utilize these areas for sportfishing, sailing, swimming and the aesthetic and scenic qualities.

The urban areas are the cities, towns and tourist developments within the basin. The urban areas in the river valley are mainly supported by agricultural activities while the coastal cities and towns are supported by tourism and the fishing industry. Revenues received from agriculture, fisheries and tourism are used to purchased goods and services from outside the region to enhance productivity in the economy. The larger city of Puerto Vallarta itself is a tourist attraction with its traditional Mexican architecture, cobblestone streets and many tourist shops. In addition, many urban areas produce large amounts of wastes which are generally treated and discharged into the major rivers or directly into the bay.

Water enters the watershed system mainly through rainfall and river inflow from the upper reaches of the Ameca River. The majority of the rainfall evaporates, while the remainder exists in the system as surface flow to the bay or infiltrates to the groundwater. Rain that falls on the land travels over the surface to the bay or to the rivers that discharge into the bay, carrying with it sediments and other materials washed from the surface. Some of this surface runoff as well as some of the river water infiltrates to the groundwater. During certain parts of the year water is diverted from the Ameca and used for crop irrigation. In some cases groundwater is also pumped for irrigation purposes, although to a lesser extent. Urban areas pump large amounts of groundwater for human consumption and general use. The amount of water pumped varies seasonally according to the number of tourists visiting the area. Wastewaters from cities, towns and tourist facilities are discharged to the bay or to the rivers which empty into the bay.

Regional EMergy Table

A comprehensive evaluation of the resource base of the regional economy for 1989 is given in Table C-1. The primary renewable resources contributing to the system include sun, rain, wind, waves, tide and river inflow from the upper reaches of the Ameca River. Table C-1 lists the renewable resources and their solar EMergy contributions to the system. The total renewable EMergy flow was calculated as the sum of the rain chemical potential, river chemical potential and tide. All other sources were excluded to avoid double counting, as they were derived from similar global processes.

Indigenous renewable energy within the system is derived from agriculture, livestock, fisheries, fuelwood production and forest extraction. The major nonrenewable sources within the system were topsoil erosion and water associated storages. It should be noted that all of the nonrenewable sources in the system were derived from renewable resources, and therefore their EMergy contributions to the system had already been counted. Imported fuels, goods and services were larger than indigenous sources. The largest of these imports were purchased inputs for tourism (construction materials, food, liquor), EMergy in tourists, electricity and fossil fuels. The primary export from the system was tourist service, calculated as the total dollars spent by tourist per year. Also exported were cash crops, fishery products and livestock, comprising about 15% of total exports.

EMergy Indices for Regional Analysis

Figure C-3 is a summary diagram of the Banderas Basin showing inflows and outflows from the system, as listed in Table C-2. Table C-3 lists a number of calculated indices based on the flow values of the system. The purchased inputs to the system are approximately 5 times larger than the natural inputs (item 17, Table C-3). In fact, the fraction of EMergy use derived from home sources is about 16% (item 7, Table C-3) with the remaining 84% being purchased from the outside. Item #14 in Table C-3 shows that about 49% of purchased imports are for tourist services. A comparison of total imports to exports reveals that imports are slightly higher than exports for the basin system (items 8 & 9, Table C-3). However, comparing tourist imports to exports shows exports of tourist services are larger than purchased imports supporting the tourist industry (items 10 & 11, Table C-3).

Comparing similar indices for the country of Mexico (Table C-3, column 5) with those calculated for Banderas Bay reveals that use per unit area, use per person (based on equivalent population), EMergy to dollar ratio and purchased to free ratio were all much higher for the Banderas Basin than those found for the nation. The net EMergy yield ratio was found to be lower for the basin than for the country in general.

EMergy Value of Water in the Banderas Basin

Regional Overview

Given in Figure C-4 is a summary of water flows and use in the Banderas Basin. The energies, transformities, and EMergy values for each of the numbered water flows are listed in Table C-4. Rainfall enters the basin and is either evapotranspired (70%), runs off the landscape into surface water storages (20%), or recharges ground water storages (10%). Surface water includes the nearshore waters of the Bay, and thus ocean currents are shown flowing into and out of the system with no net exchange of water. Water from the upper reaches of the Ameca River not included in the study area are shown as an input to the surface water system of the basin. Surface water has an exchange with ground waters; however, the net exchange is not known but assumed to be negligible. Evaporation from surface waters is shown leaving the system.

Groundwater recharge was estimated as 10% of rainfall from analyses by SEDUE (1990) and Roose et al. (1989). The overall storage of ground water was estimated from SEAPAL (1991) as 6.73 E+10 m^3 for an average aquifer depth of 59 meters. The total volume of pumping water for an average pumping depth of 13 meters was estimated to be 1.5 E+10 m^3. The turnover time of the aquifer calculated from a recharge rate of 1.6 E+8 m^3/yr was found to be 414 years for the total depth and 93 years for the average pumping depth. Yearly extraction of groundwater for agricultural and municipal uses is estimated as 6.85 E+07 m^3/yr (SEAPAL, 1991; SEDUE, 1990) or 43% of the total yearly recharge, resulting in an adjusted recharge rate after extraction of 9.4 E+07 m^3/yr.

Both ground water and surface water are used in the various economic sectors of the basin. The total use was estimated by SEDUE (1990) as 1.97 E+08 m^3/yr and 2.33 E+07 m^3/yr for agricultural and urban uses, respectively. The EMergies of surface and ground waters prior to extraction are listed in Table C-4 along with their values following extraction, processing and delivery, denoted as Groundwater Use and Surface Water Use in items 3 and 4, respectively.

The EMergy value for raw wastewater was calculated in Table C-1 as the sum of EMergy in consumer water and delivered foods while the transformity was determined as the EMergy divided by the energy in the wastewater. Similarly, the EMergy in treated wastewater was calculated as the EMergy inputs of consumer water, foods and treatment expenditures and the transformity was given as EMergy inputs divided by energy in the treated water. Based on transformities, treated wastewater has more EMergy per unit water input than does raw wastewater. In addition, treated wastewater has a higher transformity than processed surface and ground waters used in municipal and agricultural processes. Economic interaction (line 6, Table C-4) measures the production in the region supported by water inputs. EMergy was calculated as the total EMergy inputs to the system, while the transformity was calculated as total EMergy inputs divided by energy in the delivered surface and ground waters.

<u>Subsystem Evaluation of Water</u>

Four sectors (agriculture, urban, tourist, fisheries) of the economy were evaluated, to determine the EMergy of water and its value in economic interactions.

<u>Agriculture</u>. The EMergy analysis of irrigation water and the supported agricultural production was based on the total hectares of irrigated agricultural land in the basin (7563 Ha). Irrigated agricultural lands produce 4.55 E+4 MT of crops per year including maize, rice, beans, tobacco, mangos, and other fruits and vegetables. Eighty percent of all irrigation is derived from river sources; therefore, irrigated agricultural lands are generally located in close proximity to the Ameca River. The total volume of water extracted from the river and, to a lesser extent,

groundwater sources is approximately 1.97 E+08 m^3/yr. More than half of this water is lost to evaporation or seepage before it reaches the crop lands.

Figure C-5 represents the energy flows and interactions for the agricultural production system in the Banderas Basin. Water is delivered to the area through rainfall and the interaction of river and groundwater with pumps, irrigation ditches and human services. Nutrients are delivered to the soil along with the river water and the addition of fertilizers. Low quality solar energy interacts with soil water, soil nutrients and human services in the production of the crop. Additional human services are required to transport the crops to the market place for sale. Pesticides are imported to the system to decrease the number of insects feeding on crops. Exported crops are exchanged for money from the outside market, which is used to purchase electricity for pumping water, fertilizers, pesticides and human services, which feed back to support agriculture production.

Annual flows of EMergy through the subsystem are evaluated in Table C-5, and summarized in Figure C-6. Each of the inflows of water--purchased inputs for irrigation, other purchased inputs to crop production and crop yield--shown in Figure C-5 as sources are evaluated. The EMergy in source water totals 65.1 E+18 sej/yr, while purchased energy supporting the irrigation system was 5.4 E+18 sej/yr, or about 9% of the total EMergy of irrigation water. The total EMergy in irrigation water (70.5 E+18 sej/yr) was calculated as the sum of the EMergy in the source water and purchased inputs. The irrigation water accounts for about 55% of the total inputs to agriculture in the Banderas Basin. The transformity for irrigation water was calculated as 7.26 E+04 sej/J, the total EMergy input to the irrigation water divided by the energy in the water delivered. The EMergy in the crop yield (129.8 E+18 sej/yr) was calculated as the sum of all EMergy inputs to the system, while the transformity of crop yield was calculated as the total EMergy in the crop yield divided by energy in the crops (3.0 E+05 sej/J).

Fisheries. The average yearly catch from the Banderas Bay fishery is 1.76 E+03 MT/yr. Average yearly discharge of river water into the bay is 1.55 E+09 m^3/yr. Figure C-7 represents the energy flows and interactions for the fisheries production system in the Banderas Basin. Water enters the bay through rainfall, river discharge, tidal exchange and ocean currents. No human interaction is needed in delivery of water to the system. Nutrients are carried to the bay along with river water and exchange with the open ocean through tides and currents. Phytoplankton utilizes low quality solar energy and nutrients for primary production; phytoplankton production supports the fishery by providing a basis for the food chain. Human services, boats and fishing equipment interact with the fishery to catch fish and bring them to the market. The fish catch is exchanged for money from the outside market which is used to purchase fuels, equipment and human services which feed back to support the fishing industry.

Annual flows of EMergy through the subsystem are evaluated in Table C-6 and summarized in Figure C-8. Each of the inflows of water, purchased inputs for fishing, and fishery yield shown in Figure C-7 as sources are evaluated. The EMergy in source water from the river totals 319.7 E+18 se/yr. No purchased energy is required for transport or delivery of this water. River water input to the bay accounts for about 99% of the total inputs to fisheries production in the Banderas Basin. The transformity for fisheries water was calculated as 3.67 E+05 sej/J, which is the total EMergy input to the fisheries water divided by the energy in the water delivered. The EMergy in the fisheries yield (327.1 E+18 sej/yr) was calculated as the sum of all EMergy inputs to the system while the transformity of fisheries yield was calculated as the total EMergy in the fisheries yield divided by energy in the yield (5.04 E+06 sej/J).

Urban and Tourist Sectors. The EMergy analysis for municipal water includes water values for both urban and tourist sectors, since each derives its water from the same sources and uses the same facilities to treat and deliver the water. Eighty-five percent of all municipal water comes from groundwater sources. The total volume of water extracted for municipal use from groundwater and, to a lesser extent, the river is approximately 2.33 E+07 m^3/yr. Annual flows of EMergy for municipal water production are evaluated in Table C-7. Each of the inflows of water and purchased inputs for municipal water shown in Figures C-7 and C-8 as sources are evaluated. The EMergy in source water totals 11.5 E+18 sej/yr, while purchased energy supporting the municipal water system was 38.2 E+18 sej/yr, or about 77% of the total EMergy of municipal water. The total EMergy in municipal water (49.7 E+18 sej/yr) was calculated as the sum of the EMergy in the source water and purchased inputs. The transformity for municipal water (4.31 E+05 sej/J) was calculated as the total EMergy input to the municipal water divided by the energy in the water delivered.

Purchased inputs to the urban sector other than for municipal water were given in Table C-1, and include fuels, electricity and goods and services supporting the urban economy. Figure C-9 represents the energy flows and interactions for the urban sector of the Banderas Basin economy. Water is delivered to the urban population in potable form from river and groundwater sources using fuels, electricity, goods and services. Municipal water supports commercial production in the region both directly and indirectly,. Yield from commercial activities is exchanged for money from the outside market, which is used to purchase fuels, equipment and human services that feed back to support the urban economy and water treatment and delivery.

Annual flows of EMergy through the urban subsystem are evaluated in Table C-7 and summarized in Figure C-11. Inputs from municipal water, other purchased inputs to the urban economy, and urban yield shown in Figure C-9 as sources are evaluated. The municipal water accounts for about 9% of the total inputs to the urban economy in the Banderas Basin. Other purchased inputs to the urban sector total 499.8 E+18 sej/yr, which is about ten times larger than the inputs received from the municipal water. Total urban EMergy (549.5 E+18 sej/yr) was calculated as the sum of all EMergy inputs to the system. The EMergy in exports from the urban sector (301.7 E+18 sej/yr) was calculated as the EMergy in cash crops, fisheries products and livestock exported.

Purchased inputs to the tourist sector other than for municipal water are fuels, electricity and goods and services supporting the tourism industry. Figure C-11 represents the energy flows and interactions for the tourist sector of the Banderas Basin economy. Water is delivered to the tourist population in potable form from river and groundwater sources using fuels, electricity, goods and services. Municipal water delivered to tourist facilities supports the tourism industry in the region. Yield from tourism is exchanged for money from the outside market, which is then used to purchase fuels, equipment and human services which feed back to support the tourist industry and water treatment and delivery.

Annual flows of EMergy through the tourism subsystem are evaluated in Table C-7, and are summarized in Figure C-12. Inputs from municipal water, other purchased inputs to the tourism economy and tourist yield shown in Figure C-10 as sources are evaluated. The municipal water accounts for about 2.4% of the total inputs to the tourism economy in the Banderas Basin. Other purchased inputs to the tourism industry total 2043.9 E+18 sej/yr, which is far greater than the input received from the municipal water. Total tourism EMergy (2093.6 E+18 sej/yr) was calculated as the sum of all EMergy inputs to the sector. The EMergy in exports from the tourist sector (1977.4 E+18 sej/yr) was calculated as the total EMergy in tourist dollars spent per year.

EMergy Indices for Subsystem Analysis

Figure C-13 represents an aggregated diagram depicting the EMergy inflows and outflows for any of the subsystems, emphasizing EMergy contributions of water to the subsystem economy. EMergy indices were calculated based on the labelled flow paths in Figure C-13 for each of the subsystems, and are given in Table C-8. Items 1 through 8 in Table C-8 represent indices describing the water systems for each subsystem, including renewable (natural) and purchased inputs needed for the processing and delivering of water supplies.

Renewable EMergy inputs to water for each of the subsystems were determined, to compare the extent to which the natural systems contribute to water production. Renewable EMergy inflows to agricultural and fisheries water were much higher than those for municipal water for urban areas and tourists. The flow of imported EMergy for water production represents the attracted EMergy to the area, including imported fuels, goods and services. Municipal waters for urban areas and tourists have the greatest attracted EMergy, while agriculture and fisheries have the least. In fact, water for fisheries requires no purchased inputs, since water enters the system from river discharge and tidal exchange with no need for human interaction.

The EMergy values of delivered water were calculated for each subsystem as the sum of the renewable and imported EMergy inputs, and are given in line 3. EMergy water value was found to be highest for fisheries, followed by agriculture and municipal water. The transformities of water for each sector were calculated in the subsystem analysis tables, and are given in line 4. The transformity for municipal water was found to be the highest, followed by fisheries water and agricultural water.

The fraction of EMergy used in the supply of water attributable to renewable and purchased inputs are given in lines 5 and 6. Fisheries and agriculture have the highest percent attributable to renewable inputs and municipal water has the highest percent attributable to purchased inputs. An investment ratio was calculated as purchased divided by renewable EMergy inputs for water supply in each of the subsystems. The municipal water supply system was found to have the highest purchased-to-free ratio, and the agricultural water system had the lowest. The investment ratio for fisheries water is given as zero since no imported EMergy is needed to supply water to the system.

Water yield ratios were calculated for the water systems in each sector as the EMergy in the delivered water divided by the EMergy in purchased inputs to the water system, and was found to be greatest for agricultural water and least for municipal water systems (line 17). The EMergy yield ratio was not calculated for fisheries water, since no purchased inputs were used in delivery of the water.

Items 9 through 19 of Table C-8 represent indices describing the production and economic activities of each sector, including contributions from water and purchased inputs to support subsystem processes. Flows of purchased

EMergy for each subsystem (not including purchased imports for water processing) are given in line 9. Tourism has the largest amount of imported EMergy, followed by the urban sector, agriculture and fisheries. Likewise, the total flows of imported EMergy (purchased imports for water plus all other purchased inputs to the system) as well as total EMergy use in each subsystem are highest for tourist and urban sectors and lowest for agriculture and fisheries sectors.

EMergy in exports from each subsystem is given in line 12, with the highest amount of EMergy being exported from tourist and urban sectors. The percent of total EMergy use attributable to water inputs was calculated for each sector, and is given in line 13. Sectors with lower amounts of purchased EMergy, such as fisheries and agriculture, have a higher percent of their EMergy attributable to water inputs, whereas those with larger purchased inputs have a lower percent of their EMergy attributable to water inputs.

The fraction of EMergy used in the production or economic processes attributable to renewable and purchased inputs are given in lines 14 and 15. Fisheries and agriculture have the highest percent attributable to renewable inputs, and municipal water for urban areas and tourism has the highest percent attributable to purchased inputs. Line 16 shows a purchased-to-free investment ratio for each sector, with fisheries and agriculture much lower than the tourist and urban sectors. An EMergy yield ratio for each subsystem is given in line 17. The greatest yield per purchased inputs occurs for the fisheries sector, followed by much lesser values for the agriculture, tourist and urban sectors. The marginal macroeconomic value of water was calculated as the EMergy in the yield divided by the EMergy in raw water (line 18) or delivered water (line 19) supporting the sector economy, and is useful in determining the contribution of water to the subsystems' economy. The tourist sector was found to have the highest marginal macroeconomic value of water, followed by the urban, agriculture and fisheries sectors.

Marginal Effects of Water Increases on Net Yield

The effects of additional water supplements to each subsystem economy were determined by increasing the amount of water to each system by 5% increments and calculating the net yield supported by the increase. Net yield was calculated as the sum of all EMergy inputs to the sectors for every increment in water supply. Yield values for each successive 5% supplement of water are listed in Table C-9 for the four economic sectors. The percent changes in yield from the present yield values in each sector are also listed in Table C-9 for water increments, and are depicted in Figure C-14. Average percent change per 5% increase interval is given at the bottom of Table C-9, and is highest for fisheries, followed by the agriculture, urban and tourist sectors.

Economic Analysis of Water Use

Figure C-15 depicts a diagram of the regional watershed basin, emphasizing water flows among the subsystems. The macroeconomic values of water at different stages, from rainfall through surface and ground water extraction to wastewater generation, are given in Table C-10. Macroeconomic value is calculated as the EMergy in a cubic meter of water divided by the EMergy-to-dollar ratio of the economic region, and represents the amount of the gross domestic product attributable to the water contribution. These values are compared to more typical economic or marginal values for water, where such values were found in the literature.

From Table C-10 it can be seen that, as water is concentrated from rainfall through river flow to groundwater, its macroeconomic value increases. Macroeconomic values were found to be lowest for the least processed water sources such as rainfall, river inflow and fisheries, and greatest for the more concentrated sources such as groundwater, irrigation water, municipal water and wastewater. In addition, the macroeconomic value of each subsystem production process (referred to as pathway or interaction in Table C-10) is also given on a per cubic meter basis for water supporting each subsystem. When water is extracted, processed and delivered for an economic use such as agriculture or support of an urban population, its value increases. The more energy required in delivering water to a sector, the higher its macroeconomic value. Macroeconomic value for subsystem interactions on a per cubic meter basis is greatest for tourism, followed by the urban, agriculture and fisheries sectors.

Alternative Uses for Wastewater

Alternate uses for treated wastewater were evaluated including application to agricultural lands and discharge to wetlands.

Agricultural land application. The amount of wastewater generated for each urban center in the basin was calculated as 90% of the total water consumed. Values of wastewater generation are listed in Table C-11, along with population and consumption for the urban areas in the basin. Total irrigation requirement was estimated as the consumptive use of the crops divided by the irrigation system efficiency. Crop consumptive use was calculated using the Blaney-Criddle method, and was found to be 0.78 m/yr. The efficiency of the irrigation system was estimated to be 60% for ditch irrigation (FAO, 1979). Total irrigated land area required for recycle of the treated wastewater was calculated as the total volume of wastewater divided by the irrigation requirements, in meters (cubic meters required per square meter application area). Total irrigation requirement is then equal to 1.3 m/yr. Application areas needed to satisfy the irrigation requirement for each urban area are given in Table C-11.

DISCUSSION

Regional Overview

The regional economy of the Banderas Bay Basin is driven primarily by the tourism industry and, to a lesser extent, agriculture, fisheries and livestock production. As noted in Table C-2, 49% of all purchased inputs to the region are for tourist services. However, part of the remaining 51% of purchased inputs goes towards urban activities, which indirectly contribute to the tourism industry through supporting service industries such as restaurants and rental and travel agencies. In addition, these purchased inputs also support the general population a large percentage of which comprise the work force for the tourism industry and the related service industries.

Due to the lack of indigenous resources, such as fuels and construction materials, 84% of the EMergy input to the system must be purchased from outside the region with half of these purchases going toward tourist services. By comparison, only 26% of purchased EMergy inputs estimated for Mexico were from outside sources. The remaining 16% of EMergy inputs to the basin is derived from renewable resources such as rain and river inputs. The high EMergy-to-dollar ratio (1.07 E+13) was greater than that for both Mexico and the world average, which may result from the inability to accurately assess the large amounts of resources available in relation to dollars circulating in the economy. However, a large percentage of EMergy in the area is imported from outside the system to support tourism while money received from tourism circulates back to purchase these imports. Similarly, EMergy per capita and EMergy per unit area are also greater than those for Mexico, also due to the large amounts of EMergy in purchased inputs for tourism.

On the regional scale, net imports to the area are slightly higher than net exports. However, net imports for tourism are lower than net exports in tourist service. A higher imports to exports ratio for the region is probably due to fewer purchased imports required for cash crops, fisheries, and livestock production relative to indigenous inputs supporting these systems. The investment ratio of EMergy bought from the economy to EMergy coming from the environment without payment is 5.36, approximately twice as large as that calculated for Mexico, suggesting there is more dollar cost per unit EMergy input to the region relative to the country average. Similarly, the ratio of purchased EMergy to the total yield of the economy in the basin (1.19) is lower than the average for Mexico (3.85), suggesting the region is relying less on natural inputs to support its production processes and more on purchased inputs, on average, than is the country as a whole.

Evaluation of Water Supply Systems for Economic Sectors

An evaluation of water's contribution to an economy begins with an analysis of the systems used to extract, process and deliver the water as a commodity to interact in the production activities of the economic sectors. The first eight indices of Table C-8 describe the EMergy flows contributing to the water systems for each sector, and the amount of economic interaction required to support these systems. A comparison of transformities for water in Table C-8, line 4, shows that the urban and tourist sectors required large amounts of energy investment for provisions of water. Transformities for municipal water are five times larger than irrigation water and four times larger than fisheries water. Such high transformities reflect the large amounts of fuels, goods and services required to retrieve, process and transport water from its source to the urban centers while providing for suitable water quality.

Production subsystems such as agriculture and fisheries rely more on natural resource inputs and less on purchased inputs for delivery of water supplies. In fact, all water required for fishery production is received "free of charge" from the environment. This is further illustrated by the fact that 77% of total inputs for municipal water are purchased, while only 8% are purchased for agricultural water. The water yield ratios for each sector's water system shows how much yield is supported by purchased inputs for the water system, where higher yield ratios reflect a system that effectively matches fewer purchased inputs with renewable inputs to produce a higher quality water commodity. Although not listed in line 8, fisheries water would actually have the highest EMergy yield ratio, since no purchased inputs are needed to process the water. The yield ratio for irrigation water is approximately ten times larger than that for municipal water, because fewer purchased inputs are needed to deliver irrigation water relative to the large amounts of imports required for processing municipal water. This is also evident in the investment ratio for water systems in which three units of purchased inputs are required for each unit of renewable input for production of municipal water, while ten units of renewable EMergy is matched with one unit of purchased input for agricultural water production.

Comparing water delivery systems for the sectors shows fisheries and agricultural water supply systems are more efficient and support more water yield per amount of purchased inputs than municipal water. Another way of evaluating the contribution of water to the economy is related to the degree to which delivered water supports production processes in each sector of the economy.

Contribution of Water to the Economy

Items 9 through 17 in Table C-8 describe EMergy flows supporting production and economic processes within each sector, emphasizing EMergy contributions from delivered water. Values of purchased inputs other than water imports are given for each subsystem in Table C-8, line 9. Total imported EMergy is highest for tourist industry followed by the urban sector and least for agriculture and fisheries. The fraction of total EMergy that is purchased is 98% and 99% for urban and tourist sectors, respectively. This is not surprising, since both these sectors are predominantly dependent on imports. The agricultural sector imports 50% of its total EMergy while fisheries has only 2% of its total EMergy from purchased inputs.

A comparison of investment ratios (purchased/free EMergy inputs) for the sectors shows that agriculture and fisheries sectors have much lower ratios than that calculated for the regional economy (5.36, Table C-2, line 17), while urban and tourist sectors are nine and thirty-six times larger than the regional value, respectively. This would suggest that the agriculture and fisheries subsystems have more to sell and less to buy, and are therefore more competitive than the other sectors that are 98-99% dependent on purchased inputs.

The EMergy yield ratio is highest for fisheries and much larger than the ratio calculated for the regional system of 1.2 (Table C-2, line 16). The yield ratio for agriculture (2.01) is much less than fisheries, although still larger than the regional value. Urban and tourist sectors each have ratios just greater than 1 and, subsequently, less than the regional ratio. Higher EMergy yield ratios for fisheries and agriculture suggest more abundant renewable sources supplying the system and, therefore, more activities can be supported by these systems. The much lower ratios for urban and tourist sectors suggest that sources are no longer available for continued growth, and perhaps further development of these industries should be curtailed.

The relevance of water to each subsystem production process is reflected in the percent of total EMergy input attributable to water delivery and consumption, with fisheries having the highest influence of water (99.4%), followed by agriculture (54.3%), urban (9.04%), and tourist uses (2.37%) (Table C-8, line 13). These numbers would suggest that, although water is certainly a necessity in all of the sectors, its ability to contribute to economic growth in each of the production processes is most limited for urban and tourist sectors but may have significant effects in the agricultural and fisheries sectors.

The marginal macroeconomic value of water in its raw and processed states reveals to what extent the water source or commodity supports production in the subsystem. Tourism has the highest EMergy yield per EMergy input of raw water (181.7), followed by the urban, agriculture and fisheries sectors. The same trend is true for processed water; however, yield supported decreases by one fourth for the tourist and urban sectors, while yield decreases only marginally for the agricultural sector. This would suggest that water contributes more to the regional economy by supporting greater yields from the urban and tourist sectors. However, considering that the tourist and urban sectors have maximized their development potential, as is suggested by the very low EMergy yield ratios for each, it is not conceivable that supplying additional water to these sectors will support a significant yield. Furthermore, since the percent of total EMergy input from water is very low for both sectors compared to the large amounts of purchased inputs, increases in delivered water may not support much greater yields from either the tourist or urban sectors.

Table C-9 shows subsystem yield values for increments of 5% increases in the amount of water delivered to each sector. The tourist sector shows a 0.15% change in production for the increase in water supply delivered, while the urban sector is slightly larger, with a 0.45% increase. Compared to 2.38% and 4.59% increases in agriculture and fisheries production for each additional 5% water increase, respectively, the urban and tourist sectors do not appear to support much more yield per water input, even though the overall yield for these sectors is still greater than for either agriculture or fisheries. Supplying additional water to the urban and tourist sectors at their current state of development would not be a wise investment of EMergy, since these sectors will not be able to produce significant changes in yield for the EMergy in water invested. Additional water can support greater production in the agriculture and fisheries sectors, since these sectors efficiently match fewer purchased inputs with the available renewable EMergy in the water.

The amount of water supplying urban and tourist systems should not be reduced, however, since this is necessary to maintain the present yield from the system, and any decrease in water EMergy inputs would cause a further decrease in yield. If further development occurs in either the urban or tourist sectors, increased water would be needed, with an EMergy value matching the existing system. For systems that have not reached their development potential, water should be given priority over those that have a high marginal macroeconomic value of water, a greater percent of their total EMergy attributable to water, and an EMergy yield ratio equal to or greater than the larger system in which the subsystem operates.

Wastewater from the urban areas and tourist developments is typically discharged either to the river or directly into the ocean. The transformities of raw and treated wastewater are greater than that for river flow, and may contribute a large amount of EMergy to the bay system in addition to the river water. The transformity of wastewater is also greater than that calculated for irrigation water. Using the high quality, nutrient rich treated wastewater for irrigation purposes would contribute more EMergy to the economy through crop production than would be received from using diverted river water or pumped ground water. In other words, the agricultural system would receive a higher quality water source by utilizing treated effluent, than it would by continuing with the existing system of diverting water from surface and ground water sources. However, the costs of transporting the treated effluent from the urban areas to the agricultural regions should be taken into account. Transporting wastewater across longer distances will result in greater costs, resulting in a lower EMergy yield per purchased input for the treated water. Considering that treated wastewater is generally discharged into the Ameca River, which in turn contributes to 80% of total irrigation water, utilizing recycled wastewater may be most beneficial in close proximity to the urban areas (to reduce transport costs), or as an alternative to groundwater sources (which require greater purchased inputs for retrieval).

Comparative Values of Water Use

The macroeconomic value of water increases as water is concentrated from rainfall through surface water, groundwater and ultimately to the final consumer use (Table C-10). When water is concentrated, its volume decreases as the value added for processing and delivering increases. Therefore, the more energy used to extract, treat and deliver water the greater its EMergy content. Comparing macroeconomic values shown in Table C-10 with marginal values calculated for similar processes reveals that traditional economics usually undervalues the contribution of water to the economy. Water contributes net EMergy to the economy when its EMergy value exceeds the costs of obtaining it. As more inputs are purchased from outside the system to deliver water, its net EMergy contribution to the system decreases.

Net EMergy contributions of water to agriculture and fisheries are higher than net EMergy contributions to the municipal system. The economy can receive up to ten times the value for irrigation water than it pays in processing costs. Similarly, fisheries water contributes up to nine times the value to the economy than is paid in costs. The overall contribution of the water to the economy is measured by the agricultural, fisheries, urban and tourist production supported by water inputs. The macroeconomic values for each sector interaction given in Table C-10 show that tourism contributes more dollars to the GDP per cubic meter of water consumed than the other sectors. The urban sector contributes fewer dollars to the economy per cubic meter compared to tourism, although still much greater than dollars contributed from agriculture and fisheries. While these yield ratios suggest that tourism and urban development have high returns, the increase in yield received per increase in water supplied is much smaller for urban and tourist sectors compared to agricultural and fisheries sectors. Consequently, the increase in the number of dollars contributed to the economy as a result of additional water supplied to the tourist or urban sectors is smaller than that contributed by incremental yields from agriculture and fisheries production.

Alternative Uses for Wastewater

Application areas needed to satisfy the irrigation requirement for each urban area are given in Table C-11. The larger and more populated urban areas in Jalisco (south of the Ameca River) can provide greater quantities of recycled wastewater for irrigation, thereby supporting greater irrigated areas than the more limited urban centers in

Nayarit. Lands located at a greater distance from the Ameca River, or those whose groundwater sources are used for irrigation, would benefit the most by utilizing recycled wastewaters. Lands located near the river would also benefit from using treated effluent, since they would receive higher quality water than would be received from the river source. Two treatment plants are located in the area, one in Puerta Vallarta serving Pitillal and Puerta Vallarta, and the second outside the town of Las Juntas serving Ixtapa and Las Juntas. The costs associated with irrigation uses of effluent from several of the larger towns in the basin are given in Table C-11. Costs were estimated as the total EMergy in electricity, goods and services required to deliver the recycled water to the crop land. The total irrigated area using wastewater was calculated to be 1.72 E+08 m^2, or about 30% irrigated land in the basin.

Summary and Conclusion

The contribution of water to an economy is a factor of the intrinsic value of the water itself, the efficiency in producing and delivering the water commodity, the extent to which the economy is supported by the water, and the efficiency of the economy itself. High quality water from more concentrated sources such as groundwater, combined with large amounts of purchased inputs, is generally used to support higher yielding systems such as tourism or urban sectors. Lower quality water from river sources, combined with fewer purchased inputs, supports lower yielding subsystems such as agriculture and fisheries.

How water inputs influences each sector of an economy depends on the degree to which the sector is dependent on the water input. Less industrialized production systems such as agriculture and fisheries require greater inputs from water sources relative to purchased inputs, while urban and tourist sectors rely less on water inputs and more on purchased imports. Larger increases in production yield will result from water increases, in cases where water is a greater contributor to the production process. Water will also have a greater effect on production for those systems that have not reached or surpassed their development potential. Increased availability of any natural input to a system will not have an appreciable effect on an economy that is predominantly dependent on purchased inputs from outside the system. Considering alternate water sources such as treated wastewater can provide sectors such as agriculture and fisheries with higher quality water for less cost in extraction and delivery.

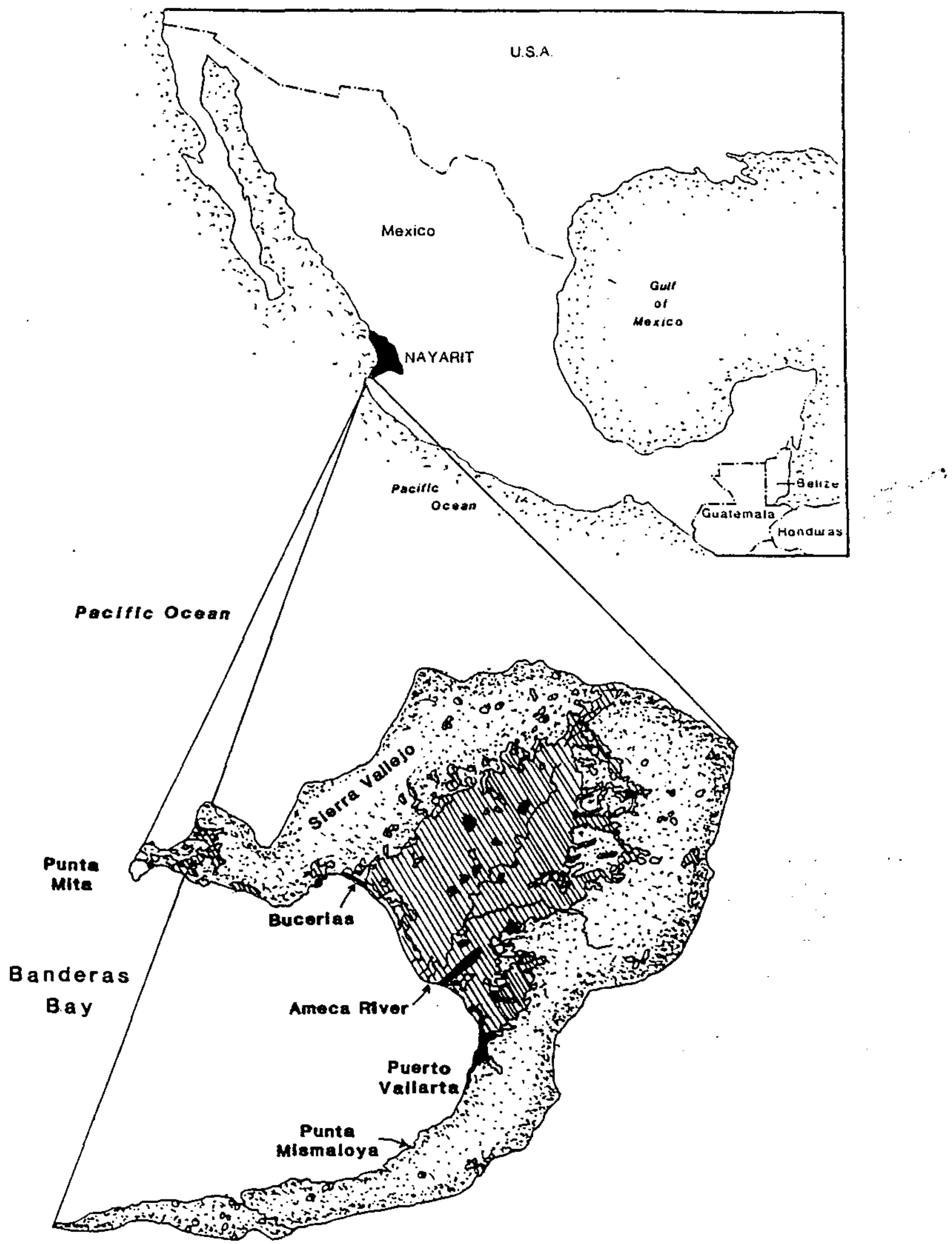


Figure C-1. Location Map of the Banderas Bay watershed basin. Black areas are urban, crosshatched areas are agriculture, and stippled areas are forested.

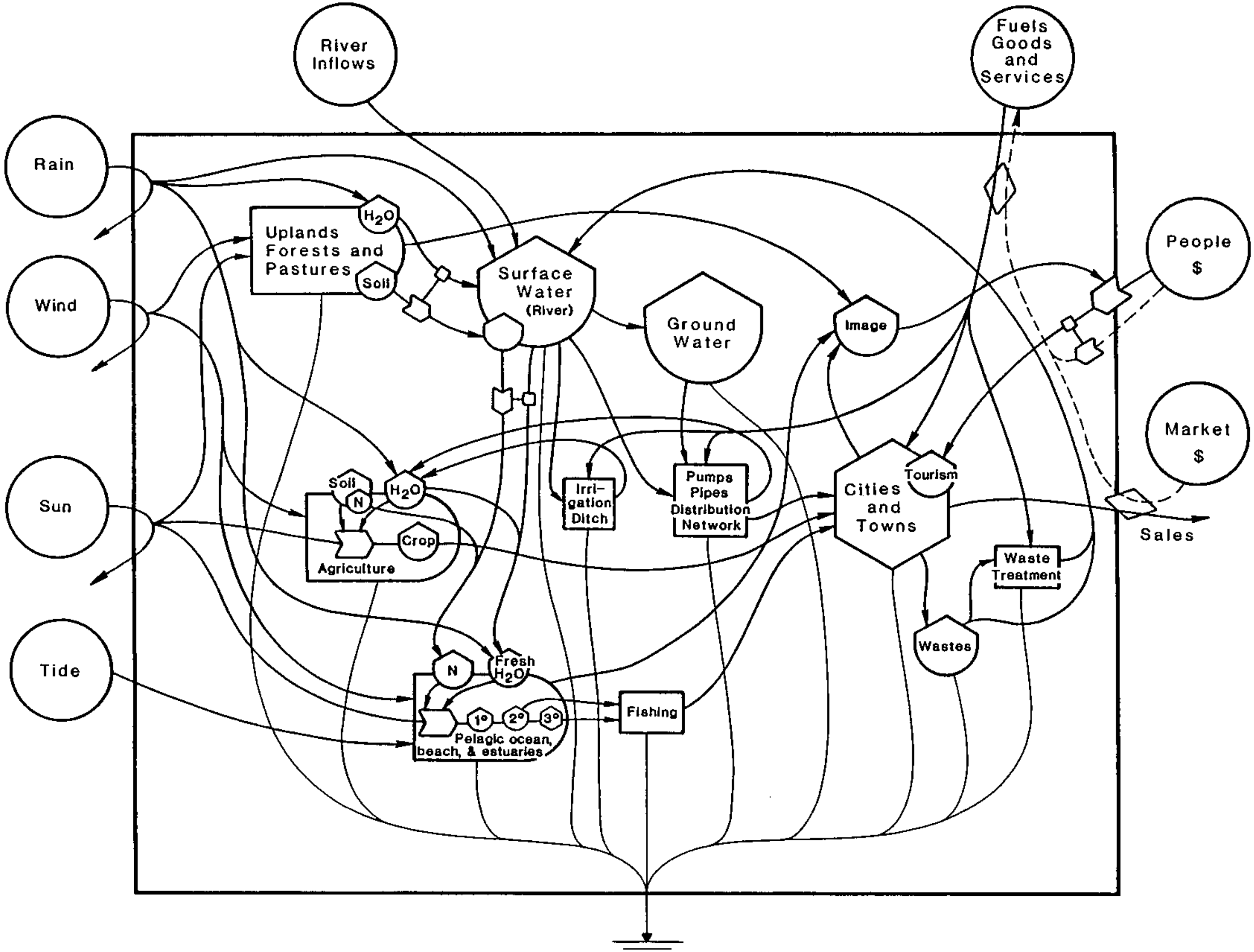
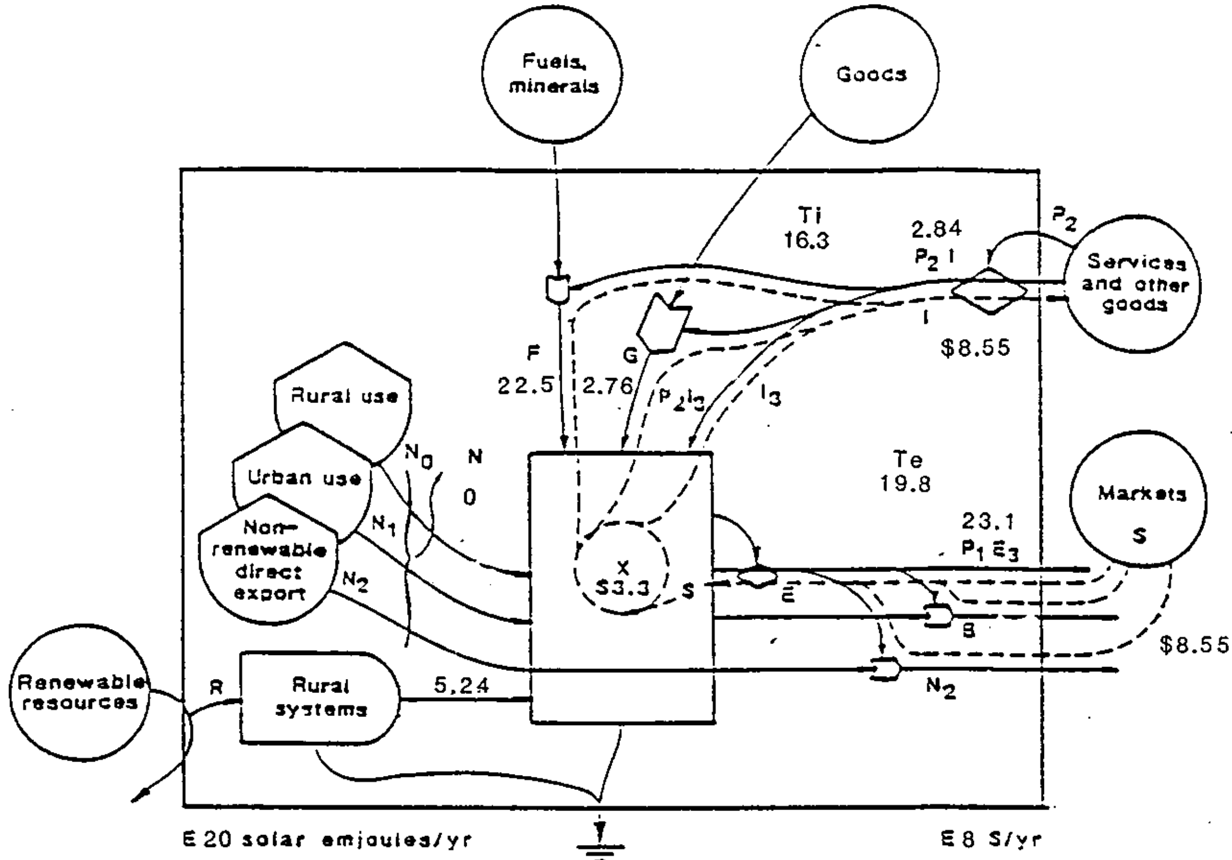
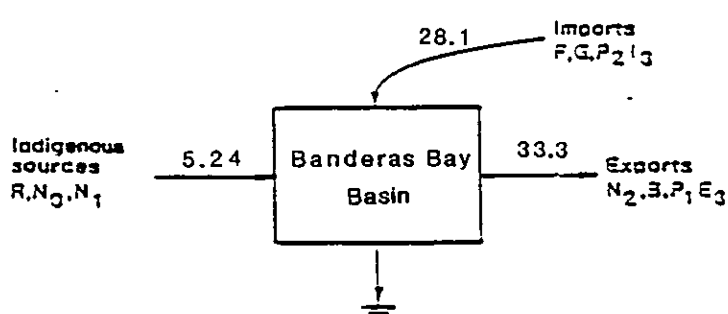


Figure C-2. Energy systems diagram of Banderas Bay watershed basin showing the interplay of renewable, nonrenewable, and purchased energies that drive the regional economy.



