ECOSYSTEM SERVICES VALUATION
FOR THE COASTAL PRAIRIE CONSERVANCY AND ADJACENT LANDS
WALLER & HARRIS COUNTIES, TEXAS

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GLOSSARY OF ACRONYMS

AES	Applied Ecological Services, Inc.
AOI	Area of Interest
BMP	Best Management Practice
CPC	Coastal Prairie Conservancy
FDR	Flood Damage Reduction
GI	Green Infrastructure
GIS	Geographic Information Systems
GPS	Geographic Positioning Systems
LiDAR	Light Detection and Ranging
OMB	U.S. Office of Management and Budget
SOC	Soil Organic Carbon
SPPEED	Severe Storm, Prediction, Education, and Evacuation from Disasters
USD	US Dollars

EXECUTIVE SUMMARY

The 1994 Katy Prairie Conference identified the ecological value of the historic Katy Prairie ecosystem through various studies, including work done by the Texas Parks and Wildlife Department, U S. Fish and Wildlife Service, The Trust for Public Land, and others. At the time, to preserve these ecological values, a landscape scale goal of permanently protecting 50,000 acres was identified. For over 25 years, the Coastal Prairie Conservancy (CPC) has purchased prairie, wetland, and agricultural lands to conserve their natural functions and provide ecological protection to the prairie landscape. Under CPC's leadership, and with widespread public support, this fee title-owned and protected land base now exceeds 20,000 acres of the existing Katy Prairie ecosystem lands located in Waller and Harris Counties, west of Houston, Texas with a small seed bank property located in Fort Bend County.

While the ecological values of these lands have always been known, CPC has never attempted to economically value the ecological services provided by these lands. Indeed, only recent advancements in evaluating ecological services make this possible now, with the goal of increasing the community's shared understanding of the economic value preserved lands provide for a region prone to flooding, on a major migratory bird corridor, and with historic and cultural agricultural connections to the region (among other values). While these properties are an important regional conservation asset, the economic valuation is not currently recognized within the policy, regulatory and planning frameworks of the region.

This project, *Ecosystem Services Valuation for the Coastal Prairie Conservancy and Adjacent Lands*, had two main goals:

> (1) to evaluate tangible ecological service values provided to the Greater Houston Region by Coastal Prairie Conservancy protected lands and
>
> (2) to create the economic foundations for a regional model for protection and restoration of Katy Prairie lands in the future based on these values.

By use of this valuation, a new compelling economic strategy for saving public monies on future infrastructure investments is envisioned because conservation lands can reliably provide the same or similar functions and services at a lower capital investment. This is particularly true when additional operations and maintenance costs for large structures, such as reservoirs or carbon capture investments, are made. Finally, this model also provides the basis for developing a conservation master plan that connects protection, restoration, and stewardship of the CPC landholdings with other regional natural or working lands and thus could help guide current and future regional land use decisions and investments.

Methods in Brief

Within the 101,000-acre Katy Prairie study area, the ecological communities were mapped using satellite imagery and classified using geostatistical analytical techniques. Satellite imagery from 2016 included Landsat multispectral imagery and Sentinel-1 and -2 radar and multispectral imagery were utilized, resulting in spatial resolution variances from 10 to 60 meters, depending on data availability. The communities utilized in segmenting the 101,000-acre Katy Prairie study area were defined as open water, wetlands, developed areas, woodlands, prairie, upland row crop, cultivated rice and pasture/fallow land.

Ecosystem services were identified and valued for the identified ecological communities on a US$/acre/year basis using the process of benefit transfer (application of pertinent literature-derived values). Ecological functions were categorized as services (work), products (consumables) and secondary services (cultural and other). Region-specific data such as measurements of stormwater infiltration rates under various ecological communities also have been used to estimate local ecosystem service values.

Using these existing valuations culled from applicable peer-reviewed literature and/or additional field and regional work, five land areas were modeled to reflect scenarios with increasing levels of restoration. The five model runs examined (1) existing conditions, (2) 20,000 acres of contiguous restored lands, (3) 30,000 acres, (4) 50,000 acres, and (5) the entire 101,000-acre study area. Values of ecosystem services at each scale of acreage and restoration were then calculated by subtracting the costs of restoration from the ecosystem service, and then multiplying the additional acreage by the unit value increase due to the ecosystem service or function most likely achieved through a restoration scenario as defined. The ecosystem services were then added to estimate the total values in US$/acre/year for the same five (5) model runs, providing both an annual value of CPC's current lands, as well as the potential value of additional conservation and restoration strategies should CPC achieve the ultimate vision of protecting 50,000 acres or more of the historic Katy Prairie. The ecosystem services that were valued in this analysis include the following: air quality; carbon sequestration; soil stability and health; flood remediation; water quality; water supply; regulation of water flow; wildlife habitat; climate moderation; agricultural products, including rice, cattle or other agricultural products; wetland mitigation; hunting and fishing; and recreation and tourism.

Conservative Results

Because local economic values were not available for all services provided, some services are viewed as "conservative" valuations taken from pre-existing work in other areas of the country or world, so long as each was peer-reviewed. AES relied on professional judgment, guidance, and knowledge to account for accurate estimations of these services and considers the results provided here to be conservative in that the figures may not represent a true "replacement" cost for similar services in this region. Regardless, the results are succinct and demonstrate the value conservation brings to the region.

Non-hydrological related ecosystem services values resulted in an estimated $31.4 million per year in value that CPC's existing conserved lands provide to the Greater Houston Region. These values were then projected over 30 years resulting in a total value of approximately $940 million for scenario 1 (existing conditions). This equates to an average of $1,568 per acre value in combined ecosystem service values annually. Projected ecosystem services over a 30-year period for Scenarios 2, 3, 4 and 5 approximated at $1.15, $1.66, $2.73, and $5.37 billion respectively.

Because the flood mitigation and hydrologic values of these lands were viewed as key considerations, AES relied on hydrologic modeling performed by Dr. Phil Bedient, the Herman Brown Professor of Civil and Environmental Engineering at Rice University, to provide the volume estimations of these lands as conserved lands versus a scenario with "full development" (among others).[1] Drawing on data from this separate report, flood reduction benefits were refined using watershed-specific hydrologic modeling that employed the same land cover classification created by AES and used for other ecosystem service valuations. These data were further informed using in-field infiltration tests performed on the main soil types across the study area on conservation and developed lands recommended by Harris County Flood Control staff. Hydrologic models for six design storm events at recurrence intervals of 2, 5, 10, 25, 50, and 100 years, and under existing land use and restored scenario conditions (20,000, 30,000, 50,000 and 101,000 acres), provided the basis for economic valuations of flood volume mitigation (e.g. reduced flood levels or flood durations resulting from the restoration of land).

As expected, the hydraulic modeling showed that upstream land preservation and restoration provides valuable flood mitigation services, particularly for recurrent events at 10, 25, and 50-year storm levels Further, restoration efforts of the existing landscape – including even the conserved lands currently managed by CPC – further reduced runoff for mid-frequency storm events (i.e., 10, 25 and 50 yr. storm events). Larger storm events (i.e., 100 yr. and greater) appeared to overwhelm the landscape regardless of changes in land use, thus, requiring additional modeling that was outside the scope of this study in order to examine the valuation and flood mitigation benefits potentially provided by larger or more strategic conservation efforts across the watershed.

We used two modeling methods to evaluate and value the flood reduction benefits of Katy Prairie ecosystem lands. Method one (1) examined reductions in stormwater runoff volumes on increasing acreages of protected/restored CPC lands. We found that an ecosystem service value of $45 million dollars per year approximates the benefits to reduced downstream floodwaters that do not have to be otherwise managed in a reservoir within the watershed. Method two (2) compared the improved infiltration and reduced runoff volumes on protected/restored CPC lands to green space in the adjacent suburban developed lands. We found that Katy Prairie ecosystem provide $331.5 to $646.5 million dollars (2017 dollars) for 10-50-year events over the range of area of interest (AOI) sizes included in each scenario. This approximates the benefits to reduced downstream floodwaters that do not have to be otherwise managed in a reservoir in the

[1] The hydrologic modeling report is attached as Appendix 6 and provides the methodology and results briefly summarized here.

watershed. At the scale of 101,000 acres of protected/restored land, the total benefit would be expected to range from $377 to 692 million, or $3,727 to $6,846 per acre as an annualize average.

Conservatively, the sum of combined annual non-hydrological and hydrological ecosystem service valued (measured, modeled, estimated and projected) in this project would have an annual per acre value ranging from $5,627 to $8,341 depending on the AOI acreage and acreages of each ecosystem type included in the modeling. For CPC's existing assets, that means that CPC lands provide an annualized estimated avoidance value for flood damage reduction (offsetting potential costs in equivalent costs to construct and maintain a new water management reservoir) benefit of between $112.5 and $166.8 million – a significant return on the public's investment in this preserved landscape.

The hydrologic modeling and thus the valuation estimates are very conservative because anticipated advances in floodwater mitigation from such factors as improved infiltration, enhanced soil health, and improved measurement capabilities are not included or captured in the models. For example, soil organic matter levels will improve as grassland restoration occurs, improved grazing occurs, and where reduced tillage agriculture occurs with a concomitant improvement in infiltration capacity as the plant roots develop vertical piping routes. Further study is recommended to better quantify the cost/benefit of the various flood mitigation measures (see Table 15).

Of particular importance is further elucidating ways to improve the infiltration rates in developed lands, currently measured as zero. It would be important to clarify regionally what alternative landscaping and soil management practices in developed landscapes, including ecological management of urban and suburban yards, might benefit the overall flood mitigation needs for the region. Currently, this study documents that the protected and restored landscapes provide highly valuable and significantly reduced runoff compared to the urban/suburban landscapes where greatly reduced infiltration rates were measured. Nevertheless, improvements by use of native landscaping and many other best management practices (BMPs) for stormwater management have been demonstrated to significantly reduce stormwater runoff from developed areas as well. Because this is outside the scope of the study however, these values are not addressed at this time.

