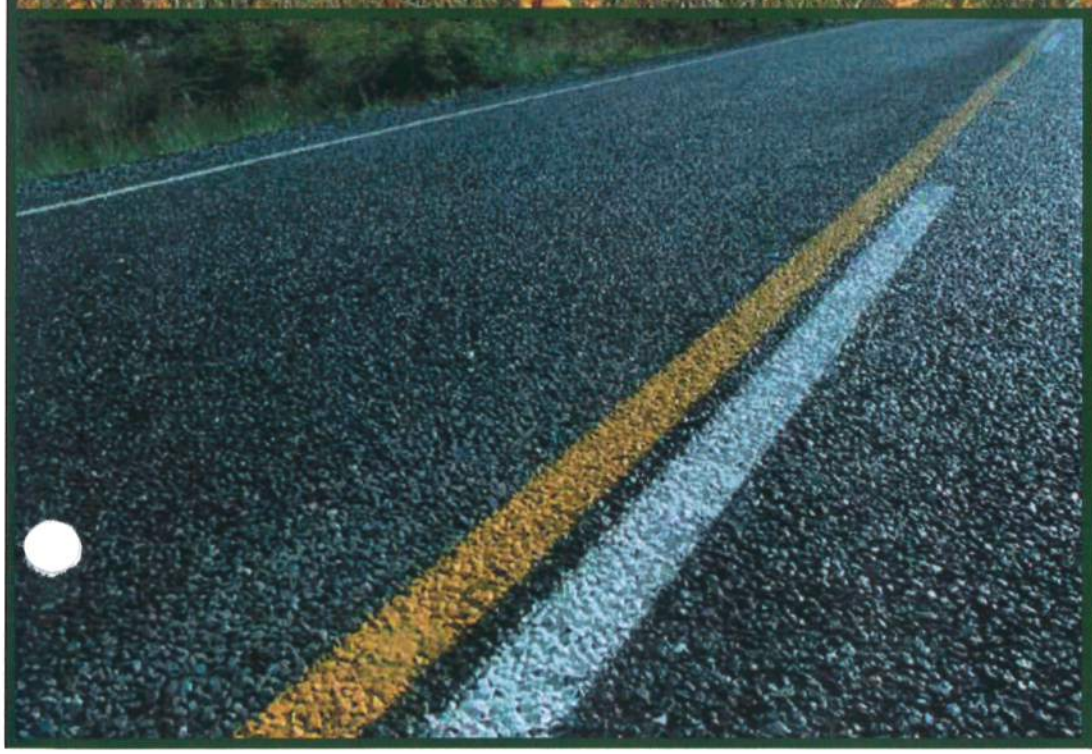
Eco-Logical

Creating a Regional Decision Support System for the Houston-Galveston Region



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Executive Summary

The Houston-Galveston region, the sixth largest metropolitan area in the United States, is home to an array of environmental resources which are increasingly impacted by development. Presently, there are no regional plans identifying critical environmental resources or mechanisms in place to inform the environmental impacts associated with transportation infrastructure on long range transportation planning. The Houston-Galveston Area Council (H-GAC) regional forecast projects a significant increase in population and employment over the next 30 years with the regional population reaching 9.5 million by 2040. This growth will necessitate an increase in the region's transportation infrastructure which may have the potential for altering the region's environmental resources such as the nationally significant Galveston Bay estuary system.

The goal of the Eco-Logical project is to develop a regional decision support system (RDSS), an interactive, Geographic Information Systems (GIS)-based mapping tool that can be used to integrate long-range transportation and environmental planning and to help identify and ultimately conserve high value environmental resources in the region. Integrating environmental and transportation planning will result in more efficient transportation project implementation by allowing transportation project sponsors to identify potential conflicts early in the planning process. It will also enhance the growing region's quality of life through preservation, conservation, and enhancement of the natural environment.

H-GAC convened an Eco-Logical Advisory Committee (EAC) to guide staff with the development of the RDSS. The EAC consisted of environmental professionals from federal and state resource agencies, as well as additional representatives from other conservation organizations. Representation included:

Governmental Agencies	**Institutions and Organizations**
GBEP	Houston Advanced Research Center
HCFCD	Katy Prairie Conservancy
H-GAC	Legacy Land Trust
Texas Forest Service	Texas A&M University – Galveston
TPWD	Texas Sea Grant/Texas Coastal Watershed Program
USFWS	The Park People
	The Trust for Public Land
	The Nature Conservancy

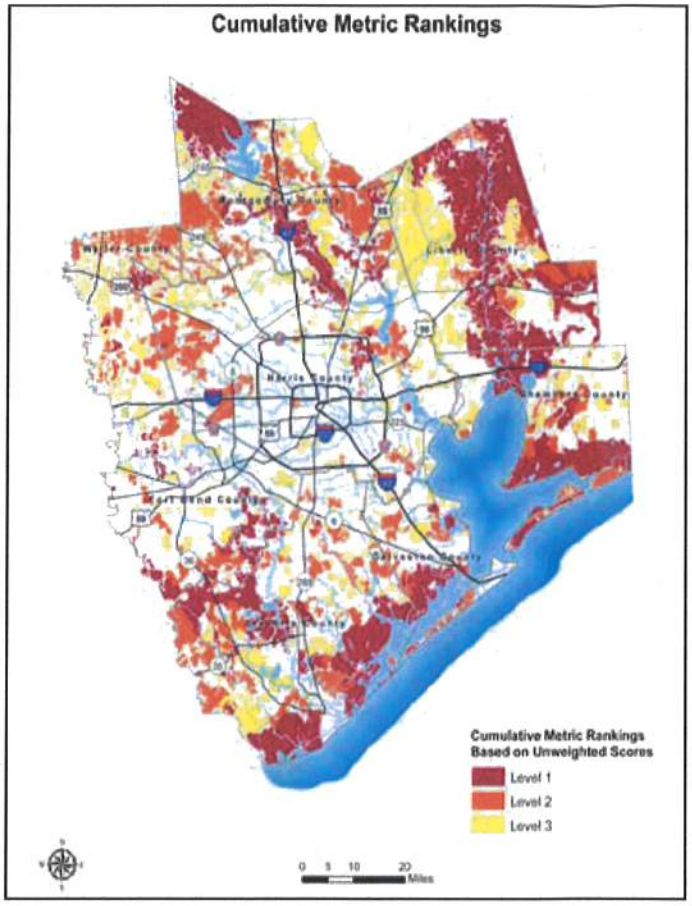
The EAC met periodically throughout the two year project. One of the tasks completed by the EAC was to define and map the ecotypes found in the region. The ecotypes include:

Tidal Wetlands	Coastal Prairies
Bottomland Forests	Water Bodies
Upland Forests	Local Icons

Next, the EAC determined the metrics that are indicators of high value environmental resources. The metrics were applied to the ecotypes that were mapped during the course of the project to determine how environmental resources are prioritized. The metrics include:

Size	Shape
Scarcity (regional and watershed)	Adjacency
Isolation	Presence of threatened and endangered species
Diversity	Quality

These metrics scores are aggregated to generate a cumulative ecological score for the proposed project, with Level 1 areas represented by the color purple being the highest priority environmental resources in the region. In addition to being able to view metrics for each resource, users of the tool may overlay potential transportation projects with the mapping tool to determine potential conflicts with Level 1, 2, or 3 environmental resources.



H-GAC then overlaid the 2035 forecasted land use pattern over the mapped ecotypes. The resulting changes are given in the following table:

Ecotype	2008 Acres	2035 Acres	% Change
Coastal Prairie	613,298	399,286	35
Bottomland Forest	855,530	465,994	46
Upland Forest	492,468	222,065	55
Tidal Wetlands	153,054	40,179	74

H-GAC intends to incorporate use of the RDSS into the 2040 Regional Transportation Plan (RTP), scheduled for completion in 2012. By incorporating the Eco-Logical project into the RTP, the impacts of transportation projects to sensitive environmental areas can be assessed prior to inclusion in the long-range plan for the region. Other users include H-GAC's Transportation Policy Council and Technical Advisory Council, Texas Department of Transportation (TxDOT), conservation planning organizations and local governments. The RDSS is unique in that it is the first consensus-driven, regional-scale tool that identifies priorities for future conservation efforts in the Houston-Galveston area. Through continued coordination of transportation planning and environmental conservation using tools like the RDSS, the Houston-Galveston region can meet the challenge of ensuring mobility for the growing population while simultaneously preserving the region's unique resources for future generations to enjoy.

1.0 Introduction

The Houston-Galveston region is home to a diverse array of environmental resources which are increasingly impacted by development. Presently, there are no regional plans identifying critical environmental resources or mechanisms in place to inform the environmental impacts associated with transportation infrastructure on long-range transportation planning.

The Houston-Galveston region is the sixth largest metropolitan area in the United States. The Houston-Galveston Area Council (H-GAC) regional forecast projects a significant increase in population and employment over the next 30 years with the regional population reaching 9.5 million by 2040. This growth will necessitate an increase in the region's transportation infrastructure. In turn, the impacts of this expanding transportation network have the potential for altering the region's environmental resources. These impacts could be felt not only on the local scale, but may also affect nationally significant resources such as the Galveston Bay estuary system[1].

The goal of the Eco-Logical project is to develop a regional decision support system (RDSS), an interactive, Geographic Information Systems (GIS)-based mapping tool that can be used to integrate long-range transportation and environmental planning and to help identify and, ultimately conserve, high-value environmental resources in the region.

1.1 Environmental Resources

The Eco-Logical project encompasses the 8-county H-GAC Transportation Management Area (TMA) shown in **Figure 1.** The TMA contains distinct ecotypes - including coastal prairie, bottomland forests, upland forests, and tidal wetlands, and over 10,000 miles of rivers, lakes, streams, and bayous.

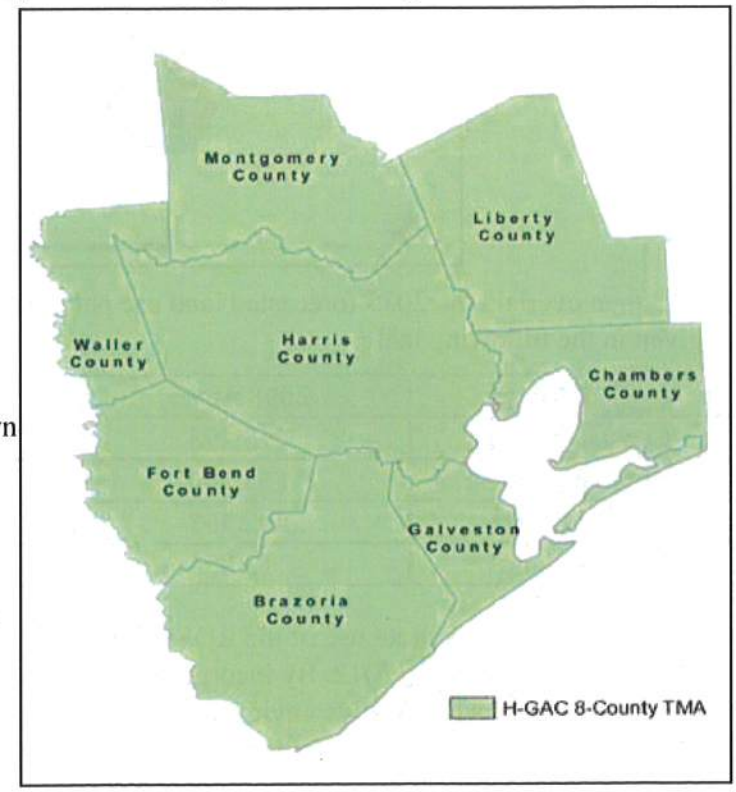


Figure 1: H-GAC 8-county Transportation Management Area

This rare confluence of waterways, marshes, swamps, ocean, prairies, and forests, all in relatively close proximity, makes the region home to an abundance and diversity of plant and animal life. Each of these resources serves particular functions not only in terms of their own sustenance as an ecological network, but also in terms of our region's quality of life, providing a vital basis for flood protection, air quality, water quality, wildlife habitat and migration routes, ecotourism, and recreation opportunities. Additionally, these resources contribute to the region's identity and sense of place, making the region truly unique.

Currently, environmental impact considerations for transportation projects in the region are not coordinated on an ecosystem basis; rather, they are project-specific, and occur late in the transportation planning process. As a result of this planning dichotomy between transportation and environment, there is the potential for transportation projects to impact remaining high-quality environmental resources.

1 One of 28 estuaries of national significance designated by the National Estuary Program.

Integrating environmental and transportation planning will result in more efficient transportation project implementation by allowing transportation project sponsors to identify potential conflicts early in the planning process. It will also enhance the growing region's quality of life through preservation, conservation, and enhancement of the natural environment. H-GAC plans to incorporate the use of the RDSS into the 2040 Regional Transportation Plan (RTP), scheduled for completion in 2012.

By incorporating the use of the RDSS into the RTP, the impacts of transportation projects to sensitive environmental areas can be assessed prior to inclusion in the long-range plan for the region. The interactive mapping components and metric evaluation of environmental benefits will also be valuable tools for conservation organizations throughout the region.

1.2 Federal Highway Administration (FHWA) Eco-Logical Program

H-GAC's work on the regional Eco-Logical project stems from a national effort of FHWA. In coordination with an inter-agency steering team, FHWA developed a ground work for integration of infrastructure planning and ecosystem-based planning.

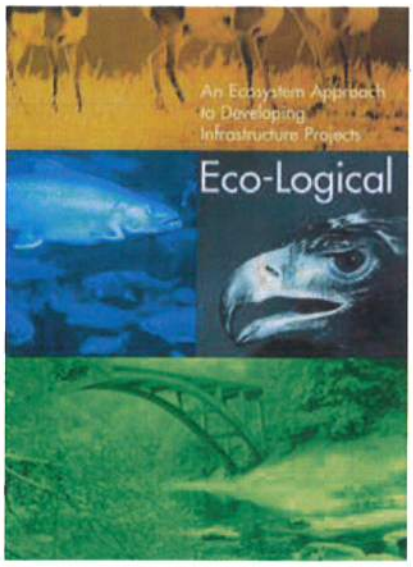


Figure 2: FHWA's Eco-Logical Guidebook

The FHWA Eco-Logical guidebook, pictured in **Figure 2,** provides strategies to agencies to advance the goals of the Eco-Logical approach. According to FHWA, "Eco-Logical is a guide to making infrastructure more sensitive to wildlife and ecosystems through greater interagency cooperative conservation." The goals of FHWA's Eco-Logical program include:

Conservation – Protection of larger scale, multi-resource ecosystems;
Connectivity – Reduced habitat fragmentation;
Predictability – Knowledge that commitments made by all agencies will be honored, i.e., that the planning and conservation agreements, results, and outcomes will occur as negotiated; and
Transparency – Better public and stakeholder involvement at all key stages in order to establish credibility, build trust, and streamline infrastructure planning and development.

In 2007, FHWA released a grant solicitation, "Integrating Transportation and Resource Planning to Develop Ecosystem Based Infrastructure Projects." H-GAC was one of 15 agencies nationwide to receive an Eco-Logical grant. The overall aim of all Eco-Logical grant recipient projects is to help advance FHWA's Eco-Logical goals through local and regional pilot projects.

The goal of H-GAC's Eco-Logical project is to advance the Eco-Logical goals through creation of a RDSS for identifying high priority environmental resources. Specific sub-goals of H-GAC's Eco-Logical project that are addressed in this report include:

- Identifying top priority areas for environmental conservation;
- Developing a metric system to prioritize environmental resources; and
- Establishing measures by which potential transportation projects may be evaluated.

Through the Eco-Logical project, environmental and transportation planning within the region will be integrated and a procedure for evaluating transportation projects through an ecosystem-based system will be established, helping to increase predictability and transparency in the planning process.

2.0 Methodology

2.1 Relationship to RTP

The regional Eco-Logical project builds off of an effort conducted during the 2035 RTP process. In 2006, H-GAC convened an Environmental Advisory Committee, which consisted of environmental professionals from federal and state resource agencies, as well as organizations and institutions with knowledge of the region's major environmental systems and resources. See **Table 1.** This committee guided H-GAC towards consistency with the provisions of SAFETEA-LU (Safe, Accountable, Flexible, and Efficient Transportation Equity Act: A Legacy for Users.

Table 1: Environmental Advisory Committee

Governmental Agencies	Institutions and Organizations
Army Corps of Engineers	Houston Advanced Research Center
Galveston Bay Estuary Program (GBEP)	Houston Wilderness
Harris County Flood Control District (HCFCD)	Katy Prairie Conservancy
H-GAC	Texas Sea Grant
Texas Commission on Environmental Quality (TCEQ) Region 12	The Park People
Texas Department of Transportation (TxDOT)	The Trust for Public Land
Texas Forest Service	
Texas Parks and Wildlife Department (TPWD)	
United States Fish and Wildlife Service (USFWS)	
United States Geological Survey (USGS) Texas Water Science Center	

This committee came together to help identify high-priority environmental resources in the region, with the goal of including this effort in the 2035 RTP. The committee identified top priority ecosystems for environmental conservation at a regional scale. The results of this preliminary effort are shown in **Figure 3.**

It should be noted that this identification was not at a geographically precise scale. The lack of geographic precision limited the applicability of the map to evaluate potential impacts of proposed transportation projects, as transportation projects have specific limits. An additional limitation was the fact that the mapping was not in an interactive, GIS-based format, limiting its application beyond inclusion in the RTP. For example, it was not possible to overlay transportation project potential alignments. The areas of concern highlighted by the committee were also not prioritized. Instead, all resources were presumed to be equal, with no metric-based evaluation of the intrinsic quality of the resources.

In light of these limitations, and looking forward toward the development of the 2040 RTP, H-GAC applied for the FHWA Eco-Logical grant to improve upon this initial effort by creating an RDSS that could be incorporated into the 2040 RTP. To begin the Eco-Logical project effort H-GAC re-convened the Environmental Advisory Committee, and additional representatives from other organizations with similar expertise. Agencies and organizations represented on the Eco-Logical Advisory Committee (EAC) are listed in **Table 2.**

This new committee met over the course of two years (2008-2010) to provide H-GAC with input and feedback into the process, mapping, metrics, and development of the RDSS. The efforts of the committee were critical to the successful completion of the Eco-Logical project because, in addition to serving as technical advisors, its members will also be end users.

Table 2: Eco-Logical Advisory Committee (EAC)

Governmental Agencies	Institutions and Organizations
GBEP	Houston Advanced Research Center
HCFCD	Katy Prairie Conservancy
H-GAC	Legacy Land Trust
Texas Forest Service	Texas A&M University – Galveston
TPWD	Texas Sea Grant/Texas Coastal Watershed Program
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	The Nature Conservancy

After convening the EAC, H-GAC began integrating elements of existing agency plans that could be used in the Eco-Logical project, such as identification of priority environmental resources, best management strategies, and metrics for evaluation. This integration is one of the recommended steps outlined in FHWA's Eco-Logical process and helps ensure that the RDSS will not duplicate or conflict with existing plans.

H-GAC solicited suggestions from the EAC for various agency management plans to review, and a thorough review of all available plans was also conducted. These plans included the Galveston Bay Estuary Program's *The State of the Bay: A Characterization of the Galveston Bay Ecosystem*; the Trust for Public Lands' *Greenprint for Chambers County*; regional plans, such as H-GAC's *2035 Regional Transportation Plan*; and state plans, such as Texas Parks and Wildlife Department's *Land and Water Resources Conservation and Recreation Plan and Wildlife Action Plan*.

Plan reviews revealed that much of the data and evaluation process needed to be created specifically for the Eco-Logical project. An initial obstacle in integrating these plans was the discrepancy in

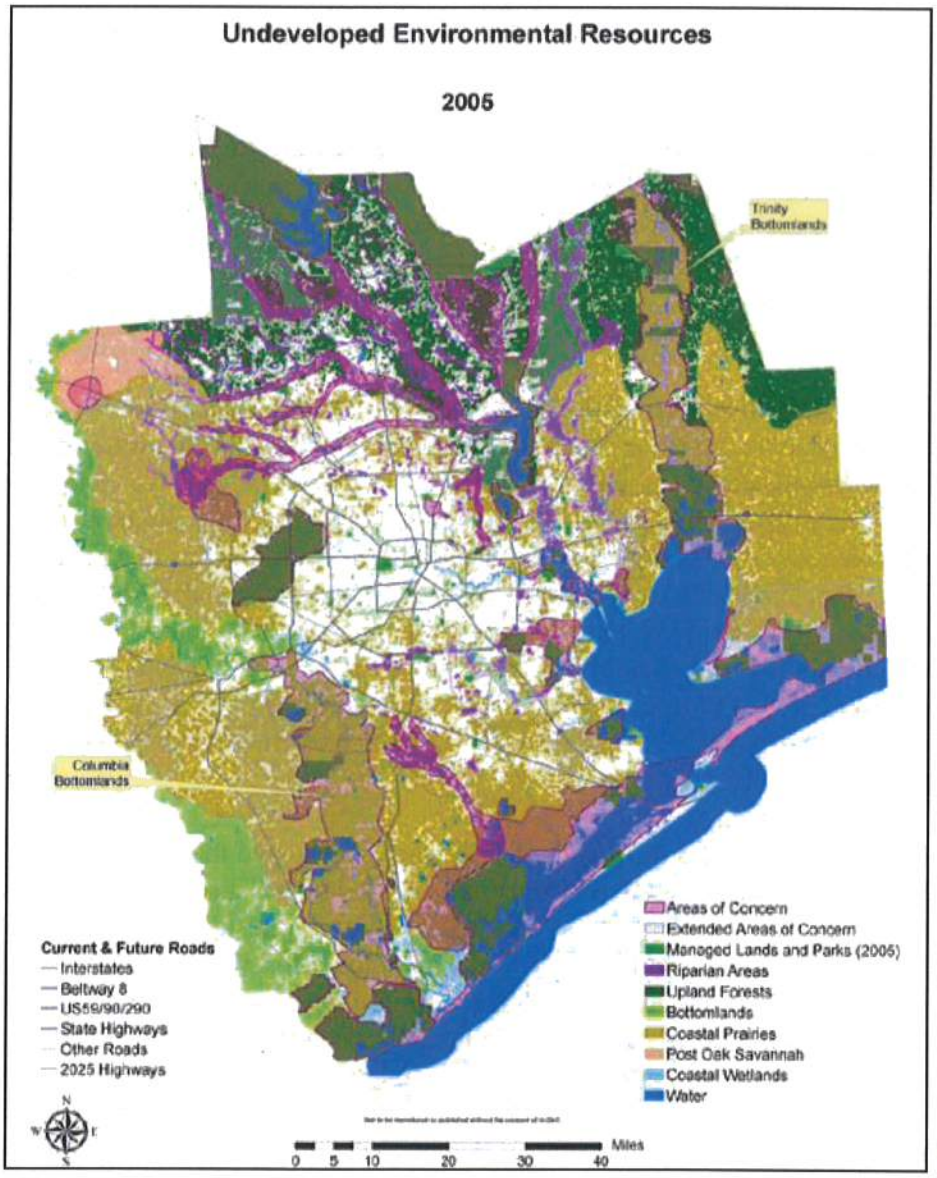


Figure 3: Undeveloped Environmental Resources

their geographic scale. Plans varied from very local, such as watersheds, to very broad, such as state-level. This geographic diversity meant that although some local areas had very rich data available, other areas had little or no data available. Consistency in the type, scale, and units of data was another issue. Some plans used GIS-based shape files while other used only paper maps that do not allow for precise identification of map items. Additionally, there was wide variation in the level of detail available for different ecotypes. A large amount of information, strategies, and data was available for wetlands in the region, while information on other ecotypes was not as readily available.

Recognition of these limitations helped to verify the need for the RDSS in the region. The RDSS provides consistent data and information across the 8-county regional scale and provides equal levels of information for all identified ecotypes in the region. The RDSS is also designed to be upgraded and enhanced as finer levels of GIS-based detail become available for areas or ecotypes.

The integration of agency plans provided valuable insights into best practices and information concerning the types of ecotypes present within the region and the ecological services that these resources provide. This information was used when considering using "level of ecological services" as the basis for prioritization of environmental resources, as well as in the development of metrics. More information concerning ecological services and metrics may be found in *2.6 Establish Criteria for Evaluation of Environmental Resources* in this report.

2.2 Verification of Locations of Environmental Resources

One of the first tasks undertaken by the EAC was the identification and verification of the ecotypes that exist within the region. Although this may appear to be a simple task, common terminologies had to be agreed upon as the literature review revealed a variety of typologies and sub-typologies used for different ecotypes throughout the region. The following section identifies the key ecotypes identified within the region and the methodology used to map each ecotype through aerial imagery.

2.3 Ecotypes within the Houston-Galveston Region

Tidal wetlands, coastal prairies, bottomland and upland forests, water bodies, local icons, and riparian corridors are ecotypes found in the region. Each ecotype contains distinct features that required unique mapping methodologies to delineate their locations within the region. Following ecotype identification, the next step was to map the ecotypes' locations. To complete this mapping process, H-GAC partnered with the Texas Sea Grant - Texas Coastal Watershed Program (TCWP), recognized as experts in aerial interpretation mapping. This mapping was very labor intensive, as the 8-county region encompasses 162 quadrangles which required more than three hours each to map. TCWP mapped the ecotypes of Galveston County as a pilot and presented it to the EAC to look for gaps in the methodology and confirm the mapping using the committee's expertise. The EAC agreed on the basic methodology TCWP would use for the remaining seven counties.