(a)



(b)

Figure C-3. Summary diagrams of the economy of Banderas Bay Basin in 1989. The top diagram shows the flows of energy from renewable and nonrenewable sources and from purchased resources that drive the economy. The circle of money within the central box is GDP. The bottom diagram is a further simplification of the economy, showing the main driving energies and balance of imports and exports.

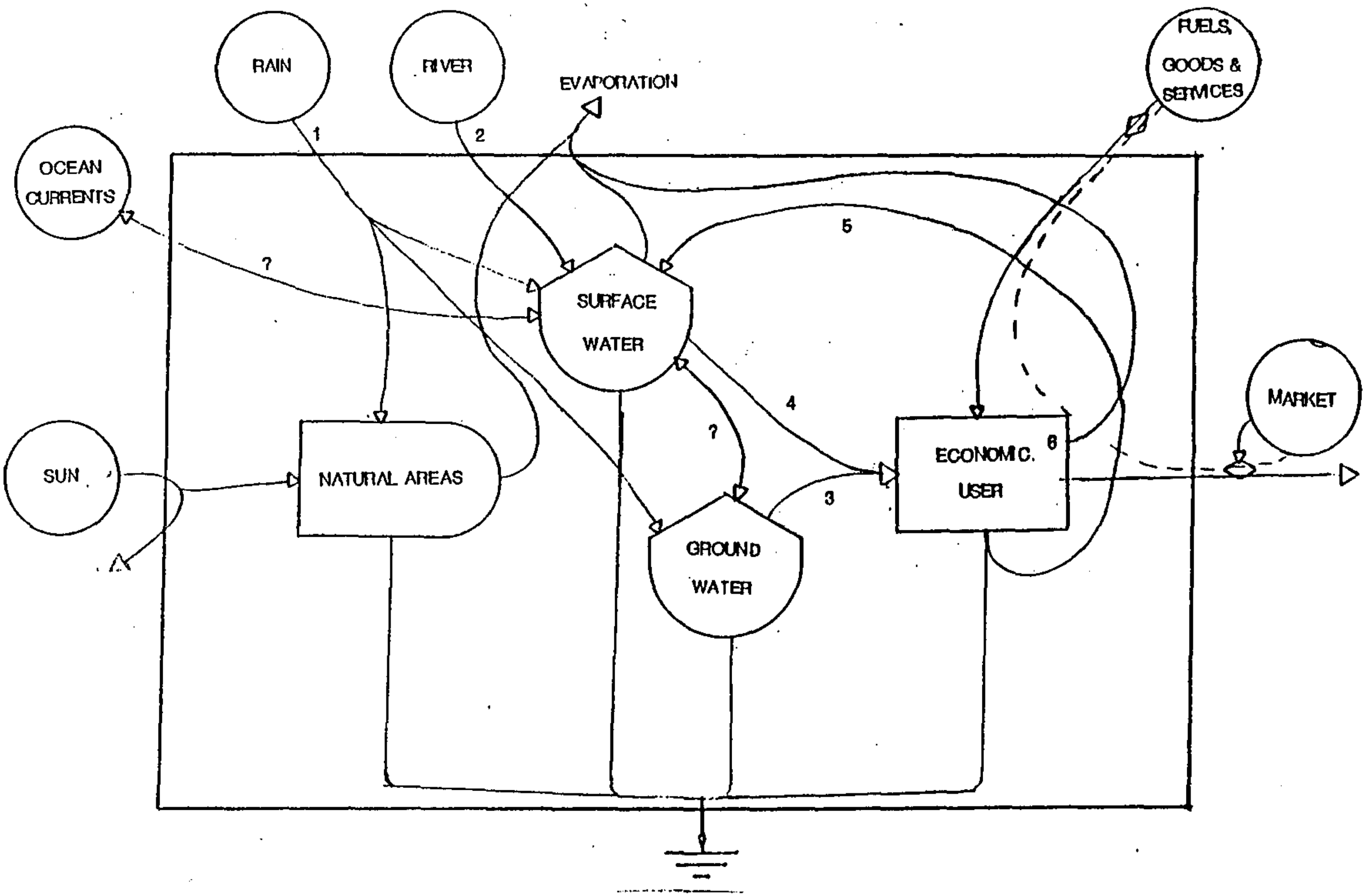


Figure C-4. The flows of water supporting Banderas Basin economy. Numbers on pathways refer to calculated values in Table 4.

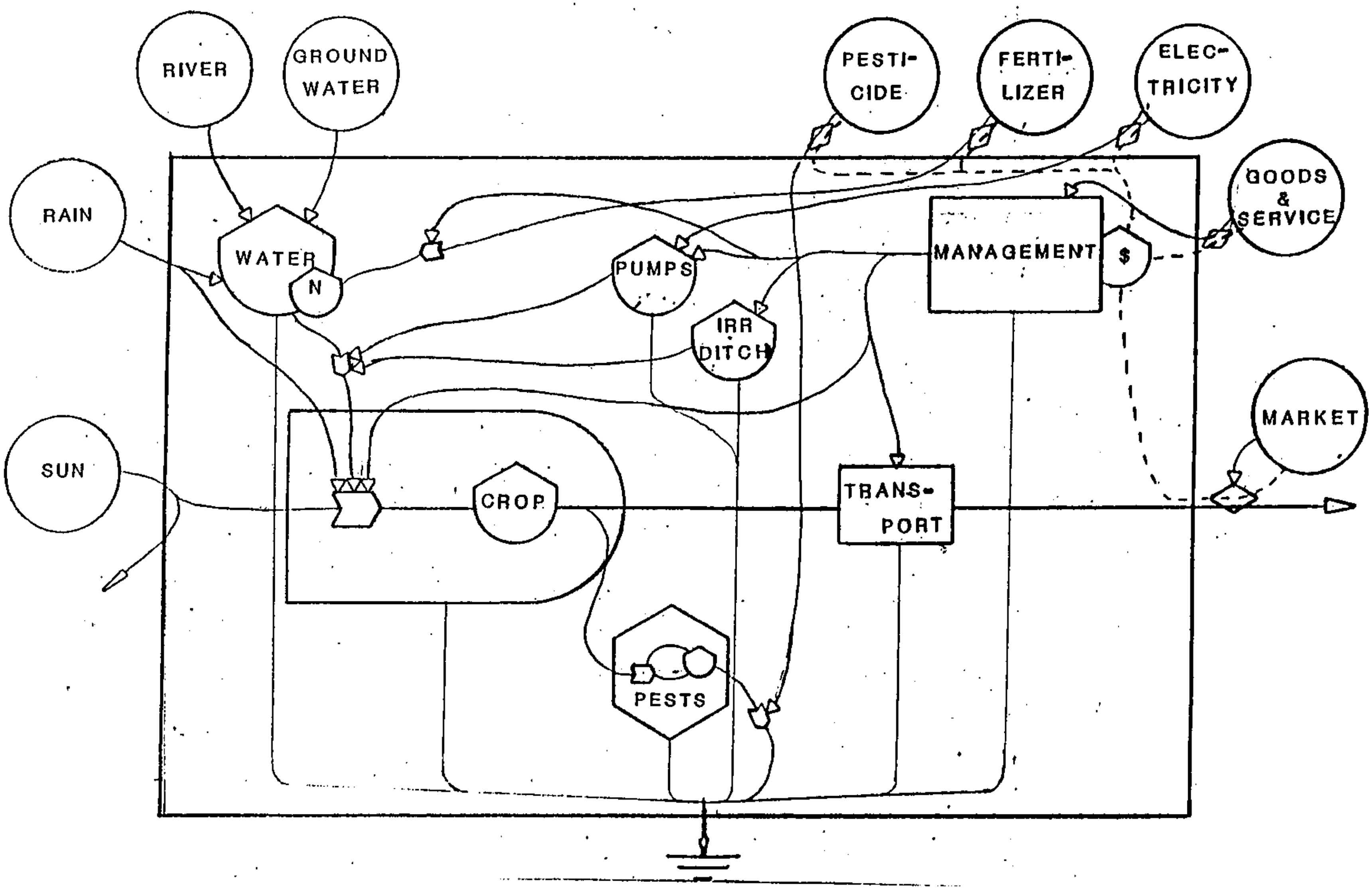


Figure C-5. Energy systems diagram of agriculture showing the interaction of water with renewable and purchased inputs.

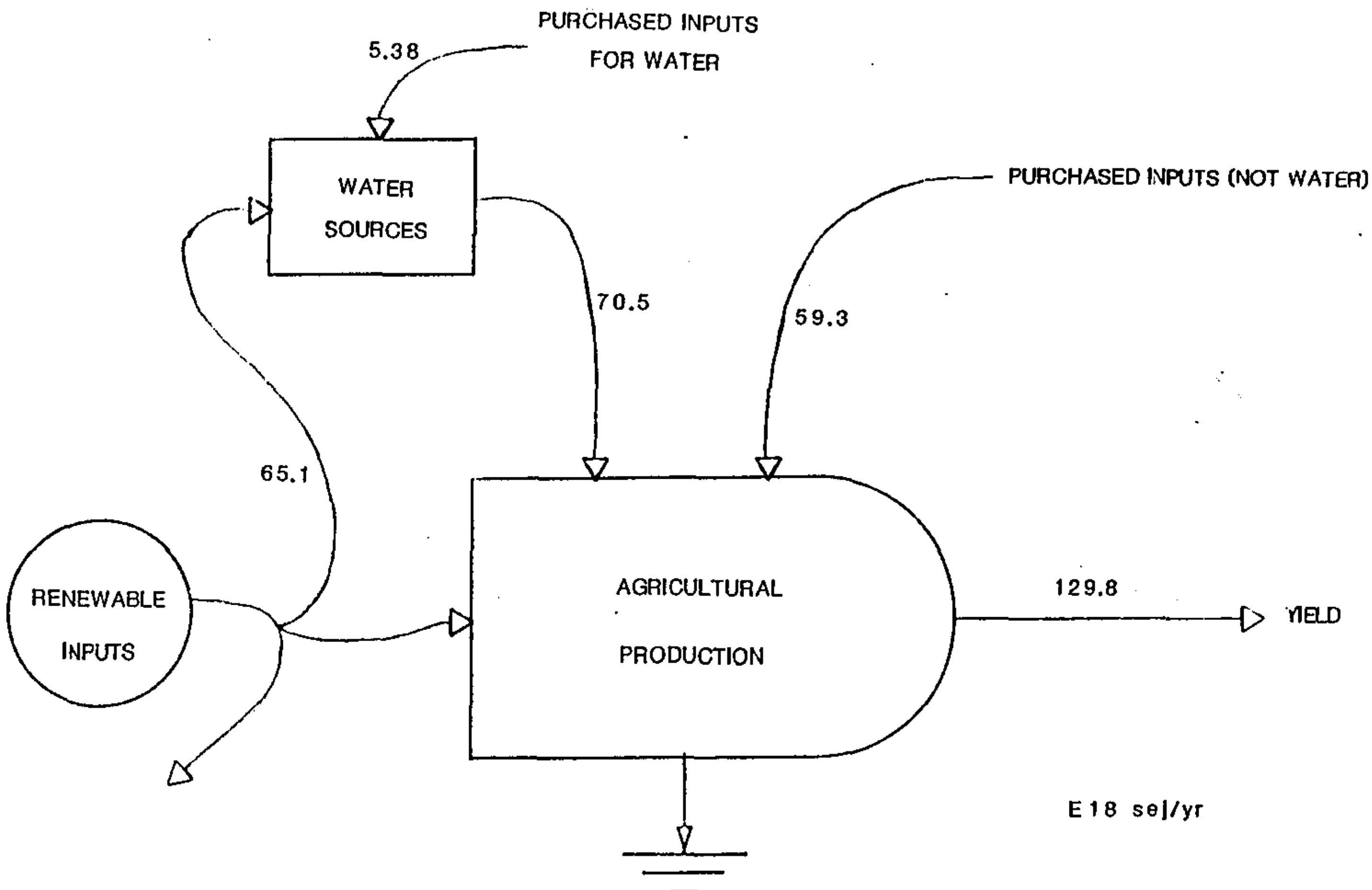


Figure C-6. Summary diagram of EMergy flows in water and purchased inputs that support agricultural production.

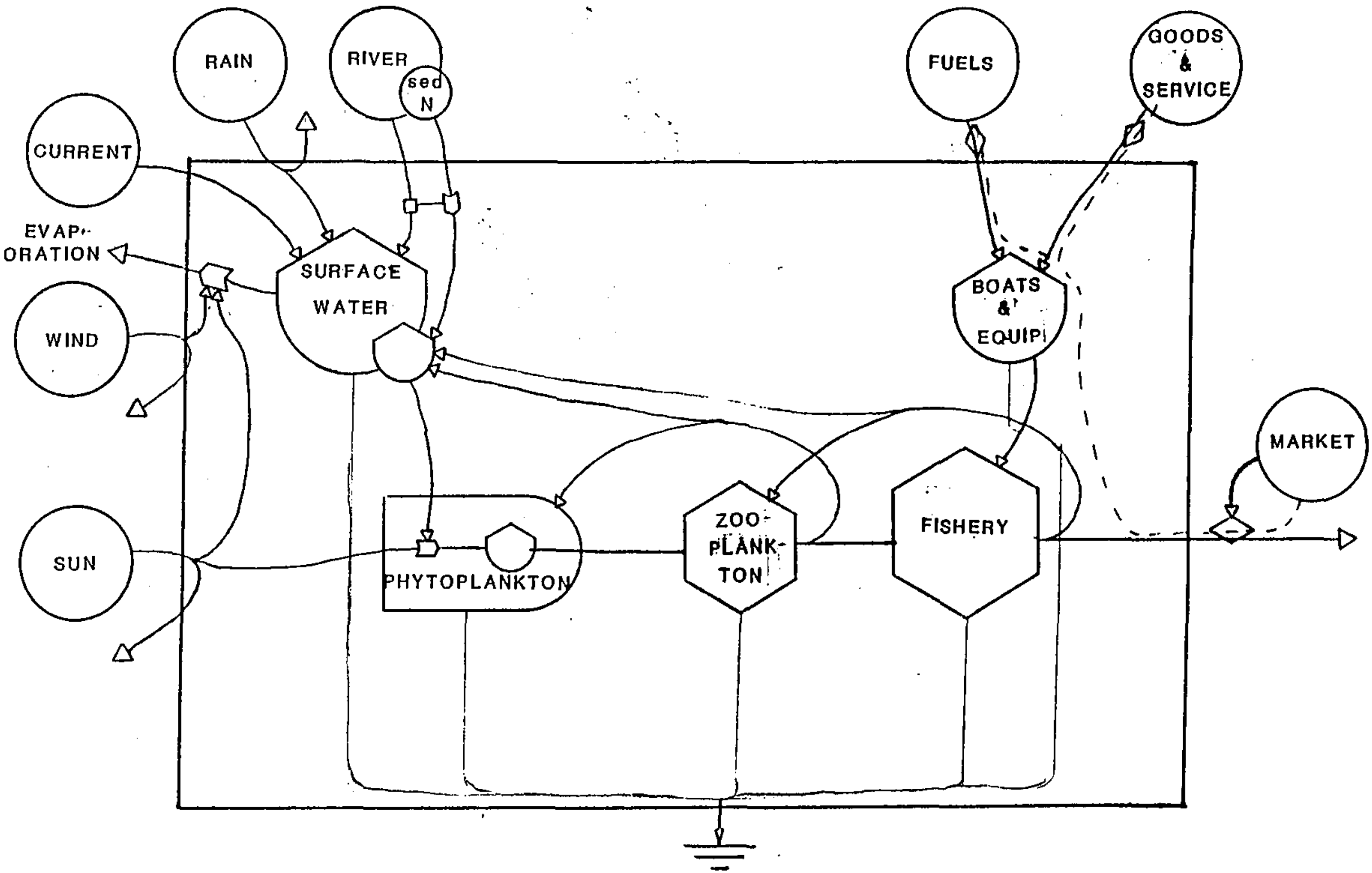


Figure C-7. Energy systems diagram of marine fisheries in the Bay of Banderas showing the interaction of water with renewable and purchased inputs.

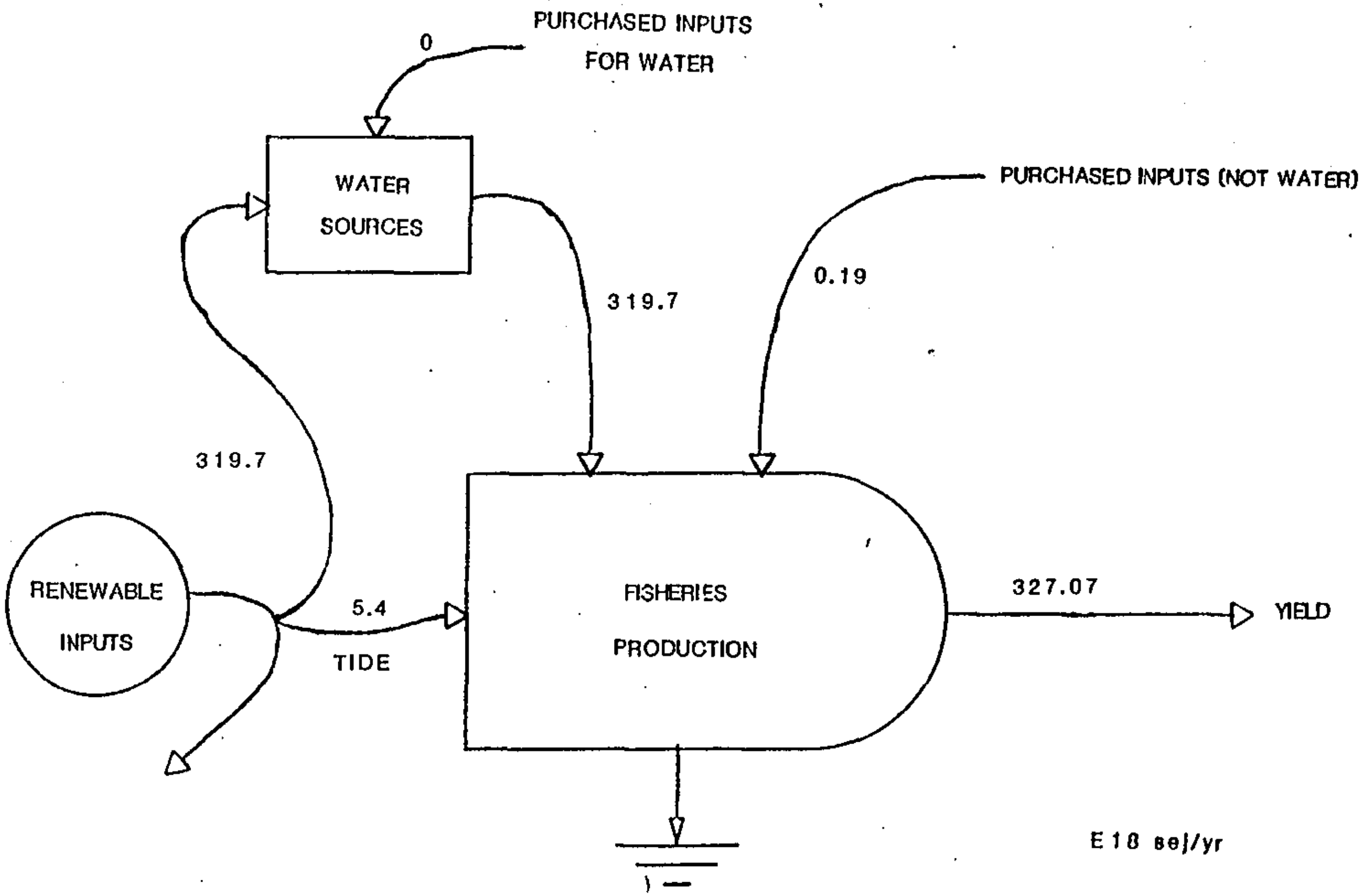


Figure C-8. Summary diagram of EMergy flows in water and purchased inputs that support the marine fishery of Bay of Banderas.

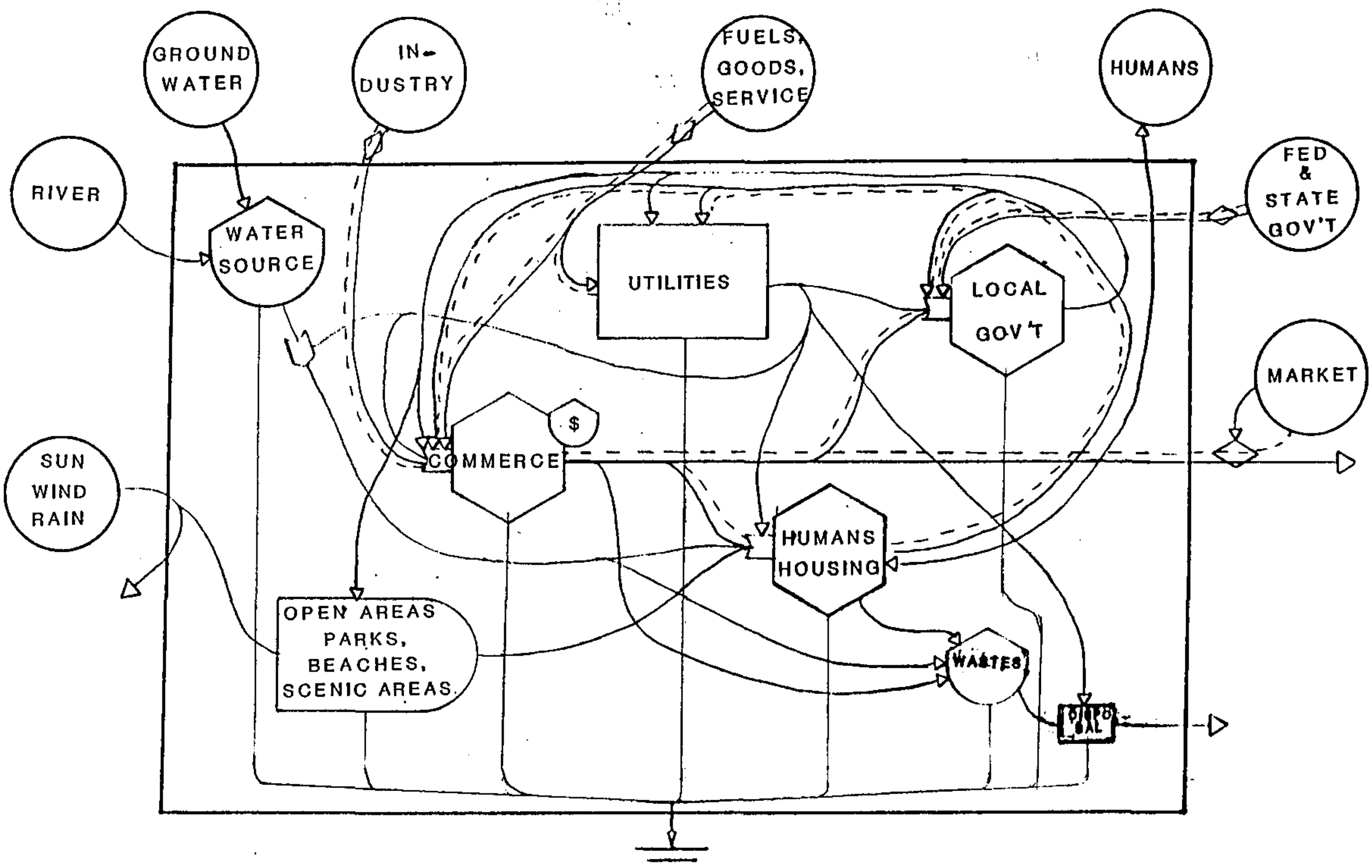


Figure C-9. Energy systems diagram of the urban sector of Banderas Basin showing the interaction of water with renewable and purchased inputs.

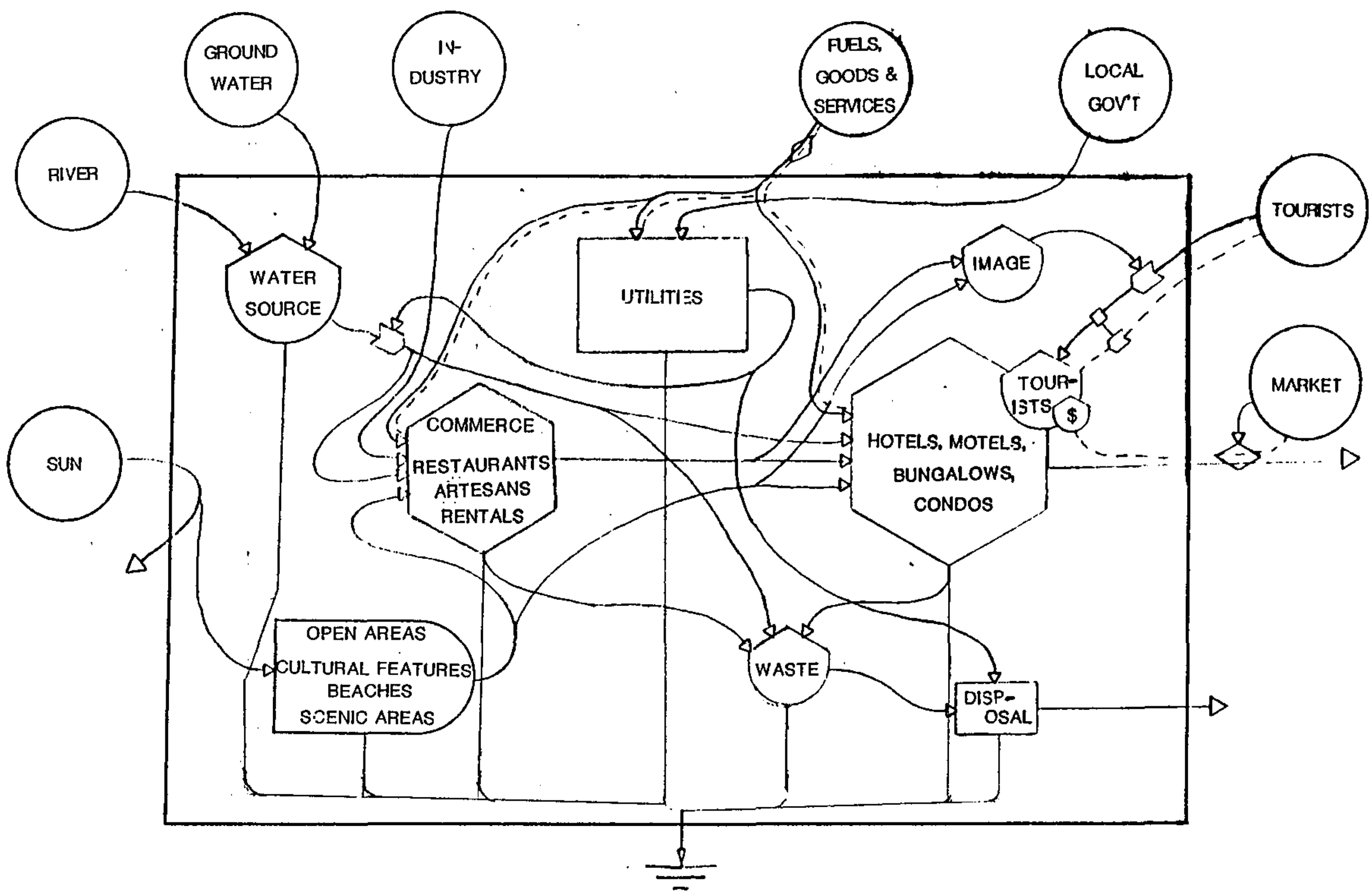


Figure C-10. Energy systems diagram of the tourism sector of Banderas Basin economy showing the interaction of water with renewable and purchased inputs.

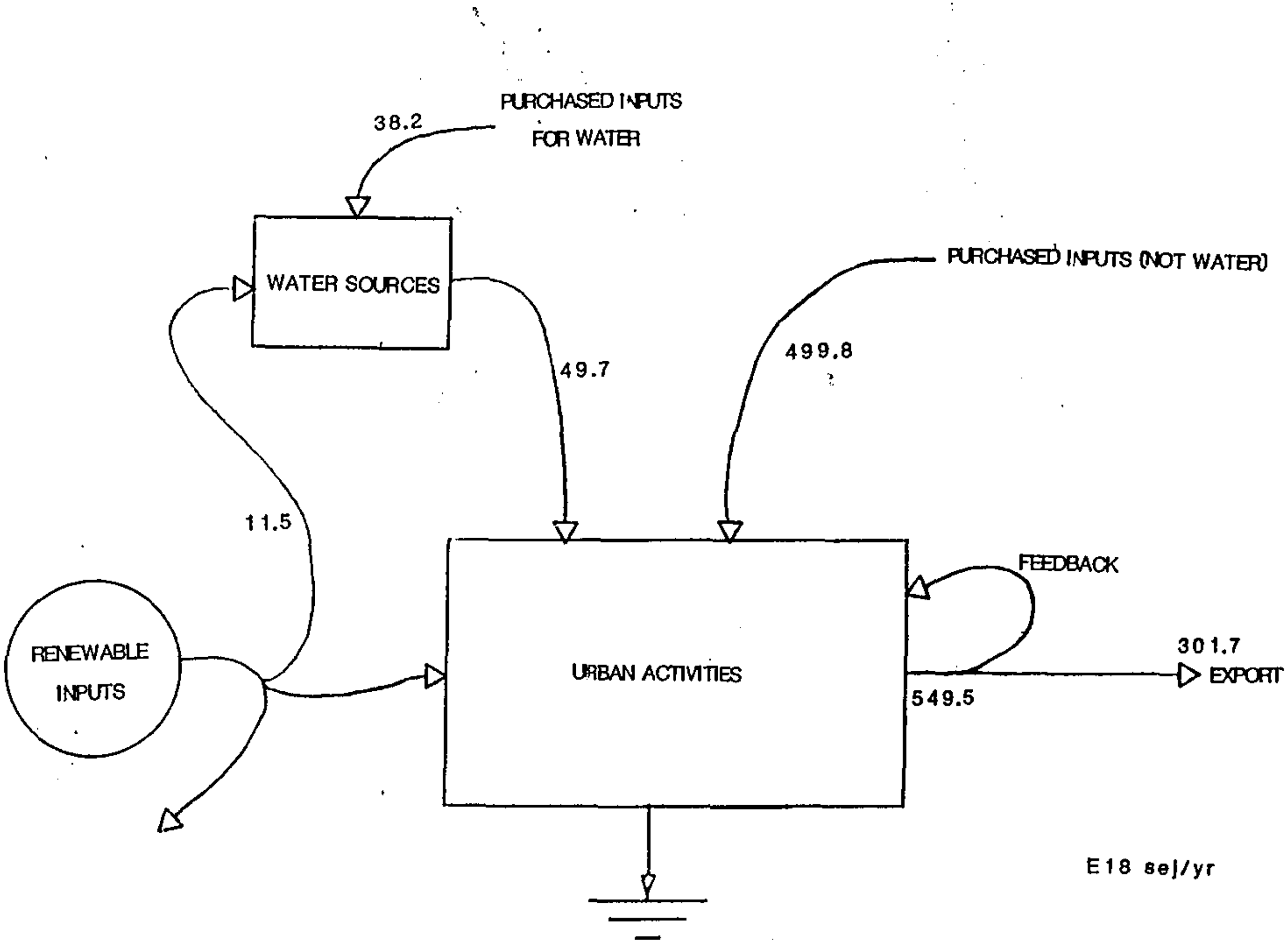


Figure C-11. Summary diagram of EMergy flows in water and purchased inputs that support the urban sector of Banderas Basin economy.

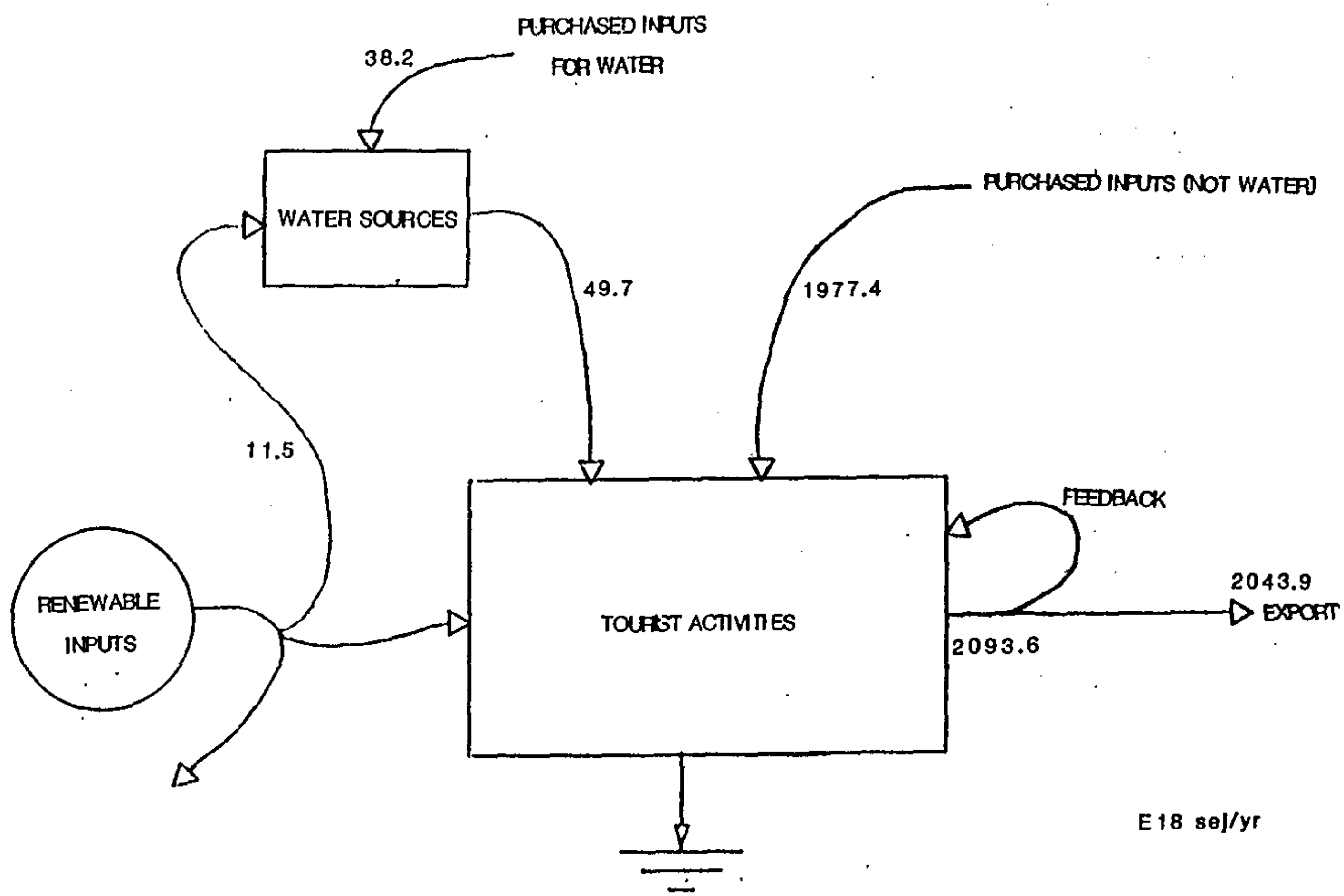


Figure C-12. Summary diagram of EMergy flows in water and purchased inputs that support the tourism sector of Banderas Basin economy.

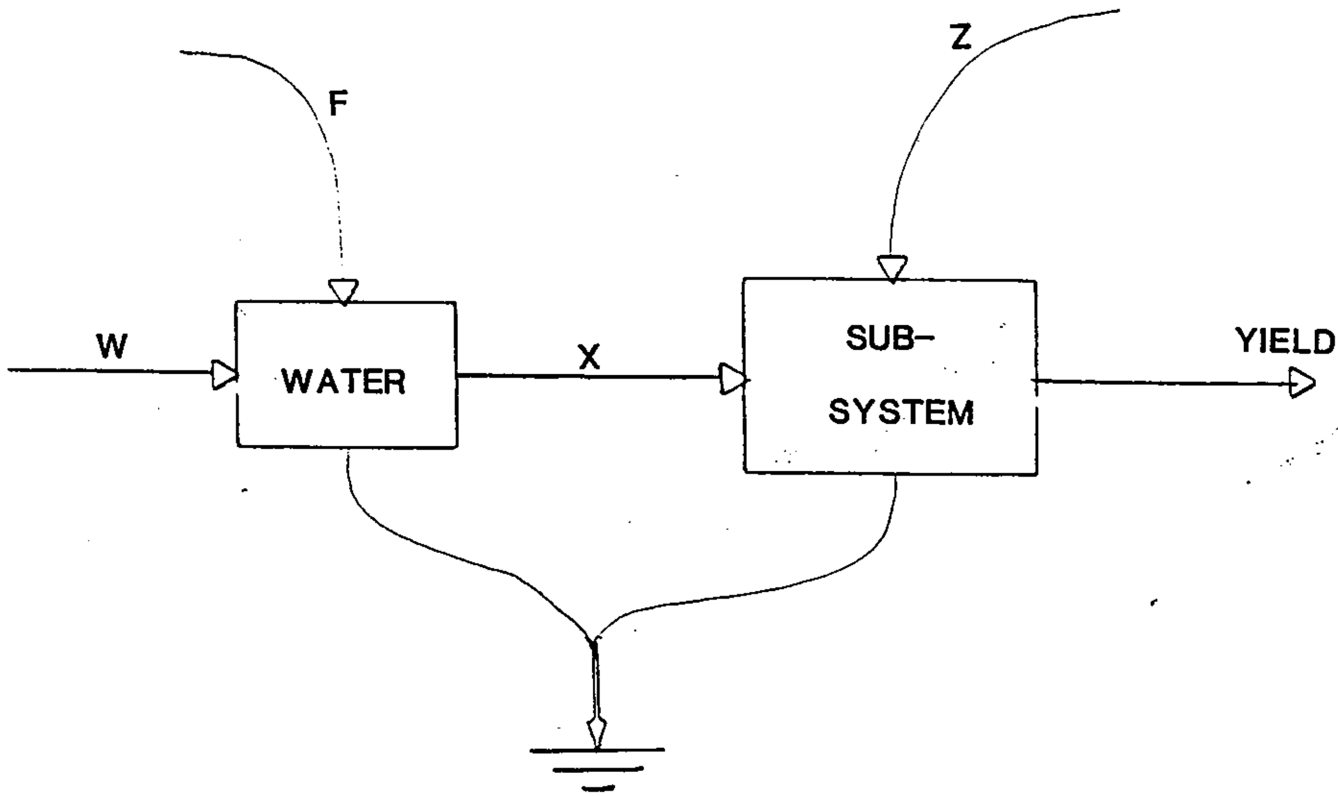


Figure C-13. Diagram illustrating the flows of EMergy supporting water use. Lettered pathways are: rain or river input (W), purchased inputs to treat and deliver water (F), water yield (X), purchased inputs to the economic sector (Z), and yield from the sector (Yield).

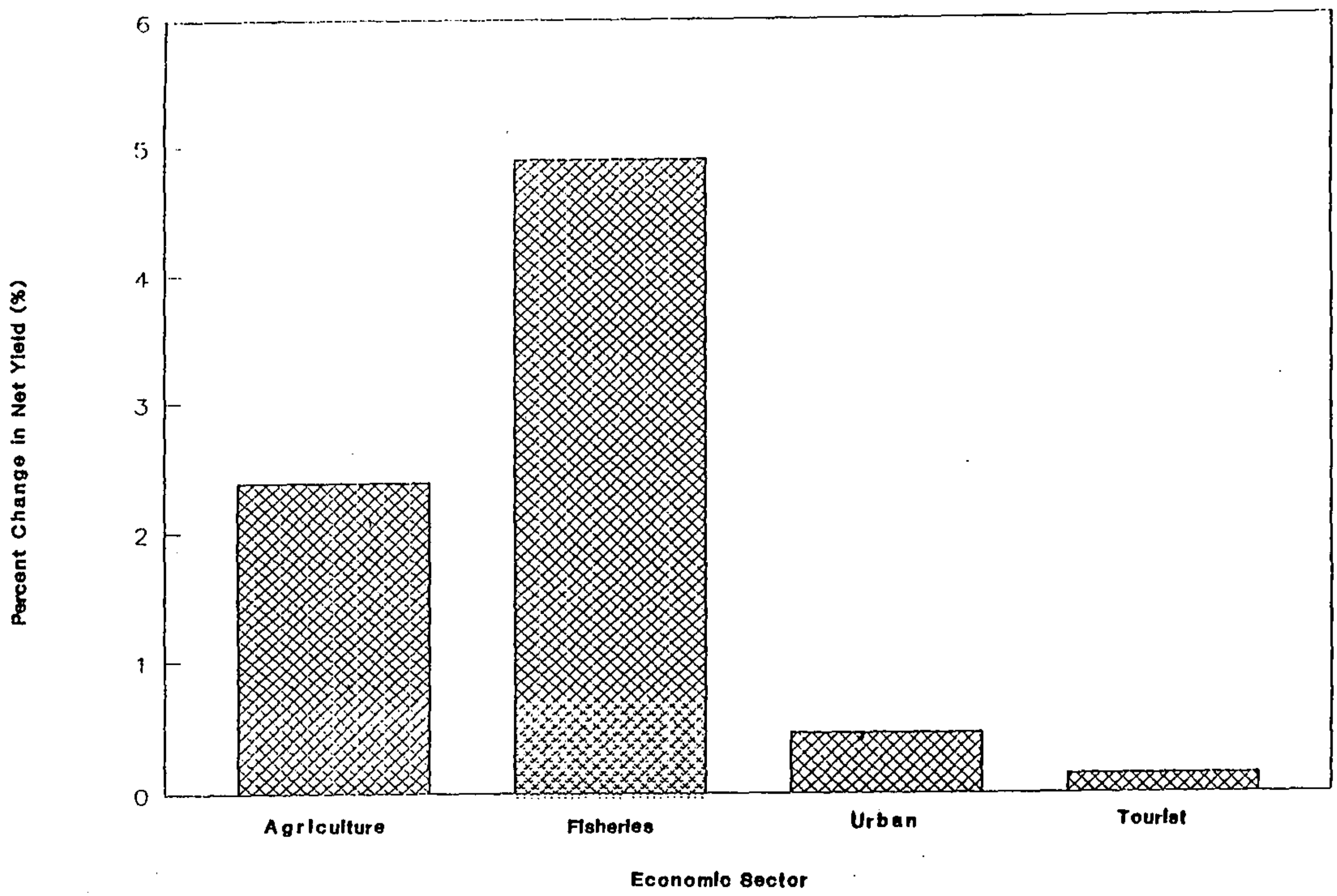


Figure C-14. Marginal effects of water increases on net yield from agricultural, fisheries, urban and tourism sectors.