In Sum

The value provided to the region on an annual basis of preserving these lands for all the various ecosystem services, including flood mitigation, was approximately $5,627 to $8,341 per acre. Yet, the timing of this report requires an obvious caveat in that future work must evaluate larger storm events like Hurricane Harvey's (1,000+ yr. event) to understand how land conservation and restoration (such as the design of water management preserves that might include an expanded and replicated Coastal Prairie Conservancy-type of preserve) might be distributed across the watersheds that are tributaries to Houston's flood prone areas. Regardless, this study demonstrates that an integrated flood mitigation strategy incorporating preservation and native prairie and wetland restoration provides significant economic value on an annual basis to the region.

I. INTRODUCTION

The Coastal Prairie Conservancy's properties are an important conservation asset in the region currently utilized by various stakeholders, from farmers, ranchers, hunters, birdwatchers, and others. But as is often the case, the lands provide ecological services that have economic values not often recognized within the policy, regulatory, and planning frameworks of the region. Because of these unrecognized values, the land regularly is the subject of proposals for land development such as new highways and housing developments. CPC lands are simply viewed and treated as undeveloped open lands with no value understood to be associated with their intrinsic ecological services. By contrast, for CPC and participating landowners, protection has been an intentional goal for their lands, with the highest and best use deemed to be conservation of important ecological resources while perpetuating the uses and conditions of a working landscape.

Unlike unprotected open space, CPC's properties have a more certain future. Because they are permanently protected, the land will continue to provide ecosystem service benefits to the region, such as flood control, carbon sequestration, pollinator and wildlife habitat, and recreational opportunities. It is this certainty of future land use that provides an opportunity for these lands to be valued for their ecosystem services. For example, Harris County (Harris County Flood Control District et al. 2015) has begun to recognize and document the flood damage reduction (FDR) services provided by CPC lands. Optional strategies for flood control in the future might include the protection and restoration of additional Katy Prairie ecosystem lands to achieve a desired level of flood protection. This designated level of flood protection achieved by the ecosystem services of undeveloped land can be compared to other FDR investment options, such as relocation of buildings from unsuitable low-lying, flood-prone lands; retrofitting existing reservoirs; and/or storm sewer improvements. When the costs of engineered FDR are considered, the protection, restoration, and enhancement of grasslands and other ecosystems often provide ecosystem services with very high valuations at a relatively low cost of investment.

Once land is converted to agricultural uses or developed, critical ecosystem services are diminished or lost. Around the world, many recognized methods are employed to assign monetary values to ecosystem services to aid government or communities in addressing these lost values. These economic values, in turn, facilitate societal acceptance, protection, and restoration of conservation land as a viable – and indeed often more fiscally conservative alternative – to the typically costlier engineered strategies that can accomplish similar results. FDR is often the focus of such initiatives.

To illustrate this phenomenon, in rapidly developing urban centers, such as Chicago or Milwaukee, it has become increasingly important to find and protect the remnants of native prairie, similar to lands on the Katy Prairie, or equivalent lands that can be ecologically restored to optimize their ecosystem service values based on economic estimates to "replace" those same ecosystem service values through engineered solutions. In recognition of this, Illinois's Statewide Natural Area Inventory process has listed ecosystem services as one of its program benefits. Similarly, green infrastructure plans for cities and regions such as Chicago, Milwaukee, and Kansas City have begun acknowledging the values of ecosystems, such as those provided by the Katy Prairie, when reviewing placement or location of government infrastructure projects. Other parts of the country are prioritizing protecting and restoring remnant ecosystems because of the economic valuations associated with the lands – again, typically it is far less expensive to protect the lands already providing these important ecosystem services than to allow these services to be lost and then replaced by investing in engineered solutions to replace the lost natural services. Once natural areas are protected, and often after necessary ecological enhancement or restoration, these lands add further ecosystem services values because of the nature of restored ecologic function – from carbon sequestration in soils to flood mitigation. Increasingly, at regional scales and within the regional master plan frameworks, conservation is the highest and best use and value for these lands.

The ***Ecosystem Services Valuation for the Coastal Prairie Conservancy and Adjacent Lands* project** had the following goals:

1. **Evaluate tangible ecological service values provided to the Greater Houston Region by Coastal Prairie Conservancy protected lands.** This analysis is focused on documenting the measurable ecosystem functions and services provided by CPC lands to the Greater Houston Region. Dr. Bedient's hydrology/hydraulic modeling efforts combined with AES' ecological analysis and GIS modeling have enabled the creation of ecological and hydrological mapping which are foundational to this valuation project.

2. **Create the economic foundations for a regional model for understanding the expanded protection and restoration of Katy Prairie ecosystem lands can provide in the future based on the regional ecosystem services values of such protected lands.** The vision is using this valuation model to create a compelling economic strategy for saving public monies on future infrastructure investments and FDR by instead investing those dollars or similar dollars in restoration and further conservation efforts. The study model will also provide the basis for developing a conservation master plan that connects protection, restoration, and stewardship of the CPC landholdings with other existing natural, open, or working lands. This, in turn, can be used, to help guide regional land use decisions and investments.

The results demonstrate an annual economic value for more than simply Flood Damage Reduction and provide further support for CPC's goals of restoration and further conservation.

II. ECOSYSTEM SERVICES VALUATION

Through myriad interrelated ecological functions, each ecological landscape supports a diversity of plants and animals and provides a variety of ecosystem services and products valued by humans. Ecosystem goods and services are typically defined as "the benefits human populations derive, directly or indirectly, from ecosystem functions" (Costanza et al. 1997). Such services, usually grouped by specific ecological community or vegetative land cover type, refer to the physical and biological work from the community. For example, wetlands perform services of retaining water, improving water quality, and providing wildlife habitat. Prairies are known for services of infiltrating and retaining storm water, building and retaining soil, and sequestering atmospheric carbon. Goods are direct products produced by an ecosystem, used directly by humans (e.g., lumber, fish, crops) or with assigned market values (e.g., flood water storage capacity, huntable wildlife, game fish, and areas for outdoor recreation).

It is an ongoing challenge to find the most accurate, cost-effective, useful, and transparent methods of assigning values to various ecosystem services, so those values can, in turn, become associated with acreages of mapped ecosystems within a landscape. Because the original research needed to measure ecosystem functions and products and use those data to estimate ecosystem values is most often time-consuming and expensive, benefit transfer has become a standard practice of assigning values in most multi-faceted, landscape ecosystem service valuation projects. It is the main mechanism for valuation used in this project. An increasing number and variety of such projects have been conducted by an equally diverse contingent of investigators. As one might expect, there is a wide variety in the types of ecological services and ecological communities represented along with a variety of valuation or monetization methods.

Methods and Approach

In this section we describe our methods and approach to ecosystem valuation for CPC lands. We begin with a discussion of our approach to a literature and information review. We summarize the ecosystems of CPC lands that form the basis of our information review, providing greater detail on mapping methods in Chapter III, and summarize from our literature review accepted ecosystem services and products definitions and economic valuation categories.

Literature and Information Review Methods

Numerous technical papers from across the country and globe were reviewed to assign economic values through the process of benefit transfer to ecological services that are relevant to the CPC landscape and its ecosystems. Appendix 1-1 contains the primary references used in our ecosystem services valuation and a column denoting the geographical locations. The documented values of these ecosystem services and goods are summarized in Appendix 2. Values from CPC contracts for farming, grazing and hunting over parts of their landholdings were also used for establishing dollar values (Appendix 3). Finally, other regional valuation data were used where the values provided by a regional study were in general alignment with other literature findings, and/or where an explanation provided appropriate and adequate differentiation from the literature records.

The authors used the following general guidance to locate and assign economic values to ecological services associated with mapped ecological communities:

- Values from regional studies were favored over values from non-regional studies once the authors confirmed the alignment in measurement and valuation methods reported in the literature. We provide an explanation whenever a non-regional value was selected over a regional value.

- Ecological communities outside of the ecoregion of the study area were included in this assessment if the authors judged that those communities were similar enough to inform the value of ecological communities within the study area.
- Monetary values of ecosystem services were reported per cited references. They were not adjusted to reflect 2017 values because most of the studies were current, within the last decade.[2]

Professional judgment and knowledge of the site-specific landscape and its ecosystems also were used when no values were available for the geographic area or when a range of values was given. For example, for a range of values from a study, we typically selected a midpoint value, except where a reliable, locally documented value was available. We transferred some values between ecosystems within the study region, such as using the general recreation/hunting value located for wetlands as well as for upland prairies.

Ecological Communities

Existing CPC ecological communities focused the literature and information review. For this study, the ecological communities were mapped and modeled using satellite image analyses combined with field observations following the methodological details in Chapter III.

The ecological communities of CPC in the area of interest (AOI) (i.e., study area) include:

- Open water (lakes, ponds, rivers, streams, etc.);
- Wetlands;
- Developed (roads, parking lots, roofs, etc.);
- Forest or Woodland (forest, woodland, savanna, shrub-land);
- Prairie (remnant or restored native prairie).
- Upland row crops (primarily corn)
- Cultivated rice
- Pasture/Fallow Land subdivided into healthy pasture (based on high biomass which is called Shrub-Pasture in this report), and degraded pasture (based on low biomass—called Grass-Pasture in this report).

For the purposes of economic evaluation, similar ecological communities were lumped together even if the nomenclature was not exactly the same as in the literature reference. For example, a *native grassland* referenced in a paper would be lumped in our *prairie* community. *Pasture* referenced in a paper would be lumped with *prairie* if we could discern that the forage stock was primarily native prairie species, or in *pasture* if we could discern that the forage stock was primarily non-native planted grasses or legume forage plants.

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[2] Because dollars were not adjusted to 2018 dollars, the overall valuations are deemed conservative as the report does not attempt to account for inflation.

II. Ecosystem Services Valuation

Definitions and Descriptions of Ecological Services and Products

Ecosystems generate outputs that humans can designate as services and products. All of these emerge from the complex ecological functions of the ecosystem under consideration. They can, in turn, be valued for their benefits to humans. For this project, each of the ecological communities present in CPC and neighboring lands was evaluated in our literature review to document ecological services, comprised of direct products, secondary products, and secondary benefits that it provides. These are summarized below (Table 1). In general, we followed the analytical framework provided by the U.S. Office of Management and Budget (OMB) (cited in Wainger and Ervin 2017) which is: (1) monetize what can be monetized; (2) quantify what cannot be monetized; and (3) describe what can be neither monetized nor quantified.