Due to the regional nature of the RDSS, the EAC agreed that ecotypes of a minimum of 100 acres would be mapped. The literature review conducted by H GAC also supports the assumption that 100 acres is the minimum size at which habitat benefits are generally sustained . While smaller ecotype polygons are also beneficial to the region, the scale of the mapping effort was such that not every small ecotype complex could be captured. It is the intent that larger, unfragmented ecotype parcels that have the highest ecological value are identified. Also of note in the methodology is that each ecotype is mapped independently. For example, while many ecotypes overlap within a complex, such as forest areas containing patches of freshwater wetlands, the coded ecotype was the one with the most coverage within a contiguous area. Anything in the region that does not fall into one of the mapped ecotypes is considered a "non-ecotype" and appears without shading within the RDSS.

2.4 Ecotype Information and Mapping Methodology

Each ecotype in the region contains distinct species, provides varying levels of ecological services, and faces discrete challenges to preservation. Each ecotype was delineated in the aerial interpretation mapping with its own methodology. **Table 3** provides a breakdown of the acreage of each regional mapped ecotype.

Table 3: Ecotypes by Acreage

Ecotype	Acres	Number of Features
Tidal Wetlands	153,054	142
Coastal Prairie	613,298	459
Upland Forest	492,468	276
Bottomland Forest	855,530	345

Tidal Wetlands

Located along the region's coast, tidal wetlands are transition zones that allow for land and water to gently meet. Here, salt water meets land, and hydrophytic plants that have adapted to such environments grow, filtering water with their special adaptations and providing oxygen to the water system through their roots.

Due to their high levels of oxygen and nutrients, tidal wetlands are excellent nurseries for fish, crabs, and other shellfish, which in turn support commercial and recreational fishing industries. In addition to aquatic life, there are myriad mammalian, amphibious, reptilian, and avian species that find habitat in the tidal wetlands, several of which are threatened or endangered. Shorebirds and other neo-tropical migratory bird species are especially prevalent in the tidal wetlands.

Tidal wetlands also provide other ecological functions that keep Galveston Bay and the Gulf clean and safe for swimming. Wetlands improve water quality by filtering many of the pollutants out of surface waters before they reach the coast.

Figure 4: Tidal Wetlands (Photo by Linda Shead)

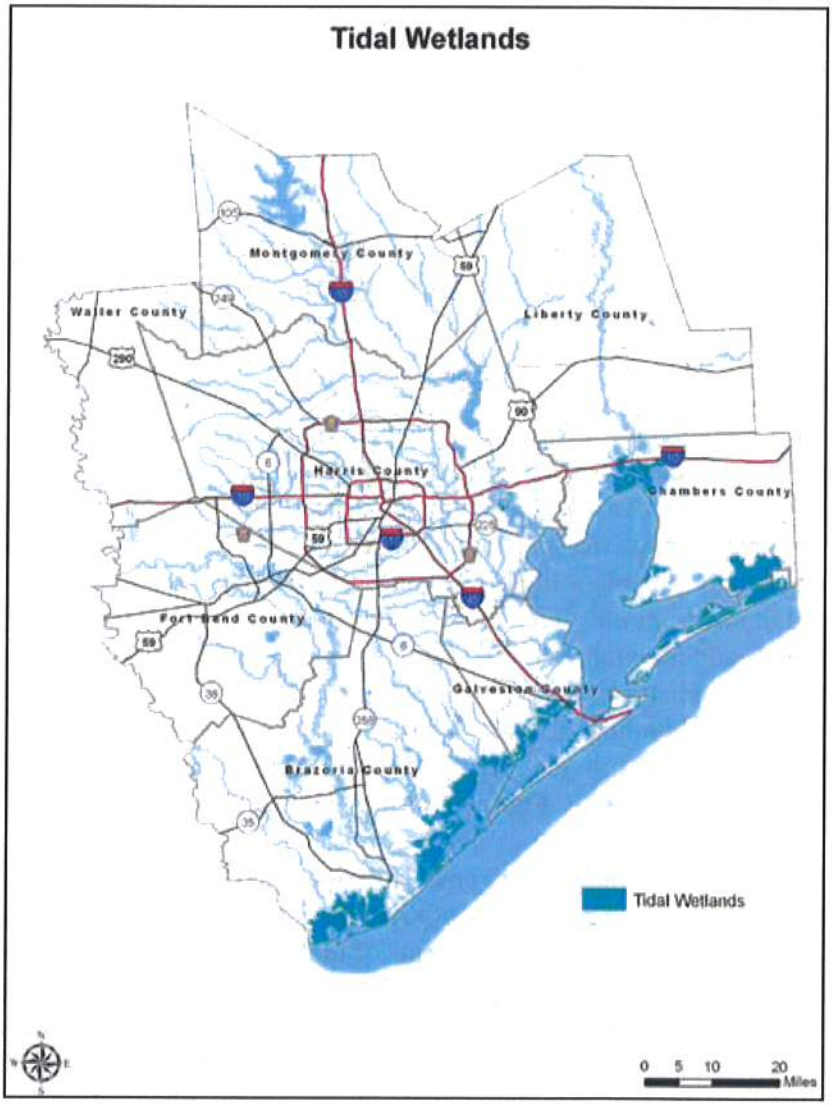


Figure 5: Tidal Wetlands in the H-GAC Region

In addition, wetlands act as buffers against flooding, including hurricane storm surges. Furthermore, wetlands reduce shoreline erosion and stabilize the banks.

Commercial and industrial development threatens these tidal wetlands. Outside of preserved tidal wetlands, this development occurs at an increasing rate. Other threats include hurricanes, subsidence, rising sea levels, and coastal erosion. Currently, wetlands protection occurs mainly through the federal permitting process for dredge and fill operations or land acquisitions.

Approximately 40,000 acres of the region's tidal wetlands are contained within publicly owned nature preserves or parks including the Mad Island Marsh Preserve, the Anahuac National Wildlife Refuge, and the Brazoria National Wildlife Refuge. **Figure 4** shows an example of a tidal wetland. Of note, freshwater wetlands, while recognized as an important environmental resource within the region, were not mapped as a separate ecotype because of their small size (less than 100 acres), but are subsumed within other ecotype categories depending on their location. For example, there may be freshwater wetlands present within a mapped prairie ecotype polygon. This was necessary due to the regional scale of the mapping performed. **Figure 5** shows the locations of the region's tidal wetlands.

To delineate the location of tidal wetlands in the region, all areas within the National Wetland Inventory (NWI) Estuarine Marsh Classification were classified as tidal wetlands and confirmed through aerial photography to not be developed. The Estuarine Marsh System consists of deepwater tidal habitats and adjacent tidal wetlands that are usually semi-enclosed by land but have open, partly obstructed, or sporadic access to the open ocean, and in which ocean water is at least occasionally diluted by freshwater runoff from the land.

Coastal Prairies

The largest ecotype in the region, coastal prairies provide many important ecological functions. Coastal prairies are habitat for many native animal species, including the Houston toad, Attwater's prairie chicken **(Figure 6)**, and the Texas Prairie Dawn-flower, all endangered. The region's coastal prairies are widely known for the role they play in annual bird migrations, providing necessary food and shelter to birds from the Pacific and Eastern flyways. In addition, the coastal prairies reduce flooding by allowing infiltration, the process by which water enters soil. The plant life of the coastal prairies also removes pollutants from the air, soil, and water by absorbing certain metals and minerals via root systems, a process known as phytoremediation. The prairie system also contains freshwater wetlands containing a variety of plant and animal species. Coastal prairies provide recreational opportunities and offer scenic attributes that contribute to the visual identity of the region. **Figure 7** shows the locations of the region's coastal prairies.

Figure 6: Endangered Attwater's Prairie Chicken (Photo by USFWS)

The coastal prairie ecotype, once covering the majority of the region, is now highly fragmented. This fragmentation is a result both of urbanization and agriculture. Presently, only a small portion of unaltered prairie remains, including segments of the Katy Prairie, Damon Prairie, and prairie in Chambers County identified by the Eco-Logical mapping process. These prairies contain large contiguous tracts and unleveled land, representing prehistoric land morphologies. Fortunately, much of the agricultural land in the coastal prairie system has retained environmental functions, such as providing bird habitat. However, the remnants of the coastal prairie system remain threatened by urbanization.

There are conservation efforts for various prairies within the system. The Katy Prairie Conservancy protects over 10,000 acres of prairie land from development, and the Attwater Prairie Chicken National Wildlife Refuge provides native habitat for Attwater's prairie chicken, a federally-protected endangered species. **Figure 8** displays a coastal prairie in the region.

The Nature Conservancy has two preserves in the region for gulf coast prairies and marshes, the Pierce Marsh Preserve and the Texas City Prairie Preserve. Additional regional efforts include the Armand Bayou Nature Center prairie restoration program, preserving 645 acres in the Galveston Bay watershed, and the Anahuac National Wildlife Refuge, a 34,000-acre refuge for wildlife and prairie habitat.

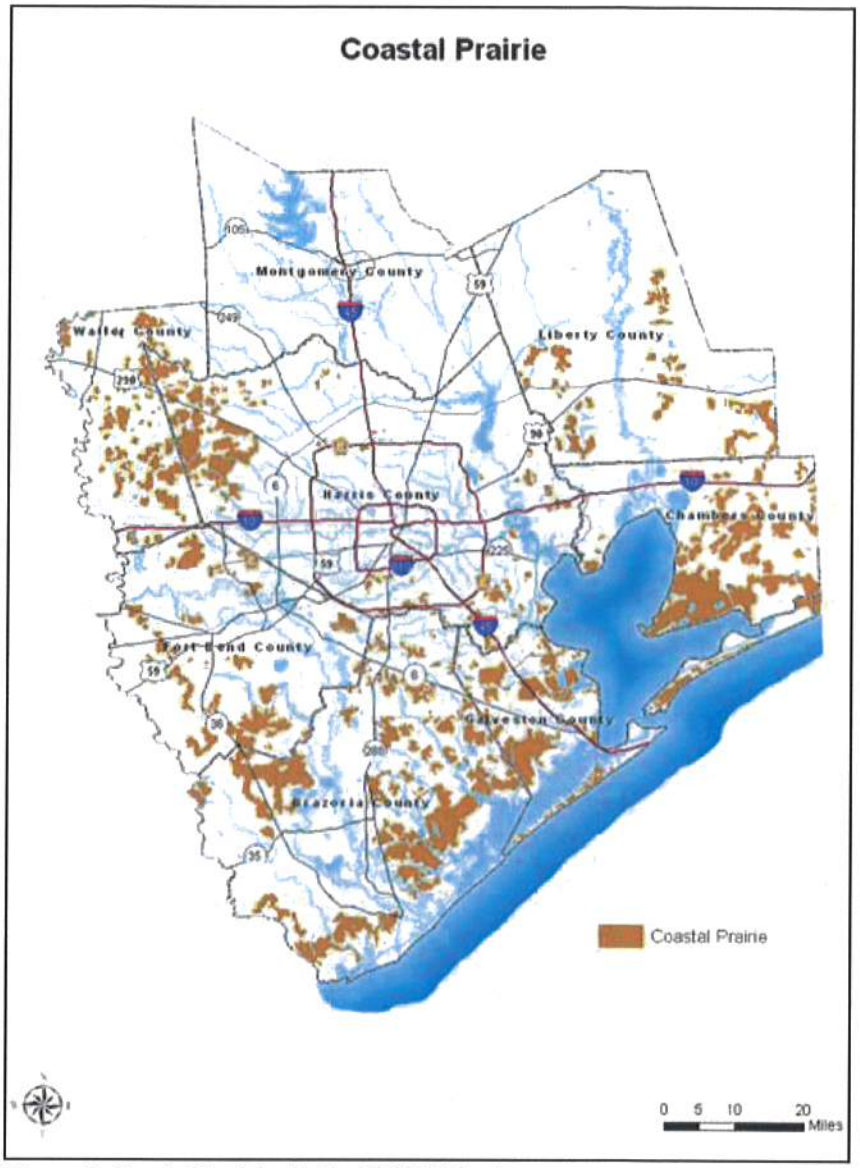


Figure 7: Coastal Prairies in the H-GAC Region

Prairies contain distinct features that aid in the mapping of their location. The most salient and recognizable prairie habitat feature on the Upper Texas Gulf Coast is the prairie pothole–pimple mound complex. The term "pothole" refers to a freshwater depression. Potholes are similar to, but much smaller, than marshes. "Pimple mounds" are small mounds, usually one to two feet tall, which exist among prairie pothole complexes. These complexes are particularly important to birds migrating across the western Gulf of Mexico.

Figure 8: Gulf Coast Prairie (Photo by John Ward, TxDOT)

These habitats are the first source of freshwater encountered by migratory birds and are heavily used by songbirds, shorebirds, waterfowl, and other waterbirds, as well as resident wildlife and livestock in times of drought. Pothole complexes that have never been land leveled are easy to delineate on aerial photography. TCWP developed a three-fold categorization based largely on the nature of the preserved topography which is described in *2.8 Define Metrics Based on Characteristics of Mapped Polygons.* The prairie pothole complexes are found largely on ancient meander ridges of the ice-age rivers that laid down most of the sediments of the Upper Gulf Coast of Texas.

Forests

Forests are much simpler to delineate as a whole than prairies, but more difficult to sub-categorize. The simplest categorization employed was to divide the delineation of the forest ecotype into upland and bottomland forests. For mapping purposes, "Upland" forests are those that are present outside of the 100-year Federal Emergency Management Agency-(FEMA) defined floodplain. "Bottomland" forests are those that are present within the 100-year FEMA-defined floodplain.

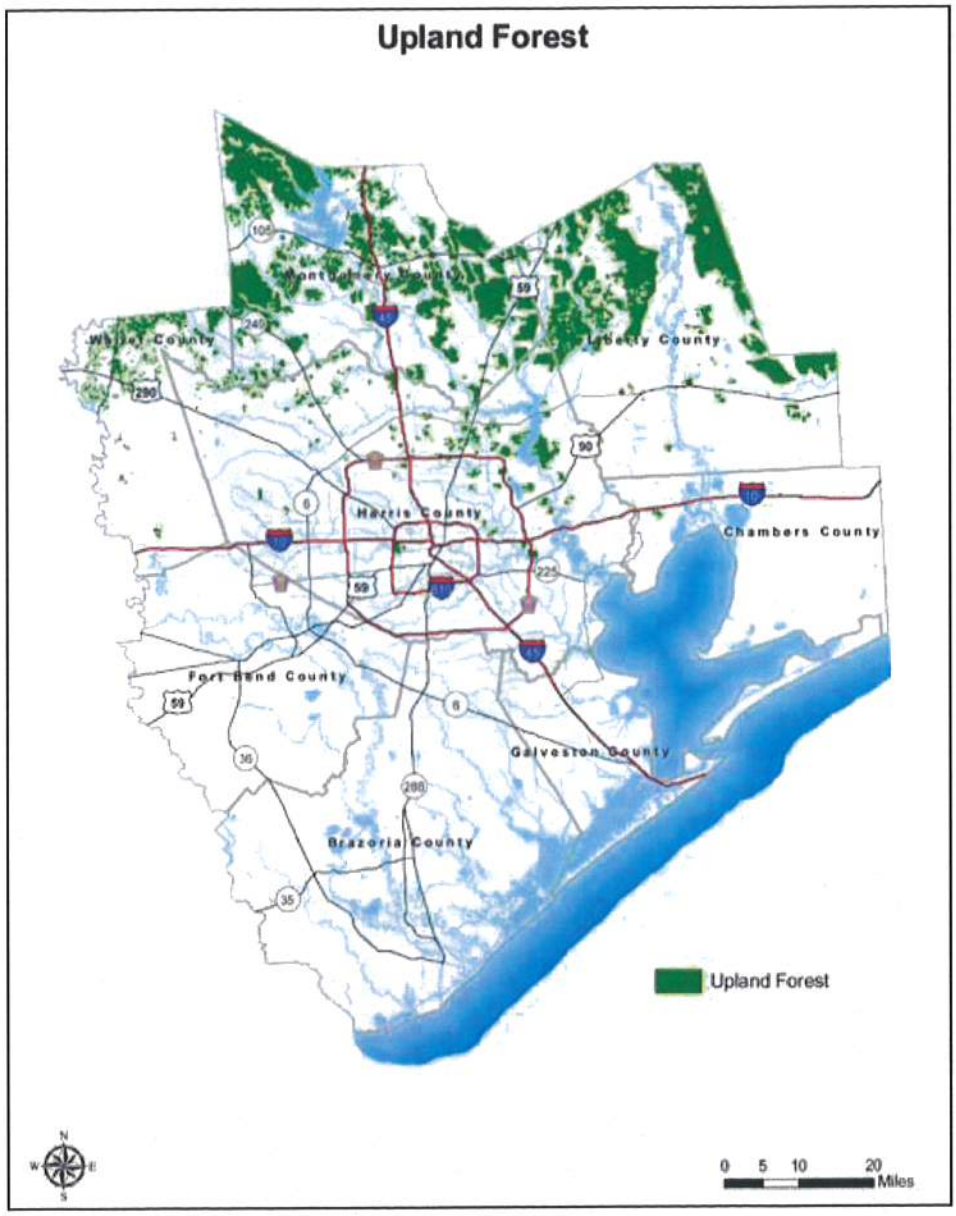


Figure 9: Upland Forests in the H-GAC Region

Upland Forests: In the upland forests a thick upper canopy of pines provides shade for the understory growth of ferns, lichens, shrubs, and mosses. Upland forests, currently found throughout Montgomery and Liberty counties, are home to a range of bird species, such as bald eagles, wood storks, and the endangered red-cockaded woodpecker. The upland forests also provide water supply to Lake Houston – regionally a major source of drinking water. **Figure 9** shows the region's upland forests.

The thick canopy of the upland forest also helps mitigate the urban heat island effect by providing shade and cooling the urban air. As flooding is a problem throughout the region, it is important to note that the upland forests prevent downstream flooding through their ability to percolate stormwater. Loss of the upland forests, like loss of wetlands, would contribute to increased flooding. Upland forests are at an extremely high risk of urbanization, conversion to agriculture or loblolly pine plantations, and over-harvesting. **Figure 10** shows an upland forest in the region.

Bottomland Forests: Bottomlands are low-lying alluvial areas along a river. Two major bottomland areas exist in the region: the Columbia Bottomlands and the Trinity Bottomlands, which follow the Brazos and Trinity rivers respectively. These bottomlands are home to forests that offer habitat for some of the area's most sensitive species, including rare, isolated tree species such as cypress and oak tupelo trees.

The biodiversity of the bottomland forest provides habitat for neotropical migratory birds, wading birds, and song birds. The bottomlands also act as natural floodplains, contributing to flood abatement and erosion prevention through the filtering, infiltration, and retention of stormwater runoff. **Figure 11** shows a map of bottomland forests in the region. **Figure 12** shows a bottomland forest in the region.

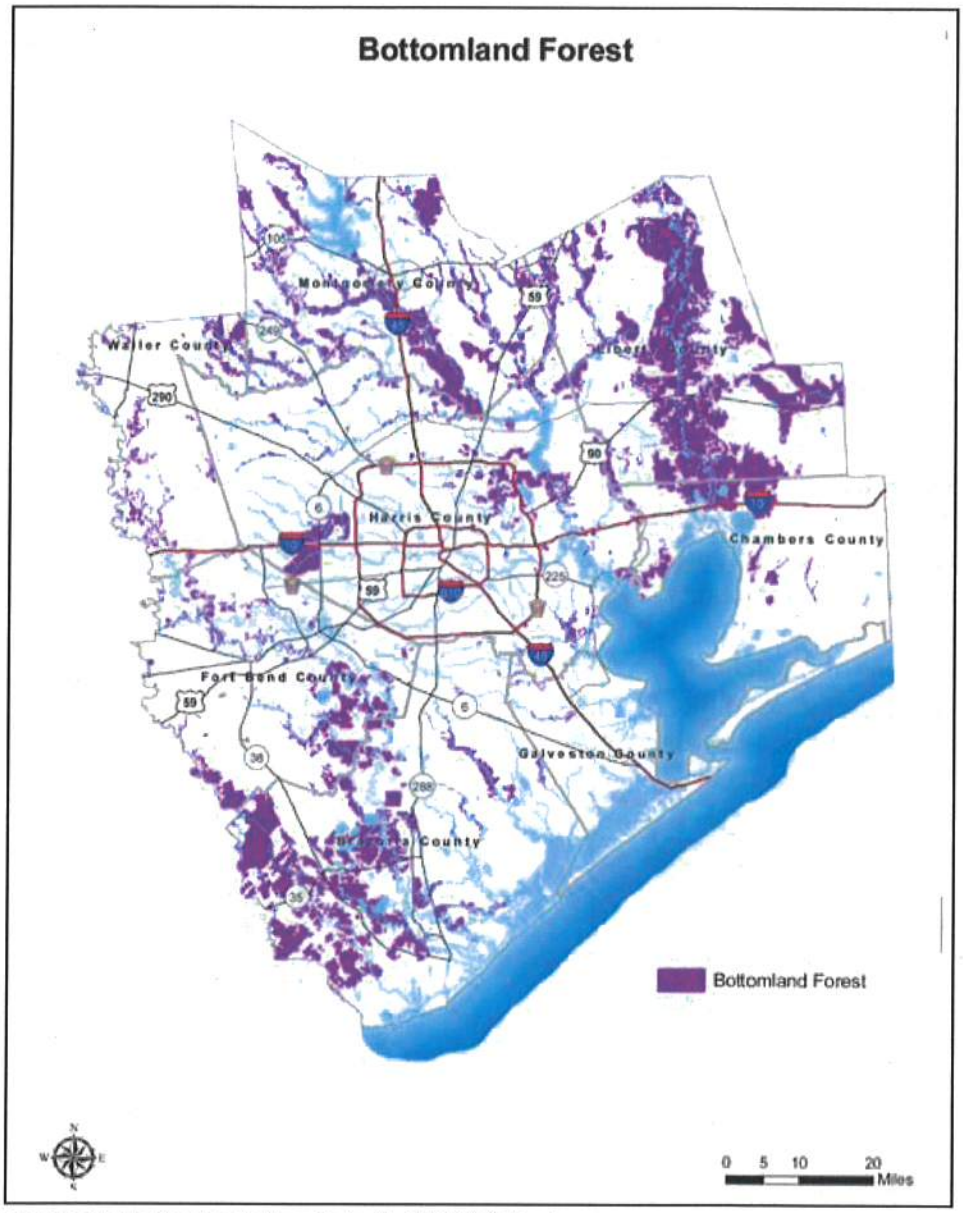


Figure 11: Bottomland Forests in the H-GAC Region

The bottomlands have faced a variety of threats over the years: conversion to loblolly pine plantations, conversion to agriculture and pasture lands, whole-scale logging, and flooding through the creation of reservoirs. Approximately 75 percent of the bottomlands in the region have already been lost, with approximately 170,000 acres left undeveloped. Today, the bottomland forests face new threats in the form of invasive species, such as the Chinese tallow tree, and urban development.

Figure 10: Jones State Forest
(Photo by TFS)

Figure 12: Large Tree In Columbia Bottomlands **(Photo by Mickey Merritt, TFS)**

Water Bodies

The region's lakes, rivers, bays, bayous, creeks and other water bodies are included as a layer in the RDSS. The region is covered by 50 watersheds, as defined by the US Geological Survey. They are categorized into three parts and are described in *2.8 Define Metrics Based on Characteristics of Mapped Polygons.* **Figure 13** shows the region's water bodies.

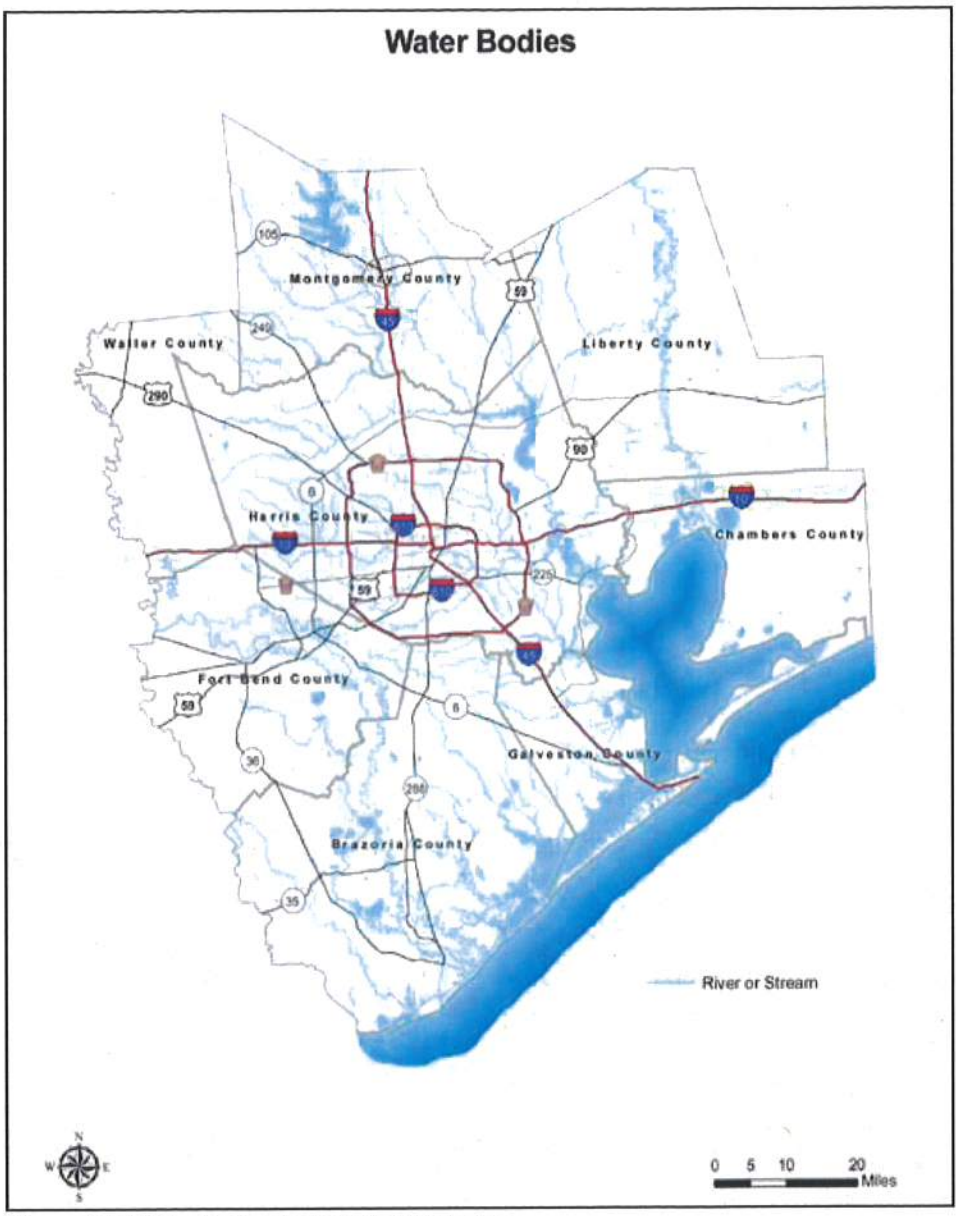


Figure 13: Water Bodies in the H-GAC Region

Local Icons

A local icon is something regarded as exceptional or unique by a community that would not fall into one of the defined ecotypes. For example, an historic oak tree would be considered a local icon. Typically these local icons will be within "non-ecotypes," such as developed areas. The EAC agreed it was important to recognize these features to help ensure their continued preservation. Local governments and conservation organizations will have the opportunity to identify and map local icons as the RDSS is presented to them during H-GAC outreach conducted in spring 2010.