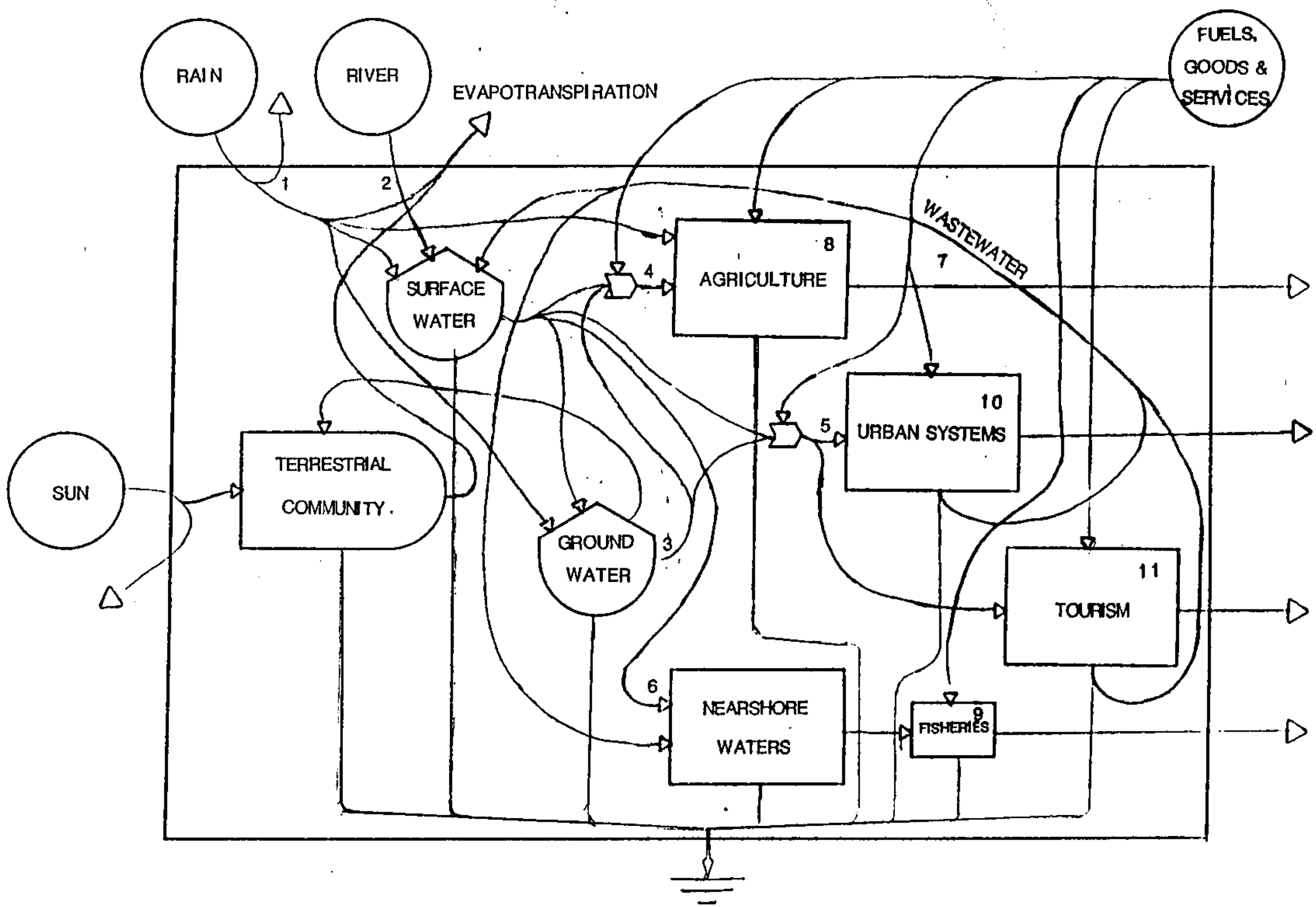


Figure C-15. Energy systems diagram of the Banderas Bay Basin including the marine fishery showing the interplay of water and purchased goods and services that yield economic products. Numbered pathways refer to calculated values in Table 10.

Table C-1. EMergy evaluation of Banderas Bay Basin watershed, 1989.

Note	Item	Raw Units	Trans-formity (sej/unit)	Solar EMergy (E16 sej)	Macroeconomic Value (E5 1984 US$)
RENEWABLE RESOURCES:					
1	Sunlight	5.99E+18 J	1.00E+00	599.486	24.98
2	Rain, chemical	5.62E+15 J	1.82E+04	10215.857	425.66
3	Rain, geopotential	1.26E+15 J	1.05E+04	1324.035	55.17
4	Wind, kinetic	8.11E+15 J	1.50E+03	1213.752	50.57
5	Waves	5.61E+13 J	3.06E+04	171.339	7.14
6	Tide	5.71E+13 J	1.68E+04	96.138	4.01
7	River Geopotential	4.25E+14 J	2.78E+04	1182.654	49.28
8	River, Chem Pot	8.68E+15 J	4.85E+04	42063.600	1752.66
9	Topsoil formation	8.42E+14 J	7.38E+04	6210.799	258.79
				52375.596	
INDIGENOUS RENEWABLE ENERGY:					
10	Agriculture prod	6.67E+14 J	4.81E+05	32094.749	1337.29
11	Livestock prod	3.14E+13 J	2.00E+06	6276.991	261.54
12	Fisheries	6.50E+12 J	2.00E+06	1299.840	54.16
13	Fuelwood prod	3.40E+16 J	1.87E+04	63619.651	2650.84
14	Forest extraction	4.06E+14 J	3.49E+04	1415.494	58.98
NONRENEWABLE SOURCES FROM WITHIN SYSTEM:					
15	Top Soil, erosion	5.68E+14 J	7.38E+04	4189.825	174.58
16	Potable Water Storage	4.78E+10 J	1.54E+04	0.074	0.00
17	Groundwater	8.14E+14 J	1.82E+05	14800.695	616.70
18	Agricultural water	9.71E+14 J	7.44E+04	7224.240	301.01
19	Municipal water	1.15E+14 J	3.87E+05	4450.500	185.44
20a	Raw Wastewater	2.26E+14 J	5.54E+05	12534.784	522.29
20b	Treated Wastewater	1.38E+14 J	1.00E+06	13862.580	577.61
				0.000	
IMPORTS AND OUTSIDE SOURCES:					
1	Electricity	9.40E+15 J	2.00E+05	187997.114	7833.28
2	Natural Gas	1.76E+15 J	4.80E+04	8448.000	352.00
3	Oil	4.29E+15 J	6.60E+04	28319.579	1179.99
4	Steel	3.82E+09 g	1.80E+09	687.189	28.63
5	Minerals	2.19E+09 g	9.20E+08	201.480	8.40
6	Foods	9.67E+12 J	8.50E+04	82.203	3.43
7	Plastics & Rubber	9.43E+11 J	6.60E+04	6.224	0.26
8	Wood,Papr.,Text.	3.40E+13 J	3.49E+04	118.660	4.94
9	Mech.& Trans Eqp.	1.18E+09 g	6.70E+09	790.600	32.94
10	Concrete	7.48E+09 g	9.26E+07	69.265	

Table C-1. continued

Note	Item	Raw Units	Transformity (sej/unit)	Solar EMergy (E16 sej)	Macroeconomic Value (E5 1984 US$)
11	Furnishings	4.23E+13 J	4.00E+06	16919.936	
12	Liquor	2.45E+12 J	6.00E+04	14.684	
13	Services, region	4.14E+06 $	3.32E+12	1372.843	
	Services, tourism	8.14E+07 $	3.32E+12	27022.020	
14	Fertilizer	2.17E+10 g	3.45E+09	7486.500	311.94
15	Pesticides	9.63E+08 g	1.48E+10	1425.240	59.39
16	Tourist EMergy	See item 36 for calculation		41534.699	1730.63
				322496.235	
EXPORTS:					
17	Cash Crops	5.34E+14 J	4.81E+05	25675.799	1069.83
18	Fishery Products	5.20E+12 J	2.00E+06	1039.872	43.33
19	Livestock	2.51E+13 J	2.00E+06	5021.593	209.23
20	Service in exports	4.14E+06 $	3.32E+12	1372.843	57.20
21	Tourist service	5.96E+08 $	3.32E+12	197737.298	8239.12
				230847.406	

RENEWABLE RESOURCES:

1 Solar Energy. Average sunlight over the basin taken as 1.64E+02 kcal/cm^2/yr (Odum, 1987). Area = 1.16E+09 m^2 (INEGI, 1989).

Energy(J) = (1.16E+09 m^2)*(1.64E+05 Cal/cm^2/y)*(E+04 cm^2/m^2)
(1-0.30)(4186 J/kcal)
= 5.99E+18 J/yr

2 Rain (Chemical Potential). Average rainfall over the basin taken as 1.42 m/yr and 0.64 m/yr over the bay (SEDUE, 1990). Evapotranspiration rate estimated as 70 % of rainfall.

Energy (land) (J)= (1.16E+09 m^2)*(1.42 m)*(1000kg/m^3)*(4.94E+03J/kg)
= 5.57E+15 J

Energy (shlf) (J)= (area of shelf)(Rainfall)(Gibbs no.)
= 4.88E+13 J

Total energy (J) = 5.62E+15 J/yr

3 Rain (Geopotential Energy). Average elevation taken as 400 m (INEGI, 1990) and runoff rate estimated as 20 %.

Energy(J)= (1.14E+09 m2)(1.42 m)*(1000 kg/m3)*(400 m)*(9.8m/s2)
= 1.26E+15 J/yr

Table C-1. continued

4 Wind Energy.

Energy(J) = 8.11E+15 J/yr (Odum, 1987)

5 Wave Energy.

Energy(J) = 5.61E+13 J/yr (Odum, 1987)

6 Tidal Energy. Average tidal range taken as 1 m (INEGI, 1990) with a total of 730 tides per year (2 tides/day in 365 days)

Energy(J) =(1.55E+05 m2)*(0.5)*(7.3E+02/yr)*(1m)^2*(1000 kg/m3)
*(9.8m/s2)
= 5.71E+13 J/yr

7 River Geopotential. Yearly river flow, 55 m3/s (Atlas de Agua, 1987), with an elevation difference of 50 m (INEGI, 1990)

Energy(J) = (55 m3/s)(50 m)(9.8 m/s2)(1000 kg/m3)(3.1E7 s/yr)/2
= 4.25E+14 J

8 River (Chemical Potential). Based on average yearly flow.

Energy(J) =(1.74E+09m^3/yr)(1E+06 g/m^3)(5 J/g)
= 8.68E+15

9 Topsoil Formation. Taken as 1.26E+03 g/m2/yr (INEGI, 1990-Mexico)

Energy(g) = (1.26E+03 g/m^2/yr)(9.09E+08 m^2)(0.03 g organic)
(5.4 kcal/g)(4186 J/kcal)
= 8.42E+14

INDIGENOUS RENEWABLE ENERGY:

10 Agricultural Production. Based on 45,543 MT/yr (SARH, 1991).

Energy(J) = (45,543 MT/yr)(E+06 g/MT)(3.5 kcal/g)(4186 J/kcal)
= 6.67E+14 J

11 Livestock Production. Based on 8520 MT of cattle, pigs and goats (INEGI, 1990-Jalisco).

Energy(J) = (8520 MT/yr)(1.0E+07 g/MT)(4 kcal/g)(4186 J/kcal)
*(0.22 protein)
= 3.14E+13 J

Table C-1. continued

12 Fisheries Production. Based on a catch of 1.76E+03 MT/yr (SEP,1990)

Energy(J) = (1.76E+03 MT/yr)(E+07 g/MT)(4 kcal/g)(4186 J/kcal)
*(0.22 protein)
= 6.50E+12 J

13 Fuelwood Production. Taken as 4.52E+06 m3/yr (INEGI,1990-Jalisco), with 40% of the basin area used for fuelwood production.

Energy(J) =(4.2E+06 m3/yr)(0.5E+06 g/m3)(4 kcal/g)(4186 J/kcal)
= 3.40E+16 J

14 Forest Extraction. Taken as 5.38E+04 m3/yr (INEGI,1990-Jalisco), with 25% of the basin area used for forest extraction.

Energy(J) =(7.9E+07 m3/yr)(0.5E+06 g/m3)(4 kcal/g)(4186 J/kcal)
= 4.06E+14 J

NONRENEWABLE SOURCES FROM WITHIN SYSTEM:

15 Topsoil Erosion. Topsoil lost/year, 850 g/m2/yr (INEGI,1990-Mexico).

Energy(g) = (850 g/m2/yr)(9.1E+08 m2)(0.03 organic)(5.4 kcal/g)
*(4186 J/kcal)
= 5.68E+14 J

16 Potable Water Storage. 9.68E+03 m3/yr (SEDUE, 1990; SEAPAL, 1991).

Energy(J) =(9.68E+03 m^3)(10^6 g/m^3)(4.94 J/g)
= 4.78E+10 J

17 Groundwater (Aquifer). Total recharge per year taken as 10% of total rainfall over the basin (SEDUE, 1990 and SEAPAL, 1991).
Energy(J) =(2.38E+08 m^3/yr)(10^6 g/m^3)(4.94 J/g)
= 8.14E+14 J

18 Agricultural Water. Taken from calculations in Table 5.

Energy(J) = 9.71E+14 J

19 Municipal Water. Taken from calculations in Table 7.

Energy(J) = 1.15E+14 J

20a Raw Wastewater. Total wastewater generation of 2.43E+07 m3/yr, calculated as 90% of water consumed (SEDUE, 1990; SEAPAL, 1991).

Chem. Pot. = (2.43E+07 m^3/yr)(10^6 g/m^3)(4.94 J/g)
= 1.20E+14 J
OM = (180 mg/L)(1g/m3/mg/L)(5 kcal/g)(4186 J/kcal)(2.43E+07 m3/yr)
= 9.15E+13 J

Table C-1. continued

P = (15 mg/L)(1 g/m3/mg/L)(5 kcal/g)(4186 J/kcal)(2.43E+07 m3/yr)
= 7.63E+12 J
N = (14 mg/L)(1 g/m3/mg/L)(5 kcal/g)(4186 J/kcal)(2.43E+07 m3/yr)
= 7.12E+12 J

Total Energy = 2.26E+14 J

Transformity of Raw Wastewater = EMergy input of consumer water and foods, divided by energy in wastewater.

Consumer water = 4.45E+19 sej
Foods = 8.02E+19 sej
Services = ERR sej
Transformity = ERR sej/J

20b Treated Wastewater. Total wastewater generation of 2.43E+07 m3/yr, calculated as 90% of water consumed (SEDUE, 1990; SEAPAL, 1991).

Chem. Pot. = (2.43E+07 m^3/yr)(10^6 g/m^3)(4.94 J/g)
= 1.20E+14 J
OM = (19 mg/L)(1g/m3/mg/L)(5 kcal/g)(4186 J/kcal)(2.43E+07 m3/yr)
= 9.66E+12 J
P = (2.6 mg/L)(1 g/m3/mg/L)(5 kcal/g)(4186 J/kcal)(2.43E+07 m3/yr)
= 1.32E+12 J
N = (3.3 mg/L)(1 g/m3/mg/L)(5 kcal/g)(4186 J/kcal)(2.43E+07 m3/yr)
= 7.12E+12 J

Total Energy = 1.38E+14 J

Total EMergy inputs = EMergy in consumer water, delivered foods and wastewater treatment expenditures.

EMergy in consumer water and delivered foods.
Consumer water = 4.45E+19 sej
Foods = 8.02E+19 sej
Services = ERR sej

ERR sej

EMergy in Wastewater Treatment expenditures.

Table of Wastewater Treatment

Vol/yr	1.64E+07 m3/yr	(assuming 70 % is properly treated)
People served	129200	
Fuel Use	0.2802144 L/m3/yr	
Operation	27.184094 pesos/m3/yr	
Labor	15.164544 pesos/m3/yr	

Table C-1. continued

		Units	Transformity	EMergy (sej)
a Fuel	J	1.88E+14	6.60E+04	1.24E+19
b Operations Costs	$	1.66E+05	3.32E+12	5.50E+17
c Labor Costs	$	9.25E+04	3.32E+12	3.07E+17
				1.33E+19

a Fuel Use. Based on 4.59E+06 L/yr for water treatment (Seapal, 1991).

Energy = (3.36 L/m3/yr)(2.43E+07 m3/yr)(41E+06 J/L)
= 1.88E+14 J/yr

b Operations Costs. (Seapal, 1991)
= 1.66E+05 $/yr

c Labor Costs. (Seapal, 1991)
= 9.25E+04 $/yr

Transformity of Treated Wastewater = EMergy inputs of consumer water, foods and treatment expenditures, divided by energy in treated wastewater.

Transformity = ERR sej/J

IMPORTS OF OUTSIDE ENERGY SOURCES:

21 Electricity. Taken as 1.4E+09 KWH/yr (INEGI, 1990-Jalisco).

Energy(J) =(2.86E+05 KWH/yr)(3.60E+06 J/KWH)
= 5.36E+15 J

Items 22 through 33 were extrapolated from an EMergy analysis of Nayarit, Mexico prepared by Javier Venegas on the basis of use per capita

22 Natural Gas. Energy(J) = 1.76E+15 J

23 Oil. Energy(J) = 4.29E+15 J

24 Steel. Energy(J) = 3.82E+09 g

25 Minerals. Energy(J) = 2.19E+09 g

26 Foods. Energy(J) = 9.67E+12 J

27 Plastics & Rubber. Energy(J) = 9.43E+11 J

28 Wood,Paper,Textile Energy(J) = 3.40E+13 J

Table C-1. continued

29 Machinery and Transportation Equipment.

Energy(J) = 1.18E+09 g

30 Concrete. Energy(J) = 7.48E+09 g

31 Furnishings. Energy(J) = 4.23E+13 J

32 Liquor. Energy(J) = 2.45E+12 J

33a Services in imports for main economy estimated as 80% of currency value of exports. Total exports estimated as $ 5.17E+06 * 80 %.

Energy = 4.14E+06 $US

33b Services, for tourism construction and operation estimated as 50% of total Service.

Energy = 2.19E+11 $ pesos (8.14E+07 $ US)

34 Fertilizer. = 2.17E+10 g/yr (SARH)

35 Pesticides. = 9.63E+08 g/yr (SARH)

36 Tourism. EMergy in tourists calculated as EMergy per capita (half from U.S. and half from Mexico) multiplied by 4.58E+06 tourist-days per year (CCNCST, 1990).

EMergy (sej) =(4.6E+06 days/yr)[(1.6E+14 +1.9E+13)sej/cap/day]/2
= 4.15E+20 sej

EXPORTS OF ENERGY, MATERIALS AND SERVICES

37 Cash Crops. Estimated as 80 % of total crop production.

Energy = 5.34E+14 J

38 Fishery Products. Estimated as 80 % of total fisheries production.

Energy = 5.20E+12 J

39 Livestock. Estimated as 80 % of total livestock production (INEGI, 1990 - Jalisco).

Energy = 2.51E+13 J

40 Services in exports for main economy estimated as 80% of total value of fishery and agriculture production.

Energy = 4.14E+06 $

41 Tourist Service. Total tourist dollars spent per year (CCNCST, 1990)

Energy = 5.96E+08 $

Table C-2. Summary of flows in Banderas Bay Basin, 1989.

	Variable	Solar EMergy (sej)	Dollars ($ US)
R	Renewable sources (rain, tide, etc)	5.24E+20	
N	Nonrenewable sources flow within Banderas Basin.	0.00E+00	
F	Imported Electricity, Fuels and Minerals	2.25E+21	
G	Imported Goods	2.76E+20	
Ti	EMergy in Tourist Imports	1.63E+21	
P2I	EMergy Value of Service Imports	2.84E+20	
I	Dollars Paid for Imports		8.55E+07
E	Dollars Received for Exports		8.55E+07
P1E	EMergy Value of Goods and Service Exports	2.31E+21	
Te	EMergy in Tourist Services Exported	1.98E+21	
x	Gross Domestic Product (est. from Nayarit & Mexico GDP on per capita basis)		3.13E+08
P2	World EMergy/$ ratio, used in imports	1.60E+12	
P1	Mexico EMergy/$ ratio	3.32E+12	

Table C-3. EMergy indices for Banderas Bay Basin based on Table C-2, Figure C-4 and national indices for Mexico.

Item	Name of Index	Expression	Basin	Mexico
1	Renewable EMergy flow	R	5.24E+20	1.45E+23
2	Flow from indigenous nonrenewable reserves	N	0.00E+00	4.46E+23
3	Flow of imported EMergy	F+G	2.53E+21	1.51E+23
4	Total EMergy inflows	R+N+F+G+P2I	3.33E+21	7.42E+23
5	Total EMergy used, U	N0+N1+R+F+G+P2I	3.33E+21	5.72E+23
6	Total exported EMergy	P1E	2.31E+21	7.05E+22
7	Fraction EMergy use derived from home sources	(N0+N1+R)/U	0.157	0.74
8	Imports minus exports	(F+G+P2I)-(N2+B+P1E)	1.02E+21	-9.00E+22
9	Export to Imports	(N2+P1E)/(F+G+P2I)	0.69	1.6
10	Tourist imports minus exports	Ti - Te	-3.47E+20	
11	Tourist exports to imports	Te/Ti	1.21E+00	
12	Fraction used, locally renewable	R/U	0.157	0.25
13	Fraction of use purchased	(F+G+P2I)/U	0.843	0.26
14	Fraction imported as tourist service	Ti/U	0.489	
15	Fraction of use that is free	(R+N0)/U	0.157	0.26
16	Net EMergy Yield Ratio	U/(F+G+P2I)	1.186	3.846
17	Ratio of concentrated to rural	(F+G+P2I+N1)/(R+N0)	5.364	2.8
18	Use per unit area	U/(area)	2.71E+12	2.38E+11
19	Use per person	U/population	1.67E+16	7.05E+15
20	Renewable carrying capacity at present living standard	(R/U) (population)	3.14E+04	2.06E+07
21	Developed carrying capacity at same living standard	8(R/U)(population)	2.51E+05	1.65E+08
22	Ratio of use to GDP, EMergy/dollar ratio	P1=U/GDP	1.07E+13	3.09E+12
23	Ratio of electricity to use	(el)/U	0.564	0.099
24	Fuel use per person	fuel/population	1.84E+15	1.91E+15

Table C-4. EMergy values of regional water use.

#	Flow	Energy	Transformity (sej/J)	EMergy (E+20 sej)
1	Rainfall	5.62E+15 J	1.82E+04	1.022
2	River Inflow	8.68E+15 J	4.85E+04	4.206
3	Groundwater	3.32E+14 J	1.82E+05	0.604
	Groundwater Use		3.28E+05	1.088
4	Surface Water	7.44E+14 J	4.85E+04	0.361
	Surface Water Use		1.37E+05	1.019
5	Raw Wastewater	2.26E+14 J	5.54E+05	1.253
	Treated Wastewater	1.38E+14 J	1.00E+06	1.386
6	Economic Interaction	1.08E+15 J	3.10E+06	33.334

Notes:

1 Rainfall
Total volume of rainfall over land and bay areas.

2 River Inflow
Total river flow.

3 Groundwater
Total volume extracted for use not including purchased inputs.
Transformity - 1/10% infiltration * transformity of rain

Groundwater Use
Total volume extracted for use includes purchased inputs.
Transformity - weighted average of agriculture & municipal transformities.

4 Surface Water
Total volume extracted for use not including purchased inputs.

Surface Water Use
Total volume extracted for use includes purchased inputs.
Transformity - weighted average of agriculture & municipal transformities.

5 Wastewater - Raw and Treated
Total volume produced.
Transformity - based on number given in Table 1, lines 20a and 20b.

6 Economic Interaction
Sum of Surface and Groundwater use.
Transformity - EMergy in inputs / energy in water.

Table C-5. EMergy evaluation of agriculture and irrigation water.

Note	Item		Units/Yr.	Transformity (sej/unit)	Solar Emergy (E16 sej/yr)	Macroeco. Value, 1989 (E5 $)
	Natural Inputs for water					
1	Rain	J	5.58E+14	1.54E+04	861.077	25.936
2	River	J	7.31E+14	4.11E+04	3003.952	90.480
3	Groundwater	J	2.40E+14	1.10E+05	2646.805	79.723
					6511.83	196.140
	Purchased Inputs for Irrigation					
4	Electricity	J	1.18E+13	2.00E+05	236.333	7.118
5	Labor, O & M, Goods, services	$	9.08E+05	3.32E+12	301.310	9.076
					537.64	16.194
	Agricultural water					
6	Crop Irrigation	J	9.71E+14	7.26E+04	7049.476	212.334
	Purchased Inputs for Agriculture					
7	Fertilizer	J	1.39E+10	3.45E+09	4808.580	144.837
8	Pesticides	J	6.17E+08	1.48E+10	913.740	27.522
9	Labor, O & M, Goods, services	$	6.28E+05	3.32E+12	208.468	6.279
					5930.788	178.638
	Export					
10	Crop Yield	J	4.28E+14	3.03E+05	12980.264	390.972

Footnotes to Table C-5:

Agricultural Statistics from Secretariat for Agriculture and Water Resources (SARH, 1990).

Agricultural Area 11795.00 Ha = 1.26E+08 m2
Irrigated Area = 7563.00 Ha = 8.07E+07 m2
Irrigation Water = 2.60E+04 m3/Ha/yr
= 1.97E+08 m3/yr

1 Rainfall (Chemical Potential). Average rainfall over irrigated areas, taken as 1.4 m/yr (SARH, 1990).

Energy = (1.4 m)(8.07E+07 m2)(1000kg/m^3)(4.94 E3 J/kg)
= 5.58E+14 J/yr

2 River (Chemical Potential). 75.3% of irrigation water comes from river source (SARH, 1990).

Table C-5. continued

Energy = (0.753*1.97E+08 m^3)(1000kg/m^3)(4.94 E3 J/kg)
= 7.31E+14 J/yr

3 Groundwater (Chemical Potential). 24.7 % of irrigation water comes from groundwater supplies (SARH, 1990).

Energy = (0.247*1.97E+08 m^3)(1000kg/m^3)(4.94 E3 J/kg)
= 2.40E+14 J/yr

4 Electricity Use. Based on 3.28E+06 KWH/yr for pumping groundwater (SARH, 1990).

Energy = (3.28E+06KWH)*(3.6E6J/KWH)
= 1.18E+13 J/yr

5 Irrigation Labor, O & M, Goods & Services. Based on $120/ha/yr (Brown, 1992)

Misc. costs = ($120/ha/yr)(7563 ha)
= 9.08E+05 $/yr

6 Calculation for Irrigation Water

Energy = (7.36E+08 m^3)(1000kg/m^3)(4.94 E3 J/kg)
= 9.71E+14 J/yr

EMergy Input = Total of river, groundwater, electricity, goods and services.

= 7.05E+19 sej

Transformity of Irrigation Water = EMergy inputs/water energy

= 7.26E+04 sej/J

7 Fertilizer. Based on data from SARH, 1990.

= 1.39E+10 g/yr

8 Pesticides. 80 L/ha/yr and a density of 1.4 g/m3 (SARH, 1990).

Pesticide = (1.4E+06 g/m3)(.001 m3/L)(80 L/Ha/yr)(8597 Ha)
= 6.17E+08 g/yr

9 Labor, O & M. Estimated as total production costs (1.47E+06 $/yr, SAHR, 1990) minus irrigation costs, calculated as 1/3 of production costs.

= 6.28E+05 $/yr

10 Total Crop Energy. Based on 45,543 MT/yr (SARH, 1990).

Energy = (45,543 MT/yr)*(1E+06 g/MT)*(3.5 kcal/g)
*(4186 J/kcal)
= 4.28E+14 J/yr

Table C-6. EMergy evaluation of fisheries and water inputs.

Note	Item		Units/Yr.	Trans- formity (sej/unit)	Solar EMergy (E16 sej/yr	Macroeconomic Value, 1989 (E5 $)
Natural Inputs						
1	Tide	J	3.22E+14	1.68E+04	541.36	16.306
2	River, chem pot	J	7.74E+15	4.11E+04	31813.05	958.225
3	Organic Matter	J	8.33E+13	1.90E+04	158.23	4.766
					31971.28	
Fisheries Water Value						
4	Fishery Water	J	8.70E+14	3.67E+05	31971.28	962.990
Purchased Imports for Fishery						
5	Fuels	J	3.26E+13	5.30E+04	172.68	5.201
6	Misc. Goods & se	$	2.76E+04	3.09E+12	8.52	0.257
7	Labor	$	4.04E+04	3.09E+12	12.48	0.376
8	Boat Maint.	$	4.99E+02	3.09E+12	0.15	0.005
9	Engine	$	2.87E+03	3.09E+12	0.89	0.027
					194.72	
10	Total Emergy in Fisheries				32707.36	985.161
Fishery Export						
11	Fishery Yield	J	6.48E+13	5.04E+06	32707.36	985.161

Footnotes to Table C-6:

1 Tide. Based on basin and tidal characteristics.
10% of the tidal energy assumed available to the fisheries.

Bay Area = 9.01E+08 m^2
Average tidal rang 1.00 m
Density = 1.03E+03 kg/m3
Tides/yr = 730.00 2 tides/day

Energy = (9.01E+08 m2)(0.5)(1.03E+02 kg/m3)(1 m)^2(1000kg/m3)
*(9.8 m/s^2)(.10)
= 3.22E+14 J

2 River (Chemical Potential). 100% of total river chemical potential available to the fisheries.

River Flow = 1.55E+09 m3/yr

Energy = (1.74E+09 m3/yr)(1E+06 g/m3)(5 J/g)(.10)
= 7.74E+15 J

3 Organic Matter. 100% of total organic matter input to the bay is available to the fisheries. Organic matter calculations based on sediment load of river and other runoff (McCleary, 1986):

Table C-6. continued

Sediment Load = 1.788E+10-[09(Flow Volume)^1.54]

Sediment load considered as 27% silt and 5% organic matter.

River

Sediment Load = 2.52E+05 T/yr (27% silt with 5% being OM)

Energy = (3.0E+05 T/yr)(0.27)(0.05)(E+06g/T)(5.4 kcal/g)
*(4186 J/kcal)
= 7.71E+13 J

Other Runoff - estimated as 70% of total runoff.

Volume of Runoff 3.02E+08 m3/yr
Sediment Load = 2.04E+04 T/yr (27% silt with 5% being OM)

Energy = (1.72E+05 T/yr)(0.27)(0.05)(1E+06g/T)(5.4 kcal/g)
*(4186 J/kcal)
= 6.21E+12 J

Total OM = 8.33E+13 J

4 Calculations for Fisheries Water Value

Energy = (4.21E+09 m^3)(1000kg/m^3)(4.94 E3 J/kg)
= 9.14E+15 J/yr

EMergy Input = Total of tide, river potential and organic matter

= 3.20E+20 sej/yr

Transformity of fisheries water = Emergy Inputs / Water Energy

= 3.50E+04 sej/J

All calculations for purchased inputs (lines 5 through 9) were taken from and analysis carried out by Augustin Gonzalez.

10 Total Fisheries EMergy = sum of all EMergy inputs to fisheries.

11 Fishery Yield. Based on a catch of 1.76E+03 MT/yr

Energy = (1.76E+03 MT/yr)(1.0E+7 g/MT)(4 kcal/g)
(0.22 protein)(4186 J/kcal)
= 6.48E+13 J

SECTION 3D: EMergy Analysis of Tourism

by Mark T. Brown and Richard C. Murphy

INTRODUCTION

With the recently increased emphasis placed on tourism and on attracting economic investment for tourism development by many governments around the world, some hard questions are beginning to emerge. Is tourist development the environmentally benign industry it is touted to be? Is tourist development beneficial to local cultures and economies? Is tourist development a form of sustainable development that should be encouraged in developing economies of the world?

This portion of the study investigates the relationship of outside investment, in general, and tourism development, in particular, to cultural and environmental integrity, and to local economies, regional welfare, and international balance of payments. Using data from tourism development in Mexico and Papua New Guinea, and techniques of EMergy analysis, several questions related to economic development are addressed: (1) What is the carrying capacity for outside economic investment within local, undeveloped regions that is environmentally and culturally benign and economically beneficial? (2) What are the benefits and costs of differing intensities of development? (3) What intensity of economic development is most beneficial to the economy and welfare of populations?

Ecotourism and Intensity of Economic Investment

Recently, ecotourism (Laarman and Durst 1987, Boo 1989) has been coined to mean a variety of things, but primarily to mean tourism that has an ecological imperative. Ecotourism should not only seek to expose tourists to the environment of a region, but should also be balanced with the local environment and not cause cultural degradation or serious economic shifts. There is much in the literature documenting the consequences of large development projects on the culture, environment, and economy of relatively "underdeveloped" regions (e.g., Archer and Sadler 1976; Archer 1985; Burn 1975; Caribbean Tourism Research Center 1976, 1977a,b; Cohen 1978; Edelman 1975a,b; Jenkins 1982; Oliver-Smith et al. 1989; Rodenburg 1980). Some of the documented impacts are as follows:

- Cross-cultural contacts result in changes in traditional dress, habits, values, ethics, and social organization.
- Local economies become more externalized as wages are paid to populations who never used money before and who have to import goods and resources to purchase.
- Additional strain is placed on the environment to provide food, building materials, and other services like waste recycling, which result in loss of environmental value and capacity for support of the population.
- Local control of resources like land and water is lost as the result of their sale to foreign investors.

In all, the larger the development and its intensity, the greater the potential for negative impacts on culture, environment, and economy (Jenkins 1982, Rodenburg 1980). Thus, ecotourism that seeks to expose the traveler to a natural environment without regard to the effect a visitor's presence has on that environment may not be sustainable in the long run. To be truly an ecotourist development, it should neither exceed the carrying capacity of the local environment and culture, nor cause secondary or tertiary environmental degradation.

Tourism as an Extractive Industry

Economic investments in undeveloped regions of the world are, for the most part, investments in extractive enterprises. The investments are used to assemble the technology and pay the human labor necessary to extract resources and sell them for more than the costs of extraction. In a way, tourist development is an extractive enterprise. The resources are more varied: sun, wind, waves, and scenic vistas, as well as an unspoiled environment and a dissimilar culture. Unlike other extractive industry, the tourist industry does not cut, dig, or catch its resource and thereby exhaust the reserve. Yet with over-exploitation, the tourist resource is "used up" (Mathieson and Wall 1982) Too many tourists translates into loss of environmental quality and shifting of the local culture away from traditional elements that were of interest, toward the values, customs, and fads of the outside culture.

The question regarding outside investment and its sustainability is: how much is too much? At certain levels of investment and for certain resources, the extracted resource may last indefinitely because it is renewed at a rate that is equivalent to or less than the rate at which it is extracted. Under these circumstances the development is often described as sustainable. As in other types of extractive investments, tourism development has an appropriate intensity of investment at which it will not exceed the ability of the local environment and culture to absorb it (Edelman 1975a,b; Gunn and Jafari 1980). Determining the appropriate intensity of development that does not cause negative cultural, economic, or ecologic impacts is what is meant by determining the economic carrying capacity of an external investment.

The Benefits and Costs of Economic Investments

For many years, economic investments in undeveloped and developing regions have been considered beneficial to the local economy. The increased number of jobs and higher wages were cited as proof of the positive benefits of investment. For the most part, it has long been believed that the bigger the project, the greater the benefit to the local economy, since bigger always translated into more jobs and greater payrolls. In fact, the opposite in many cases was true. Large projects often displaced local populations, disordered the environment, and disrupted the local economic system. Smaller projects, scaled to the local economy and social organization, were better integrated into the economy and caused less social and environmental disruption (Jenkins 1982, Lichty and Steinnes 1982, Rodenburg 1980).

It appears that an economic investment from outside can either act to amplify existing social and ecologic order and stimulate the local economy, or it can act as a disruptive force, much like a disaster. In fact, "economic earthquake" might be a fitting way of describing what happens to local, small-scale economies and social organization when large-scale investments occur. The greater the differences in intensity between existing systems and imposed developments, the more disaster-like they become.

The Disappearing Benefits of Economic Investments

Experience has shown that some economic investments have not yielded the benefits to local economies that were anticipated (Oliver-Smith et al. 1989). This results from several different but complementary factors: First, investments from outside must be repaid. Considering current interest rates and the EMergy trade advantage enjoyed by most developed nations over undeveloped nations, investing nations receive far more from their investments than just repayment of principle and interest (Odum 1984, Odum and Arding 1991, Odum et al. 1986). The undeveloped nation finds that more national wealth flows out of their economy than flows in as the result of an unfavorable EMergy exchange ratio. Second, if the investment is from sources outside the region, little of the currency generated by it remains within the local economy (Oliver-Smith et al. 1989). Other than a local payroll and some user taxes, if a development project uses funds from elsewhere and is foreign owned, most of the currency generated is "drawn" back outside the region as profit and debt service. Third, the currency that is added to the local economy causes local inflation (Oliver-Smith et al. 1989). When more money "chases" the same amount of resources, prices rise.

Unaccountable Costs of Economic Investments

Impact analyses aimed at determining costs and benefits often fail to properly account for costs, especially social and environmental costs (Archer 1985, Burn 1975, Cohen 1983, Pigram 1980, Wang et al. 1980). When economic benefit/cost accounting is used, the benefits are easily quantified using a monetary system of value, but social and environmental costs, since they are outside the monied economy, are often not included because they are not easily or reliably quantified in monetary units. The resulting picture of economic benefits is one-sided, showing increased numbers of people employed and money flowing through the economy, but not including increased costs of social disorder, or loss of environmental systems or services.

Impacts of Economic Investments

EMergy analysis may offer a more complete perspective of the impacts of economic investments on the ecological and cultural resources of regions. A systems perspective of a region suggests that its ecological, economic, and cultural systems are closely inter-twined. As a region's economic system changes, for example, there are resulting changes in its ecological and cultural systems, as the increased economic activity affects a wider and wider spatial area and may cause changes in values and ethics. The extent of change in each of these systems is more or less dependent on the extent of change in the other. Figure D-1 illustrates the interconnections between environmental, cultural, and economic systems of regions. A balanced and well-adapted subsistence economy might have the organization depicted in Figure D-1a. Ecological resources are extracted by the economic system, converted to goods, and consumed by cultural components which, in turn, provide the necessary organizational structure and "manpower" for the economic system. By-products of the economic system are recycled back to the environment, and information and "good stewardship" are fed back from culture. The driving forces are renewable EMergies shown coming from the left side of the diagram and the nonrenewable EMergy storages from within. The overall system that develops (i.e., the levels of ecological productivity, economic activity, and cultural organization) is, to a large degree, dependent on the magnitude of renewable EMergy flow and the nonrenewable storages that are available.

Economic investment from outside can be depicted like that in the bottom diagram (Figure D-1b). Investment dollars are used to purchase fuels, goods, and services from outside the local economy. A second outside energy source now influences the system. As a result of the connections between components of the regional system, any increase in one compartment affects the other two compartments (whether they increase or decrease depends on the nature of the interconnections and is not necessarily important at this point). The bigger the influence of outside investment (that is, the bigger the magnitude of the flows coming from the top right compared to the flows coming from the left), the greater the impact. The EMergy analysis technique utilized in this study quantitatively evaluates the relative size of both of these driving energy flows in a regional economy, and suggests that the appropriate intensity of a new economic investment is one that does not alter their relative proportion significantly (Odum 1980).

The secondary impact of economic investments is also illustrated in Figure D-1b. Economic investments from outside are made as a means of financing enterprises that either directly extract natural resources (e.g., wood, minerals, fuels, or fish) and sell them to outside markets, or to develop enterprises for the conversion of resources within the local economy (hydroelectric projects or tourist developments). In either case, the "attracted" investments carry with them a significant debt that must be repaid and which is financed through the export and sale of resources. The net benefit of investments from outside to the local economy, then, becomes a matter of determining the balance between what is purchased with the investment, and the resources that are exported over the long term. Additional insight related to the net benefit from investment is gained using EMergy analysis.

One of the basic principles of the EMergy systems perspective is that true wealth comes from resources, not from money (Odum and Arding 1991). Money can be used to purchase resources, but the money in itself is not representative of wealth. Evaluating international trade and net benefit from investments using only the inflows and outflows of currency often shows a monetary balance of payments, but does not take into account the inflows and outflows of wealth. Often, the investing economy receives double benefit--the resources extracted directly, and the resources that must be extracted and sold by the developing economy in order to pay interest on outside loans. Most developing economies seek money from outside sources instead of seeking resources (the true basis of wealth), and thus often sell their wealth cheaply to purchase economic goods that have less effect in stimulating their economy and that do not lead to a sustainable future.

A Theoretical Approach to Determining Carrying Capacity of Local Environments

One theory for determining carrying capacity is that the scale or intensity of development[1] in relation to existing conditions may be critical in predicting its effect and ultimately its sustainability (Odum 1980, Odum and Arding 1991). If a development's intensity is much greater than that which is characteristic of the surrounding landscape, the development has greater capacity to disrupt existing social, economic, and ecologic patterns (Brown 1980, Odum 1980). If it is similar in intensity it is more easily integrated into existing patterns. For example, because of the differences between a heavily urbanized area and an undeveloped wilderness area, the appropriate intensity of development in each environment is much different.

Large-scale developments and those with greater intensity than the surroundings can be integrated into the local economy and environment if there is sufficient regional area to balance their effects. Much like the ecological concept of carrying capacity, where differing environments require different aerial extent of photosynthetic production for support of a given biomass of animals, environmental carrying capacity for economic investments depends on the area of "support" over which a development can be integrated. As the intensity of development increases (and therefore its consumption of resources, requirement for laborers, and environmental impacts increase), the area of natural, undeveloped environment required for its support must increase. All other things being equal, the more intense a development, the greater the area of environment necessary to balance it. Thus, the spacing between developments should increase as their intensity increases.

The methodology described in this report uses EMergy analysis to measure intensity of two tourist resorts and the local environment, and then uses a ratio of purchased EMergy to resident renewable EMergy as a means of determining carrying capacity. The theoretical construct and primary assumption is that this ratio is, in itself, a measure of the intensity of the local economy, based on how the environmental and cultural systems are adapted to the level of economic activity present. This is complicated when the local economy is in a state of flux, to which neither the ecological nor cultural systems have adapted or reached a balanced steady-state. Our rationale for using the current regional intensity of economic activity (the Environmental Loading Ratio) is that, if a new development is significantly greater in intensity than the surroundings, even if a balance has not been reached, it may further exacerbate the existing problems of cultural and ecological integration of change.

RESULTS

Systems Diagrams

Figure D-2 is a systems diagram of a region that includes, among other activities, tourism. Tourism is shown drawing on resources of the local economy and importing resources from outside. The region is shown as

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[1]Intensity may be measured using any quantity (energy, materials, money, or information) per unit time per unit area. If one uses energy per unit time, or power, expressed over a unit area, the intensity is power density (Brown 1980).

being driven by two main sources of outside EMergy: (1) free, renewable EMergies, and (2) purchased EMergies (sometimes referred to as nonrenewable since they are based on resources that are nonrenewable). Inflowing renewable EMergies combine and interact to drive the productive processes in ecological systems. Purchased inputs from outside develop systems of extraction and consumption internally, which interact with indigenous environmental resources to provide resources, EMergies and products for use and export. Money derived from exported resources and from visiting tourists is used to purchase goods and fuels from other regions.

As with any tourist facility or tourist region, there is an image maintained by the combined interaction of the environment, urban structure, culture, and the development itself. Image is the information that "draws" people from outside to visit the development. The greater the image, the greater the draw. Image is negatively affected by increased wastes in the environment (pollution), overcrowding, and loss of resources, including culture, that form the image of a region or development.

Resources are extracted or harvested from marine and terrestrial systems and sold to the local economy or to the tourist facility. Money paid by tourists for imported goods, fuels, services, and locally derived resources enters the local economy before exiting the region in quantities equal to the inflows. Increased spending by tourists drives inflation up if inflows of local and imported resources and fuels are not increased.