- **Ecological Services** refer to the actual physical, chemical, and biological work provided by a specific landscape and its ecosystems, usually measured relative to the benefits provided to humans (they also provide benefits to many other organisms). For example, wetlands perform the work of detaining water and improving water quality while also providing wildlife habitat, among other services.
- **Direct Products (Goods)** refer to products produced by an ecological community that are directly consumable (i.e., used and then replaced). For example, forests provide timber for lumber; wetlands provide waterfowl for harvest by hunters.
- **Secondary Products** refer to economic benefits associated with the work performed by an ecological community. For example, property values adjacent to or within natural open spaces may have higher economic values than properties lying some distance away. Or, agricultural crops may exhibit higher yields when there are ample pollinators available in response to habitat provided by adjacent ecosystems.
- **Secondary Benefits** refer to less tangible attributes of natural open spaces valued by people. Among the tangible and intangible benefits to public health is emotional well-being that has been associated with recreational access. A plausible resulting correlation is a healthier public who potentially have reduced healthcare costs. We report the literature findings in this study, using the language in the source publication(s). For example, a person may feel more peaceful sitting on a bench in a prairie as compared to sitting on a bench in a bus station. This positive disposition has been shown to contribute to emotional, spiritual, and physical health (Maller et. al. 2005; MEA 2005).

II. Ecosystem Services Valuation

Table 1. Ecosystem Services, Direct Products, Indirect Products, and Secondary Benefits

Ecosystem Services ("Work")	**Description of Ecological Services** This is a collective term that refers to the actual physical and biological work that the specific landscape provides. For example, wetlands perform the work of retaining water, and improving water quality while also providing wildlife habitat and many other services.
Regulate Water Flow	Maintains hydrograph stability and predictable flooding regimes in lotic and lentic systems. Quantitative values are derived from the estimated runoff value for an area of land surface. This service has significant implications in areas prone to high flooding like the Greater Houston Area.
Water Quality	Demonstrated improvement in surface water quality through natural, green infrastructure filtration.
Soil Stability	Maintains soil and slope stability and preserves the integrity of the soil-vegetation system. Quantitative values are derived from rainfall, soil erodibility, slope, land cover, and agricultural cropping practice. The data output will be estimated soil loss with a higher number representing greater erosion.
Water Supply	Maintains a natural rate of groundwater recharge and aquifer replenishment. In a simple model, the service can be quantified as the potential for land cover, soils and geological formations to receive precipitation. Depth to groundwater defines limiting locations where water is at or near the surface. In a refined model, it can be used to prioritize or assess the vulnerability of regional groundwater supply.
Air Quality	Creates or preserves high quality air for human consumption. Qualitative service level ranks are derived from relative pollution removal rates for NO_x and SO_2 by different land cover classes in one continent-wide European study (Maes et al. 2011). CMAQ grants provide a direct calculation for eliminating cars off roadways. that uses vehicle numbers, industrial operations and regional air quality basin physicality to estimate air quality conditions. American Forest and US Forest Service have calculations for estimating the air quality cleansing provided by primary forests, but these are not present in the CPC project area.
Habitat	Perpetuates or increases native wildlife species diversity at a regional scale, especially of area-sensitive and habitat specialist species. Qualitative values are derived from land cover class, polygon size, and distance to roads or buildings.
Carbon Sequestration	Creates or preserves natural rates of carbon uptake in soils and vegetation. Qualitative service level ranks are derived from relative carbon uptake rates in soil and vegetation by different land cover classes from several sources (Birdsey 1996; Lal et al. 1999; IPCC 2000; Follett et al. 2001; West and Post 2002; USEPA 2011).
Climate Moderation	Lowers the ambient air temperature through vegetation shading of the ground and impervious surfaces. Land cover influences ambient air temperature through several factors, including heat storage capacity, surface reflectivity, evapotranspiration and shade. The qualitative service level rank is derived from the assumed heat given up to air by different land cover classes.
Direct Products (Consumables)	**Description of Direct Products** This refers to consumable products produced by a community directly used by humans. For example, forests provide timber for lumber; wetlands may produce huntable wildlife.
Food, Lumber, Fiber, Meat, crops, etc.	Products generated on the landscape that are directly consumable.
Fish and Game	Production of fish and game for fishing and hunting.
Genetics and Wild Materials	This includes preserving biodiversity for unknown future uses, as well as known uses of wild materials.
Secondary Products	
Recreation and Tourism	Focused on locations that provide outdoor, nature-based active experiences contributing to human health and welfare.
Property Values	This includes natural features that are known to increase the economic value of adjacent or nearby properties.[3]
Pollination	Provides habitat for pollinators important for producing agricultural products such as fruits and vegetables.
Pest and Disease Control	Provides a refuge for native plant material that can be used to develop pest-resistant strains of plants; and managed natural areas that outcompete weeds.
Energy Savings	Mitigates for urban heat island effect.
Secondary Benefits	
Quality of Life and/or Aesthetic	Contributes to emotional well-being thereby reducing costs associated with public health
Human Health	Contributes to human health thereby reducing medical costs associated with poor health.

[3] While literature accurately supports the increase in adjacent property values for parks, this study did not attempt to value the monetary lift adjacent property owners have to the CPC lands as much of these lands are not adjacent to developed areas.

II. Ecosystem Services Valuation

Economic Valuation Categories

Broadly speaking, ecosystem services are defined as being either candidates for direct market valuation or indirect market valuation (DEFRA 2007; de Groot et al. 2002). Examples of direct market valuation include commodity production (such as timber, crops, and huntable wildlife) and services valued directly by society (such as sequestered organic carbon that can be valued as carbon offset credits or cooling services provided by shade trees).

Typical valuation categories, or methods (de Groot et al. 2002; van der Ploeg et al. 2010, and others) used in the studies from which we transferred benefits are listed below. These peer-reviewed valuations are utilized by government entities, foundations, and others engaged in planning. We have referenced the valuation method for each ecosystem service.

- **Direct Market Pricing**. This valuation uses pricing for goods and services provided by ecosystems that can bought and sold in commercial markets. Examples include carbon credits or acre-feet of irrigation water.
- **Avoided Cost**. Services that allow society to avoid costs that often stem from actual or anticipated damage to property or human health. Examples include wetland services that provide flood control to avoid property damage from floods.
- **Replacement Cost**. Services that can be replaced with engineered systems such as those that remove pollutants from air or water that would otherwise be removed via a functioning ecosystem. Often closely tied to an **Avoided Cost** valuation.
- **Mitigation and Restoration Cost**. Services whose values are estimated by calculating ecosystem restoration or replacement costs. An example is an estimate of the protective value of coastal wetlands from a hurricane derived by replacement and restoration costs post-storm (Costanza et al. 2008).
- **Hedonic Pricing**. Valuation of services that directly affect direct market prices of goods. An example of this is the influence of the ecosystem service of pollination on the productivity of specific crops. Very closely tied to this is **Factor Income** valuation that links ecosystem services to improved income of persons. An example of this is commercial fisheries being improved by healthy coastal wetlands.
- **Contingent Pricing**. This is sometimes called "willingness to pay" since it typically emanates from asking people about their willingness to pay for specific services described via a hypothetical scenario. An example of this is the willingness of people to pay entry fees for an ecological trail system or park managed by government or under community ownership or easement.
- **User Cost**. This valuation uses typical costs of a user traveling to a site combined with costs of staying in an area (e.g., food, lodging). This is typically associated with user days but can become a dollars/annum/unit area value if the annual number of visitors to an ecosystem parcel or landscape is sufficiently documented to produce a reasonable estimate.

Application of Findings to the CPC Landscape

The primary and secondary ecosystem services provided by each ecological community are summarized below in Table 2. (also, in Appendix 2-2). This table illustrates our assessment and classification of the main ecosystem services provided by CPC and surrounding lands. The assessments were derived from availability of relevant data in available literature combined with knowledge of the occurrence (e.g., acreage, distribution on the landscape) of any given ecological community on CPC lands. To illustrate, carbon sequestration on CPC lands was ranked as an important service of wet grassland and prairie. We ranked it as a secondary service of woodlands due to the lack of mature forest systems and limited intact patches on the CPC landscape. A "no service" ranking indicates services that did not appear to rise to the level of primary or secondary services for a particular ecosystem in this landscape due to the size and/or distributions of the ecosystems, or services that simply lacked sufficient relevant supporting studies to render an opinion. If additional supporting data become available in the future, or are collected on CPC lands, we would expect changes in some of these rankings.

Table 2. Summary of the Primary and Secondary Ecosystem Services Provided by Each Ecological Community (please see Note).

		Wet Grassland	Prairie	Woodland	Pasture - Shrub	Pasture - Grass	Upland Crop	Rice Crop	Turf (Park Land)
Service	Air Quality	Secondary Service	No Service	Primary Service	No Service	No Service	No Service	No Service	Secondary Service
	C Sequestration	Primary Service	Primary Service	Secondary Service	No Service	No Service	No Service	No Service	No Service
	Soil Stability / Health	No Service	Primary Service	Secondary Service	Secondary Service	No Service	No Service	No Service	No Service
	Water Quality	Primary Service	Primary Service	Secondary Service	Secondary Service	No Service	No Service	No Service	No Service
	Water Supply	No Service	Primary Service	Secondary Service	Secondary Service	No Service	No Service	No Service	No Service
	Regulate Water Flow	Secondary Service	Secondary Service	Secondary Service	No Service	No Service	No Service	No Service	No Service
	Habitat	Primary Service	Primary Service	Primary Service	Secondary Service	No Service	Secondary Service	Secondary Service	Secondary Service
	Climate Moderation	Secondary Service	Secondary Service	Primary Service	No Service	No Service	No Service	No Service	Secondary Service
Direct Product	Commodities	No Service	No Service	Secondary Service	Primary Service	Secondary Service	Primary Service	Primary Service	No Service
	Mitigation	Primary Service	No Service	No Service	No Service	No Service	No Service	No Service	No Service
	Hunt / Fish	Primary Service	Primary Service	Primary Service	Secondary Service	Secondary Service	Secondary Service	Secondary Service	No Service
Secondary Product	Recreation and Tourism	Primary Service	Primary Service	Primary Service	No Service	No Service	No Service	No Service	Primary Service
	Property Values	Primary Service	Primary Service	Primary Service	Secondary Service	Secondary Service	Secondary Service	Secondary Service	Primary Service

Legend	
(blue)	Primary Service
(green)	Secondary Service
(white)	No Service

Note: *"Property Value" is included in the above table to only provide the context for where property appraised value may be considered in this process. Property appraised value is not considered in this ecosystem services analysis.*

Most ecosystem services have no direct market values, resulting in the use of indirect valuation strategies such as the value of engineered water filtration systems for the water cleansing services otherwise provided by wetlands,[4] or the cost of building and maintaining a reservoir to maintain a water supply that might be provided by a river or wetland system. Still other services are given

[4] Indeed, CPC lands have benefited greatly by providing wetland mitigation credits and banking opportunities for the region, further supporting the underlying assumption in this report that these conserved lands provide economic value.

monetary values through evaluating a combination of direct and indirect valuations. An example of this is soil stability (erosion protection) valued by avoided costs of losing and then replacing topsoil at market prices. The goal of ecosystem service valuation in all cases is to provide information that can be used in decision-making that relates to human welfare, not just ecological changes (Wainger et al. 2010). It has been argued that the values assigned are not "true" values of the ecosystem under consideration, but rather a means to allow for the design of incentives for preservation and restoration (Heal 2000). Thus, the valuations are often viewed as "conservative" valuations addressing a finite number of direct or indirect values currently considered for such landscapes but arguably not assigning a true value for other more amorphous services provided by open land.