Riparian Corridors

Riparian corridors are the transitional areas adjacent to rivers, streams, and bayous. An example of a riparian corridor is shown in **Figure 14**. There are many riparian zones in the region, such as Spring Creek, Cypress Creek, and Clear Creek.

Riparian areas provide necessary wildlife habitat for sensitive species and protect soil and water from erosion and pollution. Significant development within riparian corridors has already occurred within the region, in many cases within the

Figure 14: Trinity River Bottomlands (Photo by Mickey Merritt, TFS)

floodplain. Floodplain development results in increased flooding risks and impaired water quality. Riparian corridors were not mapped as separate units. Because these corridors overlap the other ecotypes, the riparian corridors were incorporated into the tidal wetlands, coastal prairies, upland forests and bottomland forests ecotypes.

2.5 General Mapping Methodology Information

For all ecotypes, TCWP accomplished the delineation using 2008 H-GAC aerial imagery for Brazoria, Fort Bend, Galveston, Harris, Montgomery, and Waller counties; 2006 H-GAC imagery and 2005 National Agriculture Imagery Program imagery for Chambers and Liberty counties; and 1996, 2004 and 2006 imagery for background references in some areas. Because the imagery used in the analysis was developed before Hurricane Ike made landfall in September 2008, no hurricane impacts were documented. Conditions on the ground may be different than those in the aerial imagery. For example, areas that were mapped as residential prior to Hurricane Ike could be mapped as undeveloped now due to damage from the storm. **Figure 15** shows the mapped ecotypes in the region.

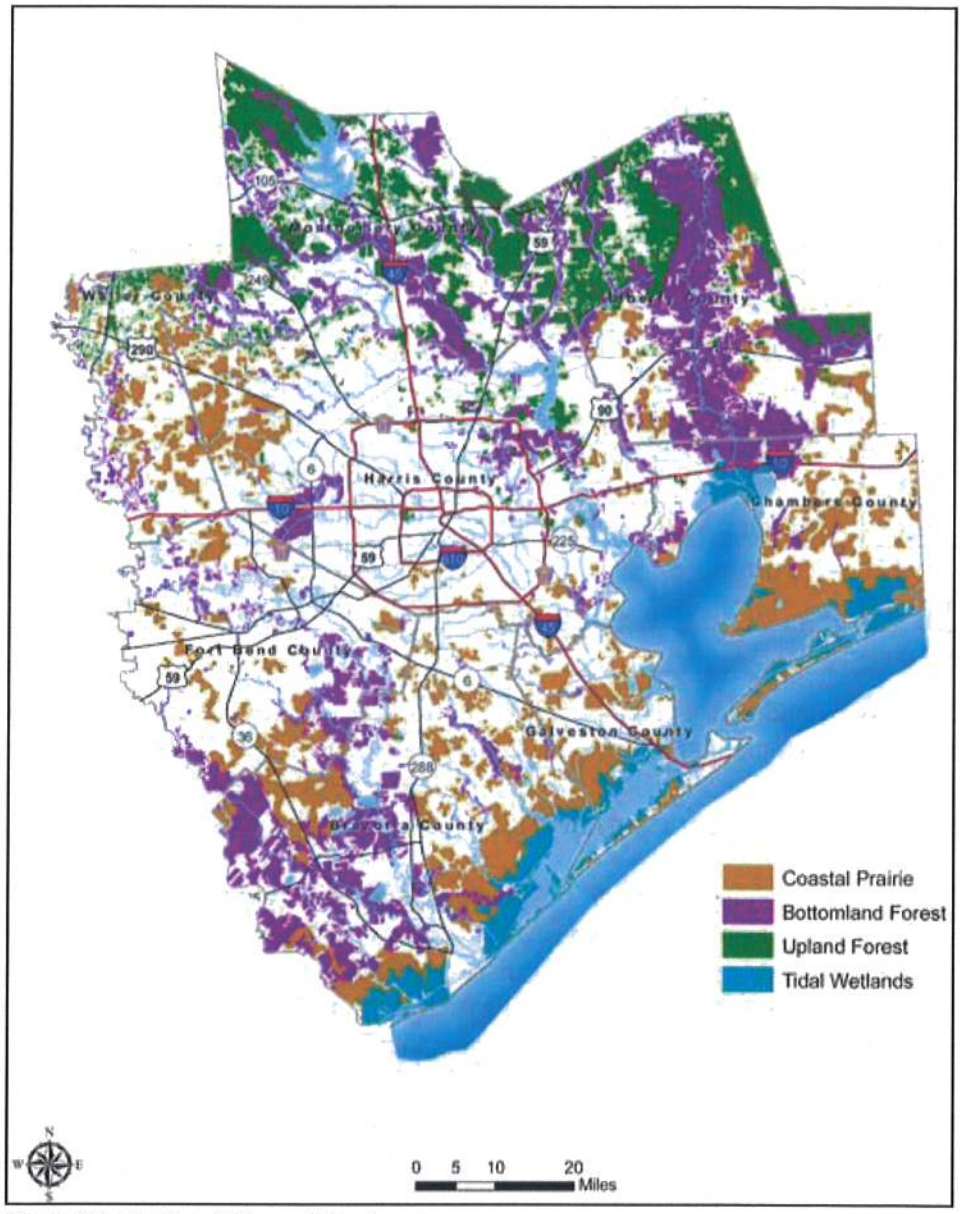


Figure 15: Regional Mapped Ecotypes

2.6 Establish Criteria for Evaluation of Environmental Resources

In order to create the RDSS, a mechanism by which to evaluate and prioritize the mapped environmental resources was required. The prioritization of resources recognizes the fact that not all mapped resources are of equal ecological value. Without a prioritization mechanism, the mapping of environmental resources described in the previous section remains solely a map that cannot be incorporated into policy and transportation evaluation project decisions. Creation of evaluation criteria also provides a more robust set of information about the mapped resources. There is no one established methodology for prioritizing environmental resources in established literature or in existing agency plans.

An additional challenge for this Eco-Logical project is that it is evaluating a host of ecotypes, each with its own intrinsic ecological values. Two methodologies were evaluated for this project: prioritization based on level of ecological service provided by the ecotype and establishment of metrics based on the individual characteristics of each individual polygon mapped in the region. A polygon is a distinctly mapped ecotype feature, in general, consisting of a minimum of 100 acres.

2.7 Ecological Services

The establishment of criteria for the evaluation of the mapped ecotypes ecological value was an iterative process, beginning with prioritizing ecotypes based on the ecological services they provide. A member of the EAC referred H GAC staff to an article that discussed valuing ecological services. While the list of services was global in nature, the EAC was able to pare down and revise the list to one that was relevant to ecological services provided by ecotypes present in the region. Those services are listed in **Table 4.**

Table 4: Ecological Services Provided by Ecotypes in the H-GAC Region

Control Erosion	Provide Quality of Life Benefits
Cycle and Store Nutrients	Provide Recreation
Improve Air Quality	Reduce Greenhouse Gases
Maintain and Improve Water Quality	Reduce Storm Surge Impacts
Moderate Temperatures	Regulate Timing and Distribution of Water Flows
Provide Food Production	Sustain Bio-Diversity
Provide Flood Protection	

The EAC conducted several exercises to prioritize and identify the level of ecological services each ecotype provides. First, the EAC ranked the ecological services in order from highest to lowest importance from a conservation standpoint. Next, H-GAC staff presented the EAC with three methods of assigning a value to each service. A copy of the methodology for this exercise is included in Appendix A.

For the next exercise, the EAC was to determine the level of ecological service provided by each ecotype, resulting in a prioritization of the ecotypes found within the region based on their level of ecological services provided. There was much discussion about whether a methodology based on level of ecological service would provide the best prioritization for the RDSS. The consensus of the EAC was that ecotypes prioritized as a whole could result in a map that would indicate one ecotype was more important ecologically than another. Since each ecotype contributes to the overall function of the system, this method of prioritization was not recommended. Additionally, the EAC recognized that within a given ecotype not all areas are of an equal quality. A consensus was reached that information concerning the types of ecological services provided by different ecotypes would be incorporated as background information for each ecotype but not used as a method to prioritize the resources. A possible future application that could use level of ecological service information would be to evaluate the cost-benefit of ecological services provided by ecotypes for the region which could aid in policy decisions. The EAC agreed that there were many other, more quantitative, factors that needed to be considered that were not incorporated into the prioritization based on ecological services, including size, shape, scarcity, adjacency, fragmentation, presence of threatened and endangered species, diversity, and quality.

2.8 Define Metrics Based on Characteristics of Mapped Polygons

The list of metrics to be evaluated was created after a thorough literature review and discussion with the EAC concerning how the intrinsic value of ecotypes can be measured **(Table 5).** The metrics selected for inclusion in the RDSS all are able to be calculated using GIS tools, meaning that they are all quantitative based (with the exception of the quality metric.) GIS queries allow for the calculation of each metric individually and can also provide the sum of the metrics, as well as allow for weighting of the metrics.

The metrics are calculated for each polygon, regardless of its ecotype, resulting in the ability to identify individual polygons of the highest intrinsic ecological value. There are over 1,200 mapped polygons in the region. A factor analysis was also conducted to confirm that the individual metrics were calculated independently of one another. A copy of the factor analysis is available in Appendix B.

Table 5: Metrics and Definitions Developed by EAC

Name	Description	Interpretation
Polygon Size	Percent of the number of whole 100 acres contained within a polygon relative to the max observed number (for the same ecotype as the polygon for which the statistic is being computed)	larger size --> higher score (large polygons are more valuable)
Polygon Shape	Percent of the perimeter of a circle with the same area (as the polygon) relative to the actual perimeter	more compact --> higher score (elongated polygons are less valuable); low score is associated with low compactness
Regional Polygon and Ecotype Scarcity	Maximum of either: (a) smallest area (of any polygon) relative to the actual area (of a polygon) *100 or (b) fewest number of polygons (for any eco-type) over actual number of polygons (for an ecotype) *100	more abundant --> lower score (rare ecotypes are more valuable)
Watershed Ecotype Scarcity	Maximum of either: (a) smallest area (of any polygon in a watershed) relative to the actual area (of a polygon) *100 or (b) fewest number of polygons (for an ecotype in a watershed) over actual number of polygons (for an ecotype in a watershed) *100	more abundant --> lower score (rare ecotypes are more valuable)
Polygon Adjacency	Percent of the boundary (relative to the total polygon perimeter) shared with polygons of other ecotypes. Rescaled so that max=100, min=0	higher score indicates polygon shares boundary with ecotypes and is thus more valuable
Polygon Isolation	Minimum distance (of all pairs) to another polygon of the same ecotype.	less isolated --> higher score
Presence of Threatened and Endangered Species	If a polygon overlaps with the threatened and endangered species area (as defined by GIS-ST) then 100, else 0	No species = 0 (threatened species are valuable)
Diversity	Overlay polygons with a one square mile grid, count the number of different ecotypes inside each grid cell. Find the maximum number of ecotypes in any grid cell. Divide the number of ecotypes by the maximum number, multiply by 100%. Record the score. Repeat the process 15 times, each time shifting the origin by a quarter mile. Take the maximum of the 16 scores and assign it to the polygon.	more diversity --> higher score (diversity is valuable)
Polygon Quality	User-defined (ranges between 0 and 100); the default value is 100. Defined by science committees.	100 means highest quality

Size

The size of an ecotype polygon refers to its mapped area. Size is an important contributor to the value of an ecotype polygon because large, unfragmented environmental resources are, holding other metrics constant, more able to sustain wildlife populations than smaller ones because "edge effects" are reduced. Edges occur where an ecotype, such as a coastal prairie, meets a non-ecotype, such as a roadway or housing development. These edges may have different conditions than the center of the ecotype polygon and create a disturbed environment that can further be altered by invasive and/or and predator species **(Figure 16).** As an ecotype is developed into a non-ecotype, it becomes broken into smaller areas that affect the type, abundance, and diversity of species that can exist. In general, a minimum polygon size of 100 acres was used in the ecotype mapping.

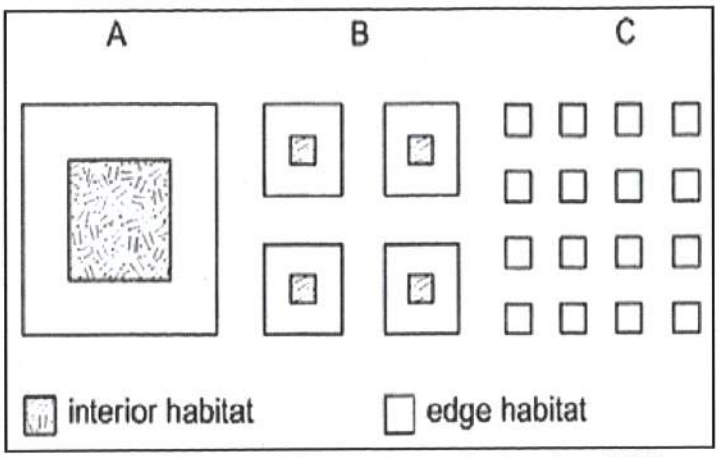


Figure 16: Large patches provide habitat for interior wildlife species. Fragmentation shown in B and C decreases the amount of interior habitat and increases the edge

Shape

An ecotype polygon's shape affects its functionality and ability to sustain wildlife populations, similar to the size metric, due to the occurrence of edge effects. A circular polygon is the ideal shape for non-riparian zone ecotypes because it has the fewest edge effects. **Figure 17** illustrates this concept.

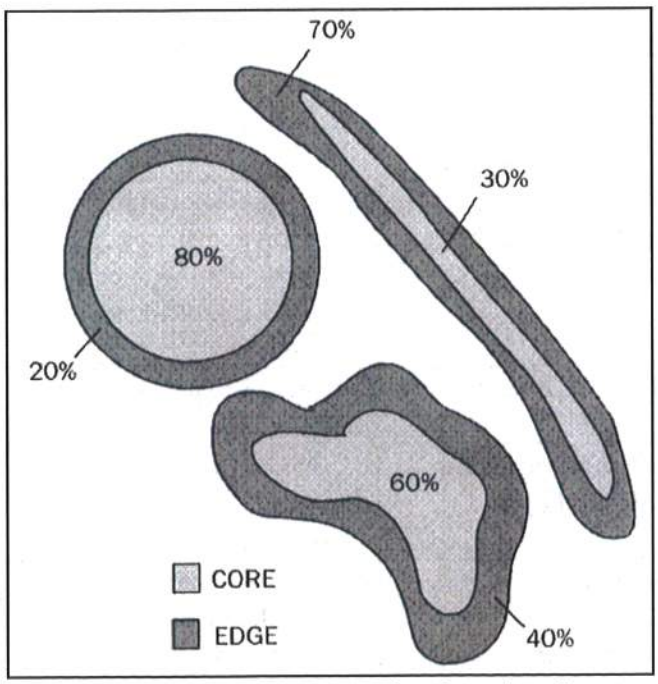


Figure 17: Patch shape and edge. The edge to interior ratio of a habitat patch is affected by patch shape. A more convoluted, irregular or linear patch will have a higher proportion of edge, thus, increasing the number of edge species and decreasing the number of interior species.

Scarcity

The scarcity of an ecotype was measured on both a regional and a watershed scale. For both scales, the more abundant an ecotype, as measured by the number of polygons of said ecotype present, the lower score it received. The scarcity metric gives a higher score to rarely-occurring ecotypes in the region, or rare within a sub-area of the region (as measured by watersheds).

Regional scarcity was measured at the 8-county scale, comparing ecotype polygons to the number of polygons for the entire region. It is recognized that scarcity within the region does not necessarily reflect scarcity of said ecotype within a broader geographical context. For example an ecotype may only exist in a limited capacity in the region but be prevalent elsewhere in the state or the nation.

Despite the limitation of not being able to compare scarcity beyond the region, scarcity is regarded as an important metric. The EAC also agreed that a smaller scale measure was necessary to garner those areas that would be incidental on a regional scale but may be the only ecotype polygon of its kind in the area surrounding it. This smaller scale follows the boundaries of USGS-delineated watershed boundaries.

Adjacency

The adjacency metric describes contiguity of an ecotype to a different ecotype or non-ecotype. In terms of ecotype function, it is more beneficial for a polygon to be adjacent to another ecotype polygon rather than a non-ecotype, such as a road or housing development, because edge effects are reduced.

Isolation

The EAC discussed the inclusion of a fragmentation metric; however, an independent method that did not overlap other metrics (such as size and adjacency) was not found in the literature review. A concept called "nearest neighbor" was introduced, and the EAC accepted it as an alternative to measuring fragmentation. This measure answers the question "What is the minimum distance of one ecotype polygon to the next like ecotype polygon?" The nearest neighbor is the neighbor with the least physical separation. The model calculates the distance of each polygon of a particular ecotype to like polygons and rates more highly those that are less isolated. The principle behind the nearest neighbor concept is that polygons of the same ecotype that are close together may once have been part of a contiguous ecotype complex and could potentially be restored. For example, in **Figure 18,** polygon E is the nearest neighbor to polygon A. Polygon B would be the most distant neighbor to polygon A. The distance for the nearest neighbor would be compared to the distances for the nearest neighbors of all polygons.

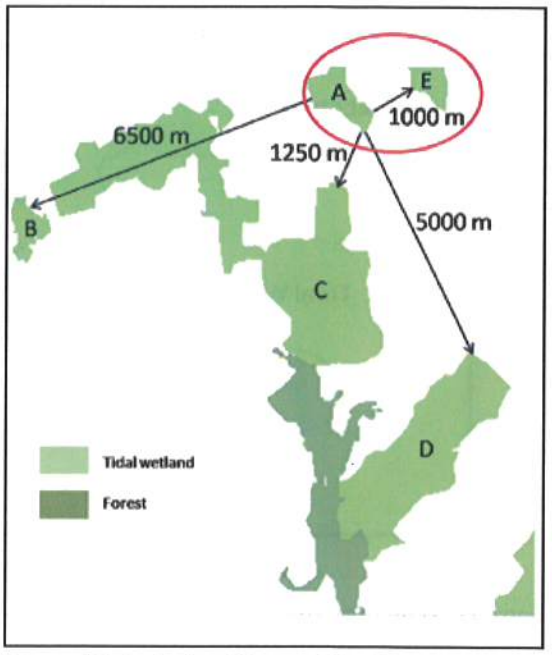


Figure 18: Isolation Measured by Nearest Neighbor

Presence of Threatened and Endangered Species

The EAC discussed the importance of including the presence of threatened and endangered species (T&E) in the RDSS. There are many limitations with T&E species data. First, the lists of federal and state T&E species are available on a county-level only. No specific information is given as to the precise location of T&E species. Second, because of the status of these species, federal and state agencies are hesitant to provide this precise information to the public (note that all data included in the RDSS will be transparent and publicly available online). The EAC noted that species are tied to habitats so anything included in the T&E metric would need to be habitat-specific. Given the regional scope of the project, this level of detail was not feasible.

The best available public T&E data was the U.S. Environmental Protection Agency (EPA) Region 6's Geographic Information System Screening Tool (GISST), an environmental assessment tool developed to provide a systematic approach to making decisions concerning complex projects, such as those subject to the National Environmental Policy Act (NEPA). The GISST uses socioeconomic and environmental data, including T&E species, to provide screening level assessments of the potential environmental vulnerabilities of project locations or the impacts of specified activities. One of the limitations with the GISST T&E data is that it provides point locations of where T&E species have been identified previously. No point data where T&E species may exist based on habitat are provided. Additionally, the point data does not provide details regarding the type of species (animal or plant). However, given the lack of availability of improved detailed information, the EAC agreed that the GISST was the best source of information available to the public. In the RDSS, the T&E metric is a "yes/no" question, with 100 points added to an ecotype polygon's score if a T&E point falls within the ecotype polygon boundary. If no T&E point falls within those boundaries, zero points are added to the ecotype polygon score.

Diversity

For the RDSS, diversity is measured as the number of different ecotype polygons in a one-mile grid. In order to remove bias associated with the origin of the grid placement, the process is calculated a total of 15 times, each time shifting the origin by a quarter-mile along the vertical and/or horizontal axis, then taking the highest value for each polygon. Diversity is valued because it allows a wider variety of species habitat. **Figures 19 and 20** show high and low diversities in one-mile grids.

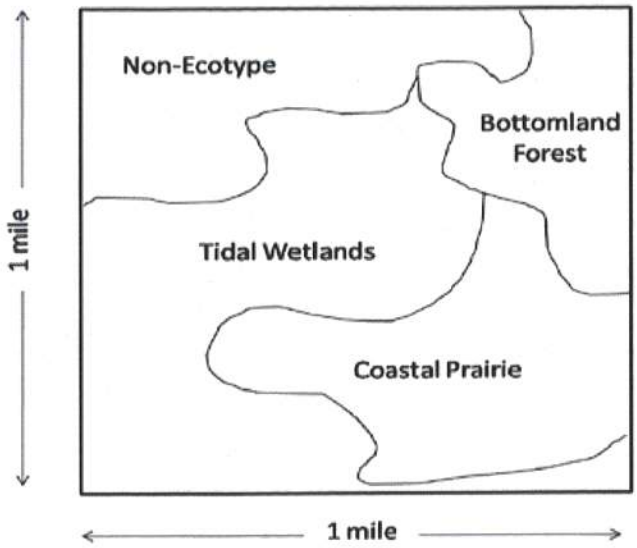


Figure 19: High diversity

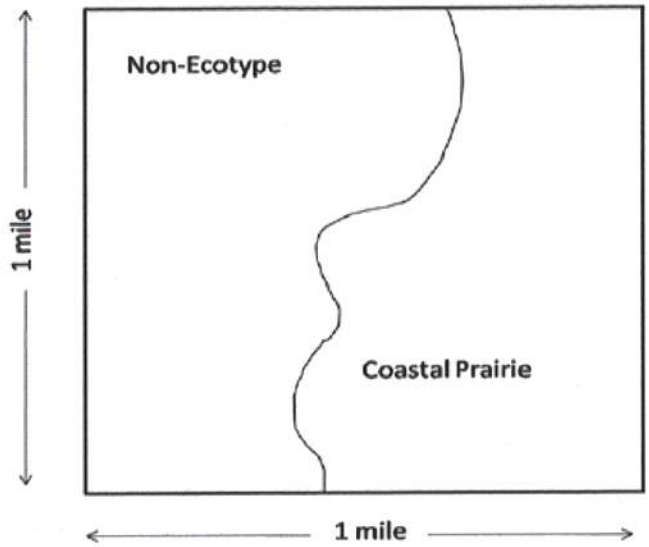


Figure 20: Low Diversity

Quality

The previous metrics are quantitative in nature and can be calculated automatically by the RDSS GIS-based model. Each of the other metrics helps to get at the overall "quality," or intrinsic value, of the ecotype polygon but still does not fully capture the on-the-ground condition of a particular ecotype polygon (such as soil conditions, presence of invasive species, etc.).

As these are qualitative assessments that explore the unique conditions of what constitutes quality for each ecotype, a science committee of ecotype -specific experts was convened to establish a methodology for quality assessment of coastal prairie, bottomland and upland forests, and tidal wetlands. These quality assessments were made on a polygon by polygon basis. **Table 6** provides a breakdown of the ecotype quality classifications by acres.