A simplified systems diagram of the main driving energies and internal processes of a tourist resort facility is given in Figure D-3. As in the regional diagram in Figure D-2, image plays a central role in "attracting" tourists. The regional image is augmented by the attributes of the resort facility including beach, grounds and landscaping, and assets (or hotel structure and furnishings). The main production function of the hotel provides goods and services for tourists by combining potable water, food and liquor, fuels, electricity, goods and materials, and labor. The assets and tourists are also part of the production function. Money income from tourists is used to pay for all of the above goods and services, shown as the dashed lines accompanying each purchased flow of energy. The diagram in Figure D-3 is the diagram from which the EMergy analysis of tourism in Papua New Guinea (Doherty et al. 1992) and Mexico were performed.

EMergy Analysis of National Economies

Summary statistics and indices that were generated from the national analysis of Papua New Guinea and Mexico are given in Table D-1. Total EMergy use varies from a low of 1216 E+20 sej/yr (PNG) to a high of 78,600 E+20 sej/yr (USA). GNP varies by 3 orders of magnitude, with PNG having a GNP of only 0.005% of the USA GNP. Probably the most telling relationships are the various ratios (rows 5-10). The EMergy/money ratio, a measure of relative buying power, shows that the USA has the lowest ratio, thus when US dollars are used to purchase goods and services from Mexico or PNG, the benefit to the US economy is 1.6 to 1 and 30 to 1, respectively. The USA has the highest EMergy density -- over 4 times that of Mexico and about 3 times that of PNG. EMergy per capita in the USA and PNG are similar, but result from different driving energies. The main EMergies driving the PNG economy are inflows of renewable energy (about 70%) of the economy while nonrenewable EMergy flows are the dominant sources of EMergy of the US economy (about 75%).

EMergy per capita in the USA is 5 times that characteristic of Mexico. The world EMergy exchange ratio, which is a relative measure of world buying power (or trading advantage), shows that the USA has the highest trade advantage; it receives, on the average, 2.4 units of EMergy for each unit of EMergy exported. Mexico's ratio suggests it receives 1.5 units of EMergy for each unit exported; PNG has, on the average, a net loss receiving only 0.08 units of EMergy for each unit exported (an average trade deficit of 12.5 to 1). Remarkably, the Investment Ratio is the same for the USA and Mexico (0.3), but is much lower in PNG, reflecting a low investment level per unit of renewable EMergy flow in the national economy. The highest environmental loading is in the USA; it is more than 4 times that of Mexico and 55 times that characteristic of the PNG economy.

EMergy Analysis of Tourism

Tables D-2 and D-3 give the results of the EMergy analysis of a small, high quality tourist resort on the Island of New Britain, PNG, and a "four-star" tourist hotel in Puerto Vallarta, Mexico. The facilities are as different as their total EMergy flows indicate. The PNG resort is hand-built from local materials (wood and thatching), purchases fuel to generate its own electricity, burns coconut shells for hot water, and has 12 guest rooms serving a total of about 3924 person-days per year. The Mexican hotel is built almost entirely of concrete and steel, purchases electricity, has 160 rooms, and serves a total of 37,584 person days per year.

Renewable and nonrenewable EMergy inputs for the two tourist systems reflect the differences in intensity. By far the most significant non-purchased EMergy flow in the Mexican resort is potable water use (nearly 99% of the total), while the largest flows in the PNG resort are from rain and tides. Potable water use at the PNG resort is quite small (about 228 l/person/day) as compared to the Mexican resort (1311 l/person/day).

Since there is no purchased electricity in the PNG resort, the EMergy of fuels and electricity are added together for comparison between the PNG and Mexican resorts. Probably the most telling, with respect to intensity of development, is that the Mexican resort uses more than 110 times the amount of fuels and electricity as the PNG resort, yet has less than 10 times the number of guests. Food and liquor consumption reflect the differences in the number of tourists served by the two resorts.

Total purchased inputs are similar for each of the resorts, considering the differences in size. While the total is similar, the source of the largest inputs is quite different. The greatest EMergy input in the Mexican resort is electricity (over 50% of the total), while the greatest in the PNG resort is the purchase of services from the local and world economies (added together they amount to over 50% of the total purchased EMergy).

EMergy Indices of The Tourist Resorts

Table D-4 contains summary statistics of the two resorts, and the Mexican and PNG economies, for comparison. Since the spatial area of each resort is relatively small, the percent of total EMergy flows from renewable and nonrenewable EMergy (rows 2 and 3 in Table D-4) are small in comparison with the national economies. When only the land area occupied by the resort is used, the intensity of development of both resorts is 3 to 4 orders of magnitude greater than the average for their respective economies. Per capita EMergy flows are from 6 (PNG resort) to 22 times (Mexican resort) that which is characteristic of the national economies.

Using the actual area occupied by each resort, the Environmental Loading Ratios (ELR) vary from 8 times (Mexican resort) to 4 times (PNG resort) the environmental loading characteristic of the national economy. Using the ELRs, the support areas were calculated as 156 km^2 and 117 km^2 for the PNG and Mexican resorts, respectively. In other words, to balance and reduce the ELR of each resort to that of the national economy, 156 km^2 are required for the PNG resort and 111 km^2 for the Mexican resort. Once the support area is known, the Investment Ratio (IR) is determined. The IRs show higher investments per unit of resident EMergy flow than is characteristic of the national economies (10 times the national average for the PNG resort and 9 times the national average for the Mexican resort).

EMergy Exchange of Tourism

The EMergy exchange of the PNG and Mexican resort developments are illustrated in Figure D-4. An exchange of EMergy is shown flowing countercurrent to the dollar exchange between the two economies. In both examples, the tourists are assumed to be 100% from the USA; while this is not necessarily accurate, it serves to make our point. In the top diagram, the PNG resort receives $2.8 E+5/yr as income, for which it provides 11.2 E+18 sej/yr in goods and services to the tourists (this is the EMergy that is consumed by the resort in direct support of the tourists). The Mexican resort receives $3.2 E+6/yr and provides 23.0 E+18 sej/yr in goods and services. When the income from tourists is eventually spent for import purchases from the USA, the amount of EMergy received (on average) is determined by multiplying the money spent by the EMergy/money ratio for the USA economy (1.6 E+12 sej/$). The calculated EMergy values of imported goods and services is 4.5 E+17 sej/yr (PNG) and 5.0 E+18 sej/yr (Mexico). The trade advantage for the USA in both these examples is calculated by dividing what is received by the USA by what is exported. The trade advantage over PNG is 25 to 1, and over Mexico it is 4.6 to 1. In other words, for every unit of EMergy that is sold to PNG and Mexico using money these countries received from USA tourists, the USA economy receives, on the average, 25 units and 4.6 units of value, respectively, from PNG and Mexico.

Another way of looking at value received is that an American tourist receives about 25 times the EMergy for each dollar spent in PNG at this tourist resort than if it were spent in the USA economy. The advantage in Mexico is smaller, receiving only 4.6 times the EMergy.

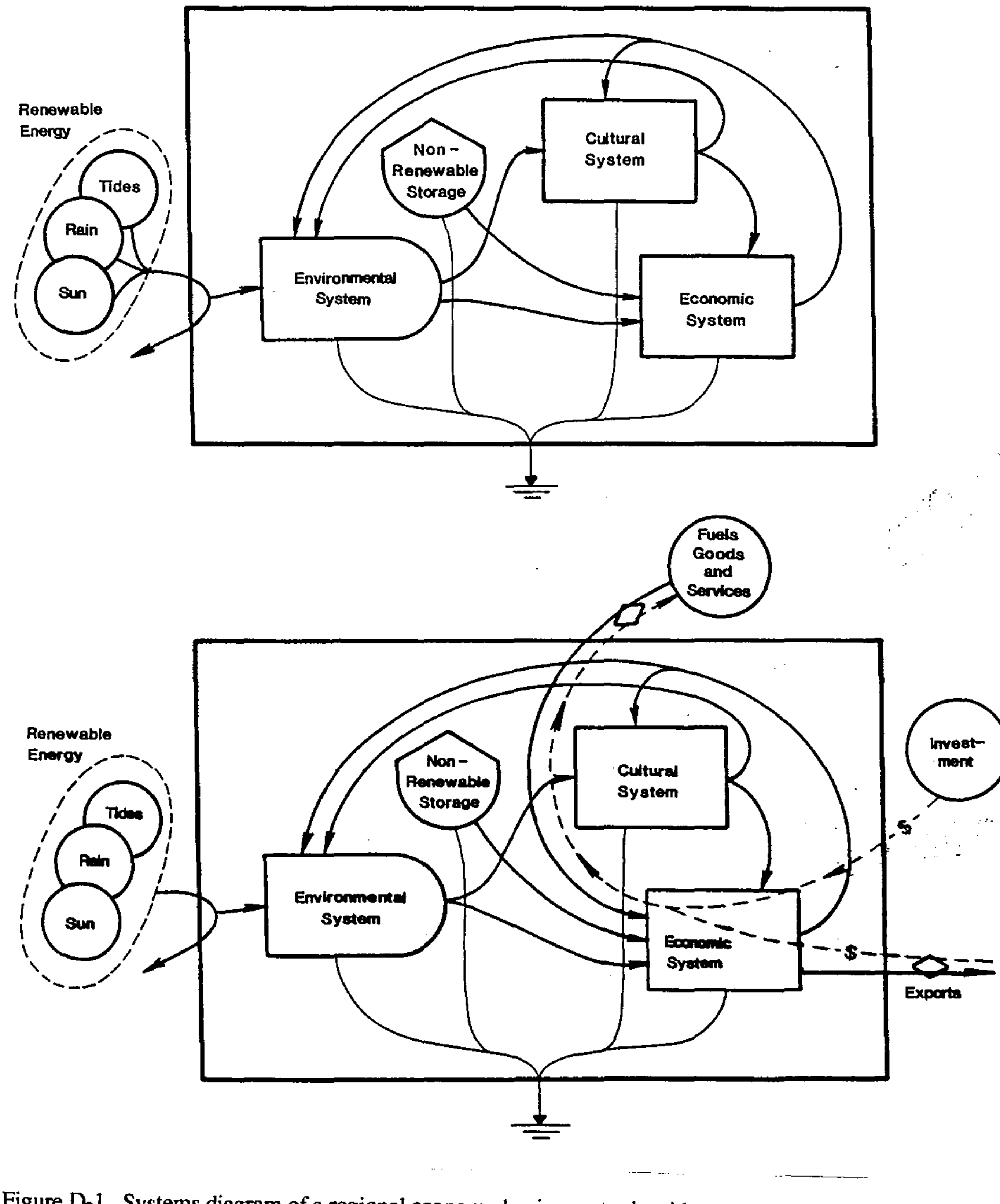


Figure D-1. Systems diagram of a regional economy having no trade with external markets (top) and an economy that has developed trade (bottom). Money is shown as dashed lines, and energy and information flows as solid lines. While invested money may circulate within the economic system, eventually, like income from exports, it is used to,purchase goods and services from external economies.

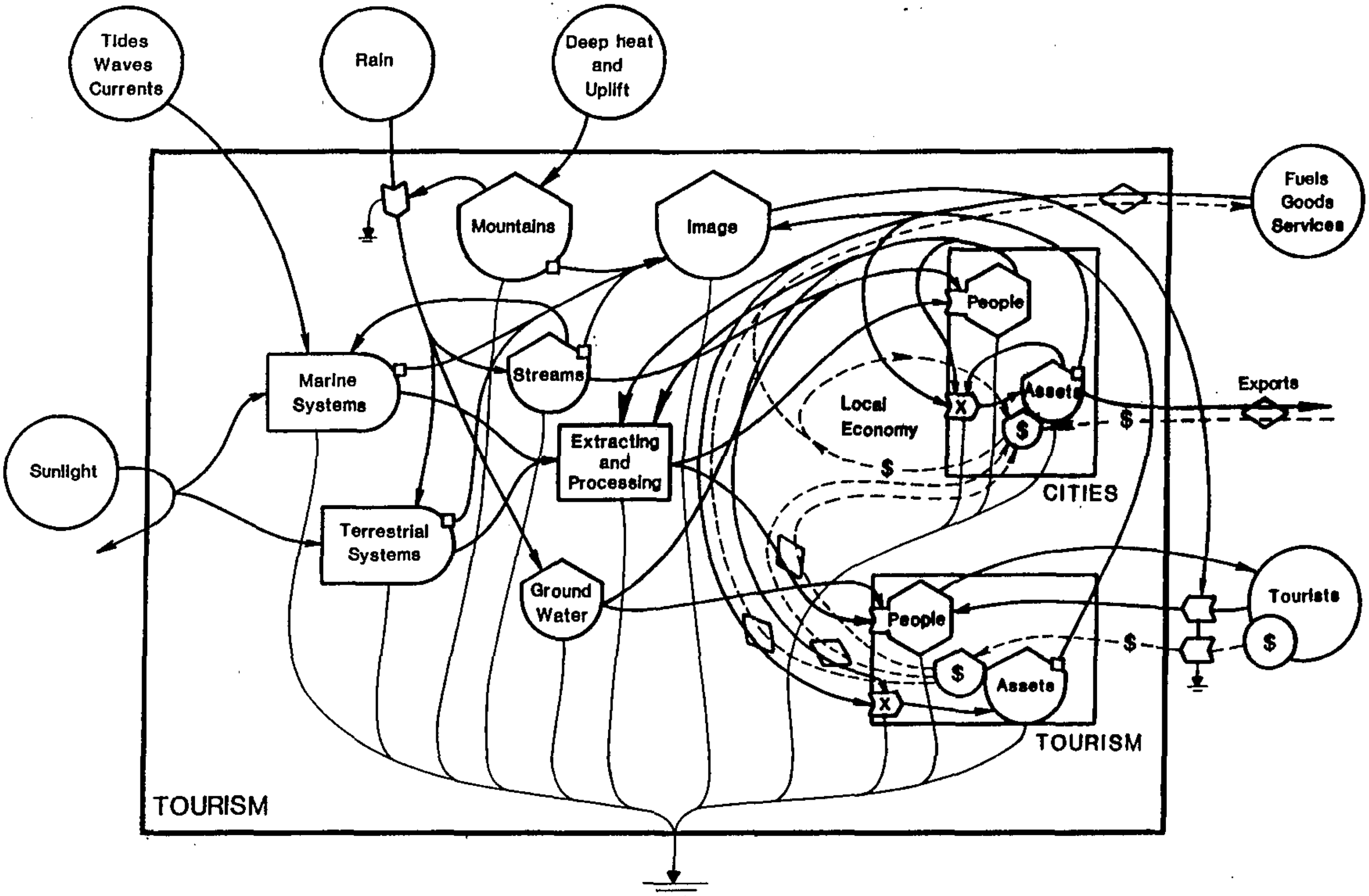


Figure D-2. Energy systems diagram of a region showing the relationship of tourism with the local economy. Often tourism is a competitive system, competing with the local economy for goods and resources. Dashed lines are money and solid lines are energy flows.

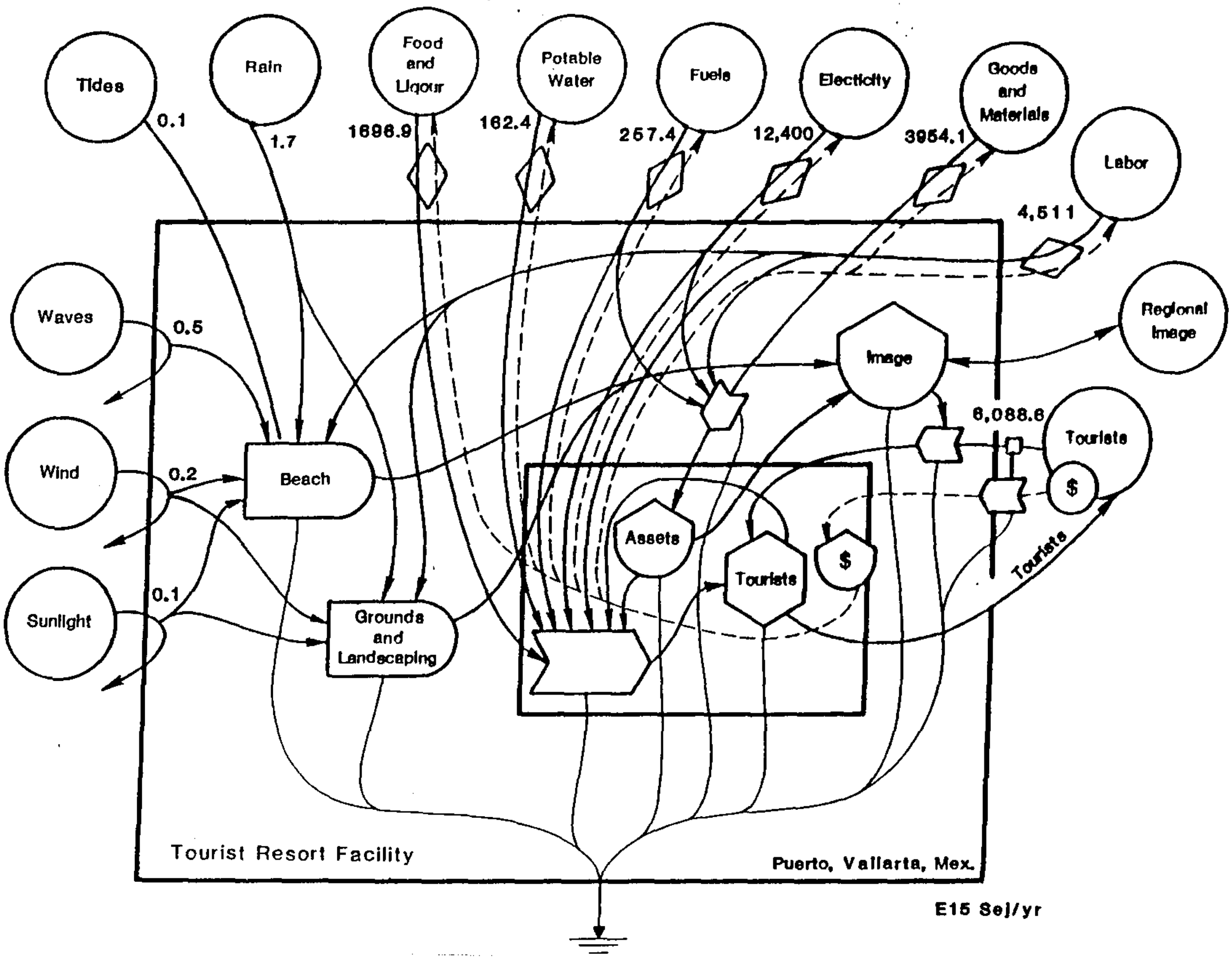
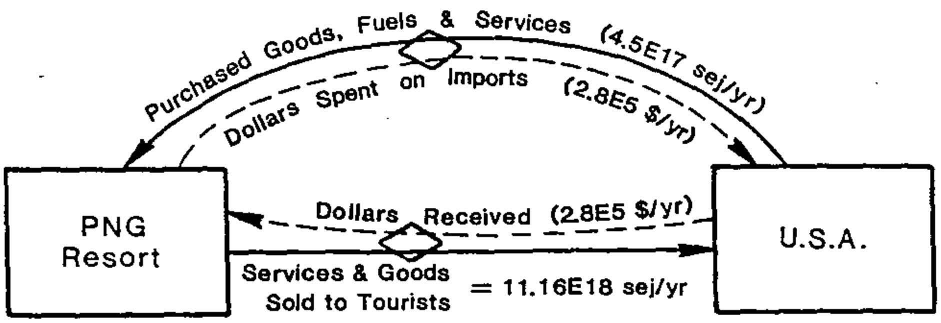
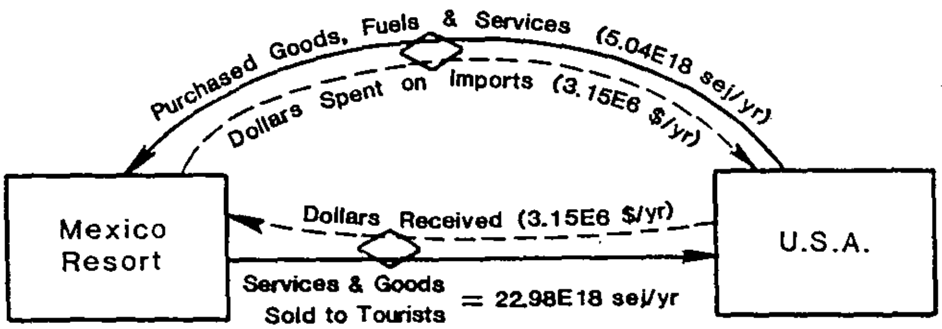


Figure D-3. Energy systems diagram of a tourist resort facility showing the main production function that provides goods and services for tourists who are attracted by the resorts image. Dashed lines are money flows and solid lines are energy flows.



U.S.A. Trade Advantage = 25/1



U.S.A. Trade Advantage = 4.6/1

Figure D-4. Diagrams illustrating the USA trade advantage when tourists spend money in Papua New Guinea (top) and Mexico (bottom). The trade advantage is calculated assuming all tourist currency is used to purchase goods and services from the USA economy.

Table D1. Comparative national EMergy indices for Papua New Guinea Mexico, and the United States

Index	PNG (1) '(1987)	Mexico (2) '(1987)	USA (3) '(1983)
Total Emergy Use (E20 sej/yr)	1216	6955	87570
Renewable Emergy Use (E20 sej/yr)	1053	1386	12355
Nonrenewable Emergy Use (E20 sej/yr)	163	5569	75215
GNP (E9 US $/yr)	2.5	185	3305
Area (E10 M^2)	46.2	196	940
Population (E6 people)	3.5	81.1	234
EMergy/money ratio (E12 sej/$)	48	3.8	2.6
EMpower density (E11 sej/m^2*yr)	2.6	3.5	9.3
EMergy per capita (E15 sej/person*yr)	37.7	8.5	37.4
World EMergy exchange ratio@	0.08	1.0	1.5
Environmental loading ratio	0.2	4.0	6.1

(1) from Doherty (1991)
(2) from Brown et al. (1992)
(3) from Brown and Arding (1991)
'@ Emergy trade advantage of country based on ratio of world EMergy/money ratio (3.8 E12 sej/$) to the EMergy/money ratio for the country.

Table D2 Emergy evaluation of tourist resort on New Britain Island, Papua New Guinea

Note	Item	Units	Units/Yr.	Transformity (sej/unit)	Solar Emergy (E15 sej/yr)	Macroeconomic value (1988 US$)
RENEWABLE RESOURCES						
1	Sunlight	J	1.74E+14	1.00E+00	0.17	3.63
2	Wind	J	1.18E+11	1.50E+03	0.18	3.68
3	Rain	J	2.41E+11	1.82E+04	4.39	91.43
4	Tidal Energy	J	2.21E+11	1.68E+04	3.72	77.56
5	Wave Energy	J	1.53E+11	3.06E+04	4.66	97.10
NONRENEWABLE STORAGES						
6	Potable water	J	2.93E+09	6.66E+05	1.95	40.64
	Sum of free inputs (sun,wind,waves omitted)				**10.06**	**209.63**
PURCHASED INPUTS						
	Construction inputs					
7	Wood	J	1.64E+09	3.49E+04	0.06	1.19
8	Concrete	g	1.70E+06	9.26E+07	0.16	3.28
9	Steel	g	5.10E+04	1.80E+09	0.09	1.91
10	Furnishings	J	3.16E+09	4.00E+06	12.66	263.72
11	Services	$	2.40E+04	4.80E+13	1,152.00	24,000.00
	Operational inputs					
12	Fuel	J	2.28E+12	6.60E+04	150.45	3,134.45
13	Electricity	J	0.00E+00	2.00E+05	0.00	0.00
14	Food	J	1.25E+13	2.50E+05	3,113.75	64,869.79
15	Liquor	J	1.28E+10	6.00E+04	0.77	16.00
16	Services (PNG)	$	1.40E+05	4.80E+13	6,720.00	140,000.00
17	Services (World)	$	1.40E+05	3.60E+12	504.00	10,500.00
	Sum of purchased inputs				**11,149.94**	**232,290.34**
18	Tourists (number)		6.20E+02	3.74E+16	23,188.00	483,083.33

NOTES:

1 Sunlight - 1.46 E5 cal/cm^2/yr

(1.46 E9 cal/m^2)(40.7 E3 m^2)(70%)(4.186 J/cal) = 1.741 E14 J/yr

2 Wind - 2.9 E6 J/m^2 (based on PNG average)

(2.9 E6 J/m^2)(40.7E3 m^2) = 1.2 E11 J/yr

3 Rain - 1.2 m/yr

(1.2 m)(40.7 E3 m^2)(1000kg/m^3)(4.94 E3 J/kg) = 2.4 E11 J/yr

4 Tidal - 1.2 meter tidal range; shore length = 500 m; assume 100 m width

(5E4 m^2)(0.5)(730 tides/yr)(1.2 m)(1.03E3kg/m^3)(9.8m/s^2) = 2.2 E11 J/yr

5 Waves - shoaling area = 50000 m^2; wave energy = 7.29 E6 cal/m^2/yr

(50000 m^2)(7.29 E6 cal/m^2/yr)(4.186 J/cal) = 1.5 E11 J/yr

6 Potable water - 593 m^3/yr

(593 m^3)(1000g/m^3)(4.94 E3 J/g) = 2.93 E9 J/yr

Notes to Table 2 continued

7 Wood - 544 m^3

(593 m^3)(5.5 kg/m^3)(15.1 E6 J/kg) = 4.9 E10 J/30yr = 1.6 E9 J/yr

8 Concrete - 284m^3 - 181kg/m^3 = 5.1 E4 kg

(5.1 E4 kg)(1000g/kg) = 5.1 E7 g/30yrs = 1.7 E6 g/yr

9 Steel - 1.53 E3 kg (based on average steel/unit concrete)

1.53 E3 kg)(1000 g/kg) = 1.53 E6 g/30 yrs = 5.1 E4 g/yr

10 Furnishings - 240 kg/room, plus 500 kg misc furnishings (estimate) = 2420 kg

(2.4 E6 g)(90%drywt)(3500cal/g)(4.186 J/cal)/ 10years = 3.16 E9 J

11 Services - total costs of construction + furnishings = $ US 200,000 (1988)

(2.0 E5 $) / 10 years = $2.0 E4 /yr

12 Fuel- 55,609 liters per year of gasoline

(5.56 E4 liters)(4.1 E+7 J/l) = 2.28E+12 J/yr

13 Electricity - elec is generated on site

(0 kwh)(3.6 E+6 J/kwh) = 0 J/yr.

14 Food - 2.645 E6 kg/yr

(2.6 E9g)(25% dry weight)(4500cal/g)(4.186 J/cal) = 1.2 E13 J

15 Liquor - 1.435 E9 liters

(1.435 E9 l)(2.11 E7 J/l) (10% alcohol) = 3.02 E15 J

16 Services - PNG = $1.4 E5 purchased from PNG @ 4.8 E13 sej/$

PNG = $1.4 E5 purchased from PNG @ 4.8 E13 sej/$

17 Services - World = $1.4 E5 purchased from world @ 3.8 E12 sej/$

18 Tourists - 620 people/yr. (5232 person days) - 37.4 E15 sej/capita

Transformity = 37.4 E15 sej/capita, assuming all visitors are American tourists

Table D3 Emergy evaluation of four star tourist hotel in Puerto Vallarta, Mexico

Note	Item	Units	Units/Yr.	Transformity (sej/unit)	Solar Emergy (E15 sej/yr)	Macroeconomic Value (1988 US$)
RENEWABLE RESOURCES						
1	Sunlight	J	9.14E+13	1.00E+00	0.09	24
2	Wind	J	1.10E+11	1.50E+03	0.16	43
3	Rain	J	9.31E+10	1.82E+04	1.69	446
4	Tidal Energy	J	4.18E+09	1.68E+04	0.07	19
5	Wave Energy	J	1.60E+10	3.06E+04	0.49	129
NONRENEWABLE STORAGES						
6	Potable water	J	2.44E+11	6.66E+05	162.43	42746
	Sum of free inputs (sun,wind,waves omitted)				**164.20**	**43210**
PURCHASED INPUTS						
	Construction inputs					
7	Concrete	g	1.15E+08	9.26E+07	10.65	2802
8	Steel	g	2.70E+07	1.80E+09	48.60	12789
9	Furnishings	J	5.72E+10	4.00E+06	228.80	60211
10	Services	$	1.41E+06	3.80E+12	5,358.00	1410000
	Operational inputs					
11	Fuel	J	3.90E+12	6.60E+04	257.40	67737
12	Electricity	J	6.20E+13	2.00E+05	12,400.00	3263158
13	Food	J	8.46E+11	2.00E+06	1,692.14	445300
14	Liquor	J	7.93E+10	6.00E+04	4.76	1253
15	Services	$	1.74E+06	3.80E+12	6,593.00	1735000
	Sum of purchased inputs				**26,593.35**	**6998250**
16	Tourists (number)		5.37E+03	8.50E+15	45,636.50	12009605

NOTES:

1 Sunlight - 1.64 E5 cal/cm^2/yr
(1.64 E9 cal/m^2)(19.03E3 m^2)(70%)(4.186 J/cal) = 9.14 E13 J/yr

2 Wind - 5.8 E6 J/m^2 (based on Mexico average)
(5.8 E6 J/m^2)(19.03E3 m^2) = 1.1 E11 J/yr

3 Rain - 0.99 m/yr
(0.99 m)(19.03 E3 m^2)(1000kg/m^3)(4.94 E3 J/kg) = 9.31 E10 J/yr

4 Tidal - 1.0 meter tidal range; shore length = 113.5 m; assume 100 m width
(1135 m^2)(0.5)(730 tides/yr)(1.0 m)(1.03E3kg/m^3)(9.8m/s^2) = 4.18 E9 J/yr

5 Waves - shore length = 113.5 m; wave energy = 3.36 E7 cal/m/yr
(113.5m)(3.36E7 cal/m/yr)(4.186 J/cal) = 1.6 E10 J/yr

6 Potable water - 49,287 m^3/yr
(4.93E4m^3)(1000g/m^3)(4.94 E3 J/g) = 2.44 E11 J/yr

7 Concrete - 5736 tonns (based on average concrete/room)
(5.736 E6 kg)(1000g/kg) = 5.736 E9 g/50yrs = 1.15 E8 g/yr

Table C-7. EMergy evaluation of municipal water consumption.

Note	Item		Units/Yr.	Transformity (sej/unit)	Solar Emergy (E16 sej/yr	Macroeconomic Value (1989) (E5 $)
	Natural Inputs					
1	River	J	1.73E+13	4.11E+04	71.026	2.139
2	Groundwater	J	9.80E+13	1.10E+05	1081.115	32.564
					1152.14	34.703
	Purchased Inputs					
3	Electricity	J	4.19E+13	1.59E+05	666.979	20.090
4	Fuel	J	4.39E+14	6.60E+04	2895.420	87.211
5	Operations Costs	$	5.52E+05	3.32E+12	183.342	5.522
6	Labor Costs	$	2.16E+05	3.32E+12	71.64	2.158
					3817.38	114.981
	Urban Consumer Water					
7	Municipal water	J	1.15E+14	4.31E+05	4969.522	149.684
	Purchased Inputs (not water)					
8	Other Inputs to Urban Sector				49980.87	1505.448
9	Total Urban Emergy				54950.40	1655.132
10	Other Inputs to Tourist Sector				162856.22	4905.308
11	Total Tourist Emergy				167825.74	5054.992
	Exports					
12	Urban Yield				30167.808	908.669
13	Tourist Yield		5.96E+08	3.320E+12	197737.30	5955.943

Footnotes to Table C-7:

Municipal Water Consumption. Taken as 2.33E+07 m3/yr for the basin (SEAPAL, 1991; SEDUE, 1990).

1 River (Chemical Potential). 15 % of total municipal consumption from river source.

Energy = (0.15 * 2.33E+07 m^3)(1000kg/m^3)(4.94 E3 J/kg)
= 1.73E+13 J/yr

2 Groundwater (Chemical Potential). 85 % of municipal water from groundwater source.

Energy = (0.85 * 2.33E+07 m^3)(1000kg/m^3)(4.94 E3 J/kg)
= 9.80E+13 J/yr

Table C-7. continued

3 Electricity Use. Based on 1.28E+07 KWH/yr (Seapal, 1991).

Energy = (1.28E+07 KWH/yr)(3.6E+06 J/KWH)
= 4.19E+13 J/yr

4 Fuel Use. 1.07E+07 L/yr used on water treatment (Seapal, 1991).

Energy = (1.07E+07 L/yr)(41E+06 J/L)
= 4.39E+14 J/yr

5 Operations Costs. (Seapal, 1991)

= 5.52E+05 $/yr

6 Labor Costs. (Seapal, 1991)

= 2.16E+05 $/yr

7 Calculations for Municipal Water

Energy = (2.7E+07 m^3)(1000kg/m^3)(4.94 E3 J/kg)
= 1.15E+14 J/yr

EMergy Input = Total of river, groundwater, electricity, goods and services

= 4.97E+19 sej/yr

Transformity of Municipal Water = EMergy inputs/water energy

= 4.31E+05 sej/J

8 Other Inputs to Urban Sector based on all inputs not directly associated with tourism (from Table C-1).

Item	Solar Emergy
Electricity	2.06E+20 sej/yr
Fuel	2.78E+20 sej/yr
Other	1.57E+19 sej/yr

9 Total Urban EMergy. Sum of natural and purchased inputs to urban system.

= 5.50E+20 sej/yr

10 Other Inputs to Tourist Sector (Brown, 1991)

10a Purchased Inputs for Tourism:

Table C-7. continued

Item	Ra	433.00	Trans-formity (sej/unit	Solar EMergy (E16 sej)
Concrete	g	7.48E+09	9.26E+07	69.243
Steel	g	1.77E+09	1.80E+09	318.189
Furnishings	J	4.23E+13	4.00E+06	16919.936
Fuel	J	2.55E+14	4.80E+04	1223.257
Electricity	J	4.04E+15	2.00E+05	80717.114
Food	J	1.09E+10	2.00E+06	2.185
Liquor	J	2.45E+12	6.00E+04	14.684
Services, constr	$p	2.41E+11	1.14E+09	27493.451
Services, oper.	$p	3.17E+11	1.14E+09	36098.158

Total Purchased EMergy Input = 1.63E+21

10b Tourist EMergy. Based on the EMergy per visitor and the number of visiting days per year.

US sej/cap/day = 1.62E+14 sej/cap/day
Mex sej/cap/day = 1.93E+13 sej/cap/day

EMergy (sej) = (4.58E+06 per-days/yr)(1.62E+14 + 1.93E+13 sej/cap/yr)(.5)
= 0.00E+00 sej

Total EMergy Inputs = Purchased + Tourist Inputs
= 1.63E+21

11 Total Tourist EMergy = sum of all EMergy inputs to tourist sect.

12 Urban Yield. EMergy of exports from the systems not directly associated with tourism (from Table C-1)

= 3.02E+20 sej/yr

13 Tourist Yield. Calculated as the total EMergy of tourist dollars spent per year (Jalisco).

= 5.96E+08 $/yr

Table C-8. EMergy indices for subsystem analysis.

Item # Fig. C-13	Name of Index	Expression	Quantity Agri-culture	Fish-eries	Urban	Tourist
1	Renewable EMergy Flow to Water System (E+18 sej/yr)	W	65.12	319.71	11.52	11.52
2	Flow of Imported EMergy for Water System (E+18 sej/yr)	F	5.38	0.00	38.17	38.17
3	EMergy Value for Water (E+18 sej/yr) (X)	W + F	70.49	319.71	49.70	49.70
4	Transformity of Water (E+03 sej/J)	X/Joules	72.57	367.49	431.02	431.02
5	Fraction Used, Renewable	W / X	0.92	1.00	0.23	0.23
6	Fraction Used, Purchased	F / X	0.08	0.00	0.77	0.77
7	Investment Ratio for Water Supply	F / W	0.08	0.00	3.31	3.31
8	EMergy Yield Ratio for Water	X / F	13.11		1.30	1.30
9	Flows of Imported EMergy for Subsystem Process - not including water imports (E+18 sej/yr)	Z	59.31	1.95	499.81	2043.91
10	Total Flows of Imported EMergy (E+18 sej/yr)	F + Z	64.68	1.95	537.98	2082.08
11	Total EMergy Use (YIELD)	X + Z	129.80	321.66	549.50	2093.60
12	EMergy in Export (E+18 sej/yr)		129.80	327.07	301.68	1977.37
13	% EMergy Attributable to Water	X/YIELD*100	54.31	99.39	9.04	2.37
14	Fraction Used, Renewable		0.50	0.99	0.02	0.01
15	Fraction Used, Purchased		0.50	0.01	0.98	0.99
16	Investment Ratio	(F+Z)/W	0.99	0.01	46.69	180.71
17	EMergy Yield Ratio	YIELD/(F+Z)	2.01	165.19	1.02	1.01
18	Marginal Macroeconomic Value of Raw (Undelivered) Water	YIELD / W	1.99	1.01	47.69	181.71
19	Marginal Macroeconomic Value of Delivered Water	YIELD / X	1.84	1.01	11.06	42.13

Table C-9. Marginal effects of water increases on net yield.

Sector	Present Yield (sej/yr)	Yield with 5% increase (sej/yr)	Percent Change in Yield, at 5%
Agriculture	1.30E+20	1.33E+20	2.384
Fisheries	3.27E+20	3.43E+20	4.898
Urban	5.50E+20	5.52E+20	0.452
Tourism	1.68E+21	1.68E+21	0.148

Table C-10. Comparative values of water.

#, from Figure C-14	Pathway or Interaction	Macroeconomic Value (a) ($/m3)	Marginal Macroeconomic Value (b) ($/m3)	Economic Value (c) ($/m3)	
1	Rainfall	0.0271			
2	River Inflow	0.0722			
3	Groundwater	0.2708			
4	Irrigation	0.1080		0.008 - 0.019	[1]
				0.077	[2]
				0.012 - 0.092	[3]
5	Urban Uses	0.6413		0.003 - 0.290	[3]
				0.0 - 3.242	[4]
6	Fisheries	0.0622		0.019 - 0.154	[3]
7	Raw Wastewat	1.5537		0.0002 - 0.0058	[3]
	Treated Wast	2.5460		0.0089	[5]
8	Agricultural Interaction		0.1988		
9	Fisheries Interaction		0.0636		
10	Urban Interaction		7.1036		
11	Tourism Interaction		27.0645		

(a) Macroeconomic value calculated in this study as follows:

1 [Total Rainfall Energy/m3 * Transformity]/[sej/$]
= [(1000kg/m3)(4.94E+03J/kg)*1.82E+04sej/J]/[3.32E+12 sej/$]
= 0.0271 $/m3

2 [Total River Energy/m3 * Transformity]/[sej/$]
= [(1000kg/m3)(4.94E+03J/kg)*4.85E+04sej/J]/[3.32E+12 sej/$]
= 0.0722 $/m3

3 [Total Groundwater Energy/m3 * Transformity]/[sej/$]
= [(1000kg/m3)(4.94E+03J/kg)*1.82E+05sej/J]/[3.32E+12 sej/$]
= 0.2708 $/m3

4 [Total Agricultural Irrigation Energy/m3 * Transformity]/[sej/$]
= [(1000kg/m3)(4.94E+03J/kg)*7.26E+04sej/J]/[3.32E+12 sej/$]
= 0.1080 $/m3

5 [Total Municipal Water Use Energy/m3 * Transformity]/[sej/$]
= [(1000kg/m3)(4.94E+03J/kg)*4.31E+05sej/J]/[3.32E+12 sej/$]
= 0.6413 $/m3

6 [Total Fisheries Water EMergy/m3]/[sej/$]
= [9.08E+18 sej/yr/1.74E+09 m3]/[3.32E+12 sej/$]
= 0.0622 $/m3

7 [Total Raw Wastewater EMergy/m3]/[sej/$]
= [1.25E+20 sej/2.43E+07 m3]/[3.32E+12 sej/$]
= 1.5537 $/m3

Table C-10. continued

[Total Treated Wastewater EMergy/m3]/[sej/$]
= [1.38E+20 sej/1.64E+07 m3]/[3.32E+12 sej/$]
= 2.5460 $/m3

(b) Marginal Macroeconomic Values calculated as amount of GDP circulating per cubic meter used for each sector.

8 [Total Agricultural EMergy Inputs/m3]/[sej/$]
= [1.3E+20sej/1.97E+08m3]/[3.32E+12 sej/$]
= 0.1988 $/m3

9 [Total Fisheries EMergy Inputs/m3]/[sej/$]
= [9.27E+19sej/1.74E+09m3]/[3.32E+12 sej/$]
= 0.0636 $/m3

10 [Total Urban EMergy Inputs/m3]/[sej/$]
= [5.5E+20sej/2.33E+07m3]/[3.32E+12 sej/$]
= 7.1036 $/m3

11 [Total Tourism EMergy Inputs/m3]/[sej/$]
= [2.09E+21sej/2.33E+07m3]/[3.32E+12 sej/$]
= 27.0645 $/m3

(c) Economic value was taken from the literature and calculated as marginal value of water according to existing or inferred market prices.

References:

[1] U.S. Bureau of Reclamation (1985)
[2] Kulshethra (1991)
[3] Gibbons (1986)
[4] Griffith (1990)
[5] Brown (1990)

Table C-11. Wastewater recycle to irrigated agricultural lands; land and EMergy investment required.

Urban Center	Pop.	Consumption (LHD)	Wastewater Generation (m3/yr)	Irrigation Area Needed (m2)	EMergy Investment (sej/yr)
Nayarit					
San Juan de Abajo	8820	209	605550	465808	3.10E+16
Bucerias	5897	604	1170047	900036	5.99E+16
Valle de Banderas	5515	394	713801	549078	3.66E+16
San Juan de Valle	4610	105	159010	122316	8.15E+15
Jarretaderas	3199	636	668354	514119	3.42E+16
San Vincente	2945	131	126734	97487	6.49E+15
La Cruz de Huanacaxt	1584	851	442813	340625	2.27E+16
Mezcales	1555	194	99099	76230	5.08E+15
El Porvenir	1095	276	99279	76369	5.09E+15
Jalisco					
Puerta Vallarta	150000	350	16917750	13013654	8.67E+17
Ixtapa	8000	250	657000	505385	3.37E+16
Las Juntas	4000	250	328500	252692	1.68E+16
Pitillal	4000	250	328500	252692	1.68E+16

Notes to Table 3 continued

8 Steel - 1356 tonns (based on average steel/room)
1.356 E6 kg)(1000 g/kg) = 1.356 E9 g/50 yrs = 2.7 E7 g

9 Furnishings - 240 kg/room, plus 5000 kg misc furnishings (estimate) = 43400 kg
(43.4 E6 g)(90%drywt)(3500cal/g)(4.186 J/cal)/ 10years = 5.72 E10 J

10 Services - total costs of construction + furnishings = 1.85 E9 pesos (1979)
(1.85 E9 pesos) / (26.24 pesos/$) = $70.5 E6 / 50 years = $1.41 E6 /yr

11 Fuel- 140,136 liters per year of liguified natural gas
(1.4 E5 liters)(2.79 E+7 J/l) = 3.9E+12 J/yr

12 Electricity - 17,199,287 kwh per year
(17.2E+6 kwh)(3.6 E+6 J/kwh) = 6.2E+13 J/yr.

13 Food - 75168 kg - 2kg/person (est.) * 37,584 people
(75.2 E6g)(25% dry weight)(4500cal/g)(4.186 J/cal) = 8.46 E11 J/yr

14 Liquor - 37.6 E3 liters -1 liter/person (est) * 37,584 people
(37.6 E3 l)(2.11 E7 J/l) (10% alcohol) = 7.9 E10 J/yr

15 Services - 4.858 E9 pesos (total yearly income, 1990)
(4.858 E9 pesos) / (2800 pesos/$) = $1.735 E6/yr

16 Tourists - 5,369 tourists/yr.
Transformity = 8.5 E 15 sej/capita, assuming all visitors are Mexican tourists

Table D4. Comparative EMergy indices for tourist resorts in Papua New Guinea and Mexico

Index	PNG		Mexico	
	Country	Resort	Country	Resort
Total Emergy Use (E18 sej/yr)	121600	11.2	695500	26.8
Percent Renewable	86.6%	0.1%	19.9%	0.0%
% renewable + nonrenewable storage	95.8%	0.1%	52.6%	0.6%
EMpower density (E11 sej/m^2*yr)	2.6	2741.8	3.5	14056.8
EMergy per capita (E15 sej/person*yr)	37.7	778.5	8.5	259.8
Environmental loading ratio	0.16	192.5	8.9	12189.5
Support Area required (m^2)	--	5.61E+07	--	4.17E+07

SECTION 3E: EMergy Analysis of Mariculture and Aquaculture

by Agustin Gonzalez

INTRODUCTION

The coastal (estuarine) zones have long been centers of human activity. Man has gathered around coastal zones and used them for many different purposes, for example: 1) living and recreation space; 2) industrial and commercial activities; 3) waste disposal; 4) food production; 5) natural preserves.