For this study, we selected the most relevant valuation categories with the best supporting data from studies documenting replacement costs, avoided costs, direct market pricing for products, and user costs for access to ecosystem benefits or products. These are summarized below in Table 3 (also in Appendix 2-3).

Table 3. Valuation Categories Reported in Scientific Literature for the Ecosystem Services Provided by Each Ecological Community (please see Note).

		Wet Grassland	Prairie	Woodland	Pasture - Shrub	Pasture - Grass	Upland Crop	Rice Crop	Turf (Park Land)
Service	Air Quality	Replacement Cost		Avoided Cost					Replacement Cost
	C Sequestration	Avoided Cost	Direct Market Pricing	Avoided Cost					
	Soil Stability / Health		Avoided Cost	Avoided Cost	Avoided Cost	Avoided Cost (negative values)	Avoided Cost (negative values)	Avoided Cost (negative values)	
	Water Quality	Replacement Cost	Replacement Cost	Replacement Cost	Replacement Cost				
	Water Supply		Measured Values and Direct Market Pricing	Replacement Cost	Replacement Cost				
	Regulate Water Flow	Replacement Cost	Not Stated	Replacement Cost					
	Habitat	No relevant data	No relevant data	No relevant data	No relevant data		No relevant data	No relevant data	
	Climate Moderation	No relevant data	No relevant data	Avoided Cost					Avoided Cost
Direct Product	Commodities			Direct Market Pricing	Direct Market Pricing	Direct Market Pricing	Direct Market Pricing	Direct Market Pricing	
	Mitigation	Direct Market Pricing							
	Hunt / Fish	Direct Market Pricing	Direct Market Pricing	Direct Market Pricing	Direct Market Pricing	Direct Market Pricing	Direct Market Pricing	Direct Market Pricing	
Secondary Product	Recreation and Tourism	User Cost	User Cost	User Cost					
	Property Values								

Legend	
	Primary Service
	Secondary Service
	No Service

Note: "Property Value" is included in the above table to only provide the context for where property appraised value may be considered in this process. Property appraised value is not considered in this ecosystem services analysis.

Valuation Challenges for the CPC Landscape

On CPC lands, valuation of secondary products and benefits associated with recreation and tourism present challenges. There are some potentially relevant data originating from user costs and direct market prices (e.g., land lease values, user costs such as licenses, transportation, food and lodging) associated with hunting. Relevant data for other nature-based recreation are harder to find for the area and especially for CPC lands. Bird-watching, for example, is a well-known recreational use of natural lands in Texas. There are studies that assign values to bird-watching, primarily through user costs and/or contingent pricing (e.g., Clucas et al. 2015; Eubanks & Stoll 1999) using the metric of user day. The difficulty arises in transferring such values from one specific place to another. Data from High Island (Bolivar Peninsula, TX), a well-known birding hotspot, cannot be accurately transferred inland to areas that do not compare in magnitude and distribution of bird-watching user days. The same is true of other nature-based passive recreation. For example, an increase in Houston bayou-based greenways was valued using a surrogate contingent-based user cost of $4.70/day/user multiplied by the projected number of new users to obtain an annual value (Crompton 2011). To transfer this, or any contingent-pricing data for CPC, we would need records of the number of user days by ecosystem. In addition, similar to bird-watching in this example, there is a problem with equivalency: intensity of use of urban paved greenways likely does not reflect use of rural unpaved trails. In summary, many of these user-based services can be valued but ecosystem-specific and landscape-specific user data are needed to assign and map per acre values by ecosystem. In the current absence of such data, the authors used professional judgement to assign a positive, negative, or neutral weight, as appropriate.

It may be that recreational asset valuation experts can provide CPC with estimations of general recreational values using other means, perhaps comparative valuations of other unimproved rural conservation lands. Unimproved, in this instance, means lands that do not have designated and improved camping locations, foot and bicycle trails with amenities such a potable water and toilets, and a lack of defined destinations (e.g., viewing platforms, signage, trails) for activities such as bird-watching or other passive nature-based activities. This lack of focused visitor destinations is an issue that may be addressed in the future. As parking areas, trailheads, viewing platforms, or similar visitor facilities are established in appropriate locations, an investment might be made to periodically assess numbers of users through such passive mechanisms as vehicle or bike counters on roads and trails.

For a GIS-driven analysis of a landscape, comprising multiple ecosystems, values are typically expressed in dollars/annum/unit area. For this type of valuation, which describes the Katy Prairie project, we have chosen US dollars (USD) expressed as USD/acre/year. Other valuations in other studies include net present value, value per annum, value per annum per area unit, value per person or household and capital or stock value (van der Ploeg et al. 2010).

Hydrology Overlay

The movement and retention of water on the CPC landscape is an important part of this valuation project. A parallel study involving a hydrological and hydraulic analysis by Dr. Bedient at Rice University (Bedient 2017) was completed using the CPC study region land cover types (existing and restored ecological communities) mapped by AES and found in this report. The purpose of the analysis was to identify the retained or reduced runoff of flood waters within the existing and restored grasslands, wetlands and other ecological settings in CPC lands as well as a larger area of Katy Prairie ecosystem lands present in Harris and Waller Counties. A detailed description of Rice University's findings is found in their study report. Short summaries of findings are included in Appendix 4. We use these findings to incorporate flood reduction values in Chapter V.

Economic Valuation of Existing CPC Ecological Communities

Assigning an economic value to each ecological service associated with an identifiable ecological community within particular landscape is a daunting task. Geographic variation, encompassing ecological differences, as well as disparities in regional and local economies, further complicate the economic valuation effort.

To illustrate, a reliable valuation estimate of a cultivated rice field can be ascertained by retrieving the average bushels produced per acre from published regional commodity data and multiplying that by the average commodity price for a bushel of rice in Texas. Where a rice field has been converted to a wetland, however, the literature reported values for water quality ecosystem services varied widely, ranging from $15 per acre (Virginia), to $3,500 per acre (California). In this type of example, judgement on the geographic similarity of the wetland types served as the basis for choosing a valuation but disparities in local economic estimates remain as part of the "noise." We examined with the scientific literature the range of values assigned to each ecosystem service and identified and selected the most appropriate values used in this valuation in Table 5 (also in Appendix 2.4).

Accurate use of the benefit transfer method of valuation is dependent on the availability of relevant studies and data. In this study, we assert that the actual values of the existing natural systems (prairie, wetlands, woodland) are more comparable to each other than the values reported in Table 4 (also see Appendix 2-4). Woodland systems appear to be valued higher due to a few key studies that focused on valuation of woodlands with fewer studies available that considered wetlands and prairies. (This disparity relates from the availability of data on lumber as a primary good that is easily quantified and valued and related to each woodland type and age). Similarly, higher values for wetlands relative to prairies is likely due to there being more studies and thus more information available that values wetlands than for prairies. Wetlands are frequently assigned economic values resulting from their mitigation roles as well as waterfowl hunting values. For this same reason, prairies are believed to be conservatively undervalued in this study simply because of limited efforts to monetize their ecological services. While future research is needed that considers local, detailed studies of the productivity and provision of ecological services by prairies with a goal of creating more accurate economic valuations of those services, this study results in initial estimations based on the available literature and additional infiltration measurements in various soil characteristics.

Economic Valuation of Ecological Services and Goods by Ecological Community

In Table 4 (also Appendix 2-4), we provide a rolled-up summary table of the values derived from the literature review for each ecosystem service, integrated with locally available values (Appendix 3). Per acre annualized values of ecological services by ecological communities ranged from a high of $2,576/acre for woodlands to an overall economic loss for pasture-grass (-$27/acre). In general, natural systems, which included wet grassland ($1,746/acre), prairies ($1,902/acre) and woodlands ($2,471/acre), received higher valuations than agricultural systems such as pasture-shrub lands ($194/acre), pasture-grass upland crop ($493/acre), and rice crop lands ($976/acre). While we did consider the value of crops produced on agricultural land, for this ecological study, economic losses associated primarily with the loss and degradation of soil (incurred through factors such as erosion, compaction, and nutritional depletion by tillage and overgrazing) represented debits and thus drove down the ecological service values of agricultural ecosystems.

Table 4. Summary of the Value of Ecological Services Provided by Ecological Communities (also in Appendix 2-4) (please see Note).