Table 6: Ecotype Quality Classifications by Acres

Ecotype	Acres	Number of Features
Coastal Prairie 1	266,838	125
Coastal Prairie 2	186,487	216
Coastal Prairie 3	159,972	118
Bottomland Forest 1	657,486	124
Bottomland Forest 2	187,364	183
Bottomland Forest 3	10,679	38
Upland Forest 1	84,357	14
Upland Forest 2	403,983	247
Upland Forest 3	3,948	15
Tidal Wetlands	153,084	142

Coastal Prairie Quality

CP1 (Highest quality) Polygons designated as CP1 have no signs of land leveling or other topographic disturbance. Meander scars and other depressions are clearly visible. Pimple mounds are clearly visible. Most areas will have some measure of native vegetation, but many, if not most, will have been heavily overgrazed with degraded vegetation as the result. Many areas will have heavy brush infestation.

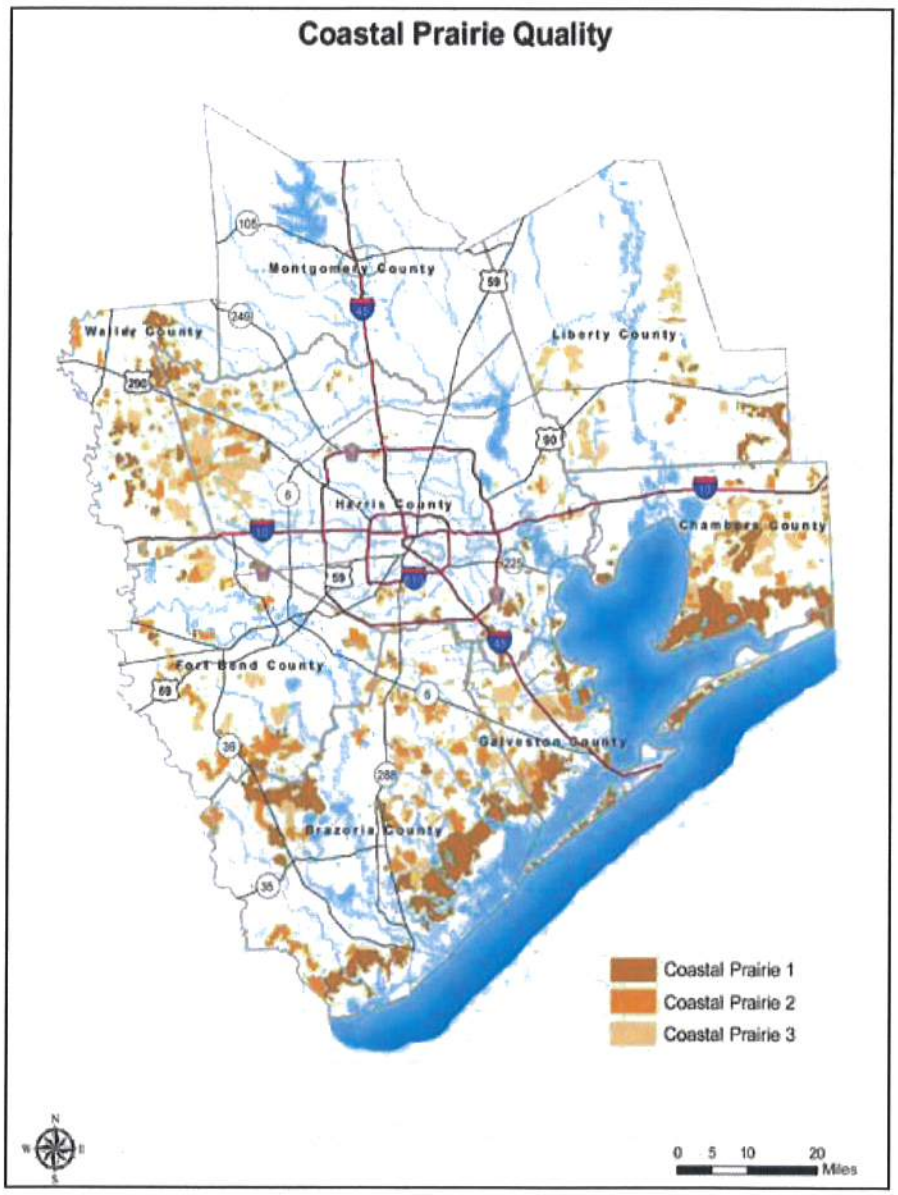


Figure 21: Quality Metric Classification for the Region's Coastal Prairies

CP2 (Intermediate between CP1 and CP3) These polygons may have been "lightly" or "moderately" land leveled, but considerable topographic diversity remains. Low level development (large lot residential, roads, oil fields, etc.) may have impacted some areas. Many areas will be very heavily impacted by invasive scrub-shrub vegetation. Because these areas generally have some landscape relief and complexity, they would be much more easily restorable than CP3s. Few if any areas would have much of a native seed bank.

CP3 These polygons have clear evidence of potholes, but these have been leveled to a large degree. No pimple mounds are evident (but their "ghosts" [a change in soil tonal pattern] may be visible). Most polygons are abandoned farmland or may currently be fallow rice field or pasture. Very little if any original vegetation may be present. There is currently little value as habitat; however, their value is in restoration potential. An examples of a successful projects is Sheldon Lake State Park in which wetlands have been restored by re-excavating leveled potholes and planting in the formerly buried topsoil. These areas are not as easily restorable as CP2, but an excellent basis is provided by the buried original prairie topsoil.

The three-fold classification is not a rigorous, quantitative classification. Precise guidelines that would enable a high ability to replicate were not developed. Because of the distinctive aerial photographic signature, the CP1 is a fairly straightforward degree of remaining landscape complexity. The CP3 class represents the lower end of what could be considered the remnants of a prairie pothole landscape. At best, there is a good possibility for restoration. The CP2 class is intermediate between CP1 and CP3. There are

more features preserved in the landscape than CP3, but enough disturbance that they could not be classified as CP1. It is important to note that this classification is qualitative and somewhat subjective; however, the qualitative nature of the classification does not invalidate its usefulness.

Figure 21 displays the quality metric classification for coastal prairies.

Forest Quality

Following TCWP's delineation of the forests, a representative of the Texas Forest Service further delineated the forests into smaller categories. Similar to the Coastal Prairie ecotype, the forests were divided into three subecotypes. **Figures 22 and 23** show the quality metric classifications for the region's bottomland and upland forests, respectively.

BF1 (Highest bottomland forest quality) Polygons designated as BF1 represent forests are of high quality and relatively old growth hardwood trees, usually large unbroken sections with a minimal amount of invasive species, minimal site disturbance and not immediately threatened by development. These forests may also protect critical watersheds or riparian zones due to their ability to reduce erosion and improve water quality. Because of the importance of forest conservation and scarcity of quality hardwood forests in the region, most public hardwood bottomlands and lands in conservation easements were classified in this category.

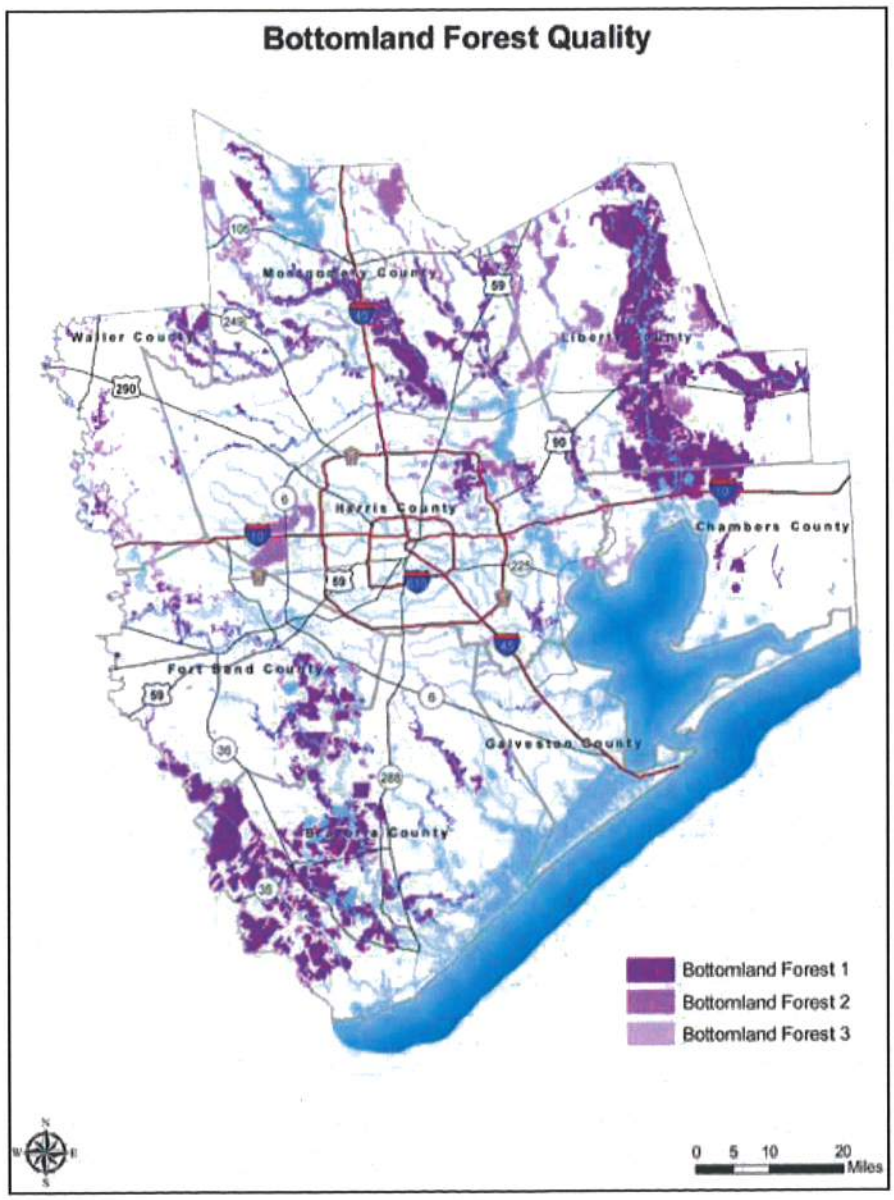


Figure 22: Quality Metric Classification for the Region's Bottomland Forests

BF2 (Intermediate quality) These polygons represent forests that have been logged during the early to mid 20th century but still contain some fairly high-quality hardwood bottomland trees, and may or may not be in large continuous sections.

They offer some protection to watersheds and riparian zones, but may be somewhat threatened by development and be fragmented. These forests usually contain a higher percentage of invasives and/or shrub layer (yaupon, privet, etc.) and may contain mixed upland/bottomland species.

BF3 These forests have been highly degraded. Invasive species

or shrubs may make up the largest percentage of the canopy. The forests may be highly threatened by development, a small tract, and severely fragmented.

They do not offer much watershed or riparian zone protection.

UF1 (Highest upland forest quality) Polygons designated as UF1 represent forests that are of high quality and relatively old growth upland trees, which may include upland hardwood species, usually large unbroken sections with a minimal amount of invasive species, minimal site disturbance and not immediately threatened by development. They may also protect critical watersheds or riparian zones by reducing erosion and improving water quality.

Because of the importance of forest conservation and scarcity of quality upland forests in the region, most public uplands and lands in conservation easements were classified in this category.

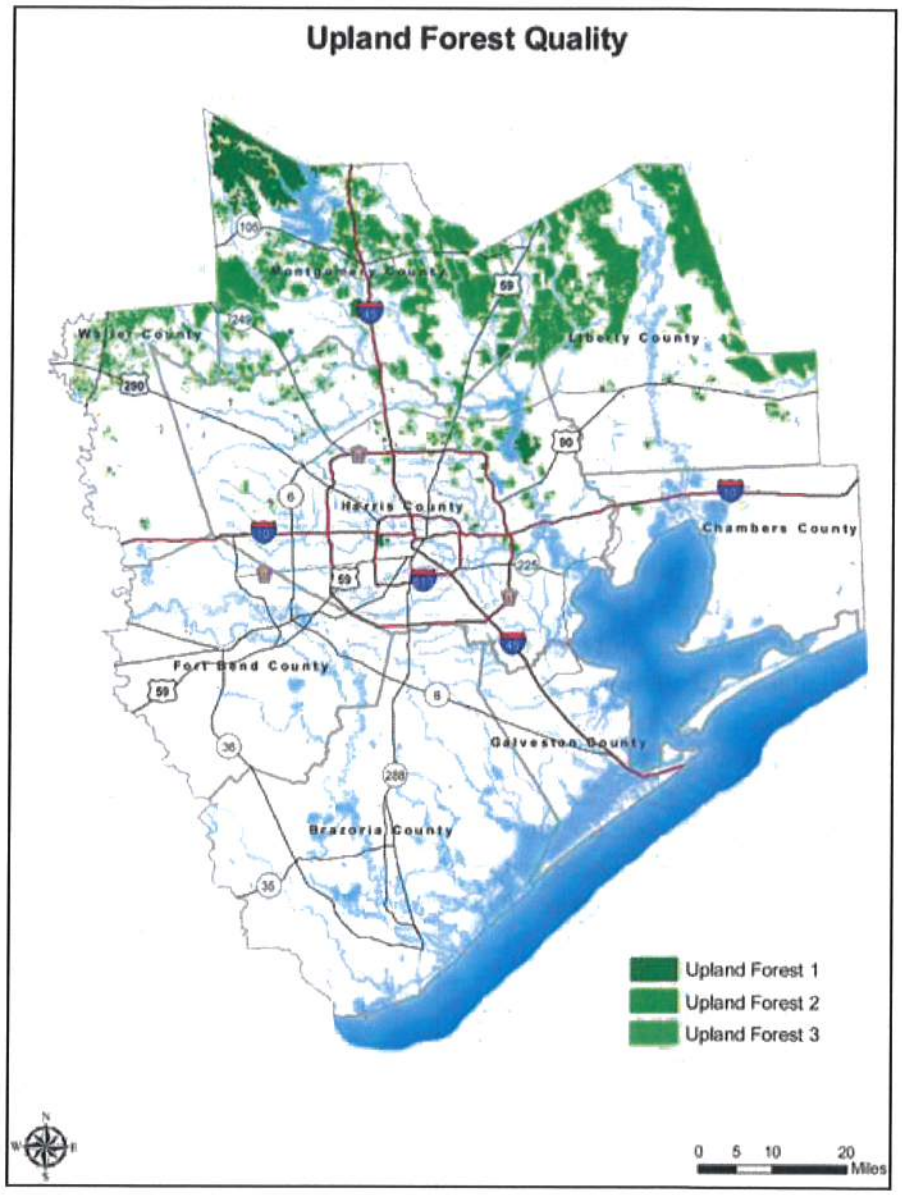


Figure 23: Quality Metric Classification for the Region's Upland Forests

UF2 (Intermediate quality) These forests, which may include upland hardwood species, have been logged during the early to mid 20th Century or are in current pine plantation production, and may or may not be in large continuous sections.

They offer some protection to watersheds and riparian zones, but may be somewhat threatened by development and be fragmented. These forests usually contain a higher percentage of invasives and/or shrub layer (yaupon, privet, etc.) and may contain mixed upland/bottomland species.

UF3 These forests, which may include upland hardwood species, have been highly degraded and invasive species or shrubs may make up the largest percentage of the canopy. The forests may be highly threatened by development, a small tract, and severely fragmented.

They do not offer much watershed or riparian zone protection. In some cases areas that were first delineated by TCWP as bottomland forest were reclassified to upland forest and vice versa. Annotations in the RDSS have been made in instances where this situation has occurred.

Tidal Wetlands Quality

H-GAC staff contacted members of TPWD, USFWS and GBEP to form a wetlands science team to assist with development of the quality metric for tidal wetlands. The general response was that development of a three-fold quality metric classification for tidal wetlands that was similar to that of coastal prairie and forests was not possible due to a lack of accuracy stemming from the regional scale of the project. The wetland science team concluded that distinguishing quality among the tidal wetlands using aerial photography would not be a sound method. On the ground surveys would be required to examine plant species; however, due to the regional nature of the project, these surveys were not feasible.

Under a 3-tiered system, tidal wetlands would be rated against one another due to the many different classifications of tidal wetlands. The consensus among conservation groups is that wetlands provide a very high level of ecological services. H-GAC staff proposed having only one tidal wetlands quality metric that is equal to the highest quality metric for forests and coastal prairies. The wetlands science team and EAC agreed that all tidal wetlands should receive the highest quality rating.

Water Bodies Quality

The region's lakes, rivers, bays, bayous, creeks, and other water bodies are included in the RDSS. They differ from the other ecotypes in that they appear as a layer in the RDSS that can be turned off and on, and no metric calculations are performed (as their intrinsic compositions differ from land based ecotypes). **Figure 24** depicts the water quality metric for the region's water bodies. These water bodies have been subcategorized into the following:

Highest quality Water bodies meet contact recreation standards established by the State of Texas.

Medium quality Water bodies can refer to two situations: Stream data are trending toward impaired; however, according to the Texas Commission on Environmental Quality (TCEQ) monitoring standards, an insufficient quantity of monitoring data are present; or No standards are established for a parameter. A screening level is established and it has been exceeded. For example, nutrient levels are elevated.

Lowest quality Water bodies are listed on EPA 303d list of impaired water bodies.

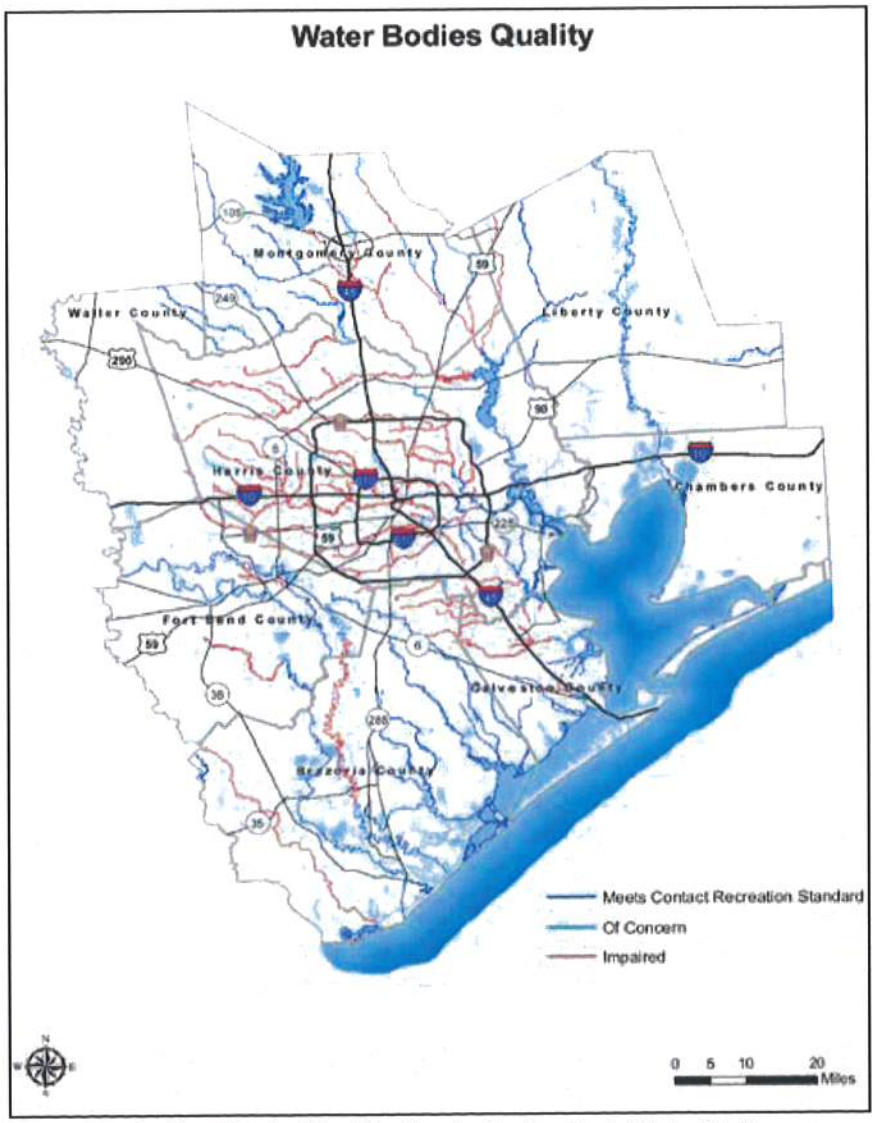


Figure 24: Quality Metric Classification for the Region's Water Bodies

Weighting of Metrics

The purpose of establishing a weighting methodology for the previously described metrics is that not all metrics may contribute equally to the overall value of the particular ecotype polygon. In a weighted system, a particular metric can be designated more important than other metrics, and a polygon's score for that more important metric is multiplied by an assigned multiplier value so that it contributes more greatly toward its cumulative score. In contrast, with an unweighted system the metrics are treated equally and the multiplier equals 1. For both methodologies, the metric scores are then added together to generate one cumulative metric score for the polygon. The polygon's score is then compared to all other polygon's scores so that the highest scoring polygons can be identified (Level 1, 2, 3 prioritization as described in *3.1 Apply Metrics to Identify High Priority Environmental Resources*).

Several weighting scenarios showed that there was little difference between weighted and unweighted metrics, and the EAC could not reach consensus on which weighting scenario would be most important. Literature review of the topic did not produce the sought-after information, nor did existing agency plans. Therefore, H-GAC staff proposed a default unweighted approach for the metrics with the possibility of allowing the user the ability to assign values for the weights for each metric. Providing for user-defined metric weights allows for a more user-driven process and greater flexibility. The EAC agreed with this proposal, and the results were incorporated into the RDSS.

2.9 Impact Buffers

A transportation project's impacts on the environment are not limited to the immediate roadway. Cumulative impacts of pollution and habitat loss can extend from several feet to miles. Noise associated with construction and new traffic can frighten wildlife and cause them to flee to areas with less noise. A tool in the RDSS allows a user to define the buffer around the proposed project's alignment and then generates a summary and scores of the polygons that would be potentially affected by the facility.

Based on the assessment of potential impacts, strategies to help avoid potential undesirable induced land use impacts can be considered. These may include access management, context sensitive design, purchase of access rights, and land acquisition and conservation[2] .

Direct Impact Buffers

The types of direct impacts vary with the ecotype affected. Construction of a new transportation facility could potentially fragment habitat and degrade water quality of nearby waterways because of increased impervious surfaces and pollutants in runoff. Project sponsors should strive to employ best management practices to minimize these water quality issues.

Wetlands, both tidal and freshwater, provide a multitude of ecological services. With the construction of a project, those areas may be filled, silted, or drained, and the ability to provide ecological services is severely reduced. It is important to note that wetlands that fall outside of the U. S. Army Corps of Engineers' jurisdiction are not federally protected and therefore have no requirements to mitigate wetland loss.

In the RDSS, the user has the option of defining an impact buffer. The impact buffer is a specified radius distance that is drawn about the centerline of a project. The default impact buffer is one mile. H-GAC staff consulted with Texas Department of Transportation (TxDOT) Houston District staff for recommendations for impact buffer distances for particular types of projects, but TxDOT staff suggested a user-defined impact buffer would be preferred. As with metrics weighting, a user-defined impact buffer allows for greater flexibility. Currently, indirect impacts are not included in the user-defined impact buffer.

2 Northeastern Illinois Planning Commission

2.10 Incorporation into RDSS

The mapped ecotypes, metrics, and buffers were incorporated into the RDSS using ArcGIS Server 9.3.1 software. Hardware included ProLiant DL360 G3 with 3 GB memory; Microsoft Windows Server 2003, standard edition operating system; and Intel 2800 MHz Dual Processor. The RDSS requires no special software because it is Internet-based and is available at the following URL: **www.h-gac.com/go/eco-logical**.

The base layer of the RDSS is the ecotypes quality. Users also have the option of turning off and on the ecotypes' color-coded layer. The (unweighted) metrics are applied to each ecotype polygon and overall cumulative metric score is generated which determines the priority level (red, orange, or yellow) for each ecotype polygon. Landcover data and water quality monitoring data are additional map layers. Methodology for these data is available in Appendix C. Users have the option of drawing points, lines, or polygons for their proposed projects and determining whether or not they want to weight the metrics. For example, a user may wish to place a greater weight on the size metric. Users also have the option of defining a buffer in different units of measure. The result is a project summary metrics table that provides a minimum, average, and maximum score for the all of the ecotype polygons intersected by the user-defined buffer. A total weighted (if selected) and unweighted minimum, average, and maximum score are also provided in the summary metrics table. A User Guide to navigating through the various functions in the RDSS is available in Appendix D. Transportation project sponsors would use this resulting information to answer the questions presented in *4.2 Examine Locations of Proposed Transportation Projects* and provide the answers in the H-GAC Transportation Economic Land Use System (TELUS) relevant to their project's impact on ecological resources.

3.0 Develop a Regional Decision Support System for Evaluation

3.1 Apply metrics to identify high priority environmental resources

After the metrics were applied to each of the mapped ecotypes polygons, a total unweighted score was given to each of the polygons. The total scores were then indexed. Natural breaks (Jenks)[3] were applied to break the total scores into three groups. Level 1 polygons represent the high priority environmental resources. **Table 7** provides a breakdown of the levels. **Figure 25** shows the cumulative metric rankings.

Table 7: Breakdown of Ecotypes within Level 1, 2, 3

Level	Color Code	Number of Polygons	Total Acres	Percent of Total Polygons	Percent of Total Acres
1 (high priority)	Red	181	933,557	15%	45%
2	Orange	484	635,872	40%	30%
3	Yellow	557	524,919	46%	25%
Total		1,222	2,114,348	100%	100%

3.2 Outreach to other environmental and transportation stakeholders and public

In order to gain public acceptance of the RDSS, H-GAC staff conducted outreach in spring 2010 with conservation agencies and organizations represented on the EAC to showcase the RDSS and how it can be utilized for long-range transportation planning and other projects in the region. H-GAC staff also used this opportunity to request locations of local icons for the RDSS. H-GAC staff will continue to speak to conservation agencies and organizations to promote the RDSS.