Estuarine waters are some of the most productive areas known on earth, exceeding the productivity per unit area of most agricultural production by a factor of two or more. However, fish harvest in the coastal zone and estuarine waters has approached the maximum sustainable yield in many parts of the world, and it is the estuarine environments which are among the most severely stressed by human, urban and industrial activities (Ketchum, 1972). The present analysis deals with mariculture and aquaculture development, towards establishing sustainable and ecologically appropriate coastal development.

AQUACULTURE DEVELOPMENT

The use of aquaculture as a source of fisheries production has been growing at a very rapid rate world wide. In 1987, world aquaculture production increased to 13.1 million metric tonnes, which was an 8% increase over the previous year. At the same time, the world commercial seafood fisheries catch was 93.3 million metric tonnes, an increase of less than 1% from 1986 (Anonymous, 1990). Although aquaculture production is only 12% of the combined total, a leveling off of the supply of seafood, combined with a rising demand for fish, may mean that aquaculture will be the growth segment of the fisheries industry in the future. This rapid expansion has resulted in substantial economic benefits for adjacent communities, with large increases in employment opportunities and tax revenues.

For many developing nations, aquaculture is viewed as an inexpensive source of protein, as well as an important solution for solving balance of payment problems. It is a desirable industry because it employs large numbers of people in areas that have not been used for traditional agriculture (Anonymous, 1990).

Mexico has approximately 8475 kilometers of coastline along the Pacific Ocean and the Sea of Cortez. Estimates by the Mexican government of coastal land physically developable for shrimp farming is about 335,000 ha. Some private estimates place this coastal resource nearer 600,000 ha. The combination of abundant coast land, tropical and subtropical climate ranges, plentiful stocks of the two most preferred and commercially successful species of cultured shrimp (*Penaeus vanemeii* and *P. stylirostris*), and low labor cost, make shrimp farming an attractive and potentially profitable venture (Dugger, 1990).

The State of Nayarit has a coastline of approximately 300 km, and about 91,000 ha of coastal land physically developable for aquaculture (Figure E-1). A forecast of aquaculture development in Nayarit was conducted to evaluate the growth of this industry within the state. Comparison between aquaculture development in Nayarit, Mexico, Latin America and the world was also made. Table E-1 describes the aquaculture development trends for these areas.

Table E-2 shows the basic production figures and growth estimates for Nayarit, Mexico, Latin America and the world, broken down by region and commodity group (i.e., fish, mollusks and crustaceans). These data show aquacultural activity between 1987 and 1989 for Nayarit and Mexico, and between 1975 and 1980 for Latin America and the world, in terms of level of production, compounded annual growth rates, tonnes of growth per year, growth in grams per year per capita, and the latest figures of production in grams per capita.

The results of this analysis show that the annual growth rate (AGR), in terms of total production of aquacultural products, between the period of 1975-1980 for Latin America and the world were 0.6% and 7.3%, respectively, indicating that Latin American aquacultural production has been growing relatively slowly compared to the world. For Nayarit and Mexico, the AGR's for the period 1987-1989 were 44.3% and 9.2%, respectively, indicating that Nayarit had the highest growth rate of the 4 regions compared (Table E-2).

With respect to fish production, Nayarit again showed the highest AGR, with 45.8% compared to 14.0, 4.4 and 4.1% for Mexico, Latin America and the world, respectively. In terms of mollusc production, Nayarit's AGR was again the highest, with 18.2%, as compared to Mexico (6.1%), Latin America (-2.8%), and the world (11.0%). For crustacean production, the AGR of 135.0% for Nayarit was much higher than the other regions, which showed AGR's of 69.0, 39.2, and 20.4%, respectively (Table E-2).

Overall aquacultural production for Nayarit was also the highest, with a production of 2116 grams per capita (gm/cap), versus 741.6, 183.6, and 1483.6. Fish production for Nayarit was highest, with 1740.5, 92.6, 50.1, and 722.9 (gm/cap), respectively. But for production of mollusks, in spite of having had the highest AGR, was only ahead of Mexico, with productions of 242.3, 601.6, 117.1, and 743.8 gm/cap. The crustacean production figures were highest for Nayarit, with 133.2, 47.5, 16.4, and 16.9 gm/cap.

The levels of production for fish, mollusks and crustaceans, as compared to crops and irrigated lands for each region, are given in Table E-3. Nayarit had the highest levels of production in terms of kg/ha of crop land for fish and crustaceans, compared to the other regions, but was only ahead of Latin America with respect to mollusc production.

It has been shown in this analysis that aquaculture in Nayarit has been developing at a high rate. When compared to Mexico, Latin America and the world, it showed the highest annual growth rate. This may be due, in part, to the fact that aquacultural activity has occurred more recently in Nayarit, with the result that growth is faster at this stage.

SHRIMP MARICULTURE

Shrimp mariculture ponds have been constructed in many developing tropical countries, to meet the large demand from the developed countries. This mariculture system is based on getting the young shrimp from the natural system, which also supports established artisanal estuarine and trawl shrimp fisheries along the Pacific coast in Mexico and Nayarit.

Figure E-2 shows the traditional system of shrimp production in the coastal area of Nayarit, including offshore waters (upper diagram), where shrimp reproduce and the larval stage develops. Shown at the bottom of Figure E-2 is the inshore, mangrove-lined estuary, where the post-larvae achieve half of their growth.

Figure E-3 shows a systems diagram of the shrimp pond mariculture system in the coastal zone of Nayarit. Estuarine waters containing post-larvae, food and nutrients are pumped into the diked ponds. More organic food is generated by the pond algae and other plants. Fertilizer, food and post-larvae are added to the system, while predators and competitors are eliminated. All of these activities require the addition of goods, services and fuels. Harvested shrimp are sold, and the money obtained is used to buy purchased items, pay interest, and repay loans, with the balance retained as profit.

The system resembles intensive agriculture, with high levels of purchased inputs per area. Water is pumped in to keep up with evaporation and seepage, and to transfer inorganic fertilizers and organic matter to support the food chain, as well as to maintain a certain required salinity, which may be affected by river diversion and damming upstream (Odum and Arding, 1991).

EMergy Analysis of Shrimp and Protein Production Alternatives for Nayarit

The shrimp pond system model diagrammed in Figure E-3 is described in Table E-4, and simplified in the upper diagram in Figure E-4 as an EMergy analysis evaluation of a 1 hectare shrimp mariculture pond. This system is compared with other protein production alternatives, such as brackish-water tilapia aquaculture, fresh-water tilapia aquaculture, and beef cattle production systems shown in Figure E-4 and Tables E-5 to E-7. Table E-8 gives a summary of EMergy inflows and ratios for these systems. Brackish-water tilapia aquaculture has the lowest EMergy Investment Ratio (EIR) with 0.89, compared to 1.02, 2.87 and 3.29 for fresh-water tilapia aquaculture, shrimp mariculture and beef cattle production, respectively.

The total renewable EMergy for shrimp mariculture was 17.0 E+15 sej/yr. Total purchased inputs were 49.3 E+15 sej/yr, better than both tilapia aquaculture systems, but behind beef cattle production (10.0 E+15 sej/yr). In terms of EMergy yield, shrimp ranked third with 67.3 E+15 sej/yr, behind brackish and fresh-water tilapia aquaculture, but above beef cattle production. While the purchased inputs for beef cattle production were the lowest, its total renewable EMergy was also the lowest, and therefore its Net EMergy Yield Ratio (NEYR) was the lowest. On the other hand, its EIR was the highest of the four systems compared.

Shrimp Mariculture vs. Brackish-Water Tilapia Aquaculture

The existing shrimp mariculture farms in Nayarit are shown in Figure E-5. The results in Table E-9 show that only 24.2% (145 of 598 ha) of the ponds built were in operation. Based on the EMergy that it takes to build one hectare of pond, nearly 4.6 E+18 sej (equal to $1.5 E+06 US$) have been invested in non-productive farms.

In addition, the average production figures for the ponds in operation, nearly 287 kg/ha, are quite low for the semi-intensive systems employed. The production for some estuarine lagoon systems in Mexico have been found to be around 126 kg/ha/yr of shrimp (Kapettsky, 1982), and the system called "Tapos" has yield up to 200 kg/ha/yr in some Mexican lagoons (Arredondo, 1986). Criteria for the development of shrimp farms estimate that extensive, semi-intensive, and intensive systems should yield approximately 500, 500-1000, and more than 1500 kg/ha/yr, respectively (Arredondo, 1986), Thus, the figures for the shrimp farms at Nayarit in 1989 were low.

Most of the shrimp farms in Nayarit are located in areas were natural vegetation is mainly mangrove forest (Table E-10). The destruction of natural habitat, which plays a vital role in the coastal area of the State, should be avoided. Furthermore, several factors suggest that any planned extension of the current amount of shrimp farming should be reconsidered.

Such expansion should be carefully assessed, taking into account that: 1) in 1989, 75% of the area already built for shrimp production was not operating; 2) for those farms that were in operation, production was low compared to what would be expected; 3) an alternative system of protein production exists with the cultivation of tilapia in brackish-water ponds and marine water cages (Watanabe, 1990; Grover et al., 1989; Hargreaves et al., 1991; Ernst et al., 1991). The EMergy analysis conducted in this study found brackish-water tilapia aquaculture to have the highest NEYR with 2.12, and the lowest EIR with 0.89 (Table E-8). Therefore, a better use of the existing infrastructure might be in trying to promote development of brackish-water tilapia aquaculture.

Previous studies (Odum and Arding, 1991) have shown that development of a shrimp industry, in order to satisfy the demand for shrimp in developed countries, drains EMergy from the undeveloped countries, because of the differences in EMergy/$ ratio, because of the large, previously unevaluated contributions of the environment to shrimp, because of the over-intensive development of some ponds, and because valuable pelagic fish catches are being used as auxiliary shrimp food. The State of Nayarit has a traditional artisanal shrimp fishery, which provides labor and food for the rural population. The resource is rich and, because of its abundance, prices are relatively low. Thus, rural people are able to feed on this resource, obtaining high quality protein for a reasonable price. If a shrimp mariculture industry is developed with the sole purpose of producing shrimp for the export market, the price of the resource will rise, reducing the standard of living of the rural population.

And finally, development of a shrimp industry will reduce mangrove forest, diminishing the nursery area for shrimp and other marine and estuarine species, which are both commercially and non-commercially important. As occurred in Ecuador, reduction of natural population as seed stock could occur in Nayarit as well (Odum and Arding, 1991).

FISHERIES DEVELOPMENT IN BAHIA DE BANDERAS

Bahia de Banderas Fishery

Banderas Bay is located on the Pacific coast of Mexico, between Nayarit and Jalisco. It is divided by the Ameca river, and serves as a border between the two states. Banderas Bay has an estimated area of about 1078 km^2, and a maximum depth of 1435 m. There are 14 fishing communities along the bay, with a fleet of 303 small boats for approximately 787 fishermen. The 1990 production of the fishing fleet at Banderas Bay was 1764.3 metric tonnes, with a total value of 10.4 billion pesos, or $3.71 million US$ (Basto, 1991).

EMergy Analysis of Different Fishing Methods

An EMergy analysis of the fishing vessels at Banderas Bay was made, in order to evaluate the different fishing methods and fishing vessels utilized. Data on the large boats (trawler type) were not available, and thus a comparison between small boats (pangas) and big boats (trawlers) was not possible. However, it has been shown in a previous report on EMergy analysis of the shrimp fishery in the Sea of Cortez (Brown et al., 1989), that large trawlers were less efficient than the pangas, even though they were more "productive". As long as the total purchased costs remain low, trawlers make "good economic sense", but it does not address sustainability or the future availability of energy and machinery.

Overfishing, in the long run, may undermine the capacity of the fish population to regenerate. If energy costs rise or populations decline, the ability of the fishery to sustain high economic investment is diminished. From a large scale perspective, the differences between these two methods of fishing suggested that a policy that encourages trawler fishing may, in the long run, be counterproductive, as the large boats require nearly 12 times the energy to harvest the same shrimp as the smaller boats (Brown et al., 1989).

Figure E-6 shows a systems diagram of the fishery in the Bay, while Tables E-11 to E-13 and Figure E-7 detail the EMergy analysis of the 3 different fishing methods used within the Bay. The fishing methods analyzed consisted of 3 different sizes of pangas, each one utilizing different fishing techniques: 1) pangas 22 ft in length use an overall fishing method (gill net, long line and cast lines), with daily fishing trips; 2) pangas with 2.3 m^3 capacity fish with gill net, with daily fishing trips; and 3) pangas with 2.9 m^3 capacity fish with long line and cast lines, with fishing trips of 4 days each. Table E-14 summarizes the 3 different fishing options on the Banderas bay. The EMergy analysis shows that total purchased inputs for boats using only long line and cast line fishing methods are the highest, with 187.7 E+15 sej/yr, followed by the pangas using the overall fishing techniques with 74.6 E+15 sej/yr, and the pangas that fished only with gill net with 42.4 E+15 sej/yr.

EMergy yields were greater for pangas fishing with long line/cast line, while yield ratios (NEYR) were better for the overall fishing pangas. The EMergy Investment Ratios were 0.33, 0.38 and 0.63 for the overall, gill net, and long line/cast line methods, respectively. These ratios indicate that the overall fishing method will yield more net EMergy, while requiring a lower investment of EMergy.

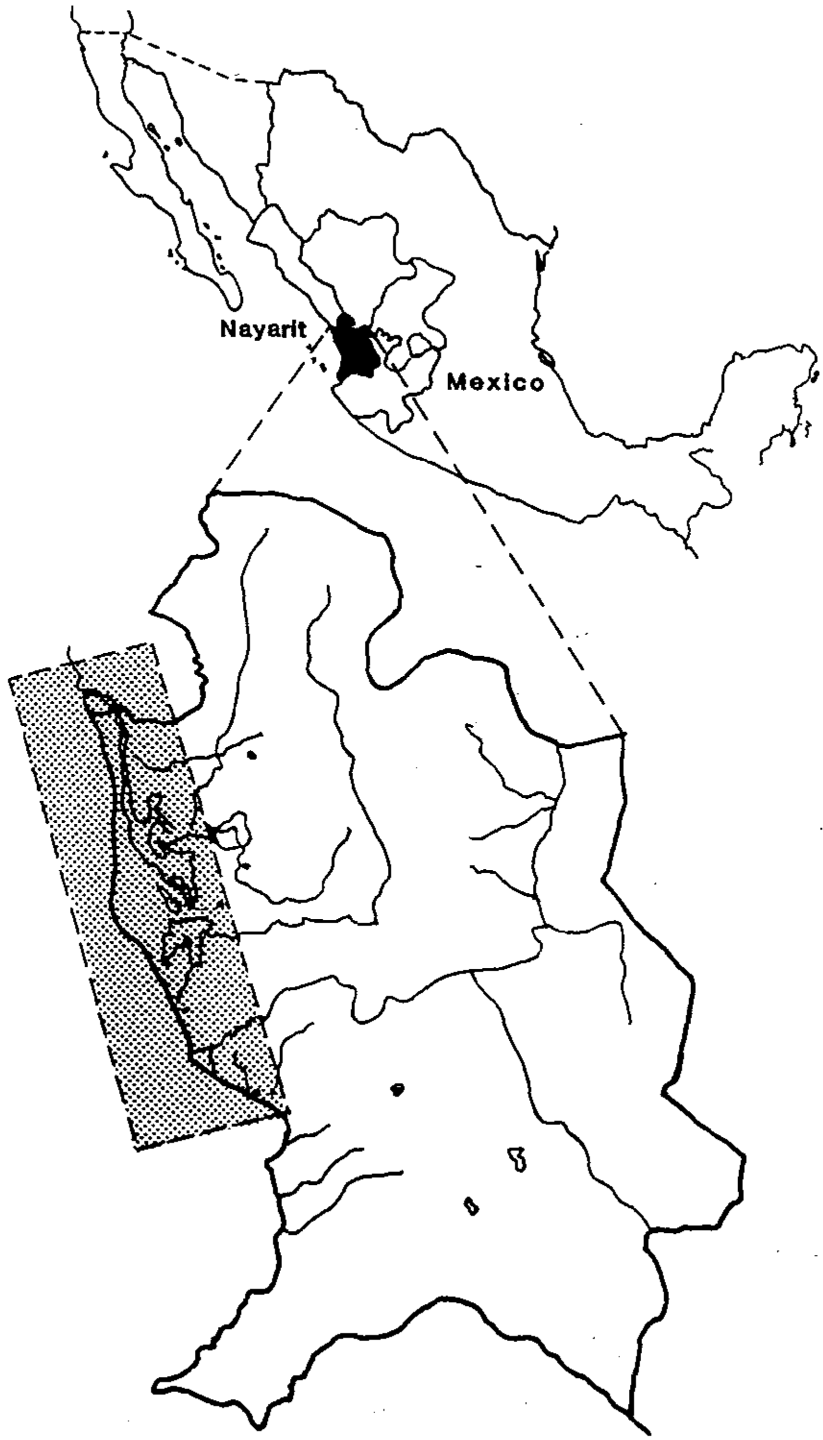


Figure E-1. Location map of the coastal area of Nayarit showing area most suitable for mariculture development (stippled area) because of its proximity to marine waters and relatively flat terrain.

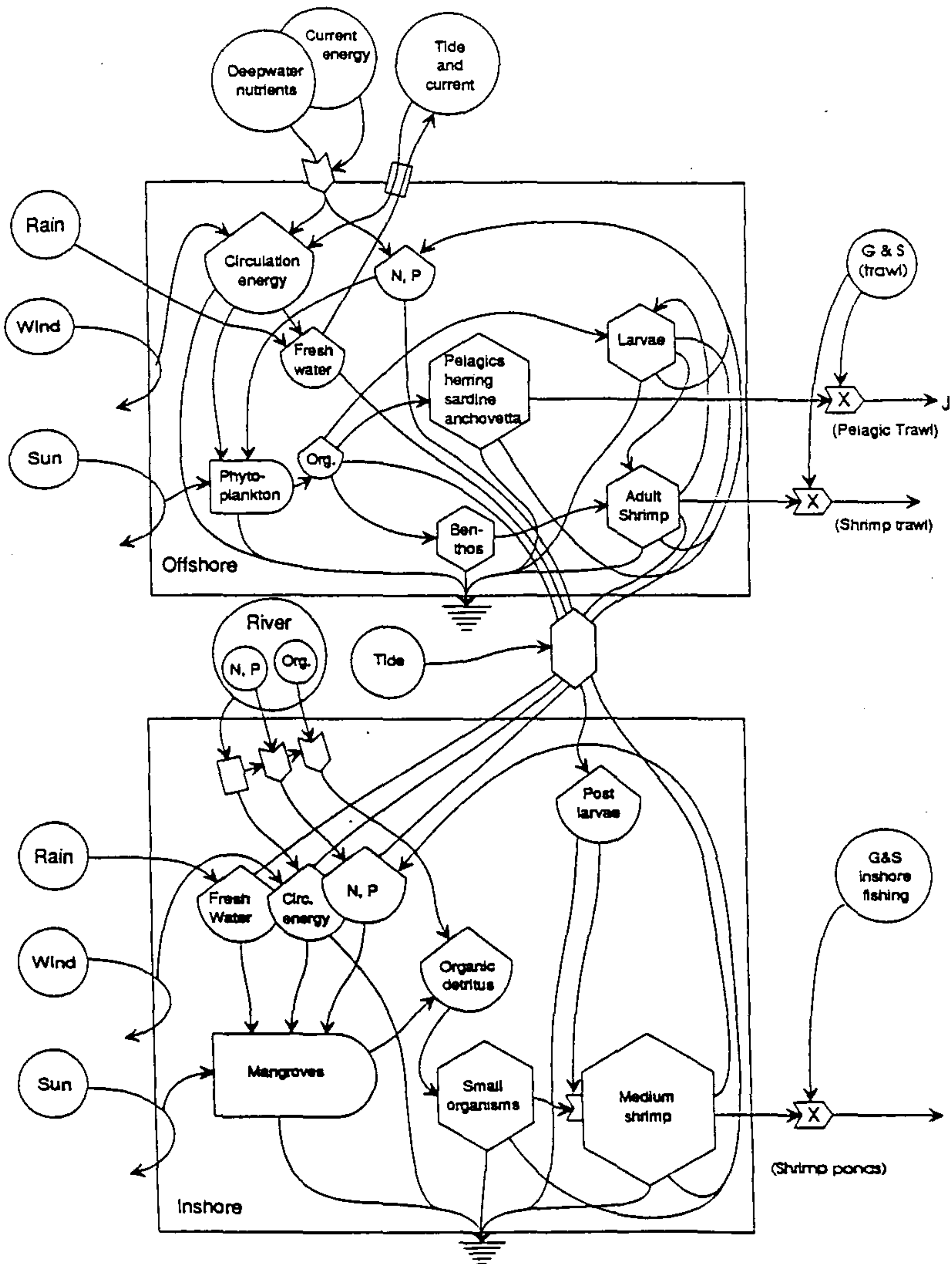


Figure E-2. Energy systems diagram of the life cycle of shrimp between inshore mangroves (below) and offshore shelf ecosystems (above). (source Odum and Arding, 1991)

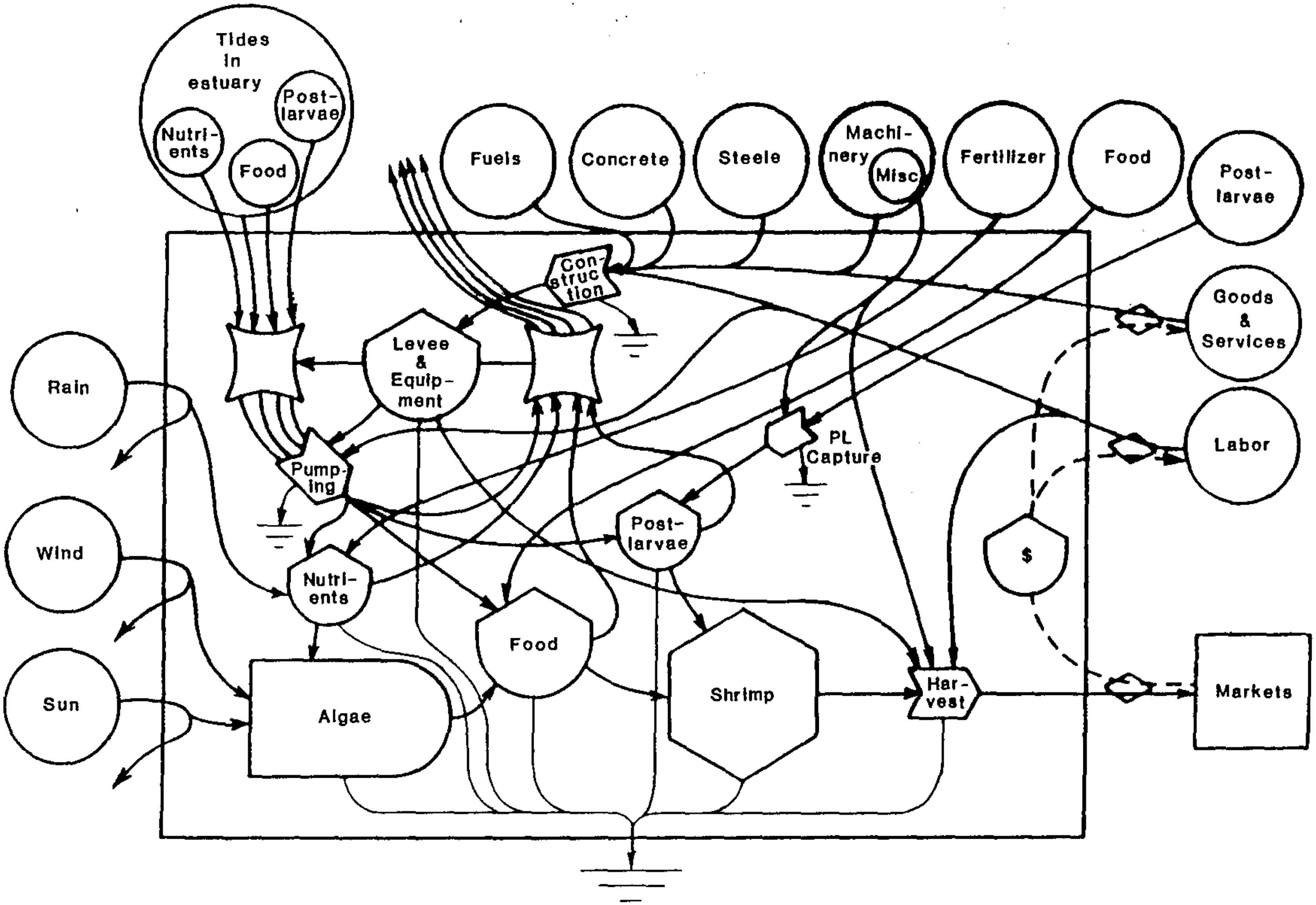


Figure E-3. Energy systems diagram of shrimp mariculture in the coastal zone of Nayarit, Mexico.

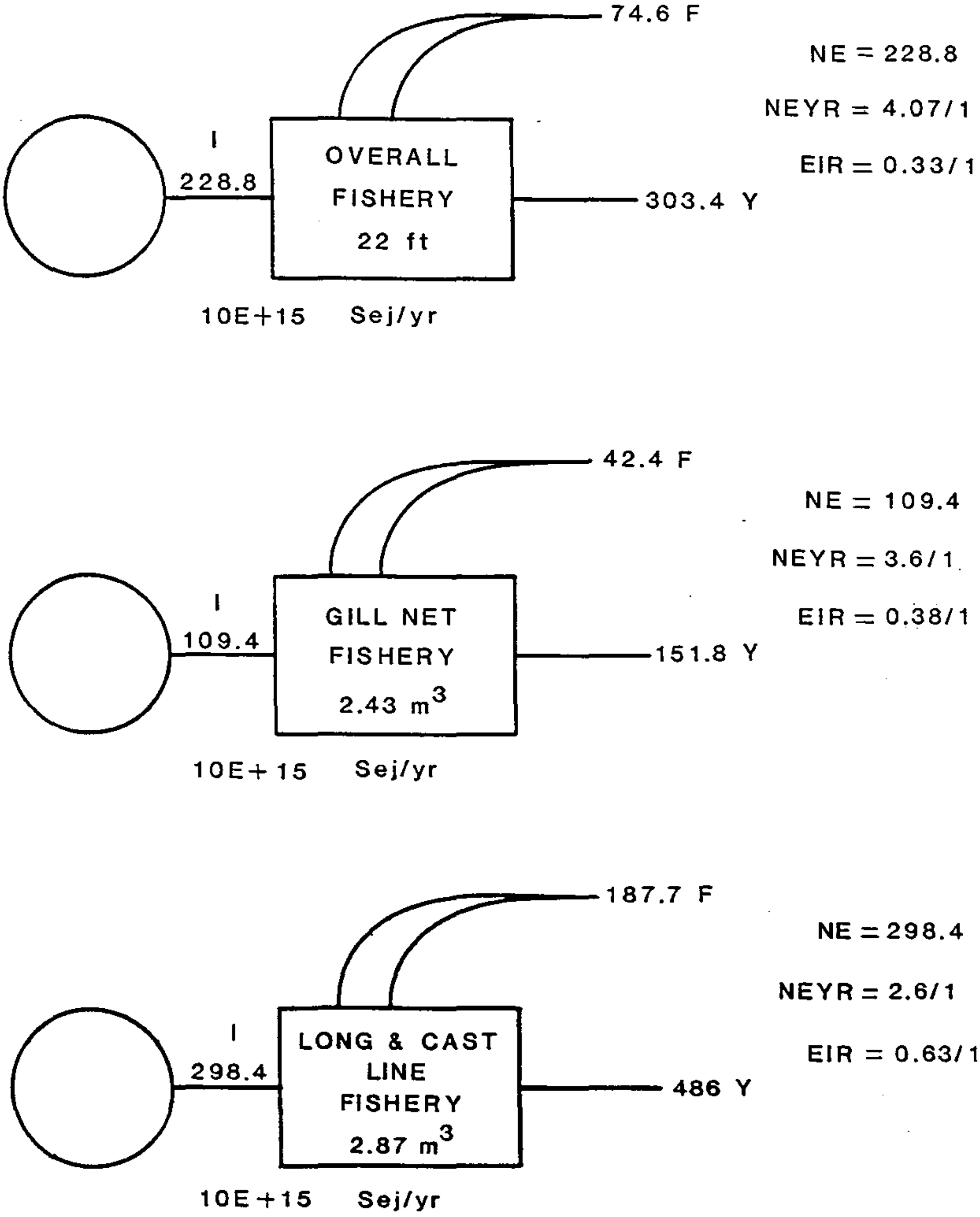


Figure E-4. Summary diagrams of EMergy costs and yields for the overall fishery of the Bay of Banderas (top), the gill net fishery (middle, and long and cast line fishery (bottom).

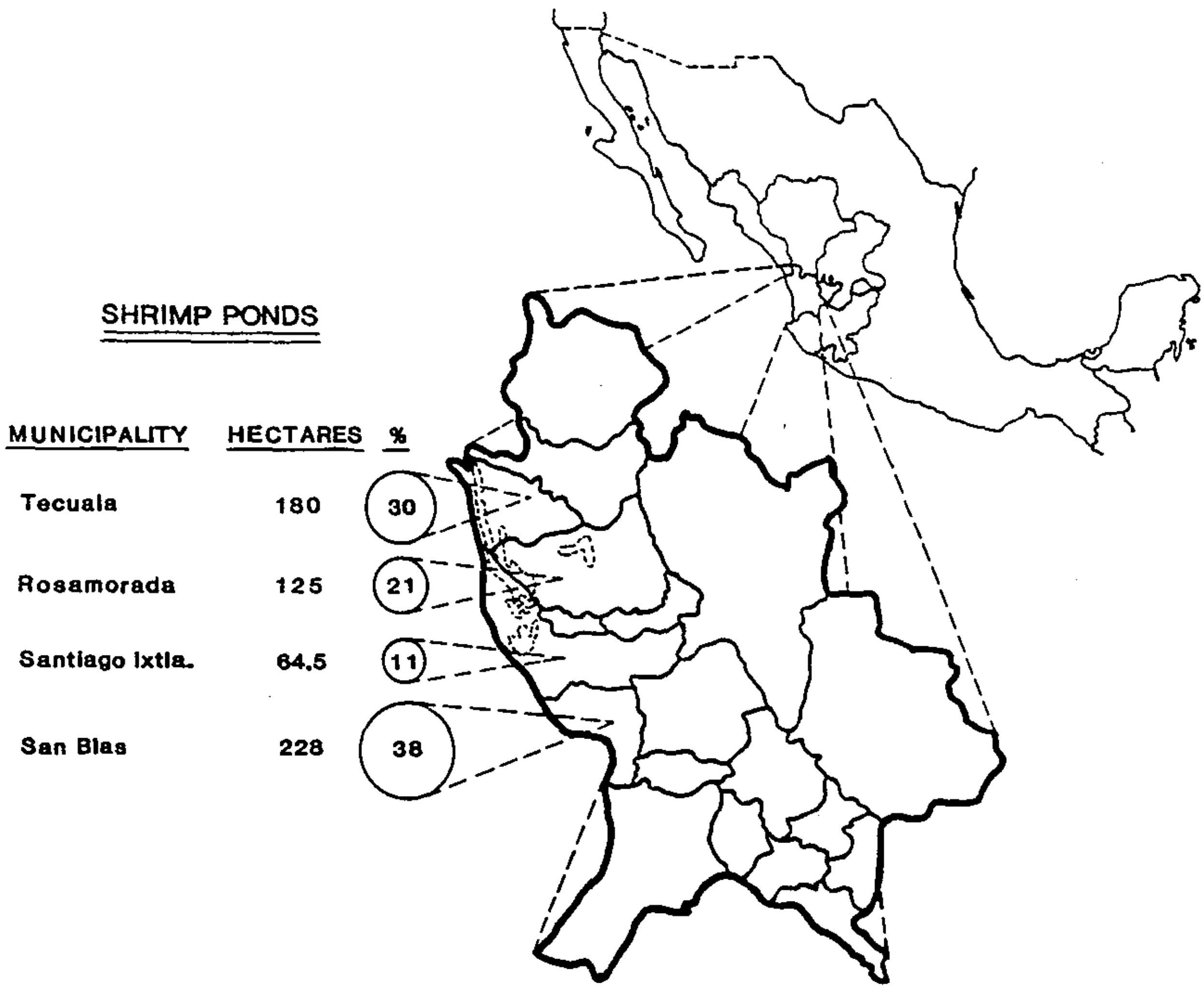


Figure E-5. Map showing the existing shrimp mariculture operations in Nayarit, Mexico.

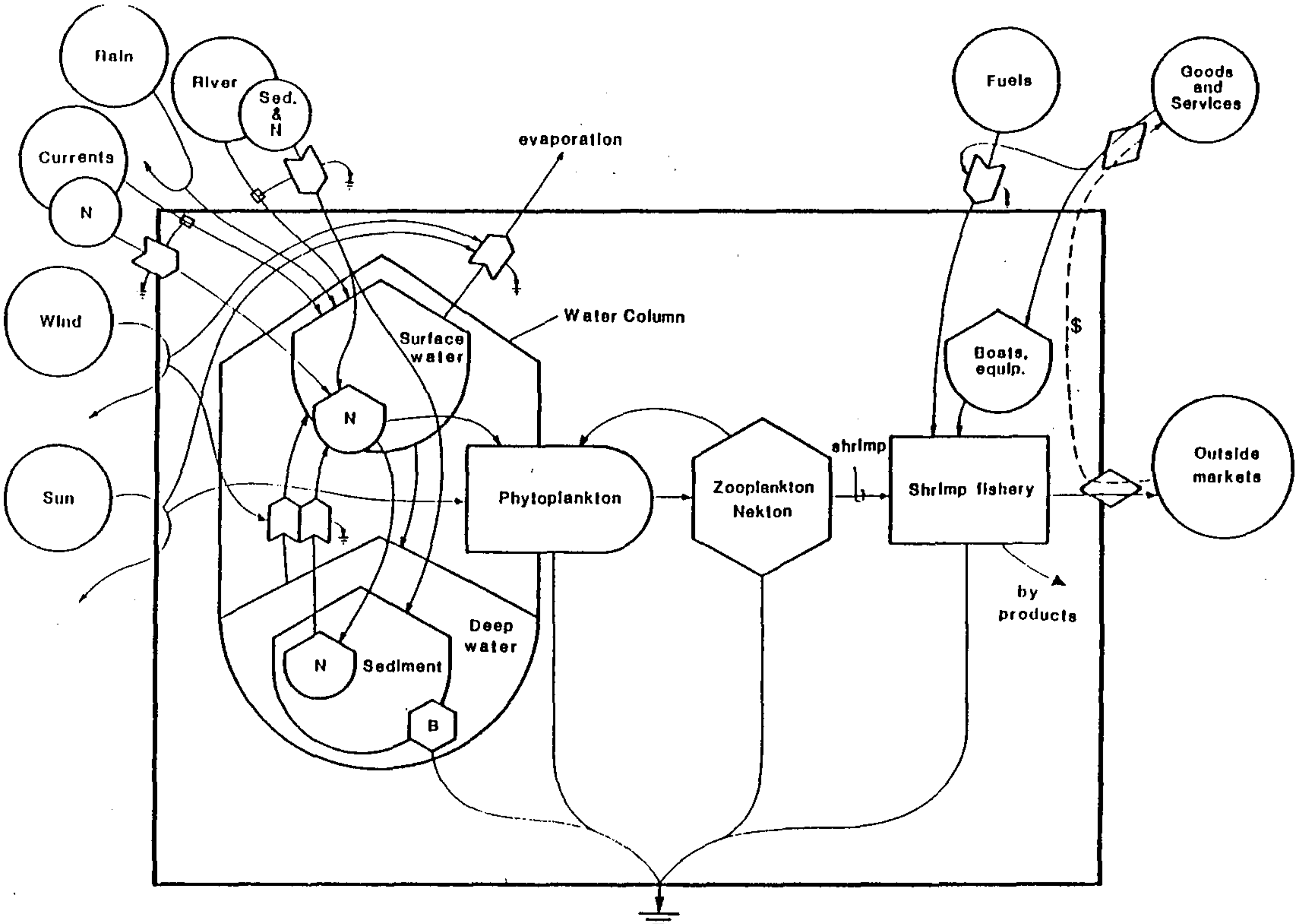


Figure E-6. Energy systems diagram of the Bay of Banderas fishery.

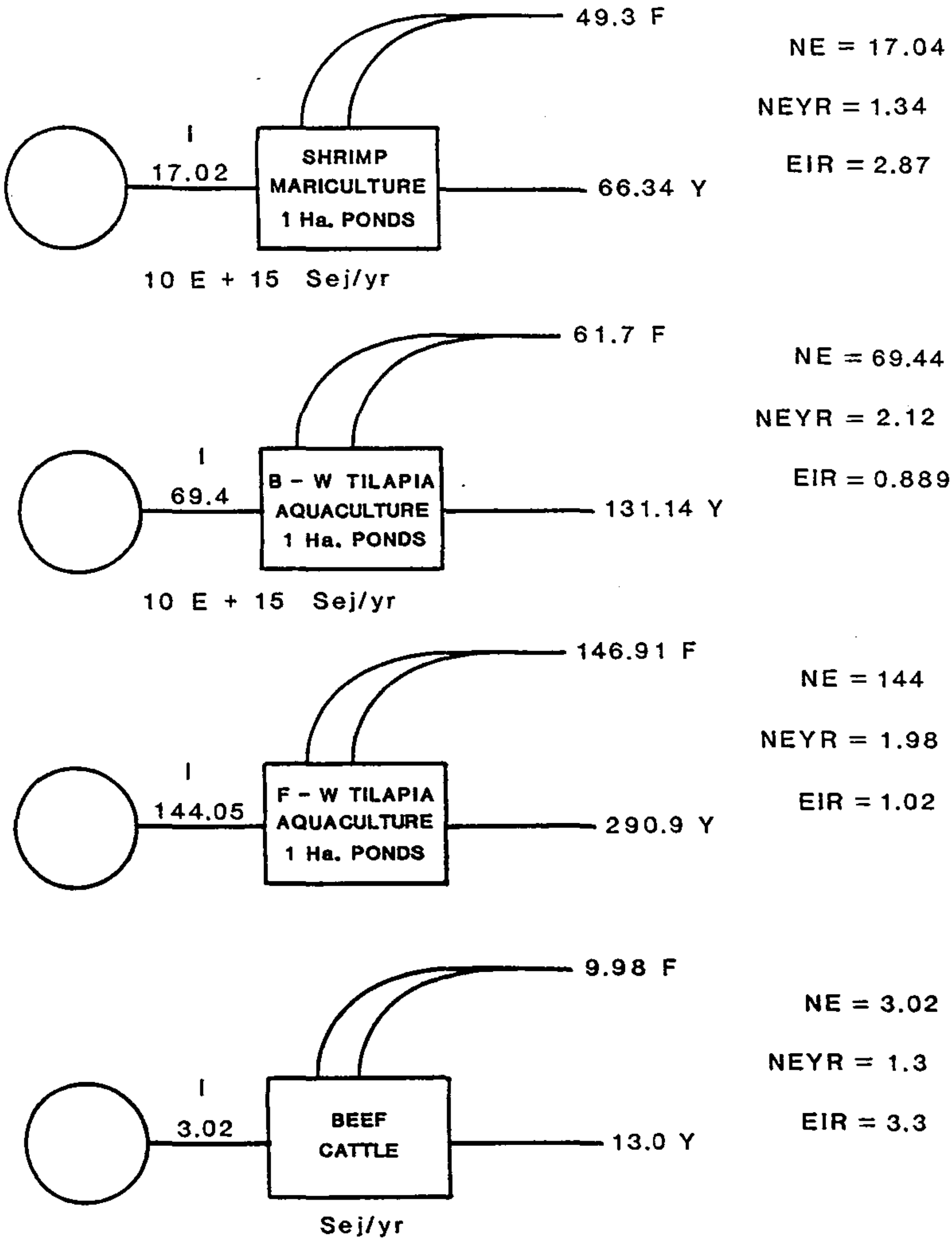


Figure E-7. Summary diagrams of EMergy costa and yields for shrimp mariculture, brackish-water tilapia, freshwater tilapia and beef cattle.

Table E-1. Regional aquaculture production data for fish, molluscs, and crustacea, for Nayarit, Mexico, Latin America, and the World.

Region	Population 1989 (1000)	Species	Production 1987 (Tons)	Production 1989 (tons)	AGRc %	Growth tons/yr	Growth g/c/yr	Production 1989 gr/cap
Nayarit	871							
		Fish	713	1516	45.82	401.5	460.96	1740.53
		Molluscs	151	211	18.21	30.0	34.44	242.25
		Crustacea	21	116	135.03	47.5	54.54	133.18
Mexico	84275							
		Fish	6000	7800	14.02	900	10.68	92.55
		Molluscs	45000	50700	6.14	2850	33.82	601.60
		Crustacea	1400	4000	69.03	1300	15.43	47.46

Region	Population 1980 (1000)	Species	Production 1975 (tons)	Production 1980 (tons)	AGRc %	Growth tons/yr	Growth g/c/yr	Production 1980 gr/cap
Latin America	363822							
		Fish	14661	18222	4.44	712.2	1.96	50.08
		Molluscs	49015	42609	-2.76	-1281.2	-3.52	117.11
		Crustacea	1140	5960	39.21	964.0	2.65	16.38
World	4436310							
		Fish	2628855	3206794	4.05	115587.8	26.05	722.85
		Molluscs	1961250	3299709	10.97	267691.8	60.34	743.80
		Crustacea	2650	75010	95.15	14472.0	3.26	16.91

Source (FAO, Fisheries Yearbooks)

Table E-2. Aquaculture production comparison for fish, molluscs and crustaceans, between Nayarit, Mexico, Latin America, and the World.