		Wet Grassland	Prairie	Woodland	Pasture - Shrub	Pasture - Grass	Upland Crop	Rice Crop	Turf (Park Land)
Service	Air Quality	$ 107	$ 3	$ 312	$ 3				$ 21
	C Sequestration	$ 152	$ 150	$ 67	$ 0				
	Soil Stability / Health		$ -	$ -	$ -	$ (119)	$ (119)	$ (119)	
	Water Quality	$ 1,100	$ 35	$ 820	$ 22				
	Water Supply		$ 1,370	$ 200	$ 1				
	Regulate Water Flow	$ 12	$ 1	$ 500					
	Habitat								
	Climate Moderation		$ -	$ 36					
Direct Product	Commodities			$ 17	$ 152	$ 76	$ 596	$ 1,079	
	Mitigation								
	Hunt / Fish	$ 48	$ 16	$ 33	$ 16	$ 16	$ 16	$ 16	
Secondary Product	Recreation and Tourism	$ 327	$ 327	$ 486					
	Property Values								
Value per Acre		$ 1,746	$ 1,902	$ 2,471	$ 194	$ (27)	$ 493	$ 976	$ 21

Legend	
	Primary Service
	Secondary Service
	No Service

Note: "Property Value" is included in the above table to only provide the context for where property appraised value may be considered in this process. Property appraised value is not considered in this ecosystem service analysis.

Note: An extensive and detailed literature review identified that valuations for some ecosystems and ecosystem services are not available. These "data gaps" have been addressed in this study by using the most appropriate and geographically similar study results as explained under "Economic valuation of Existing CPC Ecological Communities" section.

Economic Valuation of Flood Damage Reduction by Ecological Community

Economic ecosystem service values for flood damage reduction resulting from the floodwater retention and infiltration analyses were completed by Rice University (Bedient 2017). These were based in part on the geospatial analysis of the existing ecological communities derived from mapping conducted by AES. A summary of findings relative to the CPC landscape is found in Chapter V. There was also a stand-alone modeling study completed by Dr. Bedient's team and attached as Appendix 6. (Bedient 2017).

III. LANDSCAPE MODELING OF EXISTING AND RESTORED ECOLOGICAL COMMUNITIES

In this chapter, we report the results of landscape modeling of existing and restored ecological communities on CPC lands. This modeling serves as the basis for applying the ecosystem unit dollar values (Chapter II) to the CPC landscape. This modeling is used to estimate the ecosystem service values of CPC properties and the larger landscape.

We first present our land cover classification methods followed by our methods for assigning restoration costs and valuation. We then analyze the values under five scenarios: Scenario 1 (Existing Conditions) and Scenarios 2, 3, 4 and 5 (Restoration Condition at different landscape scales).

Overview of Land Cover Classification

Land cover in the area of interest (AOI) (Figure 1 and Appendix 5-1—for readable, printable AOI mapping) was classified by applying a supervised image classification method to a series of satellite images (Table 5), along with field observations of the land cover types and conditions as a reference for image interpretation and classification.

Figure 1. Coastal Prairie Conservancy Area of Interest (AOI)

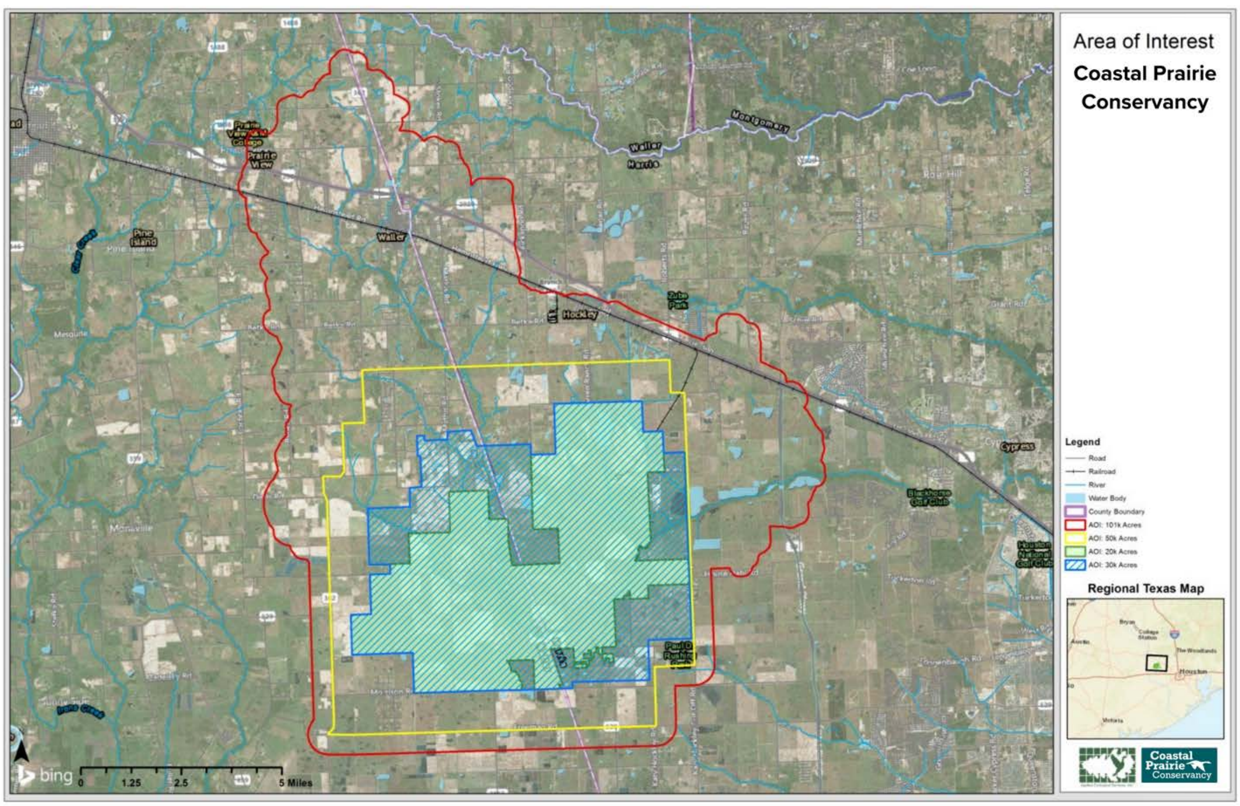


Table 5. Image Data Sources for Land Cover Classification.

Satellite	Sensor	Spatial Resolution (meters)	Number of Bands	Dates of Image Acquisition
Landsat 8	Multispectral	15-30	8	05-25-2016
Sentinel-1	Radar	10	2	07-12-2016
Sentinel-1	Radar	10	2	03-09-2017
Sentinel-2	Multispectral	10-60	13	10-09-2016
Sentinel-2	Multispectral	10-60	13	01-07-2017
Sentinel-2	Multispectral	10-60	13	03-08-2017

Images were acquired from different dates and types of sensors to meet the goals of (1) measuring characteristics of different land cover types and (2) obtaining information on seasonal variations of the same land cover type. Compared to images acquired by a sensor on a single date, image sources we selected for this project enabled us to maximize accuracy in the land cover classification and even to classify some land types which would not be achievable with images from a single date. For instance, in general, crop fields show a strong seasonal trend in growth conditions, reflected in changes in optical properties and appearance (e.g., color and texture) on images over time. This multi-temporal (multiple imagery dates) approach was used to separate crops from grassland and refine mapping of grassland types with a high level of confidence.

Multispectral (images comprised of multiple bands or wavelengths of visible or non-visible light detected by the sensor satellite image analysis was especially focused on the separation of prairie, pasture-shrub, pasture-grass, and wetlands from grasslands and some types of agricultural land. Agricultural lands often benefitted from multi-temporal analysis (multiple dates) as this enabled detection of crop growth progression and distinguished and confirmed annual row crop land use from field examination. By contrast, other ecosystem types often were consistently classified with a single image, with multi-temporal imagery corroborating the findings as each successive image was analyzed. Water, impervious or developed lands, turf grass lands, and forest/woodlands were consistently classified with a single image.

Each image was classified by using a supervised classification method, known as random forest. This method requires acquisition of reference field data over known points so that a spectral signature for each point can be used to train the classifier and computer program to accurately identify and map each land cover type. The training locations and dataset used GPS-located field points at field-selected sites that were screened jointly with AES and CPC staff in April 2017. The finalized training procedure was used to develop an initial and subsequent classification with characterization algorithms applied to the entire AOI for land classification.

Methods for Costs and Valuations for Ecosystem Restoration

The costs of restoring and enhancing degraded ecological communities over five years are described in Table 6 (also in Appendix 2-1). Costs were generated by the experienced ecological restoration staff at AES, basing estimates on 250-acre units. In general, restoration and enhancement tasks include soil preparation, seeding, selective woody and herbaceous species removal, and prescribed burning. Each restoration task with estimated costs was confirmed by CPC staff to reasonably represent the costs for the same treatments on CPC lands.

Table 6. Summary of Costs Associated with Restoring Ecosystem Services Within Mapped Ecological Communities.

Task	Unit	Unit Price*	Comments	5 yr	Ea Yr
PRAIRIE - ENHANCE					
Supplemental seeding	Acre	$ 600			
Weed management - 5 Years	Acre	$ 1,250	assumes $250/year/ac		
Prescribed Burn	Acre	$ 75	per burn	$ 1,925	$ 385
PASTURE TO PRAIRIE					
Herbicide	Acre	$ 120	Assumes 2 times		
Soil prep	Acre	$ 60	Assumes 1 time		
Seeding	Acre	$ 800			
Weed management - 5 Years	Acre	$ 1,250	assumes $250/year/ac		
Prescribed Burn	Acre	$ 75	per burn	$ 2,305	$ 461
WETLAND - ENHANCE					
Spot herbicide	Acre	$ 120	assumes 1 application		
Supplemental seeding	Acre	$ 800			
Supplemental planting	Acre	$ 1,750	Assumes 500 each (typical 32/38 ct. flat plugs)		
Weed management - 5 Years	Acre	$ 1,250	assumes $250/year/ac		
Prescribed Burn	Acre	$ 75	per burn	$ 3,995	$ 799
RIPARIAN WOODLAND - ENHANCE					
Selective woody brush removal	Acre	$ 2,000	highly dependent on density		
Supplemental seeding	Acre	$ 800			
Weed management - 5 Years	Acre	$ 1,250	assumes $250/year/ac		
Prescribed Burn	Acre	$ 75	per burn	$ 4,125	$ 825
UPLAND WOODLAND - ENHANCE					
Selective woody brush removal	Acre	$ 2,000	highly dependent on density		
Supplemental seeding	Acre	$ 800			
Weed management - 5 Years	Acre	$ 1,250	assumes $250/year/ac		
Prescribed Burn	Acre	$ 75	per burn	$ 4,125	$ 825
ROW CROP (UPLAND) TO PRAIRIE					
Herbicide	Acre	$ 60	Assumes 1 time		
Soil prep	Acre	$ 60	Assumes 1 time		
Seeding	Acre	$ 600			
Weed management - 5 Years	Acre	$ 1,250	assumes $250/year		
Prescribed Burn	Acre	$ 75	per burn	$ 2,045	$ 409
RICE FIELDS (LOWLAND) TO WETLAND					
Herbicide	Acre	$ 80	Assumes 1 time		
Soil prep	Acre	$ 80	Assumes 1 time		
Seeding	Acre	$ 600			
Weed management - 5 Years	Acre	$ 1,250	assumes $250/year		
Prescribed Burn	Acre	$ 75	per burn	$ 2,085	$ 417

*based on 250-acre units

Economic values of ecosystem services for each existing CPC ecological community were calculated using two standard methods: (1) a subtractive method in which restoration costs were subtracted from the total value; and (2) an additive method in which restoration costs were added to the total value. As explained under Section II. Ecosystem Services Valuation — Economic Valuation Categories, there are at least seven routinely used valuation methods. This project has used two methods - a direct market pricing method and a replacement cost method. When applied, these two methods create a new ecosystem service value under a future restored scenario for an ecosystem.