3 Natural breaks (Jenks): Classes are based on natural groupings inherent in the data. Break points are identified by picking the class breaks that best group similar values and maximize the differences between classes. The features are divided into classes whose boundaries are set where there are relatively big jumps in the data values. (ESRI)

Presentation of project to EAC, H-GAC committees, local governments and other organizations

Transportation planning agencies

H-GAC

H-GAC will integrate the information derived from the RDSS into the long-range transportation planning process including the project prioritization process.

Transportation Policy Council

The Transportation Policy Council (TPC) provides policy guidance and overall coordination of the transportation planning activities within the region. The TPC consists of 26 members representing cities and counties, TxDOT, the Metropolitan Transit Authority of Harris County (METRO) and three at-large members appointed by the H-GAC Board of Directors.

Technical Advisory Council

The Technical Advisory Committee (TAC) provides reviews and evaluates H GAC's regional transportation plans and provides recommendations to the TPC. The TAC is an appointed body comprised of representatives of member governments and citizen interest groups with expertise in transportation planning. TAC members are appointed by the TPC to assist with the coordination of the Transportation Improvement Program, Regional Transportation Plan and other transportation planning activities.

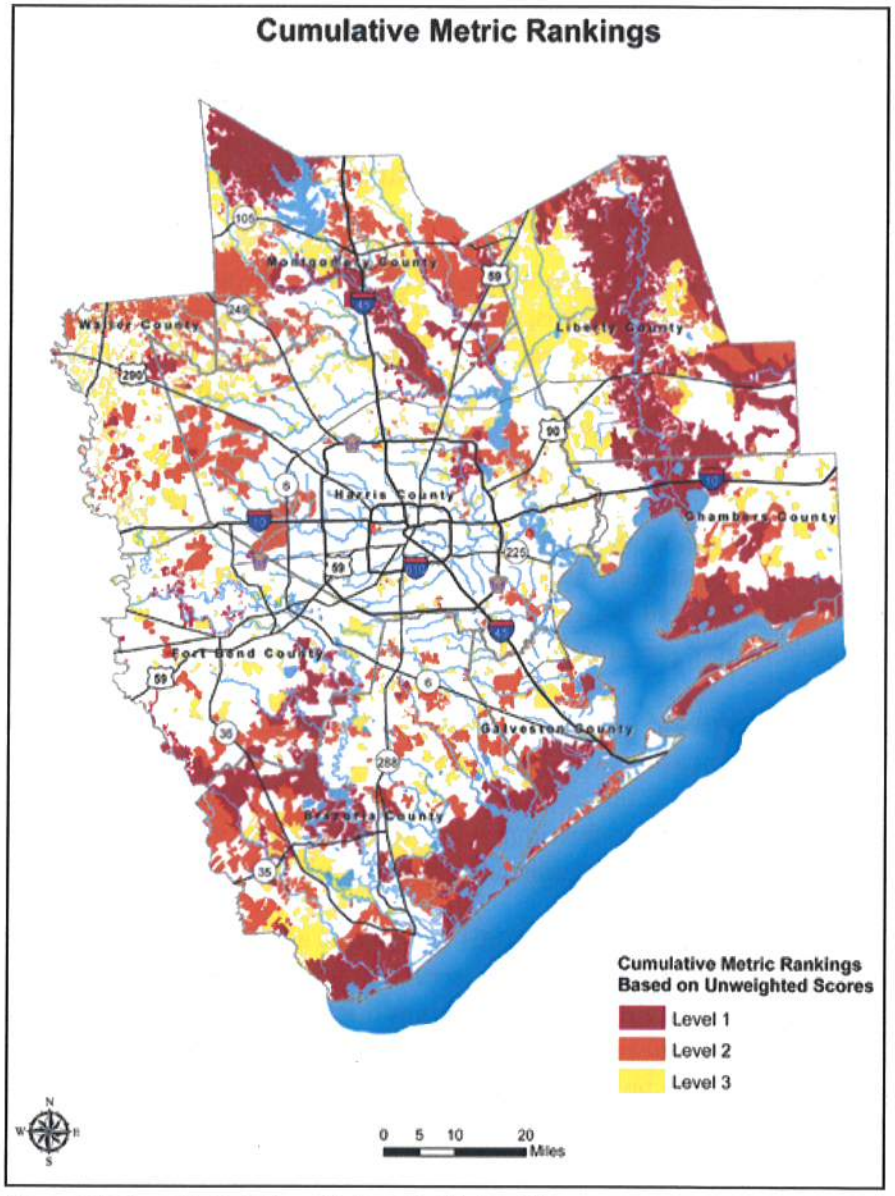


Figure 25: Level 1, 2, 3 Cumulative Metric Rankings

The Eco-Logical project was presented as an information item for feedback and discussion to TAC on March 26, 2010, and TPC on April 23, 2010. Comments were favorable. In addition, participating EAC agencies provided letters to H-GAC in support of the Eco-Logical concepts and incorporating the RDSS into the RTP and TIP. These letters of support are available in Appendix E.

The Texas Department of Transportation

TxDOT, as the major project sponsor of transportation projects in the region, will be able to utilize this tool in the long-range planning of transportation projects in the region. The Eco-Logical project was presented to TxDOT staff in the Houston District Office for comment and review and was received favorably.

Conservation Planning Organizations

One of the objectives of this project is that conservation groups will use the RDSS as a planning and educational tool. H-GAC anticipates that conservation organizations will work with the tool and present it their constituents, allowing for subsequent refinement and ongoing data maintenance.

Local Governments

Local governments and elected officials are often the first point of contact for the public regarding a major transportation project or resource conservation effort that may be proposed or under way in their community. In addition, local governments are the local sponsors of major transportation projects in the region. The RDSS is an online application that requires no special software so it can save local governments time and money in their initial project analysis, without the need for extensive data collection or sophisticated GIS analysis.

Outreach to local governments was accomplished through presentations to the TAC and TPC which are composed of elected officials, and H-GAC's Geographic Data Committee, which includes GIS staff of some of the region's largest cities and counties. H-GAC's Natural Resource Advisory Committee (NRAC), an H-GAC Board of Directors appointed committee of environmental stakeholders representing local governments, industry, conservation organizations and concerned citizens, and the Environmental Awareness Roundtable (EAR), a gathering of environmental professionals from local governments and other organizations also received briefings and a demonstration of the tool. Staff presented the project to the NRAC and EAR on February 4 and April 13, 2010, respectively. H-GAC staff has also presented to interested research and environmental groups including the Houston Advanced Research Center and the Texas State Soil and Water Conservation Board. H-GAC staff has notified local governments that it is available to give presentations on how to use the on-line RDSS tool.

3.3 How process will be evaluated through performance measures

Performance measures will help determine the effectiveness of the Eco-Logical project and the RDSS. As many of the transportation projects that will be evaluated using the tool have long-range implementation horizons, there may be few immediate impacts. However, the fact that the projects are being evaluated at an early stage through an established policy is an important benefit of the project.

Long-range performance measures include the amount of identified high priority (Level 1) environmental resources that are brought into conservation as well as the number of transportation projects that avoid Level 1 priority environmental resources due to the use of the RDSS. Shorter-range performance measures may include the effectiveness of the established metric system in properly evaluating transportation projects. This may be measured through collaboration with the project sponsors and incorporation of the RDSS into the 2040 RTP project prioritization and selection process. The ultimate success of the overall project will be evaluated by the successful adoption, implementation, and use of the RDSS by the identified user groups (environmental resource and conservation agencies, transportation planning agencies and sponsors, and local governments) and its ability to meet the goals of these users, such as conservation of priority mitigation sites and streamlining of the transportation project mitigation process.

3.4 Updates to the RDSS

H-GAC intends the RDSS to be a tool that evolves with the needs of the region. Critical to this effort will be the establishment of protocols for tracking changes in the ecotype conditions. H-GAC leads a consortium that regularly purchases high resolution aerial imagery, which was used in the ecotype delineation for this project. H-GAC plans to use this imagery to track development that results in changes to ecotype polygons by providing the unique ecotype polygon identification number via the RDSS ecotype map layer. H-GAC will also upload other new data layers relevant to the RDSS as they become available. A key to the further evolution of the project will be the establishment of partnerships with resource agencies,

conservation organizations and area universities to continue to refine and update the ecotype information.

4.0 Recommendations and Next Steps

4.1 Future Growth and Impact on Natural Resources

Existing and projected future land use patterns derived from H-GAC's 2035 forecasting model, a trends-based model that builds on historical growth patterns, are shown in **Figure 26.** Alternative policy initiatives, transportation investments, and market trends may reshape these growth patterns into forms that would be more beneficial to the region's environment and quality of life.

The growth forecast shows that substantial land use changes are predicted for the region by the year 2035. Residential growth in previously undeveloped areas is especially apparent in Montgomery County and other portions of the northwest region. The loss of undeveloped land, represented by green in **Figure 26**, is appreciable in every county of the region in 2035.

In the forecast, managed lands, such as nature preserves, parks, and land trusts are not considered available for development and are represented by grey in **Figure 26.** Such managed lands presently constitute 13.6 percent of the land area in the 8-county region. Although the forecast does not consider these areas available for future growth, it also does not assume any expansion of protected lands by 2035.

In order to determine the impact of the region's forecasted growth on specific ecotypes, the growth forecast in **Figure 27** was overlaid onto the map of environmental resources developed by the EAC. The map of environmental resources excludes currently developed and protected lands. The resulting map, **Figure 27,** allows for those environmental resources facing the most risk from forecasted growth by 2035 to be identified.

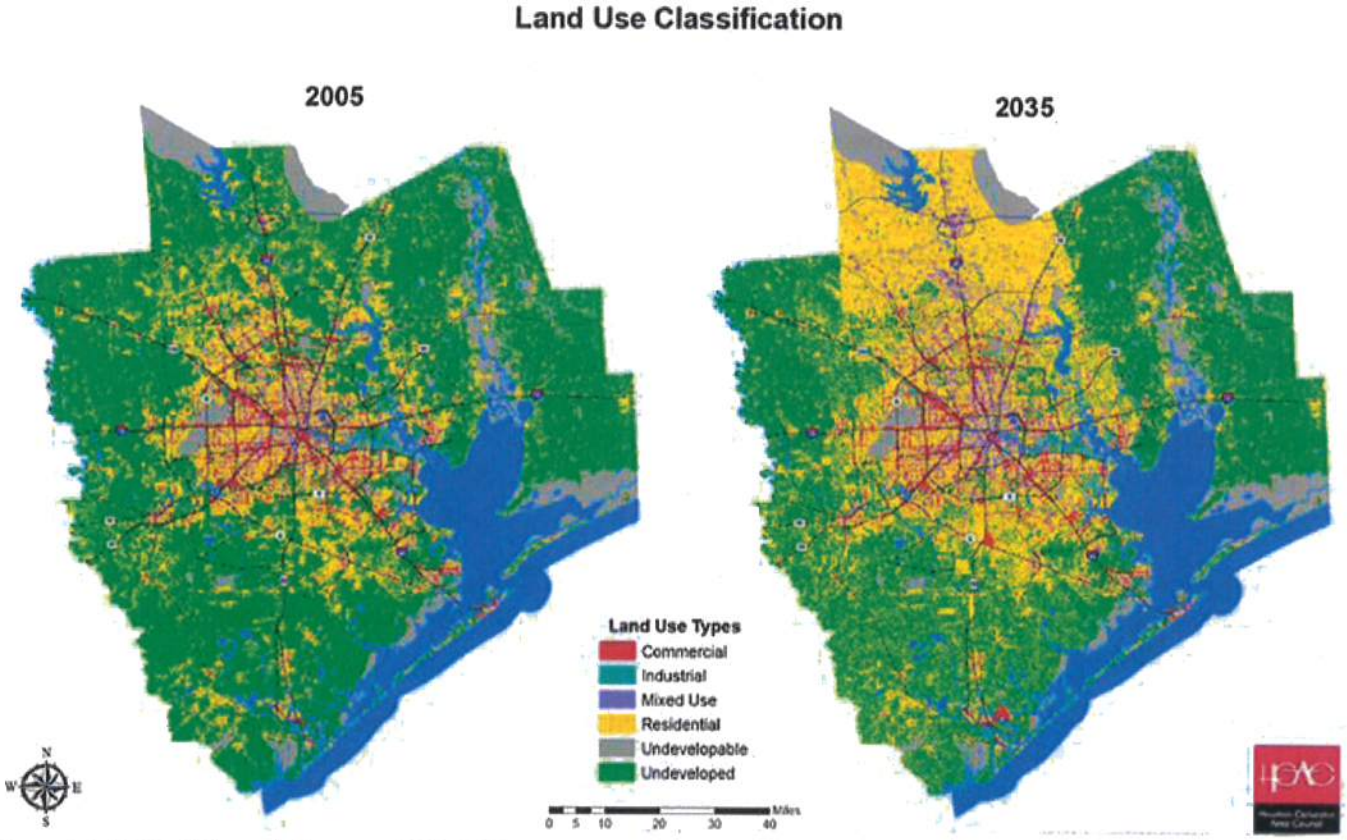


Figure 26: H-GAC Growth Forecast 2005-2035

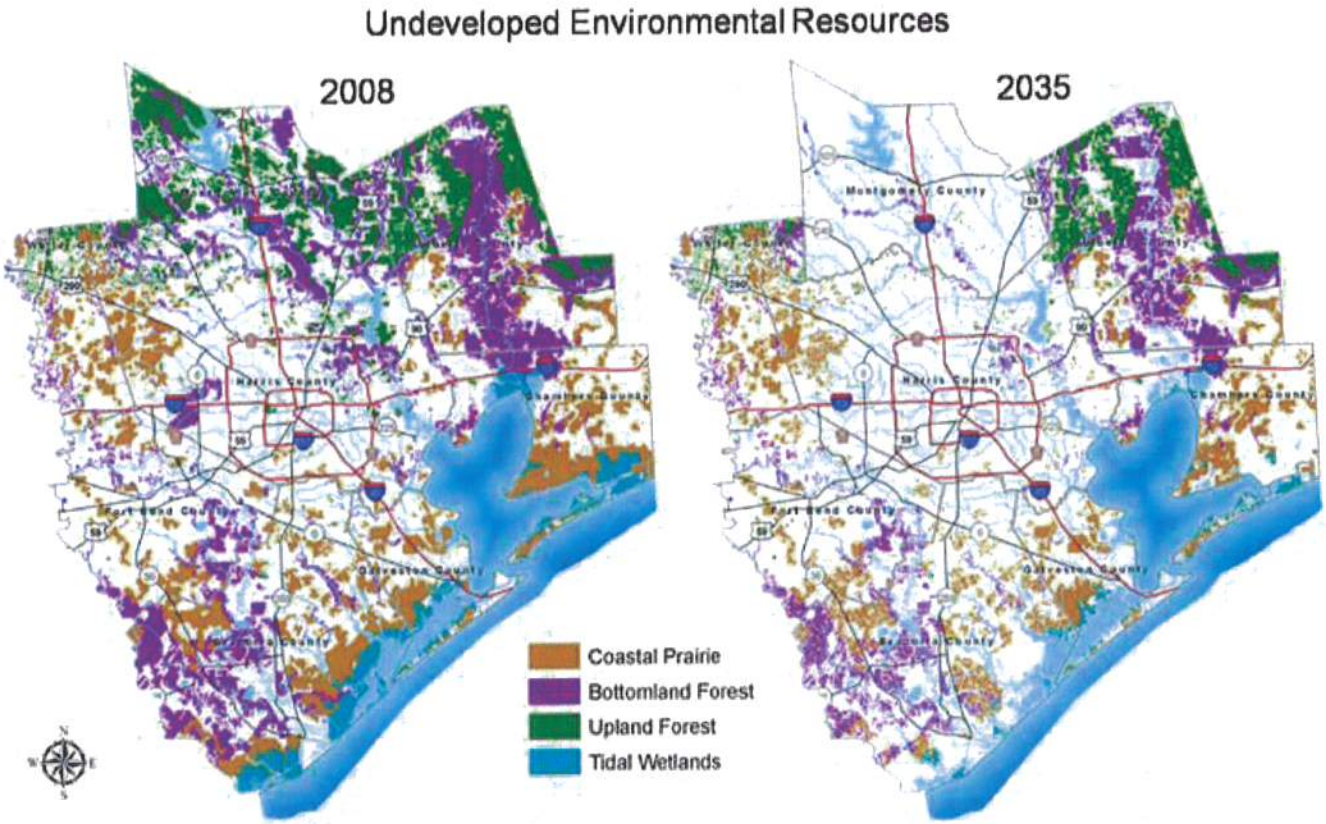


Figure 27: Undeveloped Environmental Resources 2008-2035

As can be seen from **Figure 27,** the forecasted land use pattern displays significant loss of undeveloped land, and therefore fragmentation, in the bottomlands and in the upland forest ecotypes between 2008 and 2035. **Table 8** provides a breakdown of the forecasted changes by ecotype and ecotype quality.

4.2 Examine Locations of Proposed Transportation Projects

To examine the locations of proposed transportation projects relative to areas that were rated a high priority (Level 1), H-GAC staff used the 2035 road network as a layer in the RDSS and noted the number of proposed projects in the 2035 road network that intersected a Level 1 polygon. The result was 335 proposed projects that intersect Level 1 polygons.

4.3 Recommended Applications of Eco-Logical Approach

The goal of the Eco-Logical project is to develop an RDSS to integrate long-range transportation and environmental planning and help to identify and ultimately, conserve high priority environmental resources in the region. This goal could be accomplished by making the RDSS part of the selection criteria for proposed transportation projects. A determination as to its use for this purpose will be made by TPC.

The following recommendations are examples of potential uses of the RDSS in the project prioritization and selection process. These recommended policies will be explored in the course of the next Regional Transportation Plan update, currently scheduled to occur in 2012.

Project sponsors may be asked questions in the H GAC Transportation Economic Land Use System (TELUS) that pertain to their project's impact on ecological resources. TELUS is an online system that gives project sponsors immediate feedback on their project's impacts and allows H-GAC staff to assess cumulative impacts. Those questions may then become part of the project prioritization criteria used to rank projects for inclusion within the RTP, the first step to qualify for potential funding through H-GAC.

Sponsor questions could include:

1. Did you use the Regional Decision Support System to analyze the potential ecological resource impacts of your project?
2. What buffer distance did you use?
3. What metrics weighting scheme did you use?
4. What percent of your project's total area is occupied by ecotypes?
5. What percent of your project's total area is occupied by Level 1, 2, and 3 ecotypes?

Project sponsors may be asked to justify their proposed projects impacts on Level 1, 2, and 3 polygons. A policy of project avoidance of Level 1 polygons absent extraordinary justification will be explored. For projects affecting Level 2 or 3 polygons, a policy of pursuing appropriate blended strategies including avoidance, best management practices for impact minimization, and possibly mitigation will be explored.

4.4 Best Practices

Conservation and Mitigation Strategies

What are the options for sponsors whose projects may potentially impact important environmental resources? Avoidance is the preferred alternative because mitigation strategies are unable to completely replicate the full range of services provided by ecotypes. Avoidance through realignment may be possible for some of the projects identified at the long-range planning stage through the use of the RDSS.

Table 8: Ecotype and Ecotype Quality Changes in Acres

Ecotype	Quality	Acres in 2008	Forecasted Acres in 2035	Acres Impacted	% Change
Coastal Prairie	N/A	613,298	399,286	214,011	35
	CP1	266,838	150,631	116,207	44
	CP2	186,487	121,629	64,858	35
	CP3	159,972	127,025	32,947	21
Bottomland Forest	N/A	855,530	465,994	389,536	46
	BF1	657,486	364,489	292,998	45
	BF2	187,364	94,218	93,146	50
	BF3	10,679	7,287	3,393	32
Upland Forest	N/A	492,468	222,065	270,402	55
	UF1	84,537	17,297	67,240	80
	UF2	403,983	203,247	200,736	50
	UF3	3,948	1,522	2,426	61
Tidal Wetlands	N/A	153,054	40,179	112,874	74

When realignment is not a possibility, sponsors should seek to minimize any potential harm to environmental resources. Minimization measures seek to reduce the impact on priority environmental areas through strategies such as design modifications to the project, access management techniques, Context Sensitive Solutions, or other best practices. Determination of which minimization measures are the most appropriate is dependent on the project being proposed, the types of impacts resulting, and the characteristics of the resource being impacted.

In-lieu fee programs are agreements between a regulatory agency and a public agency or non-profit organization. Under these agreements the mitigation sponsor collects funds from an individual or number of individuals who are required to conduct compensatory mitigation.

The sponsor may use the funds pooled from multiple permittees to create one or a number of sites under the authority of the agreement to satisfy the permittees' required mitigation. Legacy Land Trust is the only sponsor of in-lieu fee programs in Texas authorized by the U.S. Army Corps of Engineers. Legacy Land Trust is a community-sponsored land preservation organization and is conducting its in-lieu fee program in southern Montgomery County and north Harris County.

Mitigation banks are large (usually wetland) restoration areas that are designed to provide ecosystem benefits. The "traditional" wetlands mitigation approach mitigates on a project-by-project basis, often resulting in the conservation of small, isolated wetland parcels.

Mitigation banks are able to conserve much larger, contiguous wetland areas by allowing agencies to pay a fee to purchase credits from the mitigation bank. Ideally, mitigation banks are located in close proximity to the areas that are impacted.

Public/Private Partnerships

As funding for mitigation above and beyond what is required is limited, public/private partnerships offer an innovative financing method. An example of a public/private partnership is a joint development project in which the transportation project sponsor pairs up with local land owners to implement conservation projects and then relies on the land owners for maintenance and management.

These partnerships decrease operations and maintenance expenditures and require less monitoring than traditional arrangements. Another opportunity for public/private partnerships is incorporating environmental projects funded by outside conservation organizations into sponsor-funded transportation projects. By coordinating efforts, such initiatives are able to take advantage of economies of scale.

Figure 28: Texas State Highway 87 Revetment project built on Bolivar Peninsula, Galveston County to protect the highway from wave erosion during storm events. The wetland on the right is Spartina alterniflora planted between the revetment on the left and a breakwater, not pictured, to the right. The plantings were to mitigate approximately 1 acre impact of saltwater wetlands. The historic Galveston Lighthouse is in the background.

(Photo by Houston Environmental Staff)

The New York State Department of Transportation (NYSDOT) has successfully accomplished such partnerships through their Environmental Initiative. This program includes incorporating locally funded environmental projects such as landscaping, park amenities, stormwater basins, or wildlife plantings into NYSDOT projects. NYSDOT is thus able to leverage private and public funds by combining the construction of environmental enhancements with NYSDOT construction projects.

4.5 Moving Beyond Mitigation

By pro-actively preserving and enhancing the region's natural assets, the region can build an ethic of environmental stewardship. An approach that focuses on long-range solutions will ensure the region's natural assets will be available for future generations to enjoy.

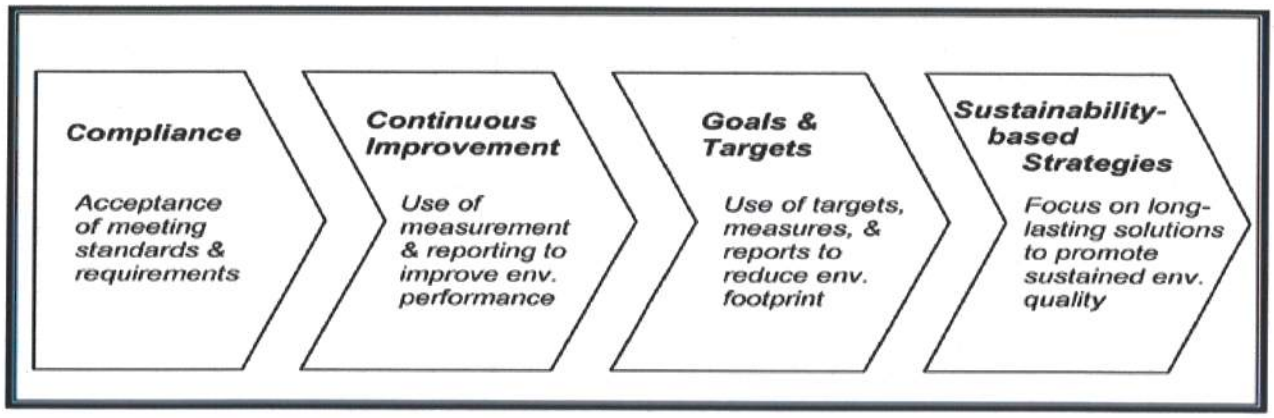


Figure 29: Moving Toward Environmental Stewardship: EPA's Model

As **Figure 29** illustrates, the evolution toward environmental stewardship moves increasingly toward future-oriented, long-range solutions, as in the 2040 RTP. The Eco-Logical process undertaken in this project and the resulting RDSS tool provide a foundation for the region to continue to create a more sustainable future.

The RDSS is unique in that it is the first consensus-driven, regional-scale tool that identifies priorities for future conservation efforts in the Houston-Galveston area.

Through continued coordination of transportation planning and environmental conservation using tools like the RDSS, the Houston-Galveston region can meet the challenge of ensuring mobility for the growing population while simultaneously preserving the region's unique resources for future generations to enjoy.