Region	Nayarit	Mexico		Latin Amer.	World
Pop 1987 (M)	0.835	81.163	Pop (75)	321.97	4069.89
Pop 1989 (M)	0.871	84.275	Pop (80)	363.82	4436.31
AGRc (%)	2.13	1.9	AGRc	2.47	1.74
Fish Prod '87 (MT)	713	6000	F-P (75)	14661	2628855
Fish Prod '89 (MT)	1516	7800	F-P (80)	18222	3206794
AGRc (%)	45.81	14.01	AGRc	4.44	4.05
Fish Prod '89 (gr/cap)	1740.5	92.55	F-P (80)	50.08	722.85
Fish Incr.(87/89) (MT/yr)	401.5	900	F-I (75/80)	712.2	115588
Fish Incr.(87/89) (gr/cap)	461	10.6	F-I (75/80)	1.96	26.05
Molsc. Prod '87 (MT)	151	45000	M-P (75)	49015	1961250
Molsc. Prod '89 (MT)	211	50700	M-P (80)	42609	3299709
AGRc (%)	18.21	6.14	AGRc	-2.76	10.96
Molsc. Prod '89 (gr/cap)	242.25	601.6	M-P (80)	117.1	743.79
Molsc Incr. (87/89) (MT/yr)	30	2850	M-I (75/80)	-1281	267692
Molsc Incr. (87/89) (gr/cap)	34.44	33.82	M-I (75/80)	-3.52	60.34
Crust Prod '87 (MT)	21	1400	C-P (75)	1140	29654
Crust Prod '89 (MT)	116	4000	C-P (80)	5960	75010
AGRc (%)	135.03	69.03	AGRc	39.21	20.39
Crust Prod '89 (gr/cap)	133.18	47.46	C-P (80)	16.38	16.9
Crust Incr (87/89) (MT/yr)	47.5	1300	C-I (75/80)	964	9071
Crust Incr (87/89) (gr/cap)	54.53	15.42	C-I (75/80)	2.65	2.04
Tot Prod '87 (MT)	885	52400	T-P (75)	64816	4619759
Tot prod '89 (MT)	1843	62500	T-P (80)	66791	6581513
AGRc (%)	44.31	9.21	AGRc	0.6	7.33
Tot Prod '89 (gr/cap)	2115.95	741.62	T-P (80)	183.58	1483.56
Tot Incr (87/89) (MT/yr)	479	5050	T-I (75/80)	395	392351
Tot Incr (87/89) (gr/cap)	549.94	59.93	T-I (75/80)	1.09	88.44

Source (FAO, Fisheries Yearbooks)

* F-P = Fish Prod. M-P = Mollusc Prod. C-P = Crustacean Prod. T-P = Total Prod.

* M = Million MT = Metric Tonnes

Table E-3. Aquaculture production for fish, molluscs, and crustaceans, on cropped land and irrigated land, for 4 regions.

Region		Nayarit			Mexico	
Pop (87) (M)		0.835			81.163	
Pop (89) (M)		0.857			84.275	
AGRc (%)		2.13			1.9	
	Fish	Moll	Crust	Fish	Moll	Crust
Prod (87) (MT)	713	151	21	6000	45000	1400
Prod (89) (MT)	1516	211	116	7800	50700	4000
AGRc (%)	45.81	18.21	135.03	14.01	6.14	69.03
Prod (89) (gr/cap)	1740.5	242.25	133.13	92.55	601.6	47.46
Crop Land (89) (Th-Ha)		218.787			24703	
Prod. (kg/Ha) of Crp-lnd	6.93	0.96	0.53	0.32	2.05	0.16
Irrig. Land (89) (Th-Ha)		133.401			4941	
Prod. (kg/Ha) of Irr-lnd	11.36	1.58	0.87	1.58	10.26	0.81

		Latin America			World	
Pop (75) (M)		321.97			4069.89	
Pop (80) (M)		263.82			4436.31	
AGRc		2.47			1.74	
	Fish	Moll	Crust	Fish	Moll	Crust
Prod (75) (MT)	14661	49015	1140	2628855	1961250	29654
Prod (80) (MT)	18222	42609	5960	3206794	3299709	75010
AGRc	4.44	-2.76	39.21	4.05	10.96	20.39
Prod (80) (gr/cap)	50.08	117.1	16.38	722.85	743.76	16.9
Crp-Lnd (80) (Th-Ha)		162132			1452212	
Prod/ (Crp-lnd)	0.11	0.26	0.04	2.21	2.27	0.05
Irr-Lnd (80) (Th-Ha)		14183			211669	
Prod/ (Irr-Lnd)	1.28	3.0	0.42	15.15	15.59	0.35

M = Million   MT = Metric Tonnes

Sources: FAO, Fisheries Yearbook; FAO, The State of Food & Agriculture

Table E-4. EMergy evaluation of shrimp mariculture in Nayarit, 1989.

Note	Item	Raw Units	Trans-formity (sej/unit)	Solar EMergy (E12 sej)	Macroeconomic Value (E9 1984 US$)
RENEWABLE RESOURCES (per ha/yr):					
1	Sunlight	4.54E+13 J	1	45.42	1.89
2	Wind	7.14E+10 J	623	44.50	1.85
3	Rain	5.27E+10 J	15423	812.94	33.87
4	Tidal Energy	1.02E+09 J	23564	24.07	1.00
5	Pump. B-Water	1.05E+11 J	15444	1623.47	67.65
6	Post-Larvae	1.40E+05 Ind.	1.04E+11	14560.00	606.67
	Sum of free inputs (sun,wind omitted)			17020.49	
PURCHASED INPUTS:					
	CONSTRUCTION INPUTS (per ha/yr, @ 10 yr useful life of ponds)				
7	Labor (man-hr.)	2.57E+07 J	1.24E+06	31.78	1.32
8	Fuel (diesel)	3.14E+09 J	5.30E+04	166.16	6.92
9	Concrete	3.70E+05 g	9.26E+07	34.27	1.43
10	Steel	1.15E+04 g	1.80E+09	20.70	0.86
11	Machinery	4.00E+05 g	6.70E+09	2680.00	111.67
12	Services (USD)	2.33E+03 $	3.09E+12	7186.04	299.42
	OPERATIONAL INPUTS (per ha/yr)				
13	Labor (man-hr.)	2.71E+08 J	1.24E+06	334.53	13.94
14	Fuel	7.80E+10 J	5.30E+04	4134.25	172.26
15	Fertilizer	4.40E+04 g	2.00E+10	880.00	36.67
16	Feed	1.30E+11 J	1.31E+05	17066.25	711.10
17	Misc. Supplies	2.65E+02 $	3.09E+12	819.44	34.14
18	Services (USD)	5.16E+03 $	3.09E+12	15957.35	664.90
	Sum of purchased inputs			49310.76	
PRODUCTION (per ha/yr):					
19	Shrimp Yield	6.20E+09 J	1.07E+07	66331.25	2763.82

Footnotes for Table E-4

1 SOLAR ENERGY:

Pond Area = 1.00 E+04 m^2 (standard 1 ha pond)
Insolation = 1.55 E+02 $kcal/cm^2/yr$ (IAM, UdeG, Circa 1988)
Albedo = 0.30 (% given as decimal) * estimate

Energy (J) = (Pond Area)*(avg insolation)*($10000 cm^2/m^2$)
(1-albedo)(4186 J/Kcal)

(J) = 4.54 E+13

2 WIND:

Pond Area = 1.00 E+04 m^2 (standard 1 ha pond)
Wind Energy = 7.14 E+06 $J/m^2/yr$ @ (1.4 E19 J/yr)/(1.96 E12 m^2)

Energy (J) = (pond area)*(wind energy)

(J) = 7.14 E+10

3 RAIN:

Pond Area = 1.00 E+04 m^2
Rainfall = 1.07 E+00 m/yr
ET = (not used for this particular case)

Energy (J) = (pond area)*(rainfall)*(ET)*(1000 kg/m^3)*(4940 J/kg)

(J) = 5.27 E+10

4 TIDAL ENERGY:

Cont. Shelf Area= 4.00 E+02 m^2 (area of the pumping station)
Tidal range = 8.40 E-01 m
Water density = 1.01 E+03 kg/m^3
tides/yr = 7.30 E+02

Energy (J) = (shelf)*(0.5)*(tides/yr)*$(\text{tidal range})^2$
(density)(gravity)

(J) = 1.02 E+09

5 PUMPED B-WATER:

Area = 1.00 E+04 m^2 (standard 1 ha pond)
depth = 1.20 E+00 m (avg. pond depth)
water exchge. = 1.00 E-01 (10 % daily)
No. of days = 3.65 E+02

Energy (J) = ((area)(depth)+(area)(depth)*(water exchange)*(days)
(1000000 gr/m^3)(.08 fresh)(3.0 J/gr))

(J) = 1.05 E+11

6 POST-LARVAE:

PL stocked = 1.40 E+05 PL @ stocking rate of 14/m^2

PL ind. = 1.40 E+05

CONSTRUCTION INPUTS (data from SEPESCA/JAL., 1989, for standard 1 ha pond):

7 LABOR (Clearing, excavat., leveling, etc.):

Man-hr = 5.90 E+02 hr/ha/yr

Energy (J) = ((man-hr)*((2500 kcal consumed/day)/24 hr)
*(4186 J/Kcal))/10

(J) = 2.57 E+07

8 FUEL (diesel):

Vol. used = 2.20 E+02 gal

Energy (J) = ((vol)*(34030 kcal/gal)*(4186 J/kcal))/10

(J) = 3.14 E+09

9 CONCRETE:

Vol. used = 3.70 E+03 kg

(g) = ((vol)*(1000 g/kg))/10

(g) = 3.70 E+05

10 STEEL:

Vol. used = 1.15 E+02 kg

(g) = ((vol)*(1000 g/kg))/10

(g) = 1.15 E+04

11 MACHINERY:

2 pumps = 4.00 E+03 kg @ 2 tons/pump

(g) = ((vol)*(1000 g/kg))/10

(g) = 4.00 E+05

12 SERVICES:

total cost = 5.29 E+07 $pesos/ha (1989)
exch. rate = 2.28 E+03 $pesos/$US (1989)

($US) = ((pesos)*(exch. rate))/(deprec. time)

($US) = 2.33 E+03

OPERATIONAL INPUTS (per ha/yr):

13 LABOR:

Man-hr = 6.21 E+02 hr/ha/yr

Energy (J) = (man-hr)*((2500 kcal consumed/day)/24 hr)
*(4186 J/Kcal)

(J) = 2.71 E+08

14 FUEL:

	Gallons/yr	Kcal/gal	Kcal/yr
Diesel =	4.76 E+02	3.40 E+04	1.62 E+07
Gasoline =	6.66 E+01	3.62 E+04	2.41 E+06
Oil =	1.06 E+00	3.74 E+04	3.96 E+04
		Total =	1.86 E+07

Total kcal = 1.86 E+07

Energy (J) = (fuel)*(kcal/gal)*(4186 J/Kcal)

(J) = 7.80 E+10

15 FERTILIZER:

Urea = 3.00 E+01 kg
Superphosph. = 1.40 E+01 kg

Total = 4.40 E+01 kg

(g) = (Fertilizer)*(1000 g/kg)

(g) = 4.40 E+04

16 FEED:

Pelleted feed = 5.46 E+03 kg

Energy (J) = (feed)*(1000 g/kg)*(5.7 kcal/g)*(4186 J/kcal)

(J) = 1.30 E+11

17 MISCELLANEOUS SUPPLIES (5 yr. depreciation time):

Total cost = 3.02 E+06 $pesos/ha (1989)
Exch. rate = 2.28 E+03 $pesos/$US (1989)

($US) = ((pesos)*(exch. rate))/(deprec. time)

($US) = 2.65 E+02

18 SERVICES:

Total cost = 1.17 E+07 $pesos/ha (1989)
Exch. rate = 2.28 E+03 $pesos/$US (1989)

($US) = ((pesos)*(exch. rate))/(deprec. time)

($US) = 5.16 E+03

PRODUCTION (per ha/yr):

19 SHRIMP YIELD:

Total yield = 1.11 E+03 kg

Energy (J) = (yield)*(1000 g/kg)*(dry weight)*(6.7 kcal/gr)
*(4186 J/kcal)

(J) = 6.20 E+09

Table E-5. EMergy evaluation of brackish water Tilapia aquaculture in Nayarit, 1989.

Note	Item	Raw Units	Transformity (sej/unit)	Solar EMergy (E12 sej)	Macroeconomic Value (E9 1984 US$)
RENEWABLE RESOURCES (per ha/yr):					
1	Sunlight	4.54 E+13 J	1	45.42	1.89
2	Wind	7.14 E+10 J	623	44.50	1.85
3	Rain	5.27 E+10 J	15423	812.94	33.87
4	Tidal energy	1.02 E+09 J	23564	24.07	1.00
5	Pump. B-Water	1.05 E+11 J	15444	1623.47	67.65
6	Fish Fingerlings	3.35 E+10 J	2.00 E+06	66976.00	2790.69
	Sum of free inputs (sun, wind omitted)			69436.49	
PURCHASED INPUTS:					
	CONSTRUCTION INPUTS (per ha/yr, 10 yr useful life of ponds)				
7	Labor (man-hr.)	2.57 E+07 J	1.24 E+06	31.78	1.32
8	Fuel (diesel)	3.14 E+09 J	5.30 E+04	166.16	6.92
9	Concrete	3.70 E+05 g	9.26 E+07	34.27	1.43
10	Steel	1.15 E+04 g	1.80 E+09	20.70	0.86
11	Machinery	4.00 E+05 g	6.70 E+09	2680.00	111.67
12	Services (US$)	2.33 E+03 $	3.09 E+12	7186.04	299.42
	OPERATIONAL INPUTS (per ha/yr)				
13	Labor (man-hr.)	7.16 E+08 J	1.24 E+06	884.53	36.86
14	Fuel	7.80 E+10 J	5.30 E+04	4134.25	172.26
15	Fertilizer	4.20 E+04 g	2.00 E+10	840.00	35.00
16	Feed	2.01 E+11 J	1.31 E+05	26321.57	1096.74
17	Misc. Supplies	8.00 E+02 $	3.09 E+12	2472.00	103.00
18	Services (US$)	5.48 E+03 $	3.09 E+12	16930.88	705.46
	Sum of purchased inputs			61702.18	
PRODUCTION (per ha/yr):					
19	Tilapia Yield	2.34 E+11 J	5.61 E+05	131138.67	5464.15

Footnotes for Table E-5

1 SOLAR ENERGY:

Pond Area = 1.00 E+04 m^2 (standard 1 Ha pond)
Insolation = 1.55 E+02 $Kcal/cm^2/yr$ IAM,UdeG, Circa,1988.
Albedo = 0.30 (% given as decimal) * estimate

Energy (J) = (pond Area)*(avg insolation)*($10000cm^2/m^2$)
(1-albedo)(4186J/Kcal)

(J) = 4.54 E+13

2 WIND:

Pond Area = 1.00 E+04 m^2 (standard 1 Ha pond)
Wind Energy = 7.14 E+06 $J/m^2/yr$ @ (1.4 E19 J/yr)/(1.96 E12 m^2)

Energy (J) = (Pond Area)*(wind energy)

(J) = 7.14 E+10

3 RAIN:

Pond Area = 1.00 E+04 m^2
Rainfall = 1.07 E+00 m/yr
E-t = not used for this particular case

Energy (J) = (pond area)*(Rainfall)*(E-t)*($1000Kg/m^3$)*(4940J/Kg)

(J) = 5.27 E+10

4 TIDAL ENERGY:

Cont. Shelf Area = 4.00 E+02 m^2 (area of the pumping station)
Tidal range = 8.40 E-01 m
Water density = 1.01 E+03 Kg/m^3
tides/yr = 7.30 E+02

Energy (J) = (shelf)*(0.5)*(tides/yr)*$(\text{tidal range})^2$
(density)(gravity)

(J) = 1.02 E+09

5 PUMPED B-WATER:

Area = 1.00 E+04 m^2 (standard 1 ha pond)
depth = 1.20 E+00 m (avg. pond depth)
water exchge. = 1.00 E-01 (10% daily)
No. of days = 3.65 E+02

Energy (J) = ((area)(depth)+(area)(depth)*(wat-exch)*(days)
(1000000 gr/m^3)(.08 fresh)(3.0 J/gr))

(J) = 1.05 E+11

6 FISH FINGERLINGS:

```
    Fish stocked =  4.00 E+04 fish stocked @ 2/m²/crop  (2 crop/yr)
     wt. @ stock =  4.00 E+01 gr/fingerling
      Energy (J) =  (# fish)*(wt.)*(5 kcal/gr)*(4186 J/kcal)

             (J) =  3.35 E+10
```

CONSTRUCTION INPUTS (Data from SEPESCA/JAL., 1989)

7 LABOR (clearing, excavation, leveling, etc.):

```
          Man-hr =  5.90E+02 hr/Ha/yr

      Energy (J) = ((man-hr)*((2500Kcal consumed/day)/24 hr)
                   *(4186 J/Kcal))/10

             (J) =  2.57E+07
```

8 FUEL (diesel):

```
       Vol. used =  2.20 E+02 gal

      Energy (J) =  ((vol)*(34030 Kcal/gal)*(4186 J/Kcal))/10

             (J) =  3.14 E+09
```

9 CONCRETE:

```
       Vol. used =  3.70 E+03 kg

             (g) =  ((vol)*(1000 g/kg))/10

             (g) =  3.70 E+05
```

10 STEEL:

```
       Vol. used =  1.15 E+02 kg

             (g) =  ((vol)*(1000 g/kg))/10

             (g) =  1.15 E+04
```

11 MACHINERY:

```
         2 pumps =  4.00 E+03 kg   @ 2 tons/pump

             (g) =  ((vol)*(1000 g/kg))/10

             (g) =  4.00 E+05
```

12 SERVICES:

```
      total cost =  5.29 E+07 $pesos/ha  (1989)
      exch. rate =  2.28 E+03 $pesos/$US  (1989)

           ($US) =  ((pesos)*(exch. rate))/(deprec. time)

           ($US) =  2.33 E+03
```

OPERATIONAL INPUTS (per ha/yr):

13 LABOR:

Man-hr = 1.64E+03 hr/ha/yr

Energy (J) = (man-hr)*((2500kcal consumed/day)/24 hr)
*(4186 J/Kcal)

(J) = 7.16 E+08

14 FUEL:

	US gal/yr	Kcal/USgal	Kcal/yr
Diesel =	4.76 E+02	3.40 E+04	1.62 E+07
Gasoline =	6.66 E+01	3.62 E+04	2.41 E+06
Oil =	1.06 E+00	3.74 E+04	3.96 E+04
		Total =	1.86E+07

Total Kcal = 1.86E+07

Energy (J) = (fuel)*(Kcal/gal)*(4186 J/Kcal)

(J) = 7.80E+10

15 FERTILIZER:

Urea = 2.40 E+01 kg
Superphosph. = 1.80 E+01 kg

Total = 4.20 E+01 kg

(g) = (Fertilizer)*(1000 g/kg)

(g) = 4.20 E+04

16 FEED:

Pelleted feed = 8.00 E+03 kg

Energy (J) = (feed)*(1000 g/kg)*(6kcal/g)*(4186 J/kcal)

(J) = 2.01 E+11

17 MISCELLANEOUS SUPPLIES (5 yr. depreciation time):

total cost = 9.10 E+06 $pesos/ha (1989)
exch. rate = 2.28 E+03 $pesos/$US (1989)

($USD) = ((pesos)*(exch. rate))/(deprec. time)

($USD) = 8.00E+02

18 SERVICES:

total cost = 1.25 E+07 $pesos/ha (1989)
exch. rate = 2.28 E+03 $pesos/$US (1989)

($US) = ((pesos)*(exch. rate))/(deprec. time)

($US) = 5.48 E+03

PRODUCTION (per ha/yr):

19 TILAPIA YIELD:

Total yield = 1.14 E+04 kg @ 95% survival and 300 gr/tilapia

Energy (J) = (yield)*(1000 g/kg)*(4.9 kcal/gr)
*(4186 J/kcal)

(J) = 2.34 E+11

Table E-6. EMergy evaluation of fresh water Tilapia aquaculture in Nayarit, 1989.

Note	Item	Raw Units	Trans-formity (sej/unit)	Solar EMergy (E12 sej)	Macroeconomic Value (E9 1984 US$)
RENEWABLE RESOURCES (per ha/yr):					
1	Sunlight	4.54 E+13 J	1	45.42	1.89
2	Wind	7.14 E+10 J	623	44.50	1.85
3	Rain	5.27 E+10 J	15423	812.94	33.87
4	Pump. G-Water	1.86 E+12 J	41000	76260.00	3177.53
5	Fish Fingerlings	3.35 E+10 J	2.00 E+06	66976.00	2790.69
	Sum of free inputs (sun, wind omitted)			144048.94	
PURCHASED INPUTS:					
	CONSTRUCTION INPUTS (per ha/yr, 10 yr useful life of ponds)				
6	Labor (man-hr.)	1.21 E+07 J	1.24 E+06	14.98	0.62
7	Fuel (diesel)	4.37 E+09 J	5.30 E+04	231.52	9.65
8	Concrete	2.59 E+06 g	9.26 E+07	239.74	9.99
9	Steel	6.90 E+04 g	1.25 E+10	862.50	35.94
10	Machinery	3.51 E+06 g	6.70 E+09	23530.40	980.44
11	Services (US$)	3.06 E+03 $	3.09 E+12	9439.95	393.33
	OPERATIONAL INPUTS (per ha/yr)				
12	Labor (man-hr.)	5.95 E+08 J	1.24 E+06	734.78	30.62
13	Fuel	2.78 E+11 J	5.30 E+04	14723.69	613.49
14	Fertilizer	4.20 E+04 g	2.00 E+10	840.00	35.00
15	Feed	4.04 E+11 J	1.31 E+05	52928.29	2205.36
16	Misc. Supplies	2.43 E+02 $	3.09 E+12	750.87	31.29
17	Machinery	7.70 E+04 g	6.70 E+09	515.90	21.50
18	Services (US$)	1.36 E+04 $	3.09 E+12	42101.25	1754.23
	Sum of purchased inputs			146913.86	
PRODUCTION (per ha/yr):					
19	Tilapia Yield	2.34 E+11 J	1.24 E+06	290962.80	12123.55

Footnotes for Table E-6

1 SOLAR ENERGY:

Pond Area = 1.00 E+04 m^2 (standard 1 ha pond)
Insolation = 1.55 E+02 $Kcal/cm^2/yr$ IAM,UdeG, Circa,1988.
Albedo = 0.30 (% given as decimal) * estimate

Energy (J) = (Pond Area)*(avg insolation)*($10000cm^2/m^2$)
(1-albedo)(4186J/Kcal)

(J) = 4.54 E+13

2 WIND:

Pond Area = 1.00 E+04 m^2 (standard 1 Ha pond)
Wind Energy = 7.14 E+06 $J/m^2/yr$ @ (1.4 E19 J/yr)/(1.96 E12 m^2)

Energy (J) = (pond Area)*(wind energy)

(J) = 7.14 E+10

3 RAIN:

Pond Area = 1.00 E+04 m^2
Rainfall = 1.07 E+00 m/yr
ET = not used for this particular case

Energy (J) = (pond area)*(rainfall)*(ET)*(1000 kg/m^3)*(4940 J/kg)

(J) = 5.27 E+10

4 PUMPED GROUND-WATER:

Area = 1.00 E+04 m^2 (standard 1 ha pond)
depth = 1.20 E+00 m (avg. pond depth)
water exchge. = 1.00 E-01 (10% daily)
No. of days = 3.00 E+02

Energy (J) = ((area)(depth)+(area)(depth)(wat-exch)(days))
(1000000 gr/m^3)(5.0 J/gr))

(J) = 1.86 E+12

5 FISH FINGERLINGS:

Fish stocked = 4.00 E+04 fish stocked @ $2/m^2$/crop (2 crop/yr)
wt. @ stock = 4.00 E+01 gr/fingerling

Energy (J) = (# fish)*(wt.)*(5 kcal/gr)*(4186 J/kcal)

(J) = 3.35 E+10

CONSTRUCTION INPUTS: Data from Hawaii Ponds (Pimentel, 1980)
for a standard 1 Ha pond
* depreciation already calculated

6 LABOR (clearing, excavation, leveling, etc.):

Man-hr = 2.78 E+01 hr/ha/yr

Energy (J) = ((man-hr)*((2500 kcal consumed/day)/24 hr)
*(4186 J/kcal))

(J) = 1.21 E+07

7 FUEL (diesel):

Vol. used = 1.13 E+02 L

Energy (J) = ((vol)*(9235 kcal/L)*(4186 J/kcal))

(J) = 4.37 E+09

8 CONCRETE:

Vol. used = 2.59 E+03 kg

(g) = ((vol)*(1000 g/kg))

(g) = 2.59 E+06

9 STEEL:

Vol. used = 6.90 E+01 kg

(g) = ((vol)*(1000 g/kg))

(g) = 6.90 E+04

10 MACHINERY:

Total = 3.51 E+03 kg

(g) = ((vol)*(1000 g/kg))

(g) = 3.51 E+06

11 SERVICES:

total cost = 6.95 E+06 $pesos/ha (1989)
exch. rate = 2.28 E+03 $pesos/$US (1989)

($US) = ((pesos)*(exch. rate))

($US) = 3.06 E+03

OPERATIONAL INPUTS (per 1 ha/yr):

12 LABOR:

Man-hr = 1.36 E+03 hr/ha/yr

Energy (J) = (man-hr)*((2500 kcal consumed/day)/24 hr) *(4186 J/kcal)

(J) = 5.95 E+08

13 FUEL:

	Liters/yr	Kcal/Liter	Kcal/yr
Diesel =	6.71 E+03	9.24 E+03	6.20 E+07
Gasoline =	5.36 E+02	8.18 E+03	4.38 E+06
		Total =	6.64 E+07

Total Kcal = 6.64 E+07

Energy (J) = (fuel)*(kcal/gal)*(4186 J/kcal)

(J) = 2.78 E+11

14 FERTILIZER:

Urea = 2.40 E+01 kg
Superphosph. = 1.80 E+01 kg

Total = 4.20 E+01 kg

(g) = (Fertilizer)*(1000 g/kg)

(g) = 4.20 E+04

15 FEED:

Pelleted feed = 1.90 E+04 kg

Energy (J) = (feed)*(1000 g/kg)*(5.08 kcal/g)*(4186 J/kcal)

(J) = 4.04 E+11

16 MISCELLNAEOUS SUPPLIES (value amortized):

total cost = 5.53 E+05 $pesos/ha (1989)
exch. rate = 2.28 E+03 $pesos/$US (1989)

($US) = ((pesos)*(exch. rate))

($US) = 2.43 E+02

17 MACHINERY:

```
        Pick-up =  1.05 E+03 kg
        Tractor =  2.80 E+03 kg
          Total =  3.85 E+03 kg  (for 5 ha farm @ 10 yr useful life)

            (g) =  ((Mach. wt.)*(1000 g/kg)/5 ha)/10 yr)

            (g) =  7.70 E+04
```

18 SERVICES:

```
     total cost =  3.10 E+07 $pesos/ha  (1989)
     exch. rate =  2.28 E+03 $pesos/$US  (1989)

          ($US) =  ((pesos)*(exch. rate))

          ($US) =  1.36 E+04
```

PRODUCTION (per 1 ha/yr):

19 TILAPIA YIELD:

```
    Total yield =  1.14 E+04 kg  (@ 95% survival and 300 gr/tilapia)

     Energy (J) =  (yield)*(1000 g/kg)*(4.9 kcal/gr)
                   *(4186 J/kcal)

            (J) =  2.34 E+11
```

Table E-7. EMergy evaluation of cattle production system in Nayarit, 1989.

Note	Item	Raw Units	Trans-formity (sej/unit)	Solar EMergy (E12 sej)	Macroeconomic Value (E9 1984 US$)
RENEWABLE RESOURCES (per 1 ha/yr):					
1	Sunlight	4.54 E+13 J	1	45.42	1.89
2	Wind	7.14 E+10 J	623	44.50	1.85
3	Rain	5.27 E+10 J	15423	812.94	33.87
4	Potable water	4.50 E+07 J	15444	0.70	0.03
5	Cattle stck.dnsty.	1.11 E+09 J	2.00 E+06	2210.21	92.09
	Sum of free inputs (sun, wind omitted)			3023.85	
PURCHASED INPUTS:					
	PASTURE ESTABLISHMENT INPUTS (per ha/yr, 30 yrs useful life):				
6	Labor (man-hr.)	1.74 E+05 J	1.24 E+06	0.22	0.01
7	Fuel (diesel)	8.25 E+07 J	5.30 E+04	4.37	0.18
8	Phosphorus	5.00 E+02 g	2.00 E+10	10.00	0.42
9	Nitrogen	3.33 E+03 g	1.69 E+06	0.01	0.00
10	Potassium	1.67 E+03 g	9.50 E+08	1.58	0.07
11	Lime	8.33 E+03 g	1.00 E+09	8.33	0.35
12	Bermudagrass Stck.	1.33 E+04 g	2.00 E+05	0.00	0.00
13	Machinery	1.83 E+02 g	6.70 E+09	1.23	0.05
14	Services (US$)	2.33 E+03 $	3.09 E+12	7208.97	300.38
	OPERATIONAL INPUTS (per ha/yr)				
	Annual maintenance of Pasture & Cattle				
15	Labor (man-hr.)	1.05 E+07 J	1.24 E+06	12.93	0.54
16	Fuel (diesel)	1.55 E+08 J	5.30 E+04	8.20	0.34
17	Machinery	3.50 E+03 g	6.70 E+09	23.45	0.98
18	Nitrogen	3.60 E+05 g	1.69 E+06	0.61	0.03
19	Phosphorus	1.50 E+04 g	2.00 E+10	300.00	12.50
20	Potassium	8.00 E+04 g	9.50 E+08	76.00	3.17
21	Lime	2.50 E+05 g	1.00 E+09	250.00	10.42
22	Misc. supplies	3.15 E+01 $	3.09 E+12	97.46	4.06
23	Services (US$)	6.42 E+02 $	3.09 E+12	1982.51	82.61
	Sum of purchased inputs			9985.86	
PRODUCTION (per ha/yr)					
24	Cattle Yield	1.86 E+09 J	7.01 E+06	13009.71	542.08

Footnotes for Table E-7

1 SOLAR ENERGY:

Pond Area = 1.00 E+04 m^2 (standard 1 ha pond)
Insolation = 1.55 E+02 kcal/cm^2/yr IAM,UdeG, Circa,1988.
Albedo = 0.30 (% given as decimal) * estimate

Energy (J) = (pond area)*(avg insolation)*(10000 cm^2/m^2)
(1-albedo)(4186 J/kcal)

(J) = 4.54 E+13

2 WIND:

Pond Area = 1.00 E+04 m^2 (standard 1 ha pond)
Wind Energy = 7.14 E+06 J/m^2/yr @ (1.4 E19 J/yr)/(1.96 E12 m^2)

Energy (J) = (pond area)*(wind energy)

(J) = 7.14 E+10

3 RAIN:

Pond Area = 1.00 E+04 m^2
Rainfall = 1.07 E+00 m/yr
ET = not used for this particular case

Energy (J) = (pond area)*(rainfall)*(ET)*(1000 kg/m^3)*(4940 J/kg)

(J) = 5.27 E+10

4 POTABLE WATER:

avge. wat intake= 1.10 E+01 gal/head/day
stck. @ = 1.20 E+00 ind/ha
growth period = 1.80 E+02 days

Energy (J) = (water intk.)*(AU)*(grwth. per.)*(3.79 L/gal)
(1000 g/L)(5 J/g)

(J) = 4.50 E+07

5 CATTLE STOCKED:

Cattle stocked = 1.20 E+00 ind./ha
wt. @ stock = 2.50 E+02 kg/ind.

Energy (J) = (# ind)*(wt.)*(1000 g/kg)(4 kcal/gr)*(4186 J/kcal)
*(0.22 prot)

(J) = 1.11 E+09

PURCHASED INPUTS:

PASTURE ESTABLISHMENT INPUTS: for (1 Ha/yr) @ (30 yr) useful life

6 LABOR:

Man-hr = 1.20 E+01 hr/ha/yr

Energy (J) = ((man-hr)*((2500 kcal consumed/day)/24 hr)*(4186 J/kcal))/30 yr

(J) = 1.74 E+05

7 FUEL (diesel):

Vol. used = 6.40 E+01 L

Energy (J) = ((vol)*(9235 kcal/L)*(4186 J/kcal))/30 yr

(J) = 8.25 E+07

8 PHOSPHORUS:

Vol. used = 1.50 E+01 kg

(g) = ((vol)*(1000 g/kg))/30 yr

(g) = 5.00 E+02

9 NITROGEN:

Vol. used = 1.00 E+02 kg

(g) = ((vol)*(1000 g/kg))/30 yr

(g) = 3.33 E+03

10 POTASSIUM:

Vol. used = 5.00 E+01 kg

(g) = ((vol)*(1000 g/kg))/30 yr

(g) = 1.67 E+03

11 LIME:

Vol. used = 2.50 E+02 kg

(g) = ((vol)*(1000 g/kg))/30 yr

(g) = 8.33 E+03

12 BERMUDA GRASS (seeding):

Vol. used = 4.00 E+02 kg

(g) = ((vol)*(1000 g/kg))/30 yr

(g) = 1.33 E+04

13 MACHINERY:

Total = 5.50 E+00 kg

(g) = ((vol)*(1000 g/kg))/30 yr

(g) = 1.83 E+02

14 SERVICES:

total cost = 5.31 E+06 $pesos/ha (1989)
exch. rate = 2.28 E+03 $pesos/$US (1989)

($US) = ((pesos)*(exch. rate))

($US) = 2.33 E+03

OPERATIONAL INPUTS (per 1 ha/yr)

(Annual Maintenance of Pasture and Cattle)

15 LABOR:

Man-hr = 2.40 E+01 hr/ha/yr

Energy (J) = (man-hr)*((2500 kcal consumed/day)/24 hr)
*(4186 J/kcal)

(J) = 1.05E+07

16 FUEL:

Vol. used = 4.00 E+00 L/ha

Energy (J) = ((vol)*(9235 kcal/L)*(4186 J/kcal))

(J) = 1.55 E+08

17 MACHINERY:

Total = 3.50 E+00 kg

(g) = (Mach. wt.)*(1000 g/kg)

(g) = 3.50 E+03

18 NITROGEN:

Total = 3.60 E+02 kg

(g) = (Fertilizer)*(1000 g/kg)

(g) = 3.60 E+05

19 PHOSPHORUS:

Total = 1.50 E+01 kg

(g) = (fertilizer)*(1000 g/kg)

(g) = 1.50 E+04

20 POTASSIUM:

Total = 8.00 E+01 kg

(g) = (fertilizer)*(1000 g/kg)

(g) = 8.00 E+04

21 LIME:

Total = 2.50 E+02 kg

(g) = (fertilizer)*(1000 g/kg)

(g) = 2.50 E+05

22 MISCELLANEOUS SUPPLIES (value amortized):

total cost = 7.18 E+04 $pesos/ha (1989)
exch. rate = 2.28 E+03 $pesos/$US (1989)

($US) = ((pesos)*(exch. rate))

($US) = 3.15 E+01

23 SERVICES:

total cost = 1.46 E+06 $pesos/ha (1989)
exch. rate = 2.28 E+03 $pesos/$US (1989)

($US) = ((pesos)*(exch. rate))

($US) = 6.42 E+02

PRODUCTION (per 1 ha/yr):

24 CATTLE YIELD:

Total yield = 4.20 E+02 kg/ind.
Energy (J) = (yield)*(ind/ha)*(1000 g/kg)*(4 kcal/gr)
(4186 J/kcal)(0.22 prot)

Table E-8. Summary of EMergy inflows and ratios for different protein production systems in the Coastal Zone of Nayarit, 1989.

EMERGY (E15 sej/yr)	Protein Production System			
	Shrimp (sej/yr)	B-W Tilapia (sej/yr)	F-W Tilapia (sej/yr)	Beef Cattle (sej/yr)
Total Renewable (I)	17.02	69.43	144.0	3.02
Construction	10.12	10.12	34.3	7.2
Operating Costs	39.19	51.60	112.6	2.7
Tot. Purch. Inputs (F)	49.31	61.70	146.9	9.98
Yield (Y)	67.34	131.13	291.0	12.99
TRANSFORMITIES (sej/J)	1.07 E7	5.61 E5	1.24 E6	7.01 E6
Net EMergy Ratio	17.04	69.43	144.0	3.02
Net EMergy Yield Ratio	1.34/1	2.12/1	1.98/1	1.3/1
EMergy Investment Ratio	2.87/1	0.89/1	1.02/1	3.29/1

Table E-9. Summary of shrimp farms in Nayarit, 1989 (Source:SEPESCA).

Municipality	No. of Farms	No. of Ha. built	No. of ha operating	Production (tons)	Avg. Prod. (kg/ha/yr)
Tecuala	3	180	-	-	-
Rosamorada	3	125	65	22	338
Santiago Ixtla.	2	64.5	4.5	2	444
San Blas	20	228	75	17.5	233
TOTAL	28	597.5	144.5	41.5	287

Table E-10. Summary of land use at shrimp farms location, 1987 (Source: SEPESCA; INEGI).

Municipality	Location	Land Use (*)	# Farms	Area (ha)
San Blas				
	San Blas	Ma,H/Ma,Pi/AtpA	4	125
	La Chiripa	Ma,Pi,AtpA,Fsb	12	48
	Chacalilla	Ma,H,H/Ma	2	37
	El Limon	Ma,AtpA	1	4
	L. y Gongora	Ma,AtpA,Pi	1	15
Santiago Ixtla.				
	San Andres	H,Fsb,AtpA,Dc	1	60
	Toro Mocho	AtpA,H,Ma,Fsm	1	4.5
Rosamorada				
	Pericos	Ma,H,AtpA,Fsm	2	65
	Pimientillo	Fsm,AtpA,H/Ma	1	60
Tecuala				
	Paso Hondo	Fsb,Ma,H,Pi,Ehm	1	60
	Quimichis	Fsb,Ma,H,Pi,Ehm	1	60
	Murillos	Atpa,Ehm,Fsb,Ma	1	60

* Land Use clasification

Ma	Mangrove	Fsb	Lower Jungle
H	Halophyte	Fsm	Medium Jungle
AtpA	Rain agriculture	Ehm	Moderate Hydric Erosion
Pi	Induced grassland	Dc	Coastal Dunes

Table E-11. EMergy costs and fish yields per year for gill net, cast and long-line fishing, in Bahia de Banderas, Nayarit, 1989.

Note	Item	Raw Units	Trans-formity (sej/unit)	Solar EMergy (E15 sej)	Macroeconomic Value (E2 1989 US$)
0	Renewable	4.24 E+10 J	5.40 E+06	228.80	740.44
	PURCHASED				
1	Fuel	3.13 E+11 J	5.30 E+04	16.57	53.62
2	Misc. Goods & Svcs	5.48 E+03 $	3.09 E+12	16.93	54.78
3	Salary	1.24 E+04 $	3.09 E+12	38.42	124.33
4	Boat	1.24 E+02 $	3.09 E+12	0.38	1.24
5	Motor	7.45 E+02 $	3.09 E+12	2.30	7.45
	TOTAL PURCHASED EMERGY			74.60	241.42
6	Fish Yield	4.24 E+10 J	7.16 E+06	303.39	981.86

Footnotes to Table E-11

1 Fuel use:

gasoline	:	8.64 E+03 l/yr/panga	
oil	:	2.40 E+02 l/yr/panga	
gas	:	2.88 E+02 kg/yr/panga	(@ 1 l/kg)

Energy (J):

gasoline: (8640 l/yr)*(8179 kcal/l)*(4186 J/kcal) = 2.96 E+11 J
oil: (240 l/yr)*(9235 kcal/l)*(4186 J/kcal) = 9.28 E+09 J
gas: (288 Kg/yr)*(1 l/kg)*(6234 kcal/l)*(4186 J/kcal) = 7.52 E+09 J

TOTAL (J) = 3.13 E+11 J

2 Miscellaneous Goods & Services includes the following:

Item	Cost (Pesos)	Cost (US$)	Life span	Cost/yr (US$)
Gill net	1.85 E+06	6.87 E+02	3 yrs	228.97
Cast line	1.38 E+05	5.12 E+01	1 yr	51.19
Long line	4.36 E+05	1.62 E+02	1 yr	162.32
Ice	1.58 E+06	5.90 E+02	1 yr	589.72
Fuel	6.13 E+06	2.28 E+03	1 yr	2283.84
Oil	3.12 E+06	1.16 E+03	1 yr	1161.58
Gas	1.44 E+05	5.36 E+01	1 yr	53.61
Others	2.54 E+06	9.47 E+02	1 yr	947.13
			TOTAL $US =	5478.37

3 Salary: 3/4 of net profit is for fishermen & 1/4 for boat

Net profit = (total catch value)-(operating cost)

total catch value = 5.26 E+07 $pesos
operating costs = 8.05 E+06 $pesos

Salary = 3/4*(net profit)

Salary = $3.34 E+07 @ 2686 $pesos/$US = 1.24 E+04 $US

4 Boat: replacement costs estimated as:

Replacement cost (RC)	=	(cost of new boat)/(life span of boat)
New boat's cost	=	5.00 E+06 $pesos
Boat's life span	=	1.50 E+01 yrs
Boat RC	=	3.33 E+05 $pesos/yr
Exchange rate	=	2.69 E+03 $pesos/$ US
Boat RC in $US	=	1.24 E+02 $US

5 Motor: replacement costs estimated as:

Replacement cost (RC)	=	(cost of new motor)/(life span of motor)
New motor's cost	=	1.00 E+07 $pesos
Motor's life span	=	5.00 E+00 yrs
Motor RC	=	2.00 E+06 $pesos/yr
Exchange rate	=	2.69 E+03 $pesos/$US
Motor RC in $US	=	7.45 E+02 $US

6 Fish Yield:

Total fish catch/yr = 1.15 E+04 kg

Energy in fish = (11500 kg)*(1000 gr/kg)*(4 kcal/gr)*(4186 J/kcal)
*(22 % protein)
= 4.24 E+10 J

Table E-12. EMergy costs and fish yields per year, for small pangas in Bahia de Banderas, Nayarit, 1989.

Note	Item	Raw Units	Transformity (sej/unit)	Solar EMergy (E15 sej)	Macroeconomic Value (E2 1989 US$)
0	Renewable	2.03 E+10 J	5.40 E+06	109.42	354.12
	PURCHASED				
1	Fuel	2.12 E+11 J	5.30 E+04	11.26	36.43
2	Misc. Goods & Svcs	3.48 E+03 $	3.09 E+12	10.75	34.79
3	Salary	5.68 E+03 $	3.09 E+12	17.54	56.75
4	Boat	1.74 E+02 $	3.09 E+12	0.54	1.74
5	Motor	7.46 E+02 $	3.09 E+12	2.31	7.46
	TOTAL PURCHASED EMERGY			42.39	137.17
6	Fish Yield	2.03 E+10 J	7.49 E+06	151.81	491.30

Footnotes to Table E-12

1 Fuel use

gasoline : 6.00 E+03 l/yr/panga
oil : 1.80 E+02 l/yr/panga

Energy (J):

gasoline: (6000 l/yr)*(8179 kcal/l)*(4186 J/kcal) = 2.05 E+11 J
oil: (180 l/yr)*(9235 kcal/l)*(4186 J/kcal) = 6.96 E+09 J

TOTAL (J) = 2.12 E+11 J

2 Miscellaneous Goods & Services includes the following:

Item	Cost (Pesos)	Cost (US$)	Life span	Cost/yr (US$)
Gill net	2.25 E+06	8.39 E+02	2 yrs	419.40
Ice	1.32 E+06	4.91 E+02	1 yr	491.44
Fuel	4.26 E+06	1.59 E+03	1 yr	1586.00
Oil	2.34 E+06	8.71 E+02	1 yr	871.18
Others	2.99 E+05	1.11 E+02	1 yr	111.32
			TOTAL $US =	3479.34

3 Salary (3/4 of net profit is for fishermen & 1/4 for boat):

Net profit = (total catch value)-(operating cost)

total catch value = 2.69 E+07 $pesos
operating costs = 6.60 E+06 $pesos

Salary = 3/4*(net profit)

Salary = $1.52 E+07 @ 2686 $pesos/$US = 5.68 E+03 $US

4 Boat: replacement costs estimated as:

Replacement cost (RC)	=	(cost of new boat)/(life span of boat)
New boat's cost	=	7.00 E+06 $pesos
Boat's life span	=	1.50 E+01 yrs
Boat RC	=	4.67 E+05 $pesos/yr
Exchange rate	=	2.69 E+03 $pesos/$US
Boat RC in $US	=	1.74 E+02 $US

5 Motor: replacement costs estimated as:

Replacement cost (RC)	=	(cost of new motor)/(life span of motor)
New motor's cost	=	1.00 E+07 $pesos
Motor's life span	=	5.00 E+00 yrs
Motor RC	=	2.00 E+06 $pesos/yr
Exchange rate	=	2.69 E+03 $pesos/$US
Motor RC in $US	=	7.46 E+02 $US

6 Fish Yield:

Total fish catch/yr = 5.50 E+03 kg

Energy in fish = (5500 kg)*(1000 gr/kg)*(4 kcal/gr)*(4186 J/kcal)
*(22% protein)
= 2.03 E+10 J

Table E-13. EMergy costs and fish yields per year, for large pangas in Bahia de Banderas, Nayarit, 1989.