Using the subtractive method, we multiplied the area of each community by the selected value(s) for provided services. The net economic value for enhanced or restored ecological communities was calculated by multiplying the area of each restored community by the selected value(s) for provided services, minus the cost of restoring that community. Caveats are described below for each ecosystem. Using the additive method, we made the same assumptions as those used for the subtractive method but added, rather than subtracted, the cost of restoration.

- **Wetland, Prairie and Woodland Enhancement.** While we are confident that many of the ecological services and values associated with an enhanced ecosystem will improve and increase over time, the literature we reviewed did not provide enough resolution to quantify such improvements. Therefore, we conservatively used the value for existing ecological services to represent enhanced services for wetlands, prairies and woodlands.
- **Pasture and Upland Crops.** We assumed that the restoration of these communities to prairie (please see Note) would result in the same value as existing prairies after five years of restoration and maintenance. Thus, we calculated a 25% increase in value for each of the four years following the commencement of restoration and maintenance on pasture and upland cropland, with a full restoration value assigned at five years.
- **Cultivated Rice.** We assumed that the restoration of rice crop land to wetland would result in the same value as existing wetlands after five years of restoration and maintenance. Thus, we calculated a 25% increase in value for each of the four years following the commencement of restoration and maintenance on rice crop land, with a full restoration value assigned at five years.

Note: Continued improved livestock grazing is compatible with the restoration of grasslands and prairies and is assumed to be part of the future management of some existing and future restoration prairie grasslands in CPC lands.

The literature reviewed reflects the varied level of effort investigators have devoted to various ecological communities and services. This, in turn, affects our ability to transfer values from previous studies. There are numerous papers, for example, on services and values associated with wetlands because wetlands have been a source of economic interest for many years. There is much less information on the services and values that prairies provide simply because they have been studied less relative to their economic values.

Additional clarification is needed for transfer of values regarding positive and negative economic values of ecosystem services. A functioning ecosystem within a landscape possesses services that are valued at a particular point in time. In the future, changes in land uses may significantly reduce the ecosystem's ability to deliver ecosystem services, even to the point of a negative ecosystem service valuation. For example, this might be true of the values assigned to a prairie if converted to row crops, relative to the ecosystem services of soil stability.

In the end, we adopted a hybrid approach by focusing on the most important primary and secondary services that each community provides, using economic values that appeared most compelling based on our understanding of the project area and relevant literature.

Ecological Communities Classification Under Scenario 1: Existing Conditions

After review and approval by CPC staff and the AES team, the remote sensing classification was refined using wetland data layers, soil moisture interpretation (wet and dry), and parcel data (e.g., rights-of-way and <1 acre residential parcels). The historic data from CropScape (https://nassgeodata.gmu.edu/CropScape/) was further fine-tuned (e.g., distinguishing corn from rice on agricultural lands) and incorporated into our land classification model. This GIS-based regional land cover classification developed for CPC included a 4-level classification that was summarized for purposes of the ecosystem service valuation as well as for the hydrology and hydraulic modeling by

Dr. Bedient. This simplified final ecosystem classification depicted below in Figure 2 (Appendix 5-2 contains maps that are for printable and readable versions) maps these data and Table 7 provides tabular data. Acreage data are also included in Table 8.

Figure 2. Scenario 1: Existing Ecological Communities in AOI

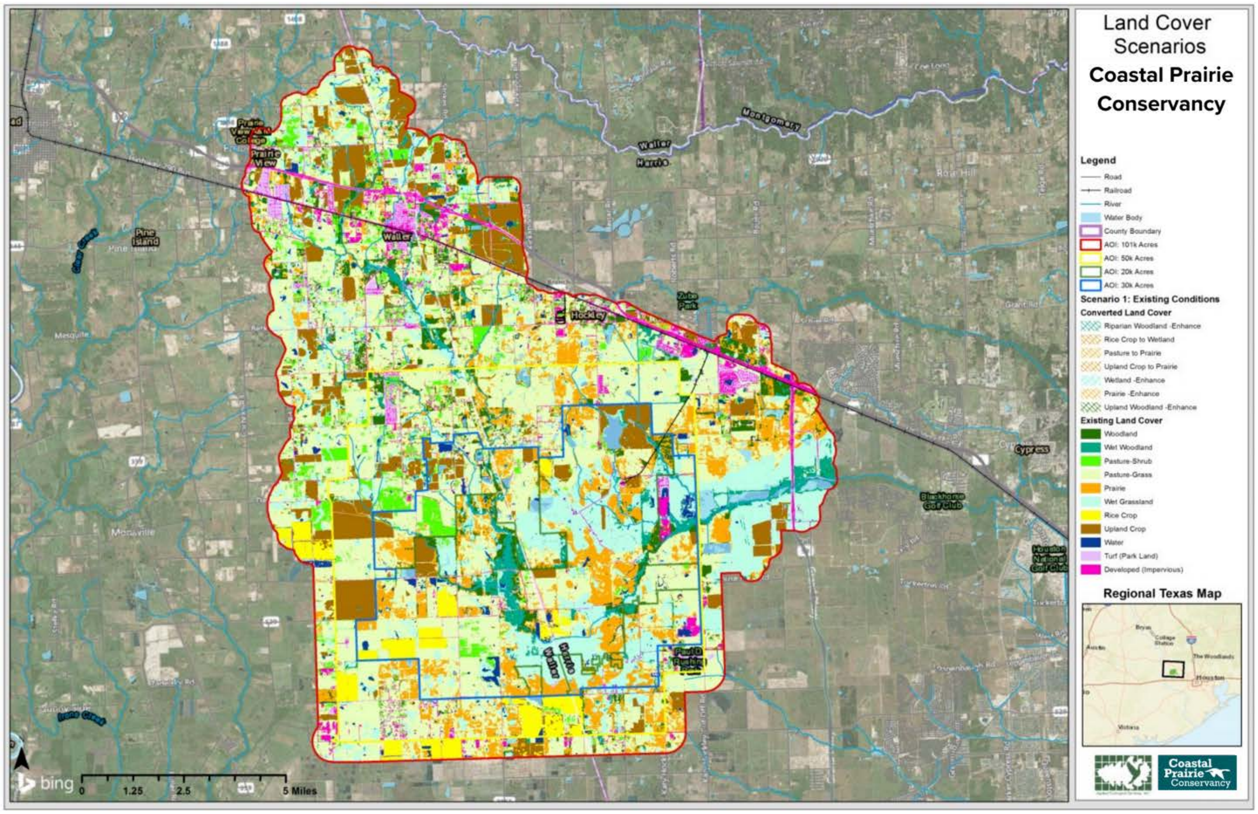


Table 7. Existing Ecological Communities Classification and Associated Acreages in AOI

Ecological Community	Acres in AOI
Developed (Impervious)	4,506
Turf (Park Land)	2,638
Water	2,427
Pasture – Grass	39,593
Pasture – Shrub	4,130
Prairie	12,126
Upland Crop	9,075
Rice Crop	2,673
Wet Grassland	15,748
Riparian (Wet) Woodland	3,555
Upland Woodland	5,041
Total Acres	**101,512**

Restored Ecological Communities Under Four Future Scenarios

In addition to mapping and documenting existing conditions (Figure 2), the project also evaluated and mapped the ecosystem service benefits of four proposed scenarios of increased protection and restoration of CPC lands within the Cypress Creek Watershed. These four scenarios are presented below in Figures 2, 3, 4 and 5 (see also in Appendix 5-2, 5-3, 5-4, and 5-5). The projected scenarios are:

- **Scenario 2.** Restoration of selected communities (ecosystem types) within the 20,000-acre AOI
- **Scenario 3.** Restoration of selected communities (ecosystem types) within the 30,000-acre AOI
- **Scenario 4.** Restoration of selected communities (ecosystem types) within the 50,000-acre AOI
- **Scenario 5.** Restoration of selected communities (ecosystem types) within the 101,000-acre AOI

In each of these scenarios, the model projects conversions of lands that are now listed as pasture-grass, pasture-shrub, and upland crop to prairie, and includes conversions of rice crop to wet grassland. In addition, the model assumes that enhancement occurs within the existing wet grassland, prairie and woodland communities. This restoration/conversion is then examined to determine how the scenario increases ecosystem service values within the AOI, as well as benefits of flood mitigation within the watershed. Although projected changes occur within the designated restoration scenario, the land classifications surrounding the restoration scenario AOI remain the same in order to model the different restoration opportunities and distinguish the economic benefit to preserving and restoring the land (as opposed to developing it or maintaining it as turf or crop land). Changes in acreage for each ecological community in each scenario are reported in Table 8.

Table 8. Existing Ecological Communities and Restored Ecological Community Acreage Under Scenarios 1-5.