Figure 30: A portion of a mitigation site on Texas State Highway 242 that was developed to be used as projects with wetland impacts needed mitigation. The portion pictured was developed for wetland impacts along the highway in east Montgomery County.

(Photo by Houston Environmental Staff)

Appendix A

Ecological Services Weighting Methodology

The Eco-Logical Advisory Committee (EAC) went through a series of steps to weigh the values of certain ecological services.

1. Verify ecotypes

2a. Separate the ecological services into three groups in order of highest importance from ecological conservation/preservation perspective.
Assign a value to the groups (for example: 3, 2, 1, respectively). OR

Ecotype	Ecological Services										
	Flood Protection =3	Water Quality & Quantity =3	Habitat =3	Erosion Control =2	Storm Surge =2	Air Quality and Carbon Sequestration =2	Rec =2	Energy Reduction =1	Nutrient Cycling =1	Food Production and Pollination =1	Cultural Resources =1
Coastal Wetlands											
Bottomlands											
Other Riparian											
Coastal Prairies											
Upland Forest											
Agricultural											
Post Oak Savannah											
Local Icon											

2b. Assign a value to each of the ordered ecological services using numbers 1-11 (Example; flood protection=11, Cultural Resources=1) OR

Ecotype	Ecological Services										
	Flood Protection =11	Water Quality & Quantity =10	Habitat =9	Erosion Control =8	Storm Surge =7	Air Quality and Carbon Sequestration =6	Rec =5	Energy Reduction =4	Nutrient Cycling =3	Food Production and Pollination =2	Cultural Resources =1
Coastal Wetlands											
Bottomlands											
Other Riparian											
Coastal Prairies											
Upland Forest											
Agricultural											
Post Oak Savannah											
Local Icon											

2c. Assign values to each of the ecological services in a non-linear manner using 25 points as the maximum number of points distributed among the 11 ecological services.

Ecotype	Ecological Services										
	Flood Protection =5	Water Quality & Quantity =4	Habitat =4	Erosion Control =2	Storm Surge =2	Air Quality and Carbon Sequestration =2	Rec =2	Energy Reduction =1	Nutrient Cycling =1	Food Production and Pollination =1	Cultural Resources =1
Coastal Wetlands											
Bottomlands											
Other Riparian											
Coastal Prairies											
Upland Forest											
Agricultural											
Post Oak Savannah											
Local Icon											

3. For each of the ecotypes, determine the level of ecological service provided by that ecotype. Levels of service include HIGH, MEDIUM and LOW.

Ecotype	Ecological Services										
	Flood Protection	Water Quality & Quantity	Habitat	Erosion Control	Storm Surge	Air Quality and Carbon Sequestration	Rec	Energy Reduction	Nutrient Cycling	Food Production and Pollination	Cultural Resources
Coastal Wetlands	H	H	H	L	H	L	M	M	H	L	L
Bottomlands	H	H	H	H	H	H	H	H	H	L	L
Other Riparian											
Coastal Prairies											
Upland Forest											
Agricultural											
Post Oak Savannah											
Local Icon											

4. Replace the "H", "M", or "L" in each cell of the table with 3, 2, or 1. High level of service = 3, Medium level of services =2, Low level of service = 1

Ecotype	Ecological Services										
	Flood Protection	Water Quality & Quantity	Habitat	Erosion Control	Storm Surge	Air Quality and Carbon Sequestration	Rec	Energy Reduction	Nutrient Cycling	Food Production and Pollination	Cultural Resources
Coastal Wetlands	3	3	3	1	3	1	2	2	3	1	1
Bottomlands	3	3	3	3	3	3	3	3	3	1	1
Other Riparian											
Coastal Prairies											
Upland Forest											
Agricultural											
Post Oak Savannah											
Local Icon											

5. Multiply the number in the box by the number in the ecological service row from Step 3. In the example below, we used option C from Step 3.

Ecotype	Ecological Services										
	Flood Protection =5	Water Quality & Quantity =4	Habitat =4	Erosion Control =2	Storm Surge =2	Air Quality and Carbon Sequestration =2	Rec =2	Energy Reduction =1	Nutrient Cycling =1	Food Production and Pollination =1	Cultural Resources =1
Coastal Wetlands	3*5=15	3*4=12	3*4=12	1*2=2	3*2=6	1*2=2	3*2=6	2*1=2	3*1=3	1*1=1	1*1=1
Bottomlands	3*5=15	3*4=12	3*4=12	3*2=6	3*2=6	3*2=6	3*2=6	3*1=3	3*1=3	1*1=1	1*1=1
Other Riparian											
Coastal Prairies											
Upland Forest											
Agricultural											
Post Oak Savannah											
Local Icon											

6. Add the multiplied totals across each row.

Ecotype	Ecological Services											
	Flood Protection =5	Water Quality & Quantity =4	Habitat =4	Erosion Control =2	Storm Surge =2	Air Quality and Carbon Sequestration =2	Rec =2	Energy Reduction =1	Nutrient Cycling =1	Food Production and Pollination =1	Cultural Resources =1	Total
Coastal Wetlands	3*5=15	3*4=12	3*4=12	1*2=2	3*2=6	1*2=2	3*2=6	2*1=2	3*1=3	1*1=1	1*1=1	62
Bottomlands	3*5=15	3*4=12	3*4=12	3*2=6	3*2=6	3*2=6	3*2=6	3*1=3	3*1=3	1*1=1	1*1=1	71
Other Riparian												
Coastal Prairies												
Upland Forest												
Agricultural												
Post Oak Savannah												
Local Icon												

7. Assign threshold values to Other Considerations:

a. Adjacency - to what types of land use or land cover or ecotype?
b. Fragmentation – What is the minimum size?
c. Threatened and endangered species – distance?
d. Any others?

Appendix B

Metrics for Factor Analysis

The SAS System 07:52 Thursday, February 11, 2010 1

The CORR Procedure

9 Variables: sze shp sca sca_3 adj iso tsp div qlt

Simple Statistics

Variable	N	Mean	Std Dev	Sum	Minimum	Maximum	Label
sze	1222	3.24304	10.62343	3963	0	100.00000	sze
shp	1222	55.66612	19.09766	68024	8.00000	98.00000	shp
sca	1222	46.56056	21.02140	56897	31.00000	100.00000	sca
sca_3	1222	22.45499	25.78505	27440	1.00000	100.00000	sca_3
adj	1222	16.14812	21.54557	19733	0	100.00000	adj
iso	1222	29.08183	39.28453	35538	0	100.00000	iso
tsp	1222	5.56465	22.93316	6800	0	100.00000	tsp
div	1222	53.79705	17.08920	65740	20.00000	100.00000	div
qlt	1222	59.57447	32.97902	72800	0	100.00000	qlt

Pearson Correlation Coefficients, N = 1222
Prob > |r| under H0: Rho=0

	sze	shp	sca	sca_3	adj	iso	tsp	div	qlt
sze	1.00000	-0.20786	0.07193	-0.03564	0.10961	0.20505	0.27077	0.11766	0.11386
sze		<.0001	0.0119	0.2131	0.0001	<.0001	<.0001	<.0001	<.0001
shp	-0.20786	1.00000	-0.19863	0.12318	-0.03459	-0.00154	-0.15321	-0.15095	-0.22892
shp	<.0001		<.0001	<.0001	0.2270	0.9571	<.0001	<.0001	<.0001
sca	0.07193	-0.19863	1.00000	0.23630	0.08251	-0.07250	0.05672	-0.16960	0.42404
sca	0.0119	<.0001		<.0001	0.0039	0.0112	0.0474	<.0001	<.0001
sca_3	-0.03564	0.12318	0.23630	1.00000	-0.04275	-0.14168	-0.03503	-0.19793	0.09643
sca_3	0.2131	<.0001	<.0001		0.1353	<.0001	0.2210	<.0001	0.0007
adj	0.10961	-0.03459	0.08251	-0.04275	1.00000	0.11794	0.08452	0.24936	0.13833
adj	0.0001	0.2270	0.0039	0.1353		<.0001	0.0031	<.0001	<.0001
iso	0.20505	-0.00154	-0.07250	-0.14168	0.11794	1.00000	0.04104	0.15323	-0.01100
iso	<.0001	0.9571	0.0112	<.0001	<.0001		0.1516	<.0001	0.7008
tsp	0.27077	-0.15321	0.05672	-0.03503	0.08452	0.04104	1.00000	-0.00380	0.14607
tsp	<.0001	<.0001	0.0474	0.2210	0.0031	0.1516		0.8943	<.0001
div	0.11766	-0.15095	-0.16960	-0.19793	0.24936	0.15323	-0.00380	1.00000	-0.07473
div	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	0.8943		0.0090
qlt	0.11386	-0.22892	0.42404	0.09643	0.13833	-0.01100	0.14607	-0.07473	1.00000
qlt	<.0001	<.0001	<.0001	0.0007	<.0001	0.7008	<.0001	0.0090	

Appendix C

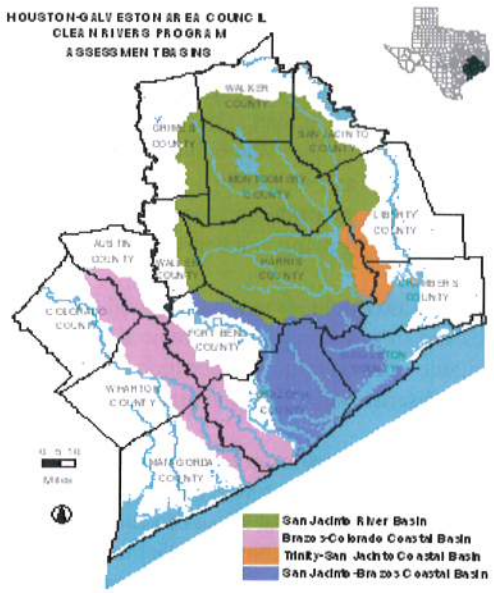
A Methodology for Developing Land Cover Data for the Houston-Galveston Area Council and Clean Rivers Program Region

1. Purpose and Goal

Land cover data are an important element in understanding the dynamics of water quality throughout individual watersheds. Knowing the land cover within a watershed, especially that adjacent to the stream channel, provides for a better distinction between environmental and anthropogenic influences affecting waterways.The purpose of this work is to assist regional and state programs in summarizing water quality for the region. An important component of the summary, is low cost, accurate land cover data that is current and easily integrated with resident data management and analytical tools. This effort will determine suitable land cover categories that most accurately represent the diverse nature of the H-GAC Clean Rivers Program (CRP) Region. The categories developed will be based on concerns, issues, and activities that face the integrity of the area waterbodies and the general environment. The end product will be a regional data set showing the general distribution of land cover throughout the region.

2. Geographic Area of Interest

The Area of Interest for this project includes the 13 county region of H-GAC and the additional areas (of San Jacinto and Grimes Counties) that comprise the four assessment basins for the CRP Region. The four basins are the Trinity-San Jacinto Coastal Basin, San Jacinto River Basin, San Jacinto-Brazos Coastal Basin and the San Bernard segments of the Brazos-Colorado Coastal Basin. The total area to be included in this project is roughly 12,500 square miles or 8,000,000 acres.



3. Expected Uses

The demand for current land cover data on a recurring basis is growing, especially in the areas of the region that are experiencing rapid change in land cover characteristics. Applications for the data include:

- Locating various land cover types within a watershed (where?)
- Determining acreage and/or percentage of each land cover type within a watershed (how much?)
- Associating water quality characteristics with land cover types and spatial patterns. (Does water quality change with land cover?)
- Assessing historical water quality data with changes in land cover temporally, identifying portions of the watershed that may be sensitive or vulnerable to water quality impairments due to surrounding land cover.

4. Definition of Land Cover types to be classified

The exact list of cover types to be defined will not be determined until an unsupervised classification and field training have been completed. Based on program goals and resources, data analysis needs, and size and diversity of the area to be classified, the intent is to define the classes listed below.

1.0 Upland
- 1.11 High-Intensity Developed
- 1.12 Low-Intensity Developed
- 1.2 Cultivated Land
- 1.3 Grassland
- 1.4 Woody Land
- 1.5 Bare Land

2.0 Wetland

3.0 Water and Submerged Land

This classification system is based on the National Oceanic and Atmospheric Administration (NOAA) Coastal Ocean Program's Coastal Change Analysis Program (C-CAP). The C-CAP classification system is hierarchical, reflects ecological relationships, and focuses on land cover classes that can be discriminated primarily from satellite remote sensor data. It was adapted and designed to be compatible with other nationally standardized classification systems, especially the US Geological Survey, Environmental Protection Agency and the Fish & Wildlife Service (CCAP Guidance 1995). Each of the classes and subclasses listed are described in greater detail below.

Developed Land (Derived from the Anderson et al. [1976] Urban or Built-up class) characterizes constructed surfaces comprised of concrete, asphalt, roofing, and other building materials with or without vegetation. This class has been divided into two subclasses based on the amount of constructed surface relative to the amount of vegetated surface present. High Intensity Developed Land contains little or no vegetation. This subclass includes heavily built-up urban centers as well as large constructed surfaces in suburban and rural areas. Large buildings (such as multiple family housing, hangars, and large barns), interstate highways, and runways typically fall into this subclass. Low Intensity Developed Land contains substantial amounts of constructed surface mixed with substantial amounts of vegetated surface. Small buildings (such as single family housing, farm outbuildings, and sheds), streets, roads, and cemeteries with associated grasses and trees typically fall into this subclass.

Cultivated Land (Agricultural Land in Anderson et al. 1976) includes herbaceous (cropland) and woody (orchards, nurseries, vineyards, etc.) cultivated lands. Seasonal spectral signatures, geometric field patterns and road network patterns may help identify this land cover type. Always associated with agricultural land use, cultivated land is used for the production of food and fiber.

Grassland differs from Rangeland in Anderson et al. (1976) by excluding shrub-brushlands. Unmanaged Grasslands are dominated by naturally occurring grasses and forbs which are not fertilized, cut, tilled or planted regularly. Managed Grasslands are maintained by human activity such as fertilization and irrigation, are distinguished by enhanced biomass productivity, and can be recognized through vegetative indices based on spectral characteristics. Examples of such areas include lawns, golf courses, forest or shrub areas converted to grassland, or areas of permanent grassland with altered species composition. This category includes managed pastures and pastures with vegetation that grows vigorously as fallow. Managed Grasslands are used for grazing or for growing and harvesting hay and straw for animal feed.

Woody Land includes non-agricultural trees and shrubs. The category alleviates the problem of separating various sizes of trees and shrubs using satellite remote sensor data but allows a height-based separation if high-resolution aerial photography are available. The class may be partitioned into three subclasses: Deciduous, Evergreen, and Mixed. These three subclasses generally can be discriminated with satellite remote sensing systems.

Bare Land (derived from Barren Land in Anderson et al. 1976) is composed of bare soil, rock, sand, silt, gravel, or other earthen material with little or no vegetation. Anderson's Barren Land was defined as having limited ability to support life; C-CAP's Bare Land is defined by the absence of vegetation without regard to inherent ability to support life. Vegetation, if present, is more widely spaced and scrubby than that in the vegetated classes. Unusual conditions such as a heavy rainfall may occasionally result in growth of a short-lived, luxuriant plant cover. Wet, nonvegetated exposed lands are included in the Wetland categories. Bare Land may be bare temporarily because of human activities. The transition from Woody Land, Grassland, or Cultivated Land to Developed Land, for example, usually involves a Bare Land phase. Developed Land also may have temporary waste and tailing piles. Woody Land may be clearcut producing a temporary Bare Land phase. When it may be inferred from the data that the lack of vegetation is due to an annual cycle of cultivation (eg. plowing), the land is not included in the Bare Land class. Land temporarily without vegetative cover because of cropping or tillage, is classified as Cultivated Land, not Bare Land.

Wetlands are lands where saturation with water is the dominant factor determining soil development and the types of plant and animal communities living in the soil and on its surface (Cowardin et al. 1979). A characteristic feature shared by all wetlands is soil or substrate that is at least periodically saturated with or covered by water. The upland limit of wetlands is designated as (1) the boundary between land with predominantly hydrophytic cover and land with predominantly mesophytic or xerophytic cover; (2) the boundary between soil that is predominantly hydric and soil that is predominantly nonhydric; or (3) in the case of wetlands without vegetation or soil, the boundary between land that is flooded or saturated at some time during the growing season each year and land that is not (Cowardin et al. 1979). The majority of all wetlands are vegetated and are found on soil.

Water and Submerged Land: All areas of open water with < 30% cover of trees, shrubs, persistent emergent plants, emergent mosses, or lichens are assigned to Water and Submerged Land, regardless of whether the area is considered wetland or deepwater habitat under the Cowardin et al. (1979) classification. The Water class includes Cowardin et al.'s (1979) Rock Bottom and Unconsolidated Bottom, and Nonpersistent Emergent Wetlands, as well as Reefs and Aquatic Beds that are not identified as such. Most C-CAP products will display water as a single class.

The CCAP Classification System does provide for a more detailed list of subclasses from what is shown above, but it is not known if those land cover subclasses will be classified during this project.

5. Sensor and Imagery Requirements

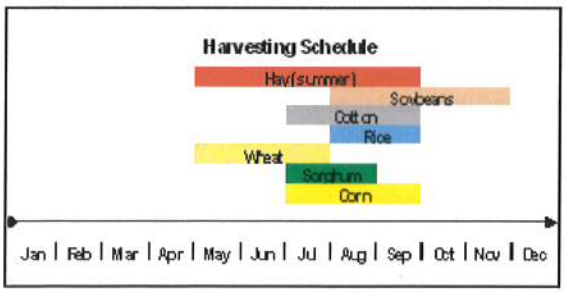
The preferred C-CAP satellite sensor system is Landsat Thematic Mapper (TM). Although the spatial resolution of TM is not as good as that of other satellite or aircraft systems, it is generally less expensive to acquire and process for large-area coverage (CCAP Guidance 1995). Spectrally, the TM sensor captures seven bands of the electromagnetic spectrum. Only six will be used (Two Middle Infra-red, Near Infrared, Red, Green and Blue Visible bands) during the classification process. TM imagery have a spatial resolution or minimum measurement unit of 30 square meters. The acquired imagery will possess little or no cloud cover, with a maximum percent of cloud cover of 20%. A TM image scene covers 185 x 172 km on the ground, or 115 x 106 miles. Our geographic area of interest will require four Landsat scenes for complete spatial coverage.

To enhance the classification of an impervious class such as Developed, the temporal period of acquisition should be in the Winter or "Leaf-off" months. February 2007 is considered a suitable timeframe for meeting our broad classification needs. However, to thoroughly delineate each of the listed land cover type, specifically Cultivated Land and Wetland, a second set of imagery will be acquired.

The Texas Agricultural Census (TAC, 1997) along with other meteorological information for the region indicate early July 2007 as a suitable second acquisition date for the classification of Cultivated Land and Water classes. According to the TAC, the three dominant crop types for the counties in this region, are Hay, Rice (irrigated), and Sorghum (refer to table on the right).

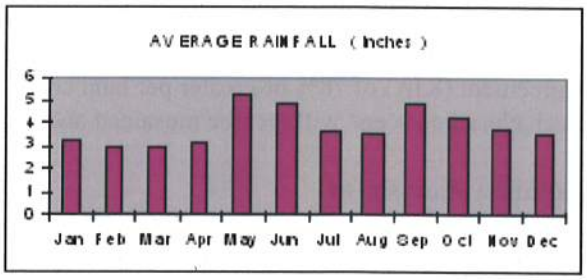
MAJOR CROP	TOTAL ACREAGE
HAY	252304
RICE	212123
SORGHUM	190793
COTTON	133156
SOYBEANS	105028
CORN	58853
WHEAT	2544

The goal of acquiring a second temporal set of imagery is to increase the confidence in our classification methodology (and subsequently a higher overall accuracy assessment). The second set of imagery will capture data prior to dates of peak crop harvesting. Individual crop types will not be differentiated during the image classification. The table to the left lists the dominant crop types for the region and their period of harvesting. Although Hay is harvested all summer, other dominant crop types are harvested during a three-month period starting in July.



Available crop information for our region indicates that all of the dominant crops shown use some type of chemical application (commercial fertilizers and pesticides). Commercial fertilizers include nitrogen, phosphorous, and potassium. Rice is fertilized with nitrogen and phosphorous while all crops utilize some form of disease or insect control using the insecticides and fungicides. Although fertilizers and pesticides may be designed to "breakdown" rapidly, and their impact on the Region's water quality is not known, determining the distribution of cultivated land is an integral part to assessing a watershed's water quality.

The National Weather Service Rainfall measurements (taken from both Hobby and Bush Airports from 1927 to 2001) indicate the wettest monthly averages are May, followed by June then September. Rainfall is consistent throughout the year with less than 2.25 inches separating the highest and lowest monthly averages. The month of July is below the annual average in rainfall. In addition, it is a summer month with a greater potential for possible sunshine making it a suitable timeframe for the second image acquisition date.



6. Image Processing Techniques and Accuracy Assessment

The most significant effort of this project will be devoted to image classification and the accuracy assessment of the classification. Prior to the classification process, several preprocessing steps will be completed. Four Landsat 7 scenes will be required to cover the study area. Two dates for each Landsat scene, representing both the summer and winter seasons, will be purchased. An attempt will be made to obtain cloud free imagery, however, if clouds are present they will be masked to prevent confusion during the image classification. Each of the scenes will be registered to a USGS 7.5 minute quadrangle base map with an allowable error of 0.5 pixels. Multi-date imagery from both the winter season and summer season will be incorporated into the image classification to provide additional spectral reflectance data on phenological changes in vegetation growth and moisture variations that occur from season to season. Multi-temporal information on the spectral reflectance of our land cover classes should allow us to separate land cover such as coniferous and deciduous forest cover and capture spectral reflectance of residential areas that are normally hidden under deciduous canopy cover during the summer.

Reflectance values of dark and bright areas in the images, such as water bodies and high intensity developed areas will be used in a regression to calibrate the overall brightness of the image scenes. This method will preserve variation resulting from seasonal changes in phenological growth of vegetation while eliminating differences in spectral reflectance that may result from sensor offset and gain and variation in scene illumination. Each scene will then be input into a tasseled cap transformation algorithm to produce an image of greenness, brightness, and moisture. The tasseled cap transformation is a data reduction technique that isolates variation in spectral reflectance that is the result of physical structures in the image scene. The resulting greenness, brightness, and moisture bands for the two corresponding scenes will be combined to form a single multi-temporal dataset for input into the unsupervised and supervised image classification.

The Image Processing Techniques (see flowchart) will involve an iterative process, using a hybrid, unsupervised and supervised classification methodology. Initiated with an Unsupervised Classification (UC), a common image processing routine (ISODATA) will serve primarily as an exploratory procedure to determine homogenous areas for the location of training sites for the supervised classification and to uncover dominant spectral signatures in the imagery. A maximum likelihood classification algorithm incorporating prior probability of evidence images for the land cover classes will be used for the supervised classification. Examples of the prior probability images include National Wetland Inventory (NWI) maps, a thresholded and reclassed NDVI image to isolate areas of vegetated and non-vegetated surfaces, and buffered TIGER road layers to isolate high and low intensity developed areas.

Following the initial supervised classification the result will be evaluated visually and through an in process classification assessment. The in process assessment will utilize the soft classification tools in Idrisi to identify the presence of any non-singleton classes, areas of uncertainty in the classification and determine which of our training sites need to be adjusted to eliminate confusion in the classification. The soft classifier is based on Dempster-Schafer theory and produces a set of images that provide statements of the degree of membership of each pixel to the designated land cover classes, and also generates an image that quantifies the uncertainty in the classification. A "cluster busting" stratification methodology as utilized in the NOAA C-CAP program may also be explored to stratify and isolate those land cover classes that are providing the most confusion in the image classification.

After a satisfactory result is achieved, an accuracy assessment will be performed using a combination of field data and high-resolution aerial orthophotography. A stratified random sampling methodology consisting of 30–100 sample points per land cover class will be used to determine the accuracy of the classification. Sample points within a reasonable distance of roads will be verified. The other inaccessible sample points will be evaluated using high-resolution aerial orthophotography. The classification methodology will be repeated until a Kappa Index of Agreement (KIA) of 70% or greater per land cover class and an overall KIA of 70% or greater has been achieved. Each classified scene will then be mosaiced and edge matched to form the final classified image of the region.

Accuracy Assessment

Data of unknown accuracy are of little value to the end user. The purpose of the Accuracy Assessment is to compile the data necessary to support credible statements regarding data accuracy. The recommended accuracy assessment for this classification is a test based on comparison with both independent field samples and corresponding sets of high-resolution aerial imagery.

The source of primary assessment data will be collected through field sampling. Field sampling data will be used to verify the classification of stratified, random, geographic locations generated by the image processing software. Industry literature recommends a minimum of 30 random locations to verify each land cover type (van Genderen and Lock 1977). If any of the field verification sites are inaccessible or located within a training site, the software will generate additional sites to verify. Inaccessible sites may be verified "virtually" using high-resolution digital orthophotography or other ancillary data sets. Field verification work will be conducted by full and part-time staff, with most of the field work completed by those involved directly with the image classification.

In addition, any available habitat data collected through the CRP Regional Monitoring effort will be included. For example, we would compare a significant number of monitoring locations with the same locations on the image to determine how many are alike. Other data sets (such as appraisal parcel data, orthophotography) will be used to strengthen field verification and the accuracy assessment. To improve the final accuracy of the image classification, we will submit watershed maps for the entire study to appropriate local area experts who are knowledgeable in the setting of a particular watershed. Based on the general use of the data, availability of project resources, our goal is to develop data that meets or exceeds an overall accuracy of 70%. That is, 70% or more of the random locations from the classified image match what is found through the direct field verification and ancillary data sets.