Note	Item	Raw Units	Trans-formity (sej/unit)	Solar EMergy (E15 sej)	Macroeconomic Value (E2 1989 US$)
0	Renewable	5.53 E+10	5.40 E+06	298.43	965.79
	PURCHASED				
1	Fuel	1.07 E+12 J	5.30 E+04	56.53	182.95
2	Misc. Goods & Svcs	1.86 E+04 $	3.09 E+12	57.47	185.98
3	Salary	2.23 E+04 $	3.09 E+12	68.81	222.69
4	Boat	2.01 E+02 $	3.09 E+12	0.62	2.01
5	Motor	1.38 E+03 $	3.09 E+12	4.28	13.84
	TOTAL PURCHASED EMERGY			187.71	607.46
6	Fish Yield	5.53 E+10 J	8.80 E+06	486.14	1573.26

Footnotes to Table E-13

1 Fuel use

gasoline : 3.00 E+04 l/yr/L-panga or m-boat
oil : 9.00 E+02 l/yr/L-panga or m-boat
gas : 1.80 E+02 kg/yr/L-panga or m-boat (@1 l/kg)

Energy (J):

gasoline: (30000 l/yr)*(8179 kcal/l)*(4186 J/kcal) = 1.03 E+12 J
oil: (900 l/yr)*(9235 kcal/l)*(4186 J/kcal) = 3.48 E+10 J
gas: (180 kg/yr)*(1 l/kg)*(6234 kcal/l)*(4186 J/kcal) = 4.70 E+09 J

TOTAL = 1.07 E+12 J

2 Miscellaneous Goods & Services includes the following:

Item	Cost (Pesos)	Cost ($US)	Life span	Cost/yr ($US)
Echosound	3.20 E+06	1.19 E+03	5 yrs	238.27
Cast line	2.18 E+05	8.13 E+01	1 yr	81.31
Long line	5.41 E+05	2.01 E+02	1 yr	201.41
Ice	5.94 E+06	2.21 E+03	1 yr	2211.47
Fuel	2.13 E+07	7.93 E+03	1 yr	7930.01
Oil	1.17 E+07	4.36 E+03	1 yr	4355.92
Gas	9.00 E+04	3.35 E+01	1 yr	33.51
Food	8.16 E+06	3.04 E+03	1 yr	3037.97
Potable water	6.48 E+05	2.41 E+02	1 yr	241.25
Others	7.16 E+05	2.67 E+02	1 yr	266.57
			TOTAL $US =	18597.69

3 Salary (3/4 of net profit for fishermen & 1/4 for boat):

Net profit = (total catch value)-(operating cost)

total catch value= 1.28 E+08 $pesos
operating costs = 4.77 E+07 $pesos

Salary = 3/4*(net profit)

Salary = $5.98 E+07 @ 2686 $pesos/$US = 2.23 E+04 $US

4 Boat : replacement costs estimated as:

Replacement cost (RC)	= (cost of new boat)/(life span of boat)
New boat's cost	= 8.10 E+06 $pesos
Boat's life span	= 1.50 E+01 yrs
Boat RC	= 5.40 E+05 $pesos/yr
Exchange rate	= 2.69 E+03 $pesos/$US
Boat RC in $US	= 2.01 E+02 $US

5 Motor : replacement costs estimated as:

Replacement cost (RC)	= (cost of new motor)/(life span of motor)
New motor's cost	= 1.86 E+07 $pesos
Motor's life span	= 5.00 E+00 yrs
Motor RC	= 3.72 E+06 $pesos/yr
Exchange rate	= 2.69 E+03 $pesos/$US
Motor RC in $US	= 1.38 E+03 $US

6 Fish Yield:

Total fish catch/yr = 1.50 E+04 kg

Energy in fish = (15000 kg)*(1000 gr/kg)*(4 kcal/gr)*(4186 J/kcal)
*(22% protein)
= 5.53 E+10 J

Table E-14. Summary of EMergy inflows and ratios for Pangas, using different fishing methods, at Bahia de Banderas, 1989.

EMERGY (E15 Sej/J)	Fishing Methods and Size or Capacity of Pangas		
	Overall (*) (22 ft. length)	Gill Net (2.43 m^3)	Long & Cast Lines (2.87 m^3)
Total Renewable (I)	228.8	109.42	298.43
Equipment	2.68	2.85	4.9
Operating Costs	71.92	39.55	182.8
Tot. Purch. Inputs (F)	74.60	42.39	187.71
Yield (Y)	303.4	151.8	486
TRANSFORMITIES (Sej/J)	7.16 E6	7.49 E6	8.8 E6
Net EMergy Ratio	228.8	109.4	298.4
Net EMergy Yield Ratio	4.07/1	3.6/1	2.6/1
EMergy Investment Ratio	0.33/1	0.38/1	0.63/1

* Overall (gill net, cast, and long lines)

SECTION 3F: EMergy Analysis of Public Health Options

by Javier Venegas

INTRODUCTION

In its 1986 State of the Environment Report, The United Nations declared:

1. People depend for their well-being on the health of the societies in which they live. This depends in turn on a decent level of sustained economic development, on a healthy environment and a proper use of its resources. The achievement of sustained development, the promotion of health, and the rational use of environmental resources are simply inseparable.

2. All over the world, in developed and developing countries alike, environmental degradation is undermining development and damaging human health. This ill-health saps the strength of the work force, and so further obstructs development, leads to greater environmental loss, and causes even more disease. Yet this vicious circle can be broken--and reversed. If the environment is improved, both economies and people will become healthier. (UNEP, 1986).

Public Policy: Interfacing Health with Humans, Economics, and the Environment.

The People. Since the objective of this study is to plan for and make recommendations on managing coastal development at a level that is both sustainable and compatible with a healthier environment, it would be incomplete if humans and their health were not considered. According to The World Resources Institute (WRI, 1992), achieving sustainable development also means redirecting or reallocating resources to ensure that basic human needs--such as literacy, primary health care, and clean water--are met first. Modification of the environment is a direct result of development projects. Any new development project or expansion of an existing facility can induce environmental degradation with adverse effects on public health (Lee, 1985; UNEP, 1986; Sutlive et al., 1987; WRI, 1992).

However, improving the health status of third world nations is not an easy task. It involves a complex meshing of factors which cannot be solved simply through modernization or development of medical care systems. All too often, policy makers and political leaders think that health and medicine are synonymous and, as a result, also think that the promotion of health requires the presence of hospitals, the training of specialized physicians, and purchasing the latest medical technology. Many studies have now demonstrated that, historically, health improvements have been associated with better environmental habitats, nutrition and education, and not so much with the presence of medical facilities and personnel (Sutlive et al., 1987).

To insure that the adverse effects of development can be counteracted, and to predict the levels of sustainable health care needed by a growing population, this EMergy analysis was undertaken. The main object was to develop a net energy analysis of rural health care as a means of helping guide policy, and to determine appropriate levels for the provision of health care services.

The Economy. Usually, if plans or projects are not economically feasible, then priority or consideration is not given to them. Globally and historically, it is an accepted fact that providing health care services to people saves lives, productivity, and money. In recent years, more importance and priority have been focused on preventive health care, due to its many advantages--especially economic ones. The premise is that, if preventive medical services can be provided to a given population, much suffering and death can be avoided, human productivity will increase, and expenditures on health will be care reduced. These factors will then yield higher economic well-being and, therefore, an excellent investment for the economy and society. The importance of this relationship is emphasized by former World Bank President Robert McNamara's address before the UN Conference on Human Environment in 1972:

> In those instances where a development project may threaten to create or intensify an existing disease problem, the Bank incorporates in the loan agreement appropriate arrangements for the requisite preventive health care measures.

In addition to including measures for disease prevention, worker safety, and health care in development projects, the World Bank has undertaken projects that directly improve the health care of people in developing countries (Lee, 1985).

The Environment. Historically, since most of the focus of the medical community has been on the care and well-being of humans as separate entities, it has almost completely forgotten about the well-being of the environment, and how its condition directly affects human health. Modern medicine has failed to emphasize the important relationship that exists between human health and the environment. It has finally become obvious to many that if we cannot maintain a healthy environment we will not be able to maintain a healthy population. We cannot have one without the other.

Most diagnostic, treatment and preventive medicine measures have been developed and kept largely within the traditional public health and medical circles without cooperative efforts or ties with other disciplines such as the environmental and ecological sciences. The results of this separation of disciplines has been global environmental degradation and infringement upon our health and quality of life. It may be that many of the degenerative diseases and cancers which the industrialized nations face today could exist at significantly reduced levels, or might even have been prevented altogether, had appropriate development and industrial policies been implemented from the beginning. What good has it done to reduce the contagious diseases in these countries if they are only being substituted by others which have been created through industrialization?

The increasing contamination of the water, soil and air on which our lives depend are examples of macroscopic environmental-medical issues. These include recent issues such as global warming and the consequences of the depletion of the ozone layer, which may be causing an increased penetration of solar and other cosmic radiation particles. Little is known about the consequences (genetic, cellular, and tissue) of radiation and gravitational influences upon human health. In its Environmental and Health Report of 1986 (UNEP, 1986), The United Nations reminded us that:

> everyone on earth is exposed to ionizing radiation from natural environmental sources--e.g. radioactivity from the earth's crust and cosmic rays from outer space--and that these natural and inescapable sources give rise to the highest average doses to which the human population is exposed.

At the present time, the health care system of Nayarit, Mexico is almost wholly concerned with treatment, having little resources for preventive medicine. It is the objective of this analysis to evaluate the costs and benefits of the existing health care system, and then to suggest appropriate levels of additional resources that might be directed into this system as preventive care. The final goal is to establish a quantitative basis for deriving additional resources for establishing a new area of medicine called Environmental Medicine (or Medical Ecology).

METHODS

The purpose of this analysis was three-fold:

1. To evaluate the costs and benefits of the existing health care system within the coastal zone of Nayarit
2. To project future health care needs based on potential growth of development and population
3. To evaluate the additional benefits that might result from increased funding for preventive medicine

A net EMergy yield ratio for health care was calculated using the EMergy costs of the health care system and the savings in "productivity" that resulted from disease treatment. Saved productivity was estimated based on the number of hours of work that were saved as a result of treating a disease. When treated, an individual returns to the work force earlier than if the disease was allowed to run its course. In addition, estimates of the number of deaths that would occur if disease was not treated were added to the labor productivity based on the loss of work hours over a life-time should a laborer die.

The contribution for improved plans will call for an ecological-economic assessment of health care based on EMergy analysis. This alternative analysis is offered because much controversy and disagreement exist regarding the applications of traditional benefit-cost analysis techniques to issues such as these (National Research Council, 1990). The results will hopefully lead to the final goal of achieving an acceptable level of sustainable development, which will be compatible at all environmental levels.

EMergy Analysis of Health Care

An EMergy analysis of health care for Nayarit's coastal rural counties was conducted. This analysis presents the health conditions which exist at a regional level, and how they are intimately associated with the environment and the economy. It demonstrates how a positive or negative change occurring at one level inherently affects the others. This should be of special interest to economists, developers, and government leaders, since the economic and ecological success or failure of a development project will most certainly rely on the ability to establish harmonious (or sustainable) relationships between the three sectors: health, economic development, and the environment.

The analysis is based on twelve of the most frequent disease categories for 1990 affecting Nayarit's coastal environments, as reported by the State's official public health agency, la Secretaria de Salud. For the purpose of gathering a more reliable data and information base, personal interviews, correspondence, and telephone conversations were conducted with officials from this agency (at the state and federal level), and with the Instituto Mexicano del Seguro Social and Instituto de Seguridad y Servicios Sociales de los Trabajadores del Estado.

RESULTS

EMergy Systems Analysis

The EMergy systems diagram is shown in Figure F-1. This figure illustrates the interrelationships (arrows) which exist between the environment, humans, disease, medicine, and economic development along the coastal zone of Nayarit.

On the outside margin, at the top and left sides of the diagram, are the principal sources of energy providing the basis for life along the coastal zone. These sources are the driving forces for the coastal marine and terrestrial systems, which in turn support the food chain base on which people survive, as well as providing the resources for their economic production and development.

If any vectors or etiologic agents (EA) such as pathogenic microorganisms, pesticides, heavy metals, radioactive material, or other toxins invade or contaminate at any level along these pathways, disease can set in. As shown in the diagram, the spread of disease by these agents (EA) can be through vectors, via terrestrial (including food), water, and air-borne mechanisms. Once it attacks one or more individuals, if the disease is communicable, it can also spread very rapidly through people and thus give way to an epidemic. Of special interest to this study will be the two pathways (via the population and economic icons) that follow:

1. If the hygienic and sanitation conditions are precarious, a vicious cycle for a given disease is readily established, and can be difficult to control.
2. If inappropriate economic production and development exists, the pollution and toxic waste produced by industry will worsen and further complicate this cycle. Occupational diseases and accidents may be created as a result.

The results of the above two mechanisms are demonstrated by way of the Waste & EA and Vector pathways which eventually contaminate the vital aerial, terrestrial, and aquatic environments, thereby further degrading them and eventually resulting in the recycling of diseases (Figure F-1).

The interest in these two pathways comes from the fact that developing countries, such as Mexico, suffer mostly from the first one. It is the one which has been virtually eliminated in the developed countries. Meanwhile, the second pathway applies almost exclusively to the industrialized world. However, since most developing nations are aspiring to reach the industrial levels of those of the developed ones, some, like Mexico, are already beginning to suffer the ill effects of both pathways (SSA, 1990). The irony is that, while people in developing countries suffer mainly from communicable diseases largely caused by underdevelopment, people in industrialized countries suffer mostly from degenerative diseases (mainly cardiovascular and cancer) caused mostly by overconsumption and inappropriate or overdevelopment (Eisenbud, 1978; Lee, 1985; UNEP, 1986; WRI, 1992).

Productivity and Money Saved by Medical Treatment

Table F-1 summarizes the results of reported and estimated morbidity and mortality cases along Nayarit's coastal counties. Twelve of the most frequently reported disease categories for this region are listed (columns) and compared or matched against other factors (rows). The purpose of this matrix was to derive estimates regarding the amount of productivity saved (in person-days or hours) as well as money saved (in earnings) on a yearly basis as a result of medical treatment. The information for Table F-1 was derived from the following sources for 1990:

1. Direct communication and correspondence with health officials at the state and federal levels.
2. First-hand information from the government and private industry's main health care providers and insurers including:
    a. La Secretaria de Salud (SSA).
    b. El Instituto Mexicano del Seguro Social (IMSS).
    c. El Instituto de Seguridad y Servicios Sociales de los Trabajadores del Estado (ISSSTE).
    d. La Secretaria de la Defensa Nacional (SDN).
    e. La Secretaria de Marina (SM).
3. The principle federal statistical agency, el Instituto Nacional de Estadistica, Geografia e Informatica (INEGI).
4. Personal knowledge and experience.

EMergy Evaluation of Rural Health Care

Results of the EMergy analysis of rural health care are given in Table F-2. This table is divided into three main sections: Renewable Resources (or free inputs), Purchased Inputs (costs), and Benefits. It summarizes the principle energy inputs and outputs (including costs and benefits) for the coastal zone rural health care system in Nayarit. The purpose is to assess the value of this system in terms of how ecologically and economically beneficial it is, so sound policies for health care can be recommended to government and developers when considering future economic growth and development. The analysis is based on assessing the balance of energy inputs and outputs into the system, based on EMergy analysis techniques previously described.

Values for the renewable resources were derived from the EMergy Analysis of Nayarit section of this report (see Section 3B), and the values for the benefits section are from Table F-1. Wave energy provides the highest solar EMergy input to the coastal zone of Nayarit (1570.75 E+18 sej/yr). The total sum of the renewable EMergy inputs is 1572.15 E+18 sej/yr. Macroeconomic contribution from renewable resources is $473.54 E+06 US$. The renewable component is included as a reference point for comparisons with the purchased inputs, and the purchased inputs (costs) includes all the major expenses for developing, operating, and maintaining the rural health care system. The values are based on a typical rural clinic operating 24 hours/day every day of the year. It maintains a professional staff of 2 (an

M.D. and a nurse) on-call 24 hours/day, who average approximately 8 hours/day of actual active working time, including weekends and holidays.

The principle expenditures in solar EMergy are: the construction costs (12.67 E+18 sej/yr), labor (10.98 E+18 sej/yr), and medical supplies (6.33 E+18 sej/yr). Their respective macroeconomic values are: \$3.81 E+06 US\$, \$3.31 E+06 US\$, and \$1.91 E+06 US\$. The total sum of the purchased inputs is 32.58 E+18 sej/yr, or \$9.81 E+06 US\$.

The potential productivity which is saved through medical treatment for the coastal counties of Nayarit was calculated as 1082.52 E+18 sej/yr (\$326.06 E+06 US\$). The potential money in earnings saved because of medical treatment was calculated as being 1109.13 E+18 sej/yr, or \$334.07 E+06 US\$.

DISCUSSION

The findings presented above provide strong evidence that an improved health care system is beneficial for the people and economy of Nayarit. The results indicate that a total of 466 million hours (58 million person-days) could potentially have been saved through medical treatment in 1990. As for the money saved in earnings, a total of \$902 billion pesos or (\$334 million US dollars) could potentially have been saved in 1990. As noted previously, these figures are just for the coastal counties of Nayarit, which represent about 52% of the state's total estimated population of 856,722 for 1990 (SSA, 1990). Adding the state's remaining 48% to the productivity and earnings-saved values gives a total of 86,136,000 (8.62 E+07) person-days and \$13.35 E+11 pesos (\$4.94 E+08 US\$), respectively. These are achievable figures if the appropriate planning and resource allocations are provided.

In comparing the results of the EMergy values of each age group and of their deaths, the values are inversely related, in contrast to the monetary and productivity values obtained. Thus, as a person grows older, his productivity and monetary contributions to society decrease, while his EMergy (embodied energy) value increases. So in terms of EMergy--as in the form of information such as knowledge, genes, etc.--society suffers greater losses when an elderly person dies than when a child does. But, in terms of economic potential, it is the child who has the greater value.

EMergy Evaluation of Rural Health Care

The results of Table F-2 demonstrate that investing in health care for the purpose of keeping a given population healthy is profitable for the economy. Applying the results from the EMergy analysis in Table F-2, certain EMergy ratios can be derived in order to assist in the ecological-economic assessment of the health care system (refer to Figure F-1). A monetary evaluation comparing the total sum of the costs (item 13) against the money which can potentially be saved in earnings (item 15) results in a 34 to 1 net benefit in terms of money, solar EMergy, and macroeconomic value (second, fourth and fifth columns). The solar EMergy comparisons (fourth column) for the productivity which is saved through medical treatment shows a 33 to 1 advantage. In EMergy terms, this comparison is referred to as the **Net EMergy Yield Ratio**. It is defined as the EMergy of an output divided by the EMergy of the input. It indicates how viable or beneficial a production process is for the economy. As a reference, a 6 to 1 ratio or better is considered competitive at present world economic levels. The higher the ratio, the better for any given system (Odum, 1983,1992).

Thus, the results demonstrate that there is a tremendous advantage for investing in health care, since the net EMergy yield ratio for productivity came out to 33 to 1, and the potential savings in earnings resulted in a 34 to 1 ratio. They also indicate that, for every unit of purchased input (in solar EMergy) invested in health care, 33 units of productivity and 34 in earnings are gained for the economy. This means that the remaining 32 units of productivity and 33 of money become available to benefit the economy in other ways. Employees will produce more and, since there earnings are increased, they will tend to spend more. Therefore, more money will circulate and become available for the local economy.

In terms of the environment, if health care can maintain the communicable diseases and pollution levels to a minimum, the environment will also benefit to a very high degree. For example, as depicted in the EMergy systems diagram (Figure F-1), if a population is suffering from a communicable disease, depending on its transmission mechanisms, the disease will contaminate any one or several of the environmental components (air, water or soil). Once this occurs, the subsequent degradation of said component, plus the recycling of the disease, will ensue. Certain diseases will even spread to other components of a system such as any susceptible flora and fauna in its path. These can then act as vectors for the further transmission or recycling of the disease.
(Feachem et al., 1977; Lee, 1985; SSA, 1990a,b). The scenario just described is a very typical and common one for the coastal zone of Nayarit. With proper planning and investments, much can be done to minimize or, in some cases, even eradicate some of these precarious health conditions.

SUMMARY AND RECOMMENDATIONS

The responsibility for solving health and other socio-economic problems has generally fallen on the government, which usually lacks the resources, technology, skills, and infrastructure to successfully accomplish this task (Bryant and White, 1982; Lee, 1985; Sutlive et al., 1987; UNEP, 1986; WRI, 1992.). Because of this, developers are now being asked to take on a greater share of this responsibility. They have been specifically targeted because of the changes that are frequently imposed on the quality of life of the people who live wherever development projects are constructed.

A more equitable plan would call for direct cooperative participation between the developers, government, and the local communities in planning for, and incorporating health care and other public welfare formulas into development projects. The recommendations that follow are general enough in nature to be applicable to almost any region similar economically, physically, and socially to Nayarit's, and are based on the results of the EMergy analysis. More detailed and specific recommendations are provided in the first volume of this study.

Because of the growing health problems arising from the contamination of the environment at all levels, it is proposed that all those involved in the public health and medical fields should:

1. Take more of a leadership role on environmental and ecological issues, and become primary advocates regarding these issues.
2. Give priority to, and designate a reasonable percentage of their research and development projects and monies to environmental and ecological issues related to health.

3. Propose and develop a new area of medicine entitled Environmental Medicine (or Medical Ecology). This would help to close the aforementioned gap which exists between human health, medicine, and environmental health, and meet the growing demand for medically-related environmental issues. Some of the tasks and roles this field would engage in include:

   a. Health education and preventive medicine activities related to the environment, in cooperation with leaders and authorities in the fields of public health, education, community planning and development, etc.
   b. Monitoring, assessing, and reporting natural or human induced environmental problems endangering human health.
   c. Be an active voting member of the state's review boards and committees regarding approval of development projects (discussed in Volume 1, Part 2 of this report).
   d. Participate in research/consultation to the state regarding issues related to health, medicine and the environment.
   e. Participate as the state's liaison between the medical, public health, environmental, and ecological sectors.
   f. Assist the federal and state authorities in identifying, monitoring, and reporting environmental violations, especially those directly endangering the health and welfare of the people.
4. Establish direct avenues of communication and joint venture projects with agencies and academic departments from the environmental and ecological disciplines.
5. Serve as consultant and source for information and data regarding health, medicine and environmental matters--especially for developers and planners.
6. Organize, possibly under the proposed state's medical ecology office, yearly (or as needed), conferences order to identify and assess health problems, recommend possible solutions, and prioritize the health and medically related environmental problems. Participants in these conferences should include knowledgeable authorities in the related disciplines including: medical doctors, public health and sanitation officials, planners, ecologists, environmentalists, educators, leaders or representatives from the government, community, and industrial sectors, etc. Once the issues have been identified and prioritized, steps towards implementing the suggested solutions should ensue.
7. Address current water-related problems, allowing no further development unless proper water utilization, treatment, and disposal plans are included. This includes obligating developers who are planning future projects to allocate a certain percentage of their energies towards solving current and future water problems that might surface as a result of their project. Depending on their resource capacity and the local deficiencies, their contribution can be in the form of money, technology, trained personnel, building material, etc.

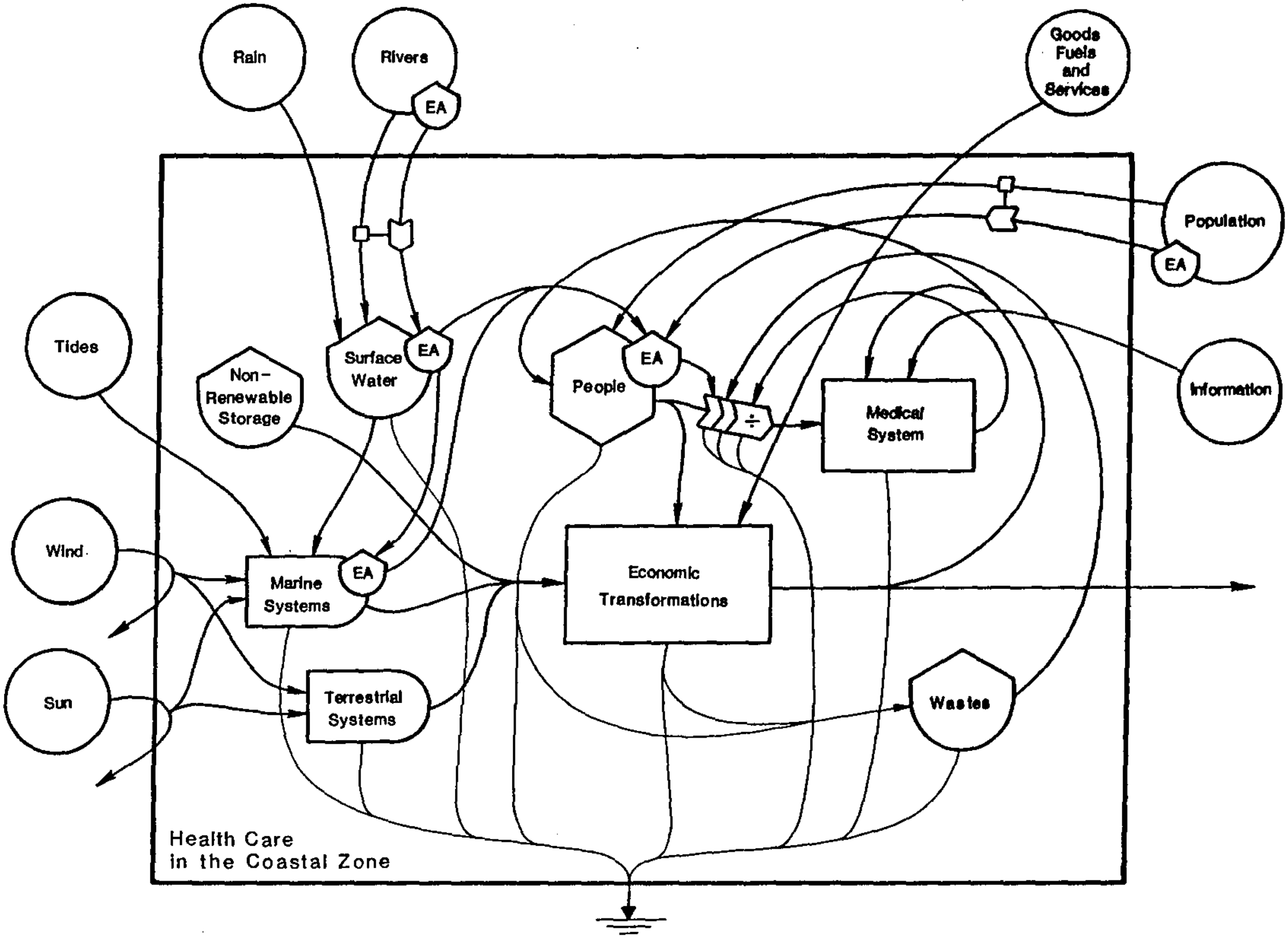


Figure F-1. Energy systems diagram of health care showing the role of the medical system on preventing and curing disease. EA = Etiologic Agents (viral, bacterial, parasitic, mycotic, and toxins.

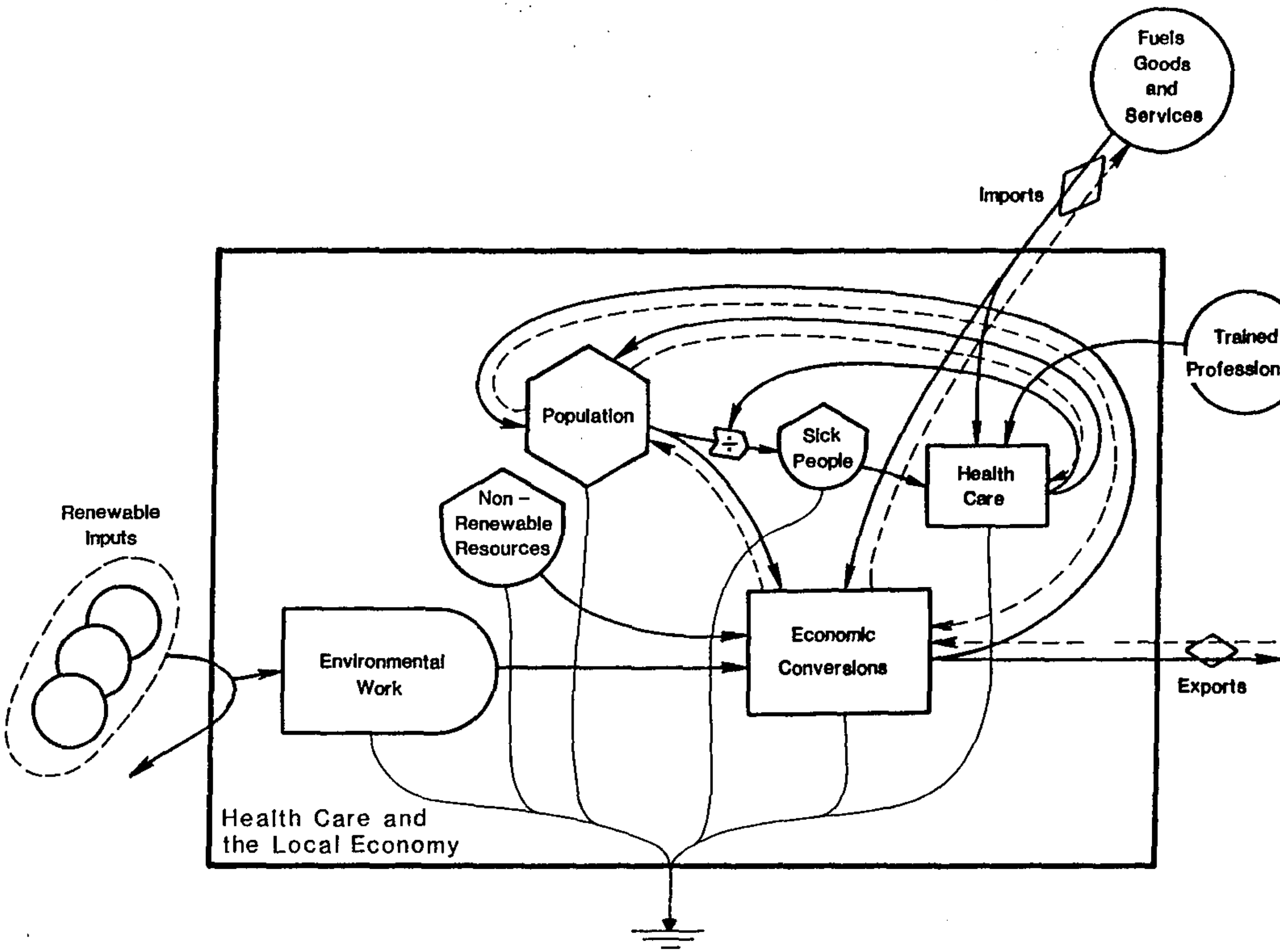


Figure F-2. Energy systems diagram of health care in the local economy.

Table F-1. Estimates on productivity and money saved (in earnings) as a result of medical treatment for reported and unreported cases plus EMergy values, along the coastal counties of Nayarit, Mexico for 1990.

Illness	Acute respir. infections	Amebiasis	Intest.infect. (diarrhea)	Intest. parasitosis	Tonsillitis/ Pharyngitis	Animal stings (Scorpion)
1. Total # of cases reported by SSA (#):	2.35E+04	7.52E+03	5.95E+03	5.87E+03	4.44E+03	1.02E+03
2. Sum of cases only in productive years (#):	3.41E+04	5.07E+03	5.30E+03	4.88E+03	4.62E+03	1.21E+03
(%):	48.30%	22.50%	29.70%	27.70%	34.70%	39.70%
3. Avg. productive hrs lost if not trt'd. (per person)*	16 hrs	18 hrs	16 hrs	20 hrs	16 hrs	28 hrs
4. Avg. productive hrs saved if trt'd.(per person)**	8 hrs	10 hrs	8 hrs	12 hrs	8 hrs	20 hrs
5. Non-death prod. cases (in hrs) lost if not trt'd:	5.44E+05 hrs	8.98E+04 hrs	8.46E+04 hrs	9.71E+04 hrs	7.40E+04 hrs	2.30E+04 hrs
6. Prod. hrs lost to death when not trt'd:	6.96E+06 hrs	8.51E+06 hrs	1.17E+06 hrs	1.88E+06 hrs	0.00E+00 hrs	4.03E+07 hrs
7. Hrs of prod'n saved when trt'd by all instit's***	2.73E+05 hrs	5.07E+04 hrs	4.24E+04 hrs	5.85E+04 hrs	3.70E+04 hrs	2.42E+04 hrs
8. Productive hrs lost to unreported non-death illnesses:	1.80E+05 hrs	4.49E+04 hrs	5.08E+04 hrs	4.37E+04 hrs	7.40E+03 hrs	1.15E+03 hrs

Table F-1. Continued.

Total # of cases in productive years: (sum of row 2 for SSA)	6.53E+04		
Total non-death prod. cases (in hrs) lost if not treated:	(1.34E+06 hrs)*(3)	=	4.03E+06 hrs/yr
Total productive hrs lost to death when not treated:	(1.42E+08 hrs)*(3)	=	4.25E+08 hrs/yr
Total hrs of production saved when treated by all institutions:	(9.08E+05 hrs)*(3)	=	2.72E+06 hrs/yr = 2.72E+6hrs/8hrs
		=	1.13E+05 person-days
Total productive hrs lost to unreported non-death illnesses:	(3.39E+05 hrs)*(3)	=	1.02E+06 hrs/yr
Total hours of production that could be saved if those untreated death and non-death cases were treated, plus the treated # of cases, in person-days:	(4.03E+06)+(4.25E+08)+(2.72E+06)+(1.02E+06)+(3.51E+07-5%) = 4.66E+08 hrs/8 hrs	=	5.82E+07 person-days
Amount saved as a result of treatment: (based on medium wage for 1990 of $15,500 pesos/day)	(15,500/8)*(4.66E+08)	=	9.02E+11 pesos = 3.34E+08 US$/yr

NOTES:

1. The # of cases reported under each disease were actual data provided by The SSA. In order to estimate the total # of cases treated by all institutions along the coastal zone, each total # of cases reported under each disease & by age grp was extrapolated (multi by 3) in the summary section.
   a. The 1990 total state population was est'd at 856,722. The coastal popualtion = 52% (451,949) of State's.

2. Productive hrs shown lost to illnesses reflect the fact that with insidious diseases, patients will continue working the first 1-2 days before seeking help while the ones with acute onsets will seek care the first day. Therefore, the hrs shown, do not necessarily reflect the duration of the disease but rather the hrs not actually working at a job or at home.
3. Age of economically productive years: 15-65 yrs
4. Avg. # of economically productive years/person: 50 yrs
5. Avg. productive hrs/day: 8.00 (weekdays: 8 hrs at work + 2 hrs at home; Sat's: 4 hrs; Sun's: 2 hrs)
6. Avg. productive hrs/year 8*360 = 2880 (excludes 5 holidays/yr)
7. Avg. productive hrs/lifetime: 2880*50 = 144000 hrs

\# The total for item 10 includes the unreported non-death cases plus the pre-productive mortality cases from which 5% was subtracted (3.51E+07-5% = 3.34E+07 hrs/yr) to exclude those lives lost even when trt'd.

\## Avg EMergy per Age Group is calculated multiplying the median for that age group by the EMergy/capita (7.57E+15 sej/person) for Mexico. Please refer to Glossary for definition of EMergy.

* If patient was cured spontaneously by letting illness run its natural course without medical intervention & based on the average 8-hr/day productive cycle at home & work.

** Hrs reflect only those after patient was treated and well enough to resume his productive cycle.

*** Due to medical treatment by all instit's (SSA, IMSS, ISSSTE, SDN, & SM) along the coastal zone. Obtained multiplying item #2 by item #4.

Table F-1. Continued.

Illness	Trauma & Poisons	Paratyphoid & Salmonellosis	Pneumonia & Bronchopneumonia	Malaria & Dengue	Hypertension (complications)	Others
1. Total # of cases reported by SSA (#):	9.88E+02	7.81E+02	5.43E+02	5.74E+02	5.21E+02	2.90E+03
2. Sum of cases only in productive years (#):	1.03E+03	7.43E+02	5.82E+02	1.24E+03	1.19E+03	5.39E+03
(%):	34.70%	31.70%	35.70%	72.00%	76.00%	62.00%
3. Avg. productive hrs lost if not trt'd. (per person)*	56 hrs	112 hrs	80 hrs	168 hrs	16 hrs	24 hrs
4. Avg. productive hrs saved if trt'd.(per person)**	48 hrs	92 hrs	62 hrs	148 hrs	8 hrs	14 hrs
5. Non-death prod. cases (in hrs) lost if not trt'd:	5.74E+04 hrs	6.09E+04 hrs	4.34E+04 hrs	1.25E+05 hrs	1.83E+04 hrs	1.26E+05 hrs
6. Prod. hrs lost to death when not trt'd:	3.12E+05 hrs	1.91E+07 hrs	3.51E+06 hrs	3.95E+07 hrs	8.29E+05 hrs	1.95E+07 hrs
7. Hrs of prod'n saved when trt'd by all instit's***	4.94E+04 hrs	6.83E+04 hrs	3.61E+04 hrs	1.83E+05 hrs	9.50E+03 hrs	7.54E+04 hrs
8. Productive hrs lost to unreported non-death illnesses:	2.87E+03 hrs	1.22E+03 hrs	4.34E+02 hrs	1.25E+03 hrs	5.49E+02 hrs	5.02E+03 hrs

Table F-2. EMergy evaluation of rural health care for the coastal zone of Nayarit, 1990.*

Note	Item	Units/Yr (J,$,Hrs, No's.)	Transformity (sej/unit)	Solar EMergy (E18 sej/Yr)	Macroeconomic Value (E6 1990 US$)
	RENEWABLE RESOURCES (free inputs) of Coastal Zone:				
1	Sunlight	6.32 E+16 J	1.00 E+00	0.06	0.02
2	Wind	1.00 E+15 J	1.50 E+03	1.50	0.45
3	Rain	5.23 E+13 J	1.43 E+04	0.75	0.23
4	Tidal Energy	3.89 E+13 J	1.68 E+04	0.65	0.20
5	Wave Energy	5.15 E+16 J	3.05 E+04	1570.75	473.12
	Sum (sunlight & wind omitted)	5.16 E+16 J		1572.15	473.54
	PURCHASED INPUTS (COSTS):				
	Construction inputs				
6	Total value	3.81 E+06 US$	3.32 E+12	12.67	3.81
	Operational inputs				
7	Cost of Labor	3.31 E+06 US$	3.32 E+12	10.98	3.31
8	Electricity	9.76 E+12 J	2.00 E+05	1.95	0.59
9	Cost of Electricity	4.01 E+05 US$	3.32 E+12	1.33	0.40
10	Medical Supplies	1.91 E+06 US$	3.32 E+12	6.33	1.91
11	Misc. Supplies	2.29 E+05 US$	3.32 E+12	0.76	0.23
12	Equipment	1.53 E+05 US$	3.32 E+12	0.51	0.15
13	Total (sum of items 6,7,9,10,11 & 12)	9.81 E+06 US$		32.58	9.81
	BENEFITS:				
14	Productivity saved	5.82 E+07 (person-days)	1.86 E+13 (sej/p-d)	1082.52	326.06
15	Potential earnings saved	3.34 E+08 US$ (9.02 E+11 pesos)	3.32 E+12	1109.13	334.07

Notes: Peso/US$ parity @ 2700 pesos/US$ (for 1990)

* Based on a total of 206 rural Clinics (SSA, IMSS, & ISSSTE) within the 7 coastal municipalities of Nayarit.

Footnotes to Table F-2:

RENEWABLE RESOURCES:

The values derived for items 1-3 were calculated by estimating the coastal zone area to be approximately half of the state's total land area. As noted earlier, the coastal zone was defined as the area of land and water found between the 100m ocean depth contour and 5 km inland from the coast & significant coastal lagoons and estuaries.

1 SOLAR ENERGY:

Land Area = 2.79 E+07 m^2 (INEGI-I, 1985)
Insolation = 1.55 E+02 $kcal/cm^2/yr$ (IAM, U de G, circa 1988)
Albedo = 3.00 E-01 (% given as decimal)

Energy (J) = (land area)*(1/2)*(avg insolation)*(1-albedo)
= (2.79 E+07 m^2)*(1/2)*(1.5 E+02 $kcal/cm^2/y$)*(E+04 cm^2/m^2)
(1-0.30)(4186 J/kcal)
= 6.32 E+16 J/yr

2 WIND ENERGY:

Energy (J) = 1.00 E+15 J/yr (estimated as 1.43% of Mexico's total, multiplied by 2; extrapolated from EMergy analysis of Mexico)

3a RAIN, CHEMICAL POTENTIAL ENERGY:

Land area = 2.79 E+07 m^2 (INEGI-I, 1985)
Rain (land) = 9.44 E-01 m/yr (IAM, U de G, circa 1988)
Rain (shelf) = 4.20 E-01 m/yr (est. as 45% of tot. rain)
Evapotrans rate = 7.50 E-01 m/yr (est. as 80% of rain)

Energy (land) (J) = (area)*(Evapotrans)*(rain density)*(Gibbs no.)
= (2.79 E+07 m^2)*(.5)*(7.50 E-01 m/yr)
(1000 kg/m^3)(4.94 E+03 J/kg)

Total energy (J) = 5.16 E+13 J/yr

3b RAIN, GEOPOTENTIAL ENERGY:

Area	= 2.79 E+07 m^2	INEGI, 1989
Rainfall	= 9.40 E-01 m	IAM, UdeG, circa 1988
Avg Elev	= 5.00 E+01 m	(estimate based on INEGI topo map)
Runoff rate	= 0.05	(.8 - ET; estimate)

Energy (J) = (area)*(% runoff)*(rain density)*(avg elev'n)*(gravity)
= (2.79 E+07 m^2)*(.05)*(1000 kg/m^3)*(50m)*(9.8 m/s^2)
= 6.84 E+11 J/yr

4 TIDAL ENERGY:

Cont Shlf Area	= 1.06 E+07 m^2	(F.P.,Abst.Inf,INEGI,1985)
Avg Tide Range	= 1.00 E+00 m	(estimate) (N.D.A.)
Density	= 1.03 E+03 kg/m^3	(Odum et al., 1983)
Tides/year	= 7.30 E+02	(est. of 2 tides/day in 365 days)

Energy(J) = (shelf)*(0.5)*(tides/y)*(mean tidal range)^2
* (density of seawater)*(gravity)
= (____m^2)*(0.5)*(____/yr)*(____m)^2*(_____kg/m^3)
*(9.8m/s^2)
= 3.89 E+13 J/yr

5 WAVE ENERGY (straight shoreline of 295 km, avg. wave height of 1 m, and avg. shoaling depth of 2m):

$$Ew = (0.125\ pgh^2)*(C)*(2.38\ E+11) \quad [\text{where } C = (gd)^{0.5}] = 1.48\ E+8m/yr$$

$$Ew = (0.125)*(1.025\ g/cm^2)*(980\ cm/s^2)*(100\ cm)^2(100^2cm^2/m^2)*(2.38\ E-11Cal/erg)$$

$$= 0.298Cal/m^2$$

$$\text{Wave Energy (J)} = (0.298\ kcal/m^2)*(1.48\ E+8\ m/yr)*(295\ E+3\ m)*(4186\ J/kcal)$$

$$= 5.15\ E+16\ J/yr$$

PURCHASED INPUTS:

Construction Inputs:

6. Total Value (based on avg. life span of 10 yrs, operating 24 hrs/day):

Est. cost per rural clinic = $5.00 E+08 pesos
Total # of rural clinics = 206
Total cost for all clinics = ($5.0 E+8 pesos)*(206 clinics)
= 1.03 E+11 pesos

Divide by 10 to get est. based on 10-yr lifespan 24hrs/day operation:
= $1.03 E+10 pesos
= $3.81 E+06 US$

Operational Inputs:

7. Cost of Labor:
(based on avg. of one M.D. & one nurse per clinic working an avg. of 8 hrs/day; and M.D.s' avg. salary of $1,894,432 pesos/mo. & nurses'of 1,717,324.80 pesos/mo.)