EXISTING CONDITION CLASS	Scenario 1 Existing Conditions (acres)	Scenario 2 Convert within 20,000-ac AOI	Scenario 3 Convert within 30,000-ac AOI	Scenario 4 Convert within 50,000-ac AOI	Scenario 5 Convert within 101,000-ac AOI
Developed (Impervious)	4,506	4,506	4,506	4,506	4,506
Turf (Park Land)	2,638	2,638	2,638	2,638	2,638
Water	2,427	2,427	2,427	2,427	2,427
Pasture-Grass	39,593	33,149	29,866	19,601	--
Pasture-Shrub	4,130	3,766	3,360	2,490	--
Prairie	12,126	8,349	6,911	4,555	--
Upland Crop	9,075	7,976	7,439	5,755	--
Rice Crop	2,673	1,769	1,766	841	--
Wet Grassland	15,748	10,898	8,581	7,098	--
Riparian (Wet) Woodland	3,555	2,404	1,976	1,771	--
Upland Woodland	5,041	4,107	3,763	2,951	--
EXISTING TOTAL	**101,512**	**81,989**	**73,233**	**54,633**	**9,571**
FUTURE CONDITION CLASS					
Pasture to Prairie	--	6,809	10,497	21,633	43,723
Upland Crop to Prairie	--	1,098	1,635	3,319	9,074
Prairie – Enhancement	--	3,777	5,215	7,572	12,126
Rice Crop to Wet Grassland	--	904	908	1,832	2,673

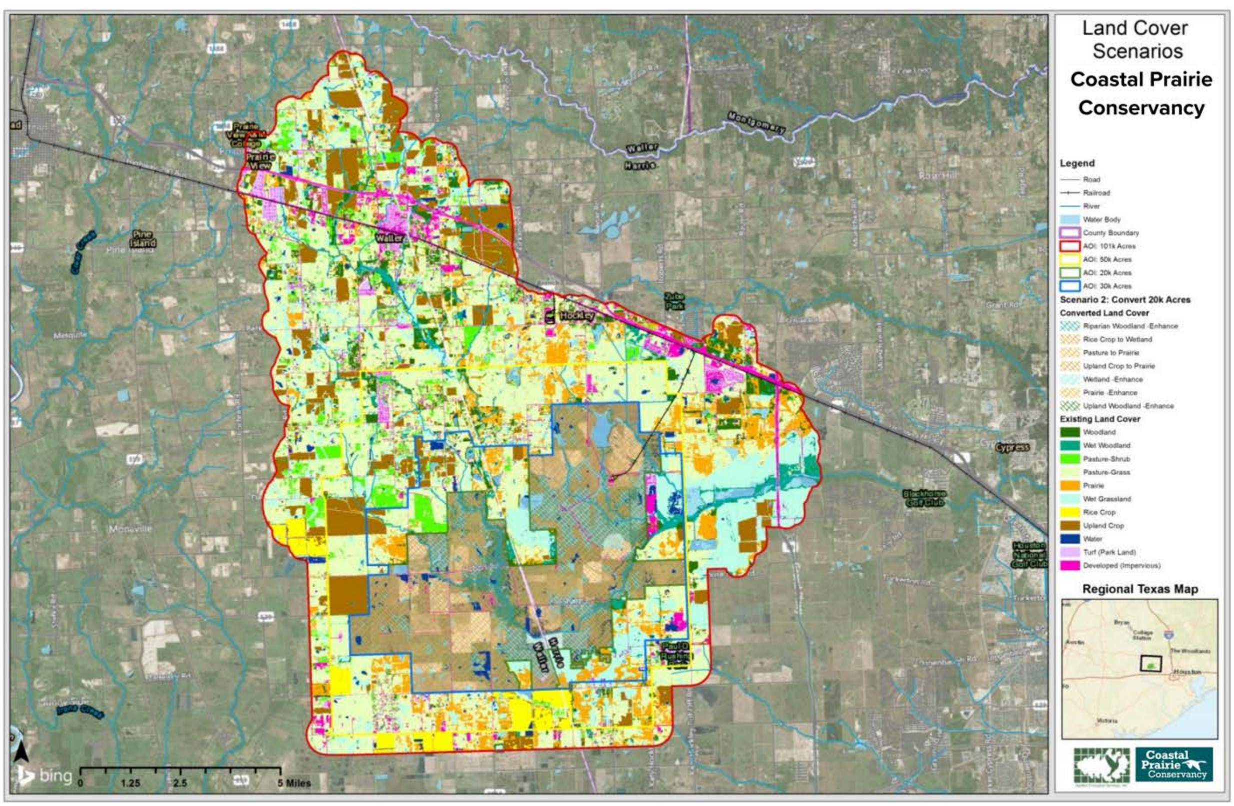
EXISTING CONDITION CLASS	Scenario 1 Existing Conditions (acres)	Scenario 2 Convert within 20,000-ac AOI	Scenario 3 Convert within 30,000-ac AOI	Scenario 4 Convert within 50,000-ac AOI	Scenario 5 Convert within 101,000-ac AOI
Wet Grassland – Enhancement	--	4,850	7,167	8,649	15,748
Riparian (Wet) Woodland – Enhancement	--	1,151	1,579	1,784	3,555
Upland Woodland – Enhancement	--	934	1,278	2,090	5,041
CONVERTED TOTAL	**--**	**19,523**	**28,279**	**46,879**	**91,941**
TOTAL	**101,512**	**101,512**	**101,512**	**101,512**	**101,512**

Scenario 2: Conversion of Lands within 20,000-acre AOI

Scenario 2 examined the benefits of conversion of ecological communities within existing Coastal Prairie Conservancy holdings. This scenario included 6,809 acres of pasture restored to prairie, 1,098 acres of upland crop land restored to prairie, and 904 acres of rice crop restored to wet grassland. In addition, all prairie, wet grassland, and woodland acres are projected as enhanced to improve ecological functions and ecosystem service values.

Scenario 2 projected changes are shown below in Figure 2 (also Appendix 5-3). Changes in acreage for each ecological community for this scenario are reported in Table 8.

Figure 2. Scenario 2: Conversion of Lands Within 20,000-acre AOI (green boundary)

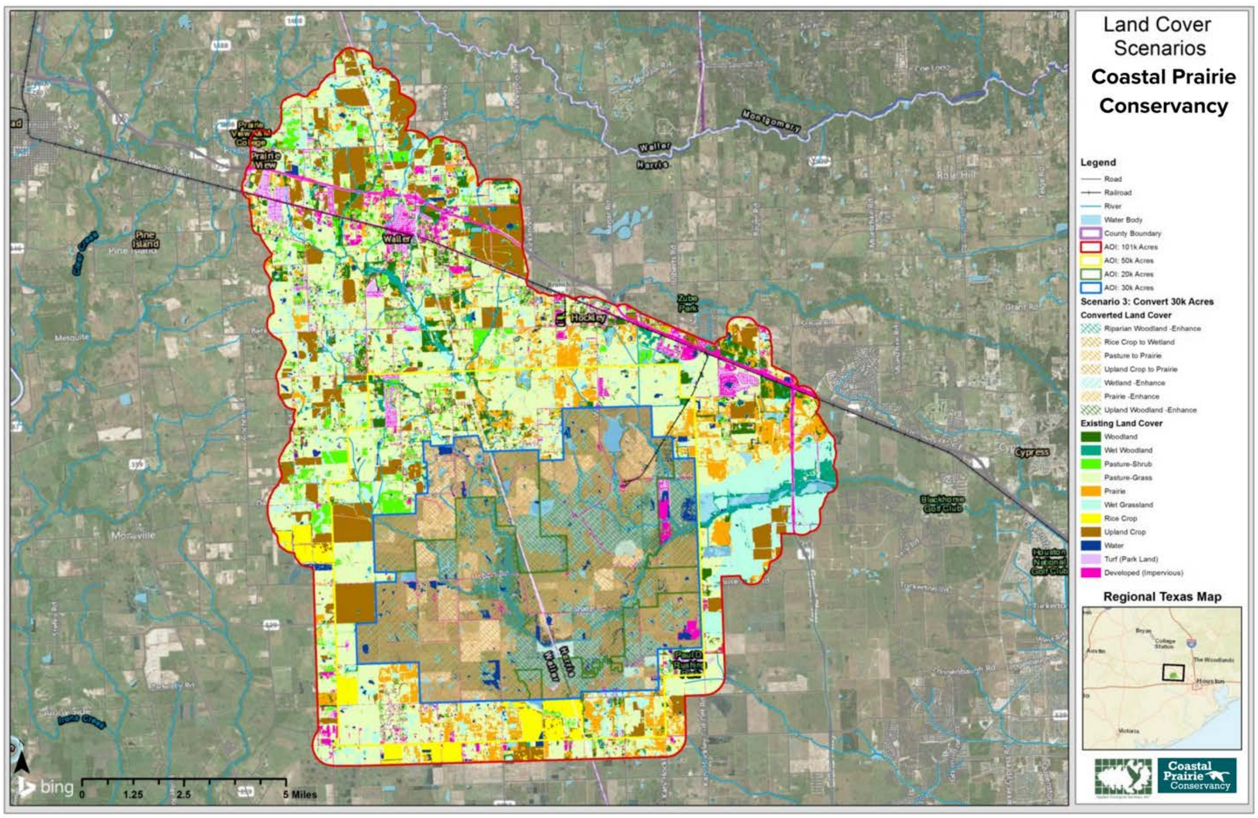


Scenario 3: Conversion of Lands within 30,000-acre AOI

Scenario 3 examined the benefits of conversion selected ecological communities within conservatively expanded Coastal Prairie Conservancy holdings. This scenario included 10,497 acres of pasture restored to prairie, 1,635 acres of upland crop lands restored to prairie, and 908 acres of rice crop lands restored to wet grassland. In addition, all prairie, wet grassland, and woodland acres are projected as enhanced to improve ecological functions and ecosystem service values.

Scenario 3 changes are shown in Figure 3 below (and in Appendix 5-4). Changes in acreage for each ecological community for this scenario are reported in Table 8.