Software and Hardware Used

The software and hardware used to support the classification and assessment tasks include the Idrisi Digital Image Processing & Geographic Information System (GIS) Software (Clark Labs, Worcester, MA.), on a Dell Pentium 4 Personal Computer with Windows 2000, and Trimble Pathfinder Pro XRS Global Positioning System (GPS) Unit. When possible, project staff will utilize ERDAS' Imagine Image Processing Software to enhance and compare image classification efforts completed with Idrisi.

7. Results

All procedures (including successes and failures), accuracy assessment, applicability of data, metadata, and instructions on how to use the final data will be documented and made available.

8. Project Timeline 2008

January	Receive, install Hardware and Software Work with historical imagery, other raster data sets for research and preparation
February	Receive Final Approval for Project Methodology
March	Acquire and preprocess Imagery (July 2007 and February 2008 Conduct Unsupervised Classification of Imagery
April	Conduct Pre-Supervised Classification Field work (determine training sites) Conduct Initial Supervised Classification Revisit those training sites with uncertain classifications Repeat Supervised Classification Conduct Field Verification (visit 30-100 per class) Conduct Preliminary Accuracy Assessment
June	Repeat Supervised Classification, Repeat Accuracy Assessment
August	Compare Supervised Classification with ancillary data
October	Complete Final Accuracy Assessment Submit Draft Project Results.
November	Incorporate any comments, Submit Final data, metadata, and results. Make all data and information available to the Internet.

9. Reference Information

Accuracy Assessment: To ensure an adequate number of accuracy assessment samples per land cover type from the stratified random sampling of the final classified image, a minimum of 30 sample points per type will be required; which allows for a 15% error in accuracy (van Genderen and Lock 1977).

Classification: The process of assigning individual pixels of a digital image to categories, generally on the basis of spectral reflectance or radiometric characteristics (REMOTE SENSING Handbook for Tropical Coastal Management).

Clean Rivers Program: The Texas Clean Rivers Program (CRP) was implemented to maintain and improve the quality of surface water resources within each river basin in Texas. The CRP is a partnership involving the Texas Natural Resource Conservation Commission (TNRCC), other state agencies, river authorities, local governments, industry, and citizens. Using a watershed management approach, CRP partner agencies work with the TNRCC to identify and evaluate surface water quality issues and to establish priorities for corrective action. For more information visit http://www.hgac.cog.tx.us/intro/introwater.html

Coastal Change Analysis Program: or C-CAP, is a cooperative interagency and state/federal effort to detect coastal upland and wetland land cover and submersed vegetation and to monitor change in the coastal region of the United States (Cross and Thomas 1992; Haddad 1992). The project utilizes digital remote sensor data, in situ measurement in conjunction with global positioning system systems, and geographic information system (GIS) technology to monitor changes in coastal wetland habitats and adjacent uplands. For more information visit http://www.csc.noaa.gov/products/sccoasts/html/ccapguid.htm

Electromagnetic Spectrum: Electromagnetic radiation is energy propagated through space between electric and magnetic fields. The electromagnetic spectrum is the extent of that energy ranging from cosmic rays, gamma rays, X-rays to ultraviolet, visible and infrared radiation including microwave energy.

Kappa Statistic or Coefficient: proposed by (Cohen, 1960) expresses the agreement between the reference points collected in the field and the categories on the map if as the condition of random agreement is removed. The Kappa coefficient is highly recommended for accuracy assessment of remotely sensed data (Congalton, 1991). The Kappa range is 0.00 to 1.00, where 0.00 is a classification no better than randomly assigning pixels and 1.00 is a perfect classification.

Land Cover/Use: A term that includes categories of land cover and categories of land use. Land cover is the vegetation or other kind of material that covers the land surface. Land use is the purpose of human activity on the land; it is usually but not always related to the land cover.

Pixel: A contraction of the words picture element, it is the smallest unit of information in an image or raster map. Referred to as a cell in an image or grid.

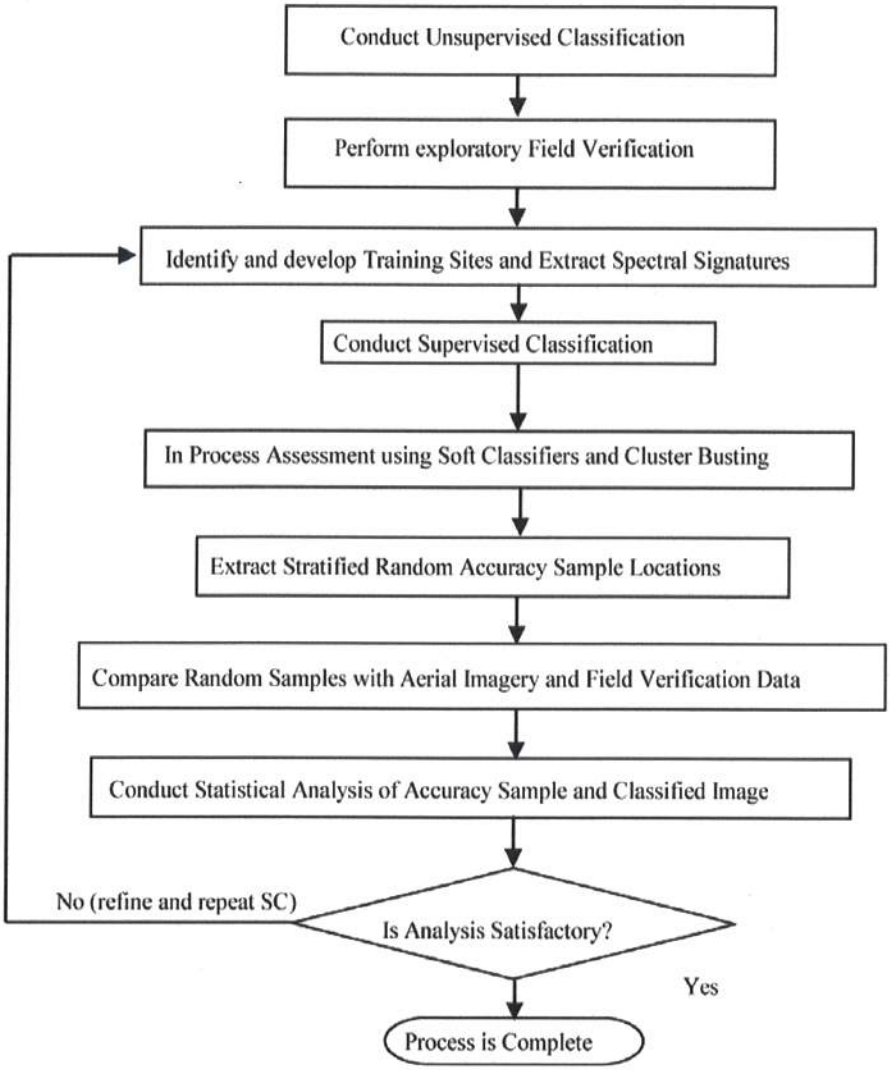
Polygon: A multi-sided geographic feature that represents an area on a map.

Real-time Differential Global Positioning System (DGPS): Real-time DGPS is the process of correcting GPS positions at an unknown location with a nearby radio beacon broadcasting a known location simultaneously. This process enables accurate (sub-meter) geographic data collection to occur.

Resolution: A measure of the amount of detail that can be seen in an image; the size of the smallest object recognizable using the detector.

Stratified random sampling: A sampling method in which the elements of the population are allocated into sub-populations (e.g. strata) before the sample is taken, and then each stratum is randomly sampled (Lund eReports in Physical Geography, No. 1, Oct. 1997).

Flowchart for the Image Processing and Accuracy Assessment Test



Water Quality Monitoring

Routine monitoring is scheduled at varying frequencies, which are determined by the parameters of concern for individual streams and/or proximity to a monitoring agency's field office and lab. Water bodies are also selected for baseline monitoring if there is a high public interest; if it has a high potential for impairment; or there is a need for continuous up-to-date water quality information. Frequencies vary from quarterly for some partners and parameters to monthly in highly impacted urban.

Data collected through routine monitoring is designed to characterize water quality trends and monitor progress in protecting and restoring water quality. This monitoring will provide an overall view of water quality throughout the river and coastal basins. Baseline monitoring will include the collection of basic field parameters at all sites and the collection of bacteria, flow, and conventional chemical parameters at sites where indicated. All laboratories doing bacteriological analysis for this program will be using the IDEXX Method for E. coli and/or Enterococcus. Chlorophyll a will be sampled on a quarterly basis at stations located in reservoirs and bay segments and coastal bayous. Field filtered orthophosphate will be collected at all sites on a quarterly basis. All monitoring procedures and methods will follow the guidelines prescribed in H-GAC QAPP, the TCEQ *Surface Water Quality Monitoring Procedures, Volume 1: Physical and Chemical Monitoring Methods for Water, Sediment, and Tissue (RG-415) and the TCEQ Surface Water Quality Monitoring Procedures, Volume 2: Methods for Collecting and Analyzing Biological Community and Habitat Data (RG-416).*

Site Characterizations by the City of Houston Health & Human Services

For years, the City of Houston Health & Human Services has been collecting water quality samples from approximately 140 sites on a monthly basis. Review of the data indicates there are many sites in the city where elevated levels of bacteria or low levels of dissolved oxygen are chronic conditions. Both the City of Houston and the Clean Rivers Program's local stakeholders are interested in determining why these chronic conditions exist. Beginning with some of the most problematic areas, HHS will target 60 sites to specifically characterize. Information regarding habitat characteristics, land cover, and potential sources of pollution will be gathered from each targeted site. This site characterization information will be made available to the TCEQ for determining how data are assessed at these sampling locations in the future.

The targeted characterizations will consist of two tiers. Tier I will address the immediate sampling site and the visible area upstream of the every sampling location. H-GAC's standard Habitat Survey Form and photographs will be used to document observations regarding the general physical and vegetative characteristics of the stream as well as any anthropogenic influences visible upstream of the immediate sampling location.

Tier II will involve a more detailed evaluation of the watershed upstream of each characterized sample site and the waterbodies within that defined watershed. Particular effort will be made to identify potential sources of pollution. Methods may include review of aerial photos, windshield surveys, walking the stream bank, or canoeing the waterway. All potential sources of pollution, such as, permitted and illicit wastewater and stormwater outfalls will be documented and their position captured using Global Positioning System (GPS) technology or the City of Houston's Geographical Information Management System (GIMS).

All potential pollution sources identified during Tier I and Tier II surveys will be submitted to the appropriate City of Houston department for follow up or further investigation. Identifying the sources of pollution will allow the City of Houston to prioritize their resources to fix the problems and will, hopefully, result in improved water quality conditions at these sites.

24-hour DO monitoring by the City of Houston Health & Human Services (HHS)

There are six priority sub-segments with Dissolved Oxygen impairments or concerns located in the H-GAC region. More data collection is needed to determine if the segments are actually impaired and need to receive a Total Maximum Daily Load. H-GAC is contracting with HHS to conduct 24 hour DO monitoring on each of the six segments, six times throughout a two year period. One event will be conducted at each site during the critical period of July/August 2009. The other five events will be conducted during the next biennium contract to complete the 2 year data set. All data collected and summarized will be submitted to the TCEQ for use in future assessments. The sites are located on segments:

- 1007K - Country Club Bayou Above Tidal
- 1007O - Unnamed No-Tidal Tributary of Buffalo Bayou (Japhet Creek)
- 1007R - Hunting Bayou Above Tidal
- 1013A - Little White Oak Bayou
- 1014M - Neimans Bayou
- 1017D - Unnamed Tributary of White Oak Bayou

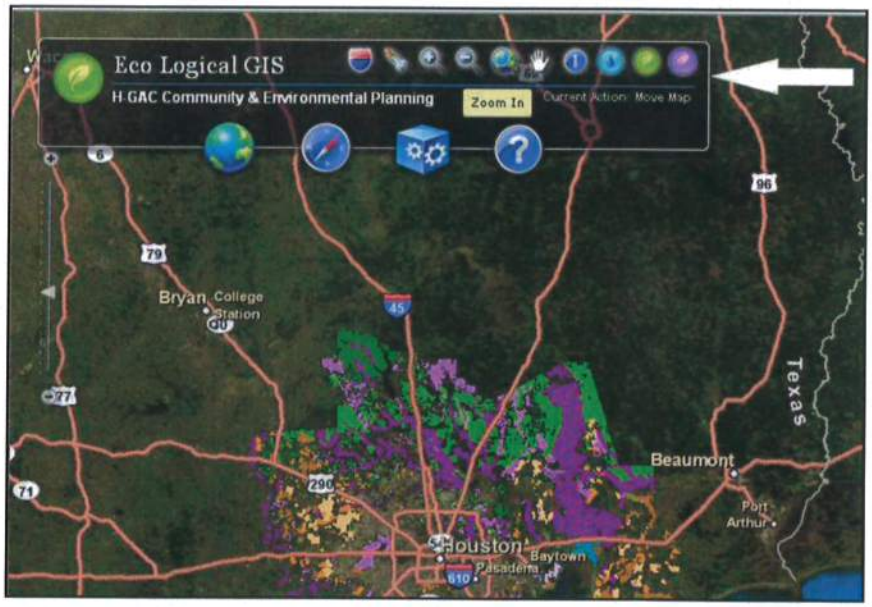
Appendix D

User Guide

The Eco-Logical GIS is a free, online decision-making mapping tool that can be used by organizations to integrate the planning process, and assist in identifying high priority environmental resources in the region. This user guide will provide you with a basic understanding of how to use the Eco-Logical GIS navigation functions as well as use the analytical models. The tool can be accessed at **www.h-gac.com/go/eco-logical**.

Upon opening the Eco-Logical GIS, first review and acknowledge the disclaimer by clicking on the *Accept* button.

You will then see a map of the H-GAC 8-county region and surrounding areas. By default, a layer showing the various types of Eco-Logical features in our region is displayed.



Navigation

Basic map navigation can be accomplished by:

- Using your mouse wheel to zoom in or out OR
- Using the buttons on the top short cut bar.

Zoom In, Zoom Out, Full Extent, or *Pan* buttons are available on the top short-cut bar. These buttons are also available in the Map Navigation menu.

For example, to zoom in, click on the *Zoom In* icon in the top short-cut bar, and then click and drag your mouse to define the area you want to enlarge.

To return to the full extent of the map and center the map on the H-GAC region, click on the *Full Extent* icon on the top short-cut bar.

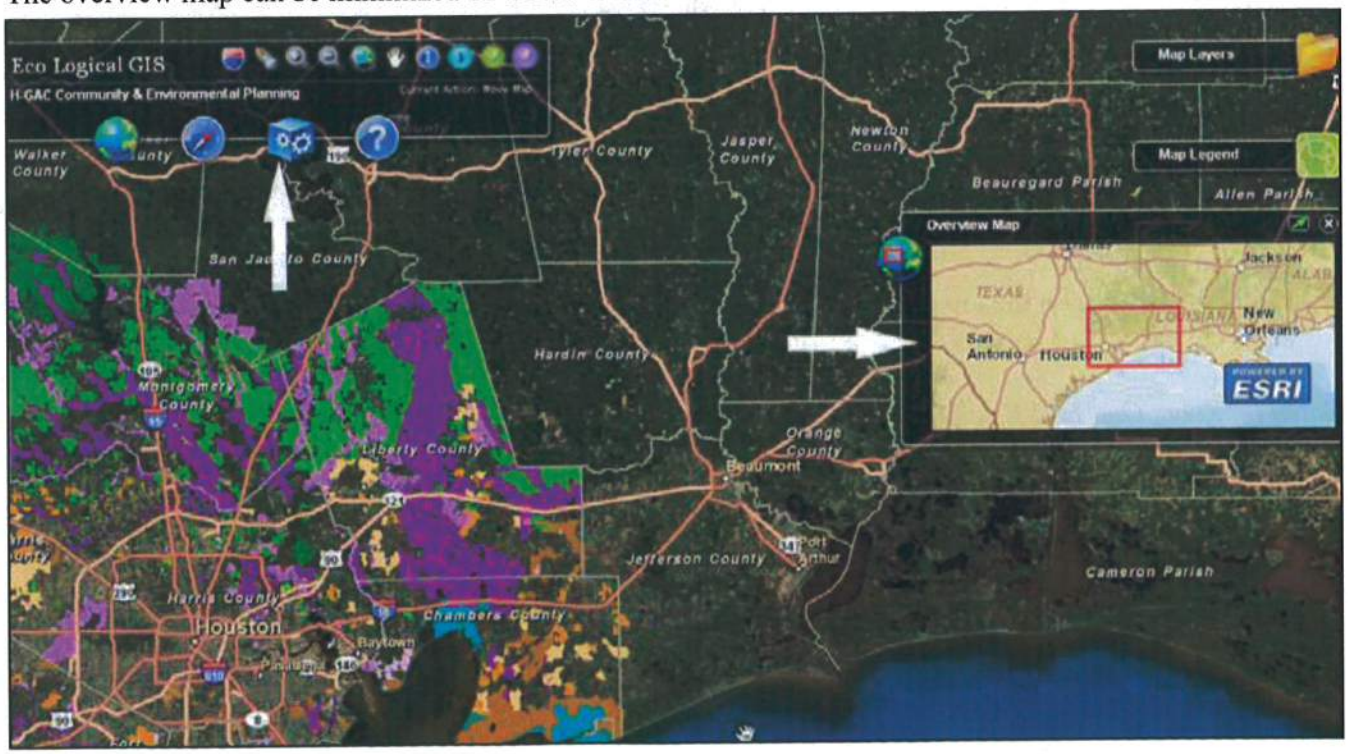
You can also use the pre-defined zoom levels along the left side using the scale slider bar to move in and out of the map.

To assist with navigation, an overview map is also provided:

The overview map is located in the Map *Views & Layers* menu, and can be opened by clicking on the icon labeled *Overview Map*.

The red box inside the overview map indicates the current extent shown in the main mapping window. The red box can also be dragged to change the main mapping window view extent. This is particularly helpful when zoomed into the map.

The overview map can be minimized or closed if not needed.



Viewing Map Layers

In addition, map layers can be turned on or off: Click on the *Map Layers* icon in the upper right corner to expand the layers window.

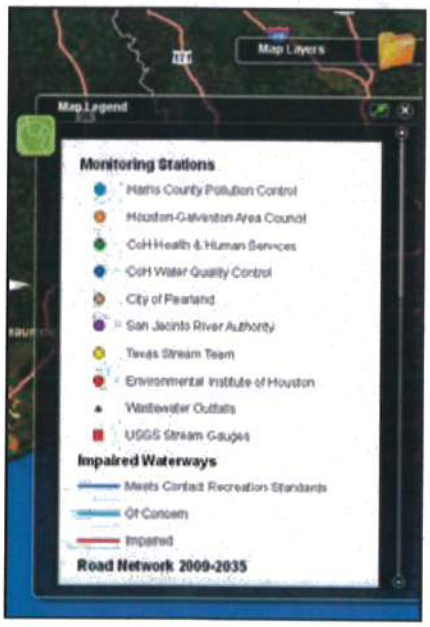
Here you can choose which layers to turn on and off, as well as set transparency levels for each layer.

The layers window can be minimized or closed at any time. If closed, it can be re-displayed by clicking on *Map Layers* under the *Map Views & Layers* menu.

Legend

The legend can be viewed by clicking on the *Map Legend* icon on the right side.

The legend window can be minimized or closed at anytime. If closed, it can be re-displayed by clicking on *Map Legend* under the *Map Views & Layers* menu.



Identifying Features

Features in the map layers window can be identified to obtain specific information about each feature by using the *Identify* tool, which can be accessed via either the short-cut bar located at the top, or within the *Tools* menu.

Click on the *Identify* tool to activate this feature, and the Identify window will open.

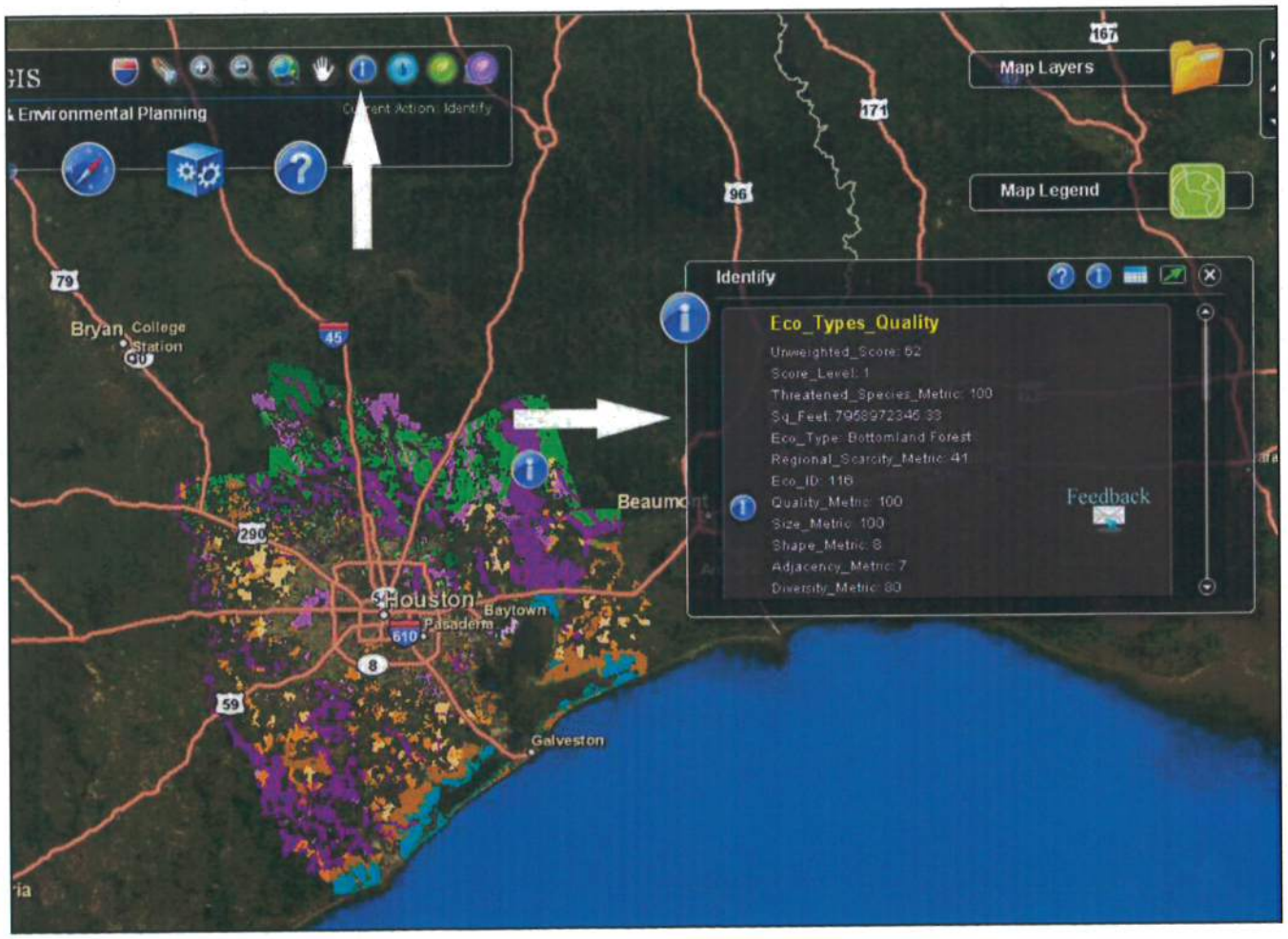
Next, click on a feature. The GIS will return detailed information on any feature located at the point where you clicked.

You can use the scroll bar to view information on the various features returned.

The blue *Question Mark* icon in the top bar of the identify window provides information on the attributes for Eco-Logical features.

By clicking on the blue *Identify* icon next to the feature, the map will zoom into the general vicinity of the identified feature.

For Eco-Logical features, we have provided a *Feedback* button. By clicking on this button you can send us feedback or ask questions about this feature in the database. This button is intended to work with your default e-mail program, so it will open a new e-mail, address the e-mail, and provide information we will need to respond to your request. A new web browser window will also open when using this feature, when you are done with your e-mail, you can close this window to return to the Eco-Logical GIS.