M.D.s': (206 M.D.s)*($1,894,432.00)*(12 mos.) = 4.68 E+09 pesos

Nurses': (206 Nurses)*($1,717,324.80)*(12 mos)= 4.25 E+09 pesos

Total cost of Labor for all 206 clinics along the coastal zone:

($4.68 E+9)+($4.25 E+9) = 8.93 E+09 pesos
= 3.31 E+06 US$

8. Electricity (based on avg. yearly use of 13,152 KwH/clinic):

(13,152 KwH)*(206 clinics) = 2.71 E+06 KwH/yr

Energy (J) = (2.71 E+6 KwH)*(3.6 E+6 J/KwH)
= 9.76 E+12 J/yr

9. Cost of Electricity:
(based on avg. use of 13,152 KwH/clinic/yr, at an avg. cost of $400.00 pesos/KwH)

(13,152 KwH)*($400)*(206 clinics) = $1.08 E+09 pesos
= $4.01 E+05 US$

10. Medical Supplies (cost based on yearly avg. of 25 million pesos/clinic):

($25,000,000)*(206 clinics) = $5.15 E+09 pesos
= $1.91 E+06 US$

11. Miscellaneous Supplies (based on yearly avg. of $3 million pesos/clinic):

($3,000,000)*(206 clinics) = $6.18 E+08 pesos
= $2.29 E+05 US$

12. Equipment (based on yearly avg. of $2 million pesos/clinic):

($2,000,000)*(206 clinics) = $4.12 E+08 pesos
= $1.53 E+05 US$

13. TOTAL: Is the sum of all the Purchased inputs (except item 7).

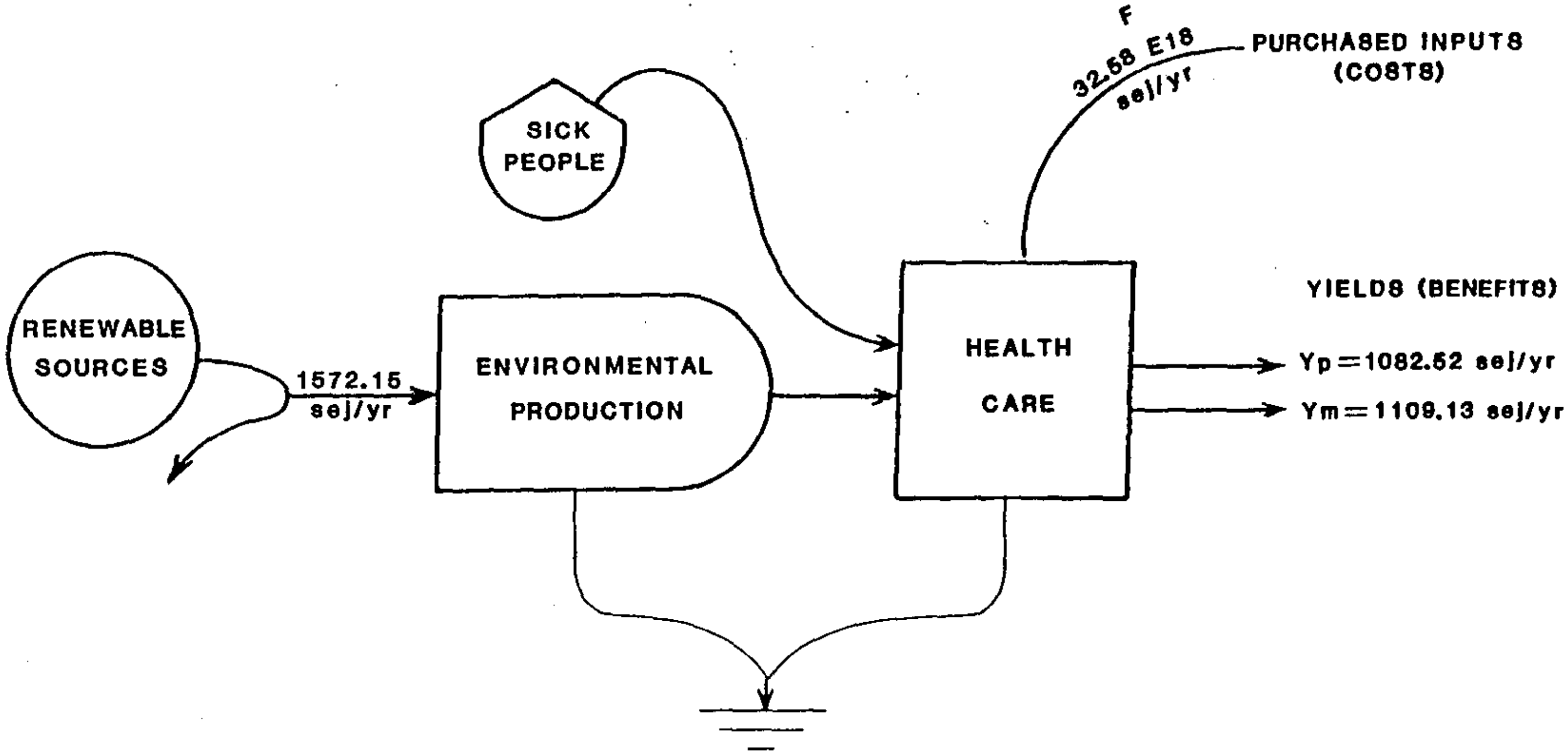
BENEFITS:

14. PRODUCTIVITY SAVED:

This value is taken from item number 10 of Table F-1. It represents the amount of productivity which is saved (through medical treatment) plus that which potentially could be saved for those untreated cases. It includes the non-death illnesses plus those resulting in death during the pre-productive (0-15) and productive years (15-65). The figure was converted from 4.68+ E08 hrs/yr saved into 5.84 E+07 person-days by dividing the hours saved/year by 8. Eight is taken to be the average daily productive cycle per person.

15. POTENTIAL EARNINGS SAVED:

This was based on the medium daily wage in 1990 for the average worker of $15,500 pesos = $5.74 US$



NET EMERGY YIELD RATIOS:

A. PRODUCTIVITY BENEFITS $= \frac{Yp}{F} = \frac{1082.52}{32.58} = 33.23$

B. MONEY (EARNINGS) BENEFITS $= \frac{Ym}{F} = \frac{1109.13}{32.58} = 34.04$

Figure F-3. Summary diagram of the potential yields from health care.

SUMMARY AND DISCUSSION

General Statement of Project Objectives

The overall objective of this study was to generate a proposed master plan for the coastal zone of the state of Nayarit, Mexico, by which the ecological and cultural resources of the coastal zone can be protected, and yet still foster development. The proposed master plan (given in Volume 1) sets a framework for determining where development can occur with minimal negative impacts, and what precautions and special regulations are necessary to insure that developed lands do not secondarily impact off-site land and water.

As part of the effort to minimize negative development impacts, studies of various "sectors" of the coastal zone were undertaken. These studies evaluated the interactions of humanity and nature using EMergy analysis to gain a different perspective for public policy options regarding resource use and protection. Most often, the decision-making process uses monetary values to determine which options related to resource development, use, or protection are the best. Yet monetary values do not adequately address commodities or services like waste assimilation, clean water, or a productive fishery, since these things fall outside the monied economy. As a result, they are under-evaluated or not considered at all in most planning and public decision-making. The studies in this volume of the report were undertaken to demonstrate a new method of evaluating resources and to provide additional insight and a quantitative basis for making policy decisions regarding resource use in the coastal zone.

The Basis for Wealth in Mexico, Nayarit and the Banderas Basin

The wealth of nations is not the amount of money that is held or controlled, but the resources that are available to drive machinery and transportation, to supply the raw materials for industrial production, and the needed chemicals for agriculture. In addition, the wealth of a region stems from its storage of soils and forests, and its climate that includes sun and rainfall; and if located at the interface of the continents and the ocean, wealth stems from tidal action, waves and ocean currents. An economy is not circulation of currency, but the circulation and use of resources, both stored resources like soils, forests, and minerals, and renewable resources like rainfall or sunshine. Currency circulation is simply a measure of the economy, much like degrees of temperature are a measure of the potential energy in a heat source. In an economy, the potential energy in resources that drive it is the actual basis for its production, and the circulation of currency is a measure of this driving force.

An economy is the sum total of productive processes that make available goods and services. The processes are extraction, collection, concentration, transformation and exchange. In each of these processes, some resource is used and some is transformed. The circulation of currency is one measure of the work or productivity of an economy. When the performance of a national economy is expressed using currency circulation, the measure is the relative dollar value of all exchanges of resources, goods and services. Called the Gross National Product (GNP) it measures the currency circulation within, and into and out of a national economy. When corrected for inflation and differing exchange ratios between currencies, yearly changes in GNP and the differences between nations can be compared. The changes and differences are enlightening, but do not reflect in any real sense the actual productivity that occurs. If GNP increases from one year to the next (after correction for inflation) it is likely that the productive processes of the economy increased as well. Similarly, a country having a higher GNP than another probably has more productivity than the other.

Increasingly, over the last several decades, an economy's production has been made synonymous with its GNP. A large circulation of currency meant the economy was productive. With this over-emphasis on the circulation of currency as a measure of economic performance has come an increased use of money as the means of determining value and wealth. This may seem appropriate, on the surface, since money can be converted to resources in almost any market place throughout the world. Yet, inherent in the use of money to establish value and measure wealth is a serious omission. Money cannot be used to measure the value of things for which there is no market. In other words, price cannot measure value of resources relative to their contribution to productive processes outside the monied economy.

Traditional economic theory is based on the premises of scarcity and the belief that the wants of humans are virtually unlimited. From these two premises comes the concept of willingness-to-pay. Essentially, the value of a good, service, or resource is determined by its scarcity and how badly an individual wants it (often called supply and demand). Traditional economic value is determined by the user; what he is willing to pay. In this context, economic value is equivalent to price. However, price says nothing about the contribution a good, service, or resource can make to an economy, only something about its scarcity and the amount of money an individual is willing to pay to obtain it. Its value to the productive processes of an economy is unchanged regardless of price. As an example, consider gasoline. While its price fluctuates based on supply and demand, the number of miles that can be driven using a gallon of gasoline remains unchanged. The actual work that can be accomplished with the gallon of gas is unchanged, yet with fluctuations in the "value of a dollar", the amount of gasoline that can be purchased with a single dollar changes.

EMergy evaluates the potential contribution of resources to the economy that are independent of monetary price. As a result, resources that are necessary inputs to an economy, but that do not carry a monetary price, can be evaluated and their contribution to productive process estimated. Using EMergy, all resources and flows of renewable energy can be included and their relative contributions evaluated. In this way, public policy decisions regarding resource use, protection, or conservation can be better facilitated, since a truer picture of their value to the economy emerges when evaluated using EMergy.

The units of measure, solar emjoules, are unfamiliar to most people. This is a serious limitation and we recognize the difficulty this presents. In this discussion, we will try to present the results of our analysis both actual as solar emjoules (sej) and as relative numbers, percents, and ratios that will allow comparative analysis, and thus help to overcome the inherent difficulties of using unfamiliar units of measure.

Mexican Economy

The following table summarizes some of the most important features of the Mexican economy:

Summary of Flows and Indices of Mexican Economy in 1989

Renewable EMergy Use	1.39 E+23 sej/yr
Non-renewable EMergy Use	4.75 E+23 sej/yr
Total EMergy Use	6.14 E+23 sej/yr
Exported EMergy	8.26 E+23 sej/yr
Imported EMergy	1.10 E+23 sej/yr
EMergy/money ratio	3.32 E+12 sej/US$
EMergy/person	7.60 E+15 sej/person
Dollars received from exports	2.28 E+10 $/yr
Dollars paid for imports	2.34 E+10 $/yr

The EMergy evaluation of Mexico gives perspective to the resource basis of the economy. In 1989, nearly 74% of the resources driving the economy were derived from non-renewable sources that will eventually decline in availability. Exports accounted for approximately 30% of the total EMergy use in the economy, and exceeded imports.

Evaluations of the economy and trade using EMergy, instead of money, show that while Mexico had a negative net balance of payments of about 1.03 to 1 when evaluated with money, it had a negative EMergy balance of payments of 7.5 to 1. In other words, the EMergy in exports was 7.5 times the EMergy in imports. The integration of local economies with the world economy is the emerging challenge of this decade. Our understanding of the hierarchical organization of systems suggests that global integration of national economies is probably inevitable. Yet, it is clear that exporting indigenous resources to the point of depletion and receiving in return lower EMergy resources from one's trading partner is neither beneficial nor sustainable. Developing countries such as Mexico face a serious dilemma as they export raw resources and import goods and services to support further extraction of fisheries, forest or mineral products. Priming the "economic pump" from outside, which seems almost a necessity, has more often than not failed in fulfilling developing countries' expectations.

Our EMergy analysis of the economy of Mexico revealed a negative EMergy balance of payments that suggest, in effect, current trading practices are a drain on the economy. So rather than boost the economy, as is hoped, it will decrease national economic well-being in the long run. All too often, economic investments for extractive purposes concentrate the affluence that results from extraction of resources in the hands of a small minority, while the population at large receives little from the sale. As a consequence, we suggest national trade policies that seek to balance EMergy exports and imports.

EMergy indices of development status lends some insight into the complexities of the policy questions facing developing nations. Gross Domestic Production (GDP) is often used as an indicator of development status, where low GDP is indicative of developing regions, and countries with high GDP, like the USA, are considered developed economies. The use of GNP as a measure of development status considers only that portion of an economy that is within the monied economy. The ratio of EMergy to GDP dollars is a measure of the buying power of the local currency and when compared between regions, could be used as a measure of relative exchange rates. Mexico's EMergy/GDP ratio is near the world average and is higher than the U.S. When a country with a low EMergy/GDP ratio purchases goods and services or lends money to countries like Mexico, the purchasing (or lending) country receives an advantage that is related to the differences in their EMergy/GDP ratios.

Mexico's EMergy/GDP ratio (in US$) was about 3.3 E+12 sej/$. When compared to the EMergy/money ratio of the United States (2.6 E+12 sej/$) it is apparent that the US has a monetary advantage of about 1.27/1, or the U.S. dollar buys about 1.27 times the EMergy in Mexico. A major question yet to be evaluated, is to what extent proposed trade agreements between the U.S. and Mexico will effect Mexico's EMergy balance of payments with the U.S. Because EMergy use per person in Mexico (about 7.6 E+15 sej/yr) was about 1/4th that of the U.S. (29.0 E+15 sej/yr), it would appear that, while labor costs are significantly lower, they will be difficult to maintain at these low levels, unless EMergy continues to be exported to the U.S. decreasing its availability in Mexico.

In all, our analyses of the relative position of developing economies to developed economies suggests that world economic policy should recognize the status of developing nations as providing much of the resources and ultimate wealth upon which developed nations survive. Developing economies should begin to reverse current thinking that export of resource wealth leads to national wealth and begin to develop internal economies slowly and efficiently to maximize internal EMergy flows.

The Economy of Nayarit

The following table summarizes some of the most important features of the economy of Nayarit:

Summary of Flows and Indices for the Economy of Nayarit in 1985

Renewable EMergy Use	15.7 E+20 sej/yr
Non-renewable EMergy Use	38.8 E+20 sej/yr
Total EMergy Use	54.6 E+20 sej/yr
Exported EMergy	55.9 E+20 sej/yr
Imported EMergy	38.7 E+20 sej/yr
Dollars received from exports	1.67 E+9 $/yr
Dollars paid for imports	1.19 E+9$/yr
EMergy/ person	6.8 E+15 sej/person
EMergy/money ratio	7.4 E+12 sej/US$

In 1985, nearly 29% of the total EMergy use in Nayarit was from renewable sources, the largest of which were tidal and geopotential energy in river inflows. The remaining 71% was from nonrenewable sources that will decline in availability over time. Nayarit's EMergy balance of payments is negative, while its monetary balance of payments is positive. The ratio of exports to imports (1.44/1) suggests that about 1.44 times as much EMergy is exported than imported. Nayarit is a net EMergy exporter to the larger economy of Mexico and, as such, provides some of the resource base for the economy of more urban and industrialized areas. One approach is to balance EMergy imports and exports to insure equity. While increasing government transfer payments may provide additional funds for purchase of imported EMergy, it may also increase local inflation. A better approach may be to provide increased opportunity for local students to receive higher education at urban universities. Since education and the resulting information transfer to humans has such a high EMergy content, equity of imports and exports might be achieved by providing scholarships for educational opportunities for the population of Nayarit in the urban universities.

Nayarit's relatively high EMergy to GDP ratio (7.4 E+12 sej/$) compared to Mexico's (3.3 E+12 sej/$) suggests that buying power is higher; i.e, a unit of money buys more in Nayarit than on the average throughout Mexico. A higher EMergy/GDP ratio makes investment from outside the state more attractive, therefore it is likely that Nayarit will continue to attract outside investment, particularly in coastal areas. However, as more and more development occurs, and the EMergy/GDP ratio declines, the buying power of local currency decreases making life more difficult for that segment of the population with low incomes.

Tourism Development, Environmental Impact, and the Local Economy

Tourist developments in undeveloped regions often compete with local populations for resources from land and marine systems, for potable water and for available land. EMergy evaluation of tourism in Mexico (Section 3D) evaluated the intensity of average tourist developments, and then determined a carrying capacity or support region that is necessary to insure that development does not have negative environmental, economic, and cultural impacts. Determination of carrying capacity was based on the premise that for development to fit within a region its intensity should nearly match the intensity of development of the region on the average. The following table summarizes several important indices for a typical tourist development in Mexico.

Summary of EMergy Evaluation of Tourism in Mexico

	4 Star Hotel	Mexico
Renewable EMergy (sej/yr)	164 E+15	--
Non-renewable EMergy (sej/yr)	22819 E+15	--
Percent renewable	0.07%	24.2 %
EMergy density (sej/m^2/yr)	12075.7 E+11	2.0 E+11
EMergy per Capita (sej/person/yr)	22.32 E+16	0.6 E+16
Ratio of EMergy exports/imports	4.6/1	7.5/1

Several interesting facts are apparent in the table: (1) the percent of supporting EMergy in tourist resorts that is from renewable sources is very small (less than 0.1%), (2) the energy intensity of tourist resorts is about 6000 times the average intensity in Mexico, and (3) the per capita energy use by tourists is about 35 times that of the average Mexican citizen. The ratio of EMergy exports to imports shows a net export for both tourism and the Mexican economy as a whole, although tourism is less.

International Trade and Tourist Resorts

The consequences of international tourism on trade balance is often seen as only beneficial to undeveloped economies, since it seems to be a non-extractive source of much needed foreign currency. What is often overlooked is the environmental support required and resources consumed to provide the goods and services for an expanded population of visitors. In essence, the resources that are consumed in support of a tourist population are "extracted" and exported with each tourist and therefore not available for consumption by the local population. In return, the local economy receives a currency income with which it purchases goods from the international market place. Evaluating tourism's economic impact by measuring only the currency input misses this important consequence. The money spent by each tourist purchases local goods and resources and environmental support (for instance, a portion of the local estuary that cannot be used by the local population for sewage disposal or fish harvest because it is being used for waste disposal of the tourist facility). When these are expressed in their EMergy equivalents and compared with the EMergy that is imported, more wealth is used and exported than is imported. Our analysis of this and other development projects in developing countries (Brown et al. 1991, Odum and Arding 1991, Odum et al. 1986) suggests that one of the main driving forces behind international trade and tourism is the fact that developed countries benefit greatly through uneven EMergy exchanges.

Carrying Capacity for Tourist Resorts

The support area calculated using the environmental loading ratio for each of the tourist developments in this study reflects the area necessary to reduce environmental loading to that which is characteristic of the national economy. In essence, the support area provides the carrying capacity of the environment to absorb the resort itself and possibly more developments of like kind (i.e., of similar size and EMergy intensity). If the size and/or intensity of a development changes, the support region will also change, since its determination is based on these factors. In this way the determination of carrying capacity using the environmental loading ratio achieves a dynamic balance that is affected not only by the environment's ability to absorb the development, but by the size and intensity of the development itself.

Carrying capacity and the concept of required support area can be expressed related to the physical size and the average number of tourists served per day. These may be more familiar ways of expressing carrying capacity. Assuming that EMergy use per tourist and per resort room does not change appreciably as the size of the facility is varied, these ratios could be used to determine, relatively quickly, the support area required for a given resort size. In the example resort in Section 3D, the Mexican hotel had 160 rooms and served 37,584 person days per year (103 tourists per day). Using its calculated support area (117 km^2), the number of rooms and average density of tourists can be determined. The support area per room in Mexico was 0.73 km^2/room and the average daily number of tourists per unit support area was about 0.9 tourists/km^2.

Sustainability of Development Projects

Economic development in the so-called Third World seems to be increasing in rate and magnitude as developed countries seek returns on investment that are higher than those characteristic of their internal economies. The result is increased rates of change in environmental, cultural, and economic systems of the Third World. Along with this, an awareness has recently developed that sustainability is a key factor to consider when analyzing potential impacts of proposed projects. Yet sustainability remains an elusive concept. It can be argued that sustainable development, in the long run (100 years or more?), is that which can be supported by the renewable flows of EMergy of a region. Development that depends on purchased resources is ultimately not sustainable, since purchased EMergy is composed of nonrenewable flows and fluctuations in world prices. Yet development that does not allow for the possibility of using purchased resources to amplify a region's environmental basis cannot give an economic return and becomes a moot point. Thus, sustainability should reflect the current intensity of development of an economy, and match it. In this way, it is no more dependent on limited supplies of nonrenewable EMergies than the economy as a whole. As the economy's use of nonrenewable purchased energies may decline, new development under these circumstances does not draw more of these energies on the average than the rest. To put it another way, what is sustainable in the USA is much different from what is sustainable in Nayarit.

Determinations of sustainability should take into account the relative mix of: (1) an economy's environmental basis (renewable EMergy sources), (2) its use of nonrenewable storages from within, and (3) its purchased goods, resources, and services. These flows drive the economy, and ultimately influence what is sustainable by defining an upper boundary to the present mix of purchased EMergy, resources from within, and renewable EMergy flows. The investment ratio described in this report is a ratio of purchased EMergy to resident EMergy, and when the ratios of development proposals are compared to the ratio for the economy in which they are imbedded, may provide one means of defining sustainability. Development proposals that have investment ratios that are higher than the economy require more purchased EMergy per unit of resident EMergy and therefore are more vulnerable, on the average, to changes in availability of purchased EMergy. Developments with lower ratios than the local economy are less vulnerable, but also yield less, on average. The investment ratio for the tourist resort evaluated in Section 3D was considerably higher than that indicative of the Mexican economy as a whole. This would suggest that, in the long run, its sustainability is questionable. However when the larger area, including its support area, is considered, the investment ratio is lower. If the suggested support area can remain undeveloped, resort development can potentially use more resident EMergy and, as a consequence, be less vulnerable to outside economic fluctuations in the prices of purchased goods and services.

Where economic development results in extraction and sale of resources to foreign economies, sustainability may be related to the trade advantage or EMergy exchange that results. If more wealth leaves the local economy than is received in exchange, the development is probably not sustainable. Balancing the exchange of wealth between that which is exported and that which is imported may lead to more sustainable developments. In the case of the tourist developments in Mexico, more wealth left the economy "embodied" in visitors than was received when the income derived from them was used to purchase foreign goods and services. In other words, tourists and the nation from which they came gained more EMergy than the nation they visited. This may not be sustainable in the long run.

Spatial Relationships of Resorts and Support Areas

There are numerous ways that resorts and support areas might be organized spatially and yet maintain a balanced environmental loading ratio. In coastal regions, much of the new tourist development is within the coastal zone to take advantage of the interface of marine and terrestrial environments and the diversity that results. Figure 6 illustrates three different concepts for a group of resort complexes in a coastal zone. Since the environmental basis of coastal regions is a blend of both marine and terrestrial productivity, the support regions (hatched areas) are composed of both of these environments. In the top illustration, resort developments are spaced along the coast, each surrounded by their appropriate support region. In the middle illustration, the same number and size developments are clustered in one area and surrounded by a support region equal to the sum of the individual areas. To maintain a balanced ELR, further development within the support areas would be restricted. The bottom illustration shows a spatial arrangement where the support region does not surround the resorts, but is located elsewhere within the region. In many cases, this arrangement may be more attractive as a means of setting aside ecological reserves or important wetland ecosystems.

We have considered only the tourist resort in our analysis and in the above illustrations of spatial arrangements. In some developing regions, where the regional economy is already relatively intense, resort development also brings infrastructure development and urban expansion resulting from increased populations. We believe that this method for determining carrying capacity and support areas could apply in these circumstances as well, if the infrastructure and increased urban developments were factored into the calculations. Feasibility studies for new developments often determine infrastructure requirements and urban expansion that will result from the development. These data could provide the basis for an expanded evaluation of carrying capacity that included secondary development.

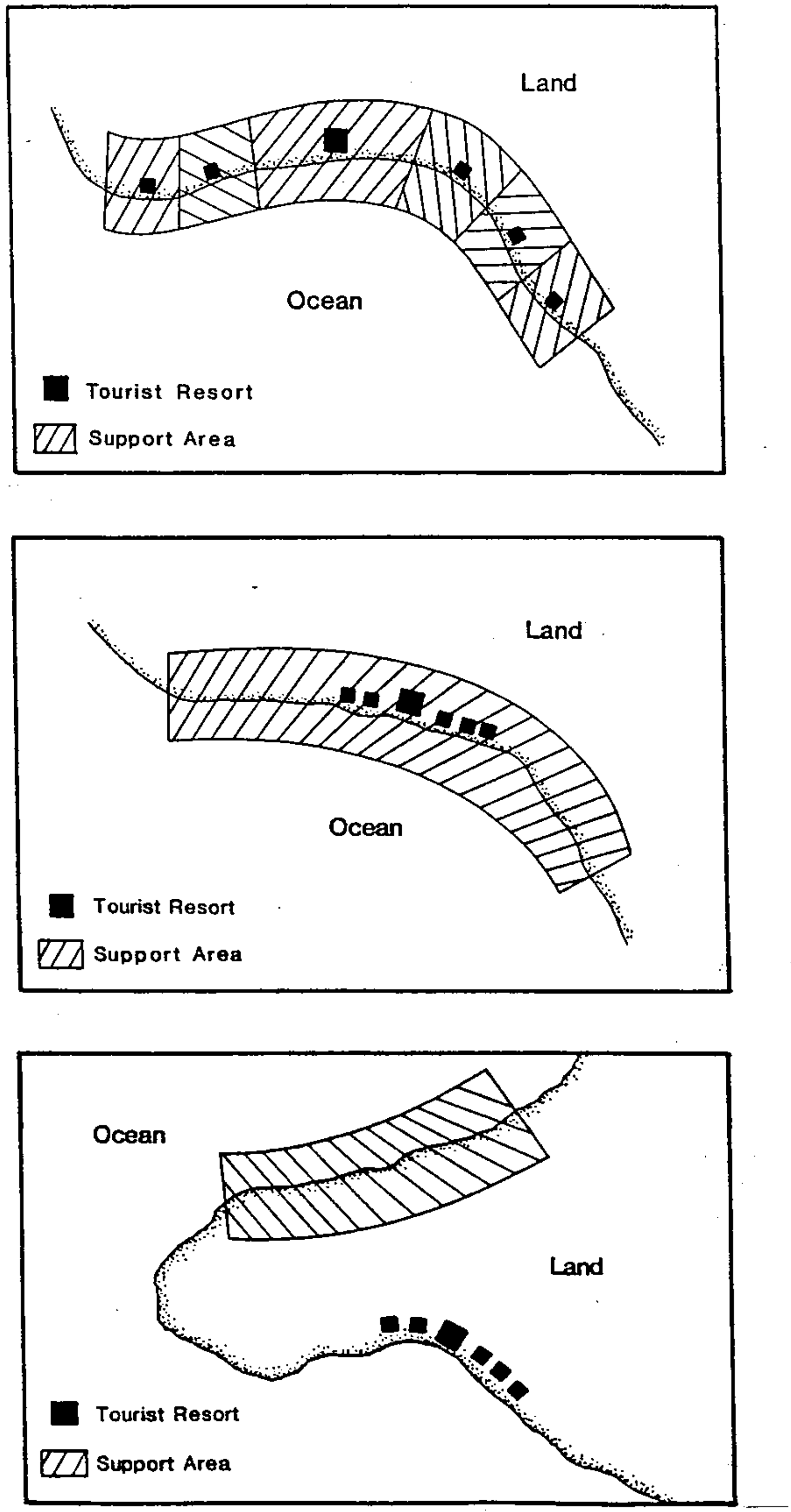


Figure 6. Schematic illustration of a coastline showing alternate ways of grouping tourist resorts within their support regions so as not to exceed economic carrying capacity of the region. In the top illustration resorts are spaced based on the size of the required support region, in the middle illustration, resorts are clustered leaving the remaining support region undeveloped, and in the bottom illustration, the support region is removed from the developed area, but is set aside as reserve area to remain undeveloped.

Options and Management of Water and Wastewater in the Coastal Zone of Nayarit

Economic vitality and carrying capacity of regions are often influenced by the interactions between agriculture, industry, and urbanization, and the need of each of these sectors for water. This is particularly true in areas with arid climates. As each of the economic sectors increases in size, the demand for water increases and a competition for water between sectors often results. Carrying capacity and economic vitality of a region may be diminished as competition and decreasing water supplies result in increased costs of water extraction, treatment and delivery. In addition to this increased demand for water, there is often a concurrent increase in the generation of wastes. The costs, both in technology and environmental deterioration, of treating and disposing of wastes can place an added drain on the economy. Practices of improper disposal of wastes can reduce environmental quality and further drain the local economy.

Public policy regarding water use and reuse that maximizes local economic vitality may be fostered using techniques of energy analysis to gain perspective on the value of water in different applications. A water policy which generates the greatest energy flux and dollar flow in the local economy may lead to the greatest economic vitality. In this study, the role of water in the regional economy of the Bahia Banderas Basin was evaluated using EMergy analysis to help determine policy options and future water use/reuse patterns. The following table summarizes some of the most important flows and indices related to water use within the coastal zone of Nayarit.

Summary of EMergy Analysis of Water and Wastewater in Bahia de Banderas Basin

Index	Ag.	Fishery	Urban
EMergy of water (E+18 sej/yr)	70.5	319.7	49.7
EMergy of Wastew. (E+18 sej/yr)	--	--	138.6
Transformity (E+3 sej/J)	72.6	367.5	431.0
Investment ratio	0.08	--	3.31
EMergy Yield ratio (raw water)	13.1	1.03	1.3
Macroeconomic Yield ratio	2.0	165.2	1.0

The EMergy value of water is highest in its support of the marine fishery of the bay, due to the large volume associated with river discharge. While its total value to the fishery in relation with other sectors is related to sheer volume, its high macro economic yield ratio suggests that diversion for other uses without regard to fishery losses would have counterproductive results. The macroeconomic yield ratio is the ratio of the EMergy yield from an economic interaction to the EMergy of the input. The macroeconomic yield ratio of fisheries far exceeds those characteristic of agricultural or urban use of water.

Economic vitality is enhanced where yield ratios are highest and investment ratios (the ratio of invested EMergy to renewable EMergy flow) nearly match those of the larger economy. Often, because the economic flows associated with urbanization are highest when compared with agricultural and fisheries, more weight is given to urban uses to the detriment of these other sectors. Yet, when compared using EMergy values, the marginal effects of water are greatest, investment ratios are lowest, and EMergy yields highest for agricultural and fishery uses. As a result, policies should reflect the importance of freshwater discharges to marine waters and insure adequate inflows to maintain fishery productivity. Small decreases in river discharges cam be magnified significantly in losses of fishery potential.

The high value of wastewater (nearly 2.5 times that of potable water) is indicative of its amplifier effect if used properly. When recycled as irrigation for appropriate agriculture its amplifier effect is nearly 32.5/1 (2.5 times 13/1); thus, yields from agriculture could be significantly higher and costs lower. Discharge to marine waters does not give as high an amplifier effect (about 2.5/1), but this effect may be overshadowed by negative impacts on tourism and human health.

Mariculture and Fisheries in the Coastal Zone of Nayarit

EMergy Analysis of Shrimp Mariculture

The following table summarizes some of the most important EMergy flows associated with shrimp production in Mexico. The evaluation was conducted to determine if shrimp mariculture has a net positive benefit to the economy of the coastal zone and if there are alternatives that might enhance productivity and thus net benefit.

Summary of EMergy Flows for Shrimp Mariculture (1 hectare)

Total renewable EMergy (sej/yr)	17.0 E+15
Total purchased inputs (sej/yr)	49.3 E+15
EMergy per unit area (sej/m^2)	6.7 E+12
EMergy inputs/yield (sej/J)	10.7 E+6
EMergy yield ratio (sej/sej)	1.34/1
EMergy Investment Ratio	2.87/1

Shrimp mariculture is about 20 times as energy intensive as the Mexican economy, on the average, (6.7 E+12 sej/m^2 compared to 3.1 E+11 sej/m^2). While this is not striking, since mariculture is concentrated in time and space when compared with artisanal fishing (3.3 E+11 sej/m^2), it suggests that the local economy cannot "afford" to purchase the shrimp produced. Intense operations (those much greater than the local economy, on the average) result in processes that produce goods with higher than average purchased inputs and must be exported to external economies whose intensity is in line with the good that is received. In the short run, increasing exports to help with monetary balance of payments may on the surface appear to be a worthy goal, as long as the maricultural operations do not result in environmental degradation that lowers local fishery production. As is often the case, intense developments affect environmental integrity and result in lowered environmental carrying capacity for local populations.

EMergy Analysis of Fisheries

Evaluation of the fishery in Bahia de Banderas suggests there are two types of small artisanal fishing boats using any combination of cast lines, long lines, and gill nets. Data requested on large trawler type boats were not available; thus the analysis is incomplete, comparing only differing types of artisanal fishing. The following table summarizes the most important features of the artisanal fishery in the Bahia de Banderas.

Summary of EMergy Analysis of Artisanal Fishery in Bahia de Banderas (per boat)

Catch per boat (Joules of protein)	4.2 E+10 J
Renewable EMergy input (sej/yr)	228.8 E+15 sej/yr
Purchased EMergy	74.6 E+15 sej/yr
EMergy inputs/yield (sej/J)	7.16 E+6 sej/J
EMergy yield ratio (sej/sej)	4.07/1
EMergy Investment Ratio	0.33/1

EMergy Analysis of Protein Production

The following table summarizes some of the main EMergy inflows and indices for three alternative methods of protein production in the coastal zone of Nayarit. Brackish and fresh water Tilapia aquaculture and beef cattle were evaluated for comparison with shrimp mariculture (above) as alternate protein production processes. While each does not compete directly for the same area of land, they do compete, in a sense for resources. Alternate uses for the same resources would best be invested in enterprises that have the highest net yield ratios.

Summary of EMergy Flows for Protein Production Systems in Mexico (1 hectare)

	B-W* Tilapia	F-W* Tilapia	Beef
Total renewable EMergy (sej/yr)	69.4 E+15	144 E+15	3.0 E+15
Total purchased inputs (sej/yr)	61.7 E+15	146.9 E+15	9.9 E+15
EMergy per unit area (sej/m^2)	13.1 E+12	29.1 E+12	1.3 E+12
EMergy inputs/yield (sej/J)	0.56 E+6	1.2 E+6	7.0 E+6
EMergy yield ratio (sej/sej)	2.12/1	1.98/1	1.3/1
EMergy Investment Ratio	0.89/1	1.02/1	3.3/1

* *B-W = Brackish water; F-W = Fresh water*

Tilapia aquaculture had higher purchased inputs per hectare of pond but, because of the higher yields, had lower EMergy per kg of yield. The inputs per hectare of beef cattle production were significantly lower than both mariculture (see above) and aquaculture, yet the yields were also significantly lower. The final result was that the EMergy inputs per yield (measured as purchased EMergy inputs per Joule of yield) for beef production were intermediate between mariculture (the highest) and aquaculture (the lowest), and the highest yield ratios were for the two aquaculture systems, followed by shrimp mariculture and beef production.

Comparison between the artisanal fishery and other methods of producing protein (shrimp, Tilapia, and beef) shows that: (1) purchased inputs per year are of the same order of magnitude as those for one hectare of shrimp, Tilapia and beef production, (2) total EMergy inputs per yield are less than shrimp mariculture, but higher than beef cattle and aquaculture, and (3) the EMergy yield ratio for artisanal fishing (4/1) is significantly higher than these other forms of protein production. Of the four methods of protein production, artisanal fishing provides the most significant return on EMergy invested.

Rural Health Options in the Coastal Zone of Nayarit

The following table summarizes the main flows of EMergy related to the rural health care system:

Summary of EMergy Flows for Rural Health Care in the Coastal Zone of Nayarit

Construction inputs	12.7 E+18 sej/yr
Operational inputs	10.1 E+18 sej/yr
Person days saved	5.82 E+7 pers-days/yr
Productivity saved	1082.0 E+18 sej/yr
Net Yield Ratio	33.2/1

Health care potentially has extremely high benefits. When expressed as an EMergy yield ratio, health care yields about 33/1. There are few investments of resources that have such high yield potential. For instance, primary energy sources like oil, natural gas, and coal have present day yields on the order of 6/1 to 10/1, while most secondary sources or conservation technologies have yields near 3/1.

These findings provide strong evidence that an improved health care system is beneficial for the people and economy of Nayarit. The results indicate that a total of 466 million hours (58 million person-days) could potentially be saved through medical treatment in 1990.

Summary and Recommendations

The perspectives gained in overview of these regions of the globe have resulted in several important recommendations related to economic and development policy that, on the surface, are counter to traditional economic wisdom. These are summarized below:

- A resource's contribution to an economy is often inverse to its dollar value

- GNP per capita as a measure of standard of living does not include important contributions from the unmonied sectors of an economy and provides a false impression of the relative well-being of a country's inhabitants. A better measure is total EMergy per capita.

- Currency exchange rates do not reflect the real buying power of a country's currency relative to another's. A better measure is the ratio of EMergy per dollar. When a country with a high EMergy/dollar ratio exports resources and then purchases goods with the money obtained from a country with a lower ratio, more total value leaves the first country than is received. Most undeveloped countries have high EMergy/dollar ratios, while developed economies have lower ones. Our calculations suggest that much of the debt now carried by the developing countries has already been paid, if the exchange ratios were calculated using EMergy instead of international currency exchange rates.

- Raw resources should not be exported in exchange for finished products. The resulting net trade deficit drains the resource-exporting economy in favor of the importing economy.

- Sustainable development projects are usually scaled where the ratio of energies derived from economic inputs to environmental energies is intermediate, the spatial scale is intermediate, and the temporal scale (the speed at which the project is done) is intermediate as well.

- For a development project that involves export to have a positive benefit to a local economy and not drain it of resources for export, the investment of economically derived energy should be equal to that characteristic of the economy as a whole.

A Definition for Ecotourism

The term ecotourism has recently become much in vogue. While it means many things to many people, its basis lies in the desire of tourists and the world tourist industry to seek out an unspoiled environment to observe "nature". Most often this means observing wildlife of some form in its natural environment. Natural environments are decreasing as population increases and development spreads, so the few that remain are deserving of special attention to ensure that the very environment upon which the wildlife depends is not degraded by tourists who seek to enjoy it. To ensure that there is an unspoiled environment for future generations, ecotourism should strive to fit within a region's carrying capacity and achieve a sustainable level of development that does not draw more from the regional resource base than it can provide. The following are several general principles that we feel are important guidelines for an ecologically based tourism industry in undeveloped regions of the globe:

Ecotourism should be environmentally benign. Environmental pollution of any sort should be cause for disqualification. An ecotourism resort should fit within the local environment's ability to handle and process wastes. Use of resources should be minimized and waste byproducts like sewage and solid wastes should be recycled. Developments should be favored that, because of their size or for cultural reasons,(1) require imports of foods and materials, (2) do not overload the local environment's ability to provide these commodities, and (3) do not produce waste byproducts that overload the environment's ability to process them.

Ecotourism should be sustainable. All ecological systems have a sustainable yield that is a function of their productivity and the positive feedback actions of those harvesting the resources. For instance, forests have a sustainable yield that is based on the production of wood on the one hand, and management actions of foresters that increase production on the other. When the sustainable yield is exceeded, declines in both the quantity and quality of the harvested resource results. With continued overload, the environmental system can degenerate to such a point that no yield is possible. Local fisheries, ecological and agricultural systems, and the local pool of labor have a sustainable yield that, if not exceeded, can provide the resources necessary for a tourist development that is sustainable in the long run; however, if exceeded, it not only jeopardizes the development, but the local population as well.

Ecotourism should be scaled to the local economy. Large developments often exceed the local economy's ability to provide start-up capital and needed infrastructure. As a result, external financing is required. Tourist developments and needed infrastructure like airports, roads, and waste treatment plants that are externally financed often result in secondary environmental degradation as resources from other sectors of the environment are extracted and sold to earn the necessary currency to pay back principle and interest on tourism related infrastructure. On the other hand, small-scale, locally financed operations are more apt to fit within current infrastructure and not require external financing.

Ecotourism development should not increase the rate of change in economic or cultural systems. The rate at which development occurs often can exceed the ability of the local culture and economy to absorb it, and while its ultimate size may not be a problem, if developed too quickly it may cause disruption. The rate of change also applies to the ability of the local environment's sustainable rates of production of resources.

Conclusion

In conclusion, we do not presume to have all the answers to the difficult questions humanity faces in its quest for sustainable development of natural resources; but we do feel EMergy analysis has promise as a means of focusing attention on the real issue of resource use and exploitation, and providing a necessary insight to make purposeful public policy decisions. Determination of resource value according to price or willingness to pay and determining a nation's wealth based on the flow of currency do not adequately measure either. A resource's contribution to an economy is independent of its price and flow of currency, while providing an index of production only accounts for human services in most cases. A better perspective of resource value and material wealth emerges if energy is used as the foundation of value and transformed to EMergy as a measure of equivalent work potential.

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