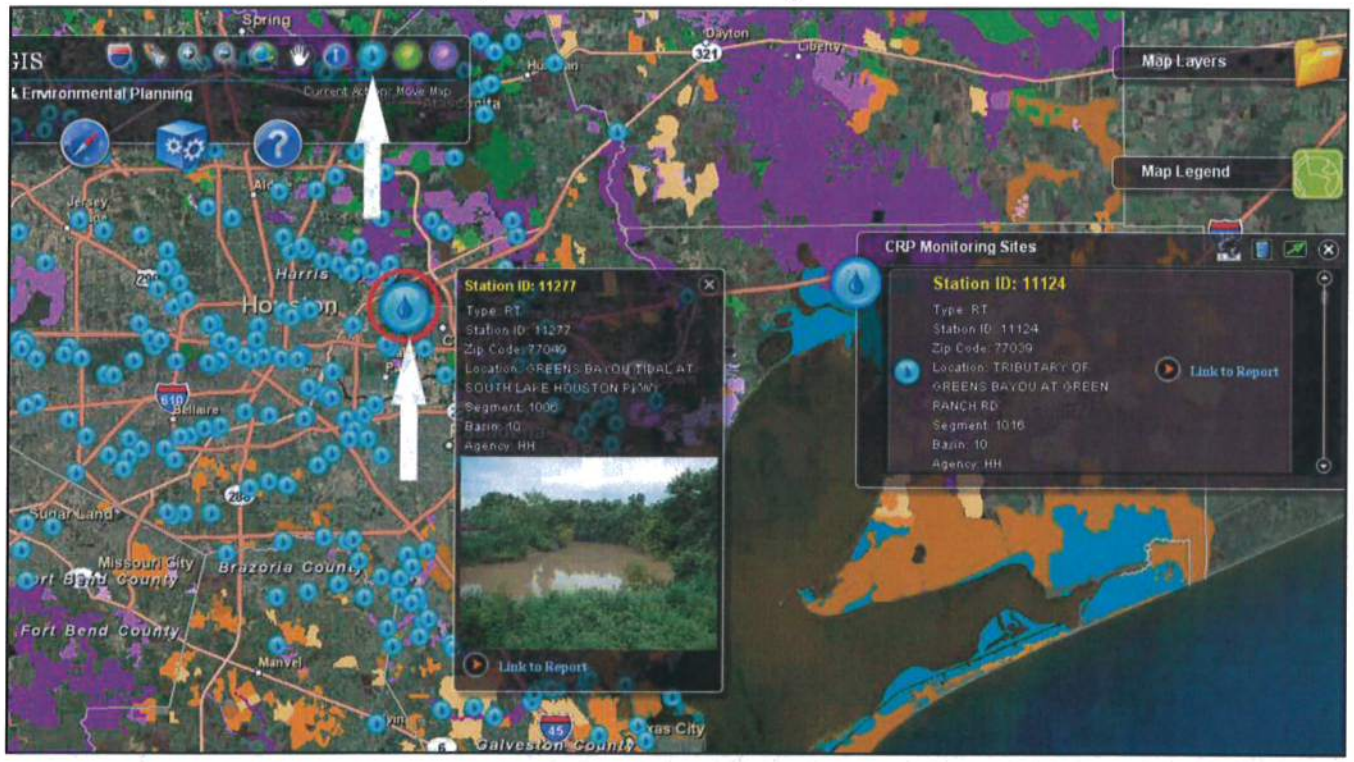


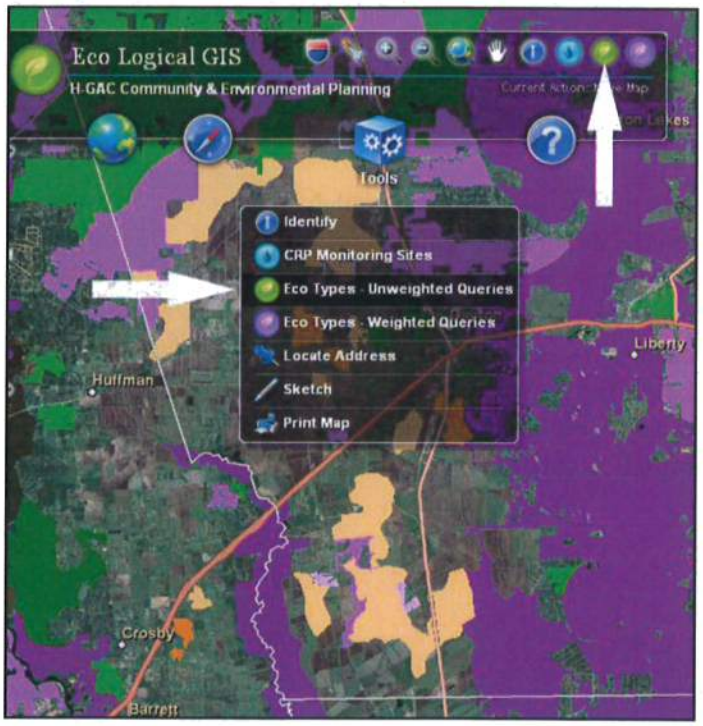
The Eco-Logical GIS also has a special identify tool for viewing information on Clean River Monitoring Sites.

To enable this tool, click on the blue *CRP Monitoring Sites* icon which is located in both the short-cut bar located at the top, and within the *Tools* menu.

The CRP Monitoring Sites window will open.

Next move your mouse over the site symbol to view monitoring site information.





Using Analytical Models

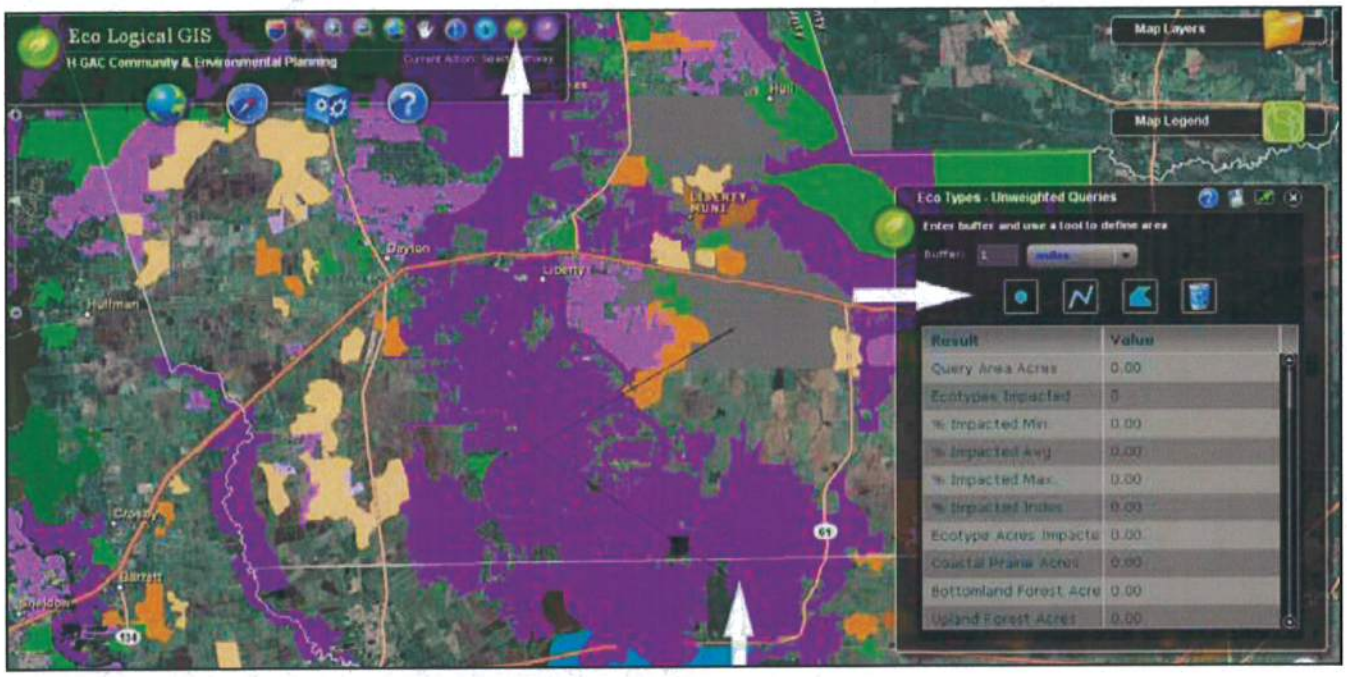
The Eco-Logical GIS contains two analytical models for assessing impacts to eco-logical resources. These models are the Eco Types Unweighted Query and the Eco Type Weighted Query. Both models are accessible via the Tools menu or the short-cut bar located at the top. The difference between Unweighted and Weighted queries is that the weighted query allows the user to define a ranking for each of the metrics used in the model, where as the unweighted query assumes all metrics are ranked equally.

To run the Eco Types Unweighted Query, click on the *Green Leaf* icon to open the model window.

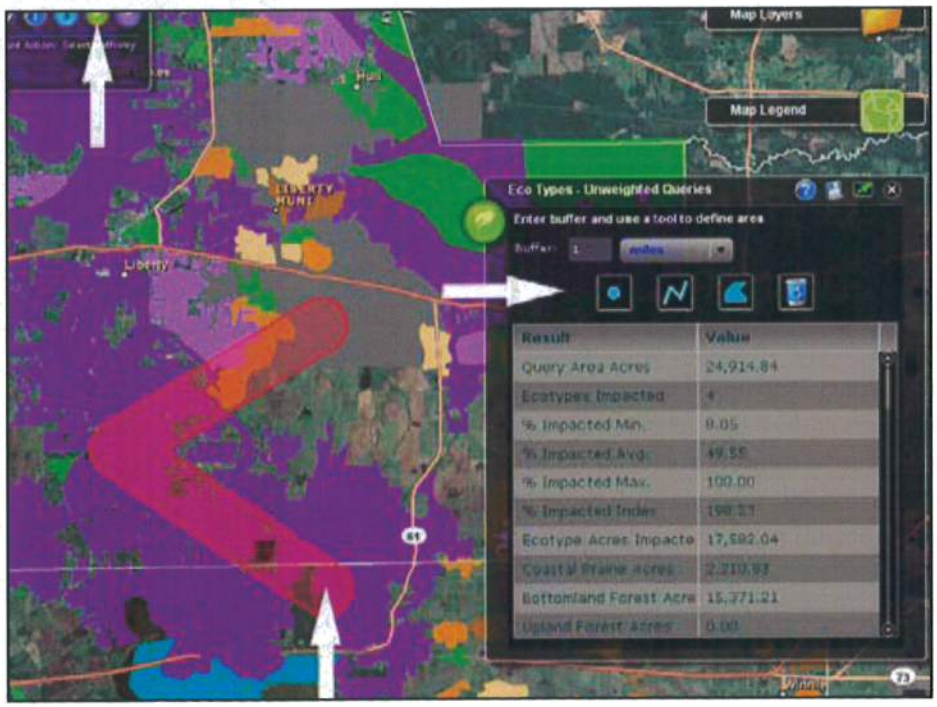
Both models allow the user to enter a buffered point or buffered line, or draw a polygon for the query area. The user can also change the units of measure for the buffer and the buffer size to miles, feet, kilometers or meters.

To run a query, click the point, line, or polygon tool. In this example we will run the query using a line and buffer.

Next, click once to begin drawing the line, and then click once again for each vertex you wish to set for the line's path. To finish drawing the line and submit the query, just double-click. The model will automatically begin when you double click.



After a few seconds, the model results are displayed in the grid within the model window. The grid can also be expanded for easier viewing, and the scroll bar to the right can be used to scroll down to view the returned statistics.



Submitting a query using a point is the same for the line, except that the user just clicks once on the map to set the location of the point.

Submitting a query using a polygon is the same for the line, with each vertex being set by a single-click and finishing with a double-click. The polygon tool does not use the buffer parameter.

The model window can be minimized or closed.

Running the Eco-Type Weighted Query is the same as for the unweighted query, just click the purple leaf icon to open the model window. The the user inputs are the same, except the user is allowed to enter weights for each of the metrics used in the model.

Weighting can be done using a series of 1 to 3, 1 to 5, or even 1 to 9. Metrics with greater weighting have higher numbers. To exclude metrics from the model, set the weight to zero.

Then submit the point, line, or polygon input as was done in the unweighted query.

The blue *Question Mark* icon in the top bar of the query window provides glossary information on the attributes for model results.

The *Disk* icon in the top bar of the query window allows the user to save the results of the query to a CSV file.

To run a new query, click the *Trash Can* icon and repeat the process.

Other Helpful Information

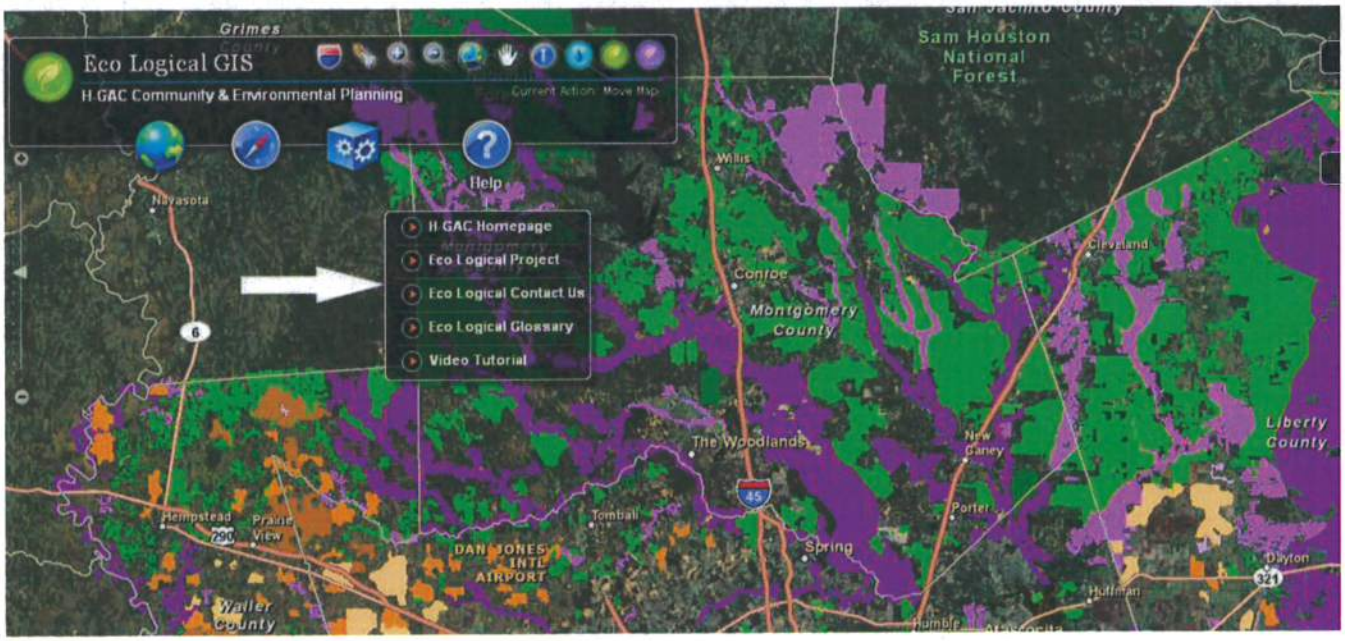
Some additional features include:

A *Sketch* tool located in the *Tools* menu to notate your map.

An *Address Locator*, also located in the *Tools* menu.

Printing a map, by clicking on the *Tools* menu and selecting *Print Map*. Here you can enter your own title and sub-title, then click on *Print*.

Eco-Logical also provides links to various H-GAC web sites, as well as to other video tutorials on how to use the application.



Appendix E

Letters of Support

GALVESTON BAY ESTUARY PROGRAM
17041 EL CAMINO REAL, SUITE 210
HOUSTON, TX 77058-2646
PH. 281/218-6461
FAX 281/218-6807
www.gbep.state.tx.us

March 4, 2010

Meredith Dang
Land Use Transportation Coordinator
Houston-Galveston Area Council
PO Box 22777
Houston, TX 77227-2777

Re: Letter of Support for Eco-Logical Regional Decision Support System

Dear Meredith,

As a participating partner in the development of H-GAC's Eco-Logical project, the Galveston Bay Estuary Program supports the integrated use of this interactive web-based tool in transportation project planning and selection. The Eco-Logical process undertaken in this project and the resulting regional decision support system (RDSS) tool presents as a unique opportunity to better unify long-range transportation and environmental planning.

As you know, Galveston Bay and the diverse, unique array of habitats in the surrounding Houston-Galveston region contribute greatly to the economy and quality of life in the Houston metropolitan area. Conservation of these valuable habitats is essential to maintaining the ecological health of Galveston Bay, and to maintaining a healthy, productive region for generations to come.

We view the constructive utility of the decision support system tool advances coordination of transportation planning and environmental conservation, and as a result can lead to significant contributions to the collective efforts of stakeholders in the region to conserve these valuable resources to the greatest extent possible while supporting continued economic growth.

Please feel free to contact me at (281) 486-1240 or e-mail at hdrummon@tceq.state.tx.us if you have any questions.

Thank you,

Helen E. Drummond
Director

HARC

HOUSTON ADVANCED RESEARCH CENTER
4800 Research Forest Drive
The Woodlands, TX 77381
281-367-1348
281-363-7936 Fax
www.harc.edu

20 February 2010

Meredith Dang
Land Use Transportation Coordinator
Houston-Galveston Area Council
PO Box 22777
Houston, TX 77227-2777

Re: Letter of Support for Eco-Logical Regional Decision Support System

Dear Meredith,

This letter is in support of the Houston-Galveston Area Council's Eco-Logical project. The Houston Advanced Research Center (HARC) has been an active partner as a member of the Eco-Logical Advisory Committee and views this project as a unique opportunity to unify goals associated with long-range transportation and environmental planning.

The Eco-Logical process undertaken in this project and the resulting regional decision support system (RDSS) tool provide a foundation for the region to create a more sustainable future. The RDSS is unique in that it is the first consensus-driven, regional-scale tool that relates transportation planning to priorities for future habitat conservation in the Houston-Galveston area.

The Houston-Galveston region is rapidly expanding in terms of the size of its human population. The region is also home to a unique array of habitats and wildlife, and we view the results of this project as a necessary step to ensure conservation of these resources. HARC believes that the tools created by the Eco-Logical project will allow conservation strategies to be integrated into the transportation planning process.

Through continued coordination of transportation planning and environmental conservation, the Houston-Galveston region can meet the challenge of ensuring mobility for the growing population while simultaneously preserving the resources that make the Houston-Galveston region unique for future generations to enjoy. Please feel free to contact me at (281) 364-6044 or lgonzalez@harc.edu if you have any questions.

Thank you,

Lisa Gonzalez
Research Scientist, HARC

Eco-Logical

Linda R. Shead, P.E.

P.O. Box 70181 /Houston, Texas 77270-0181 /C: 713.703.1123
linda.shead@sheadconservation.com

15 March 2010

Meredith Dang
Land Use Transportation Coordinator
Houston-Galveston Area Council
PO Box 22777
Houston, TX 77227-2777

Re: Letter of Support for Eco-Logical Regional Decision Support System

Dear Meredith,

As a participating partner in the development of H-GAC's Eco-Logical project, Shead Conservation Solutions supports the implementation of this interactive web-based tool into the decision-making process for transportation project selection.

The Eco-Logical process undertaken in this project and the resulting regional decision support system (RDSS) tool provide a foundation for the region to continue to create a more sustainable future. The RDSS is unique in that it is the first regional-scale tool developed on a consensus basis that identifies broad-scale priorities for future conservation efforts in the eight-county Houston-Galveston area.

By identifying these high-priority environmental resources and providing open, metric-driven information concerning the intrinsic values of each of the resources, the RDSS provides a valuable, data-driven, decision-making tool. By integrating the RDSS into the long-range transportation planning process – through requiring potential projects to screen for their impact to environmental resources prior to being accepted for inclusion in the 2040 Regional Transportation Plan – the region will, for the first time, include environmental components at the earliest planning stages. While the RDSS is not a substitute for thorough site-specific environmental analysis for specific projects, it will provide invaluable guidance as a first screening tool that could eliminate some of the larger and more widely known and understood potential environmental impacts.

By creating a transparent, time-saving process, the RDSS will be widely utilized by both transportation and environmental resource agencies. Through continued coordination of transportation planning and environmental conservation, the Houston-Galveston region can meet the challenge of ensuring mobility for the growing population while simultaneously preserving the resources that make the Houston-Galveston region unique for future generations to enjoy.

It is our hope that the Transportation Policy Council will incorporate the RDSS as part of the project prioritization process to protect the best of the region's remaining environmental resources. Please feel free to contact me at the above phone or email address if you have any questions.

Very truly yours,

Linda Shead

Linda R. Shead
Principal

Shead Conservation Solutions

Harris County
Flood Control District

9900 Northwest Freeway
Houston, Texas 77092
713-684-4000
www.hcfcd.org

February 23, 2010

Ms. Meredith Dang
Land Use Transportation Coordinator
Houston-Galveston Area Council
PO Box 22777
Houston, TX 77227-2777

Reference: Letter of Support for Eco-Logical Regional Decision Support System

Dear Ms. Dang:

The Mission of the Harris County Flood Control District (HCFCD) is to "provide flood damage reduction projects that work, with appropriate regard for community and natural values." In accomplishing this, HCFCD strives to minimize impacts to important natural resources and to do our business in such a manner that the environment of Harris County is made better in the long run. The District continuously seeks to keep itself abreast of the current state of natural resources within Harris County, even so far as having developed its own "Watershed Environmental Baseline" geodatabase system as a tool tailored to its particular planning needs.

HCFCD is a participating partner in the development of Houston-Galveston Area Council's Eco-Logical project, and because this tool is similar to the one effectively utilized by the District, HCFCD supports the implementation of this interactive web-based tool into the decision-making process for transportation planning and project selection.

The Eco-Logical process undertaken in this project and the resulting regional decision support system (RDSS) tool provide a foundation for the region to continue to create a more sustainable future. The RDSS is unique in that it is the first consensus-driven, regional-scale tool that identifies priorities for future conservation efforts in the Houston-Galveston area.

It is the considered opinion of HCFCD that, through continued coordination of transportation planning and environmental conservation, the Houston-Galveston region can meet the challenge of ensuring mobility for the growing population while simultaneously preserving the resources that make the Houston-Galveston region unique for future generations to enjoy.

It is our hope that the Transportation Policy Council will incorporate the RDSS as part of the project prioritization process to protect the best of the region's remaining environmental resources while still providing much needed improvements to the regional transportation system. Please feel free to contact me if you have any questions.

Sincerely,

Michael D. Talbott, P.E.
Director

MDT:GWL:cg

10MDT02.DOC

TEXAS FOREST SERVICE
The Texas A&M University System

February 18, 2010

Meredith Dang
Land Use Transportation Coordinator
Houston-Galveston Area Council
PO Box 22777
Houston, TX 77227-2777

Re: Letter of Support for Eco-Logical Regional Decision Support System

Dear Meredith,

This letter is in support of the Houston-Galveston Area Council's Eco-Logical project. The Texas Forest Service has been an active partner as a member of the Eco-Logical Advisory Committee and views this project as a unique opportunity to unify long-range transportation and environmental planning.

The Eco-Logical process undertaken in this project and the resulting regional decision support system (RDSS) tool provide a foundation for the region to continue to create a more sustainable future. The RDSS is unique in that it is the first consensus-driven, regional-scale tool that identifies priorities for future conservation efforts in the Houston-Galveston area.

The Houston-Galveston region is home to a unique array of wildlife habitat and ecosystems, and we view the results of this project as a necessary step to ensure an ecosystem approach to conservation of these resources. We believe that the tools created by the Eco-Logical project will allow conservation strategies to be integrated into the transportation planning process.

Through continued coordination of transportation planning and environmental conservation, the Houston-Galveston region can meet the challenge of ensuring mobility for the growing population while simultaneously preserving the resources that make the Houston-Galveston region unique for future generations to enjoy. Please feel free to contact me at 713-688-8931 or mmerritt@tfs.tamu.edu if you have any questions.

Thank you,

Michael Merritt

Michael Merritt
Bayou Region Urban Forestry Coordinator
Texas Forest Service

2020 North Loop West, Suite 106 * Houston, TX 77018
TEL (713) 688-8931
http://txforestservice.tamu.edu

Sea Grant Texas

February 16, 2010

Meredith Dang
Land Use Transportation Coordinator
Houston-Galveston Area Council
PO Box 22777
Houston, TX 77227-2777

Re: Letter of Support for Eco-Logical Regional Decision Support System

Dear Meredith,

As a participating partner in the development of H-GAC's Eco-Logical project, the Texas Coastal Watershed Program (Texas Sea Grant/ Texas A&M University) supports the implementation of this interactive web-based tool into the decision-making process for transportation project selection.

The Eco-Logical process undertaken in this project and the resulting regional decision support system (RDSS) tool provide a foundation for the region to continue to create a more sustainable future. The RDSS is unique in that it is the first consensus-driven, regional-scale tool that identifies priorities for future conservation efforts in the Houston-Galveston area.

By identifying these high-priority environmental resources and providing open, metric-driven information concerning the intrinsic values of each of the resources, the RDSS provides a valuable, data-driven, decision-making tool. By integrating the RDSS into the long-range transportation planning process through requiring potential projects to screen for their impact to environmental resources prior to being accepted for inclusion in the 2040 Regional Transportation Plan, the region will, for the first time, include environmental components at the earliest planning stages. By creating a transparent, time-saving process, the RDSS will be widely utilized by both transportation and environmental resource agencies.

Through continued coordination of transportation planning and environmental conservation, the Houston-Galveston region can meet the challenge of ensuring mobility for the growing population while simultaneously preserving the resources that make the Houston-Galveston region unique for future generations to enjoy.

It is our hope that the Transportation Policy Council will incorporate the RDSS as part of the project prioritization process to protect the best of the region's remaining environmental resources. Please feel free to contact me at 281-218-0565 or jjacob@tamu.edu if you have any questions.

Best regards,

John S. Jacob, Ph.D.
Director, Texas Coastal Watershed Program
Associate Professor and Coastal Community Development Specialist
Texas Sea Grant and Texas Agrilife Extension Service
Department of Recreation, Park, and Tourism Sciences
The Texas A&M University System

1250 Bay Area Blvd, Suite C Houston, TX 77058

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Financial support was also provided by the Galveston Bay Estuary Program, Texas Commission on Environmental Quality and the U.S. Environmental Protection Agency.

Houston-Galveston Area Council

2010
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713-627-3200

Any opinions, findings, and conclusions or recommendations expressed in this publication are those of the Author(s) and do not necessarily reflect the view of the Federal Highway Administration.