Figure 3. Scenario 3: Conversion of Lands Within 30,000-acre AOI (blue boundary)

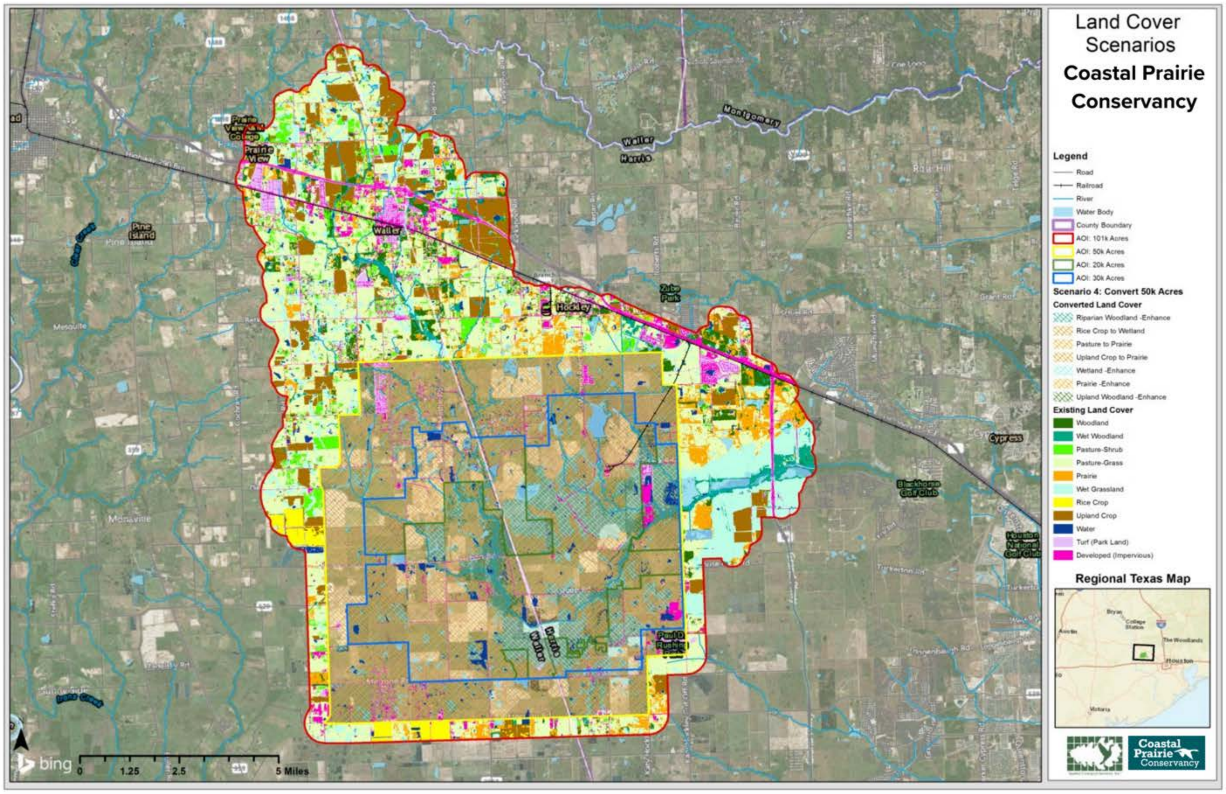


Scenario 4: Conversion of Lands within 50,000-acre AOI

Scenario 4 examined the benefits of conversion of the above ecological communities within vastly expanded Coastal Prairie Conservancy holdings. Scenario 4 included 21,633 acres of pasture restored to prairie, 3,319 acres of upland crop land restored to prairie, and 1,832 acres of rice crop land restored to wet grassland. In addition, all prairie, wet grassland, and woodland acres are projected as enhanced to improve ecological functions and ecosystem service values.

Scenario 4 changes are shown in Figure 4, below, and in Appendix 5-5. Detailed changes in acreage for each ecological community in this scenario are reported in Table 8.

Figure 4. Scenario 4: Conversion of Lands Within 50,000-acre AOI (yellow boundary)

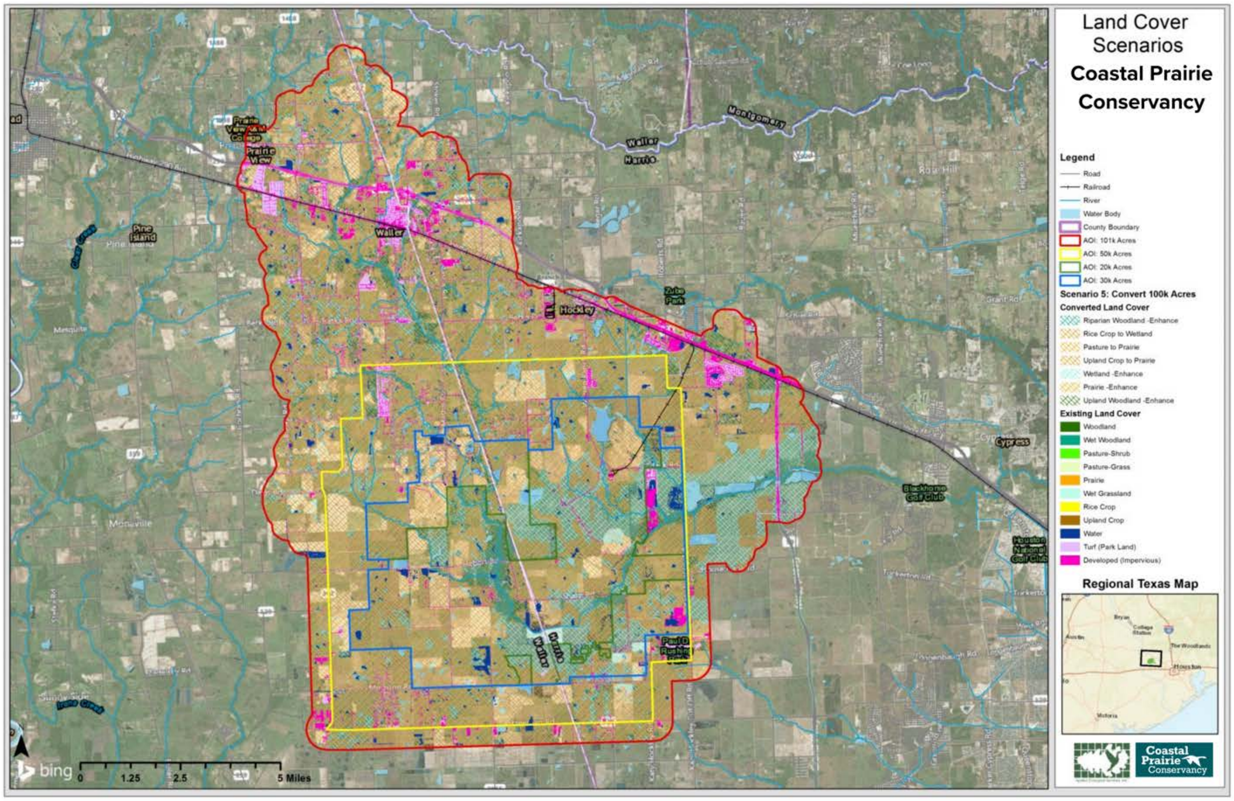


Scenario 5: Conversion of Lands within 101,000-acre AOI

Scenario 5 examined the benefits of conversion of the above ecological communities within the entire Cypress Creek watershed in the study area. Scenario 5 included 43,723 acres of pasture restored to prairie, 9,074 acres of upland crop land restored to prairie, and 2,673 acres of rice crop restored to wet grassland. In addition, all prairie, wet grassland, and woodland acres are projected as enhanced to improve ecological functions and ecosystem service values.

Scenario 5 changes are shown in Figure 5, below, and in Appendix 5-6. Detailed changes in acreage for each ecological community in this scenario are reported in Table 8.

Figure 5. Scenario 5: Conversion of Lands Within 101,000-acre AOI (red boundary)



IV. LANDSCAPE ECOSYSTEM SERVICES VALUATION

The ecological community classification described in Chapter III was used as a base layer for applying the ecosystem service values (Table 5, above and Appendix 2-4) for each ecological community type, ultimately to generate an ecosystem service valuation for the study area. In this chapter we describe the application of ecosystem services valuation to the ecological communities under existing conditions (Scenario 1), as well as the four other restoration scenarios (2-5) defined in Chapter III.

Existing and Restored Ecological Conditions

Most of the land within the study area (AOI) is degraded and, as a result, the ecosystem services provided are diminished over what would be possible for restored land. While the Coastal Prairie Conservancy's restoration efforts are ongoing but have been somewhat limited mostly to wetlands, CPC's goal is to achieve greater restoration for most conserved lands and to continue efforts to expand preserved lands to encompass at least 50,000 acres. For this reason, AES applied the costs to restore upland crop land to prairie, grass-pasture and shrub-pasture to prairie, and rice crop land to wet grassland. While ecological restoration is important, it is also envisioned that some portions of the grasslands within the protected landscape would be suitable for regenerative grazing practices (e.g. Adaptive Multi-Paddock, or AMP, grazing) that could accelerate soil carbon accruals on these lands.

Existing (non-hydrological related) ecosystem services are estimated at $31.4 million per year in value from CPC's existing conserved lands (~20,000 acres). When projected over 30 years, they result in a total value of approximately $940 million based on their existing ecological conditions (scenario 1). This equates to an average of $1,568 per acre in combined ecosystem service values annually.

Costs for these transitions are listed in Table 2 (above and Appendix 2-1). Costs are either subtracted or added to the literature-documented ecosystem service values for the ecosystems that are proposed to be restored. The subtractive method was used to determine the ecosystem valuation during the transition period and the additive method was used to estimate the future value of the restored community types. These two methods are similar to the approach used in real estate appraisals. For example, in an appraisal if a roof of a house being appraised is old and in bad need of repair, the costs to repair or replace the roof are typically accounted for by subtracting those costs from the overall appraised value of the house. And, in the same example, if a significant improvement, such as a brand-new porch has been added to a house, the cost of the porch is often added to the appraisal. The same process has been used here. Where restoration is desirable to improve the ecosystem service benefits provided by the land, this cost is deducted from the literature values. And, once the restoration is underway, the cost of this improvement has been added to the valuation. However, clearly the time required for a restored prairie to achieve the same functionality of a several thousand year old native prairie is not suggested in this analysis

Because of the large acreage that would benefit from restoration, we assume that the restoration work will take place over a period of 10-15 years, depending on funding availability. The functional conversion to the restored condition is projected to be measurable 5 to 10 yrs. after restoration is begun, depending on the ecological communities involved. By "restored condition," we mean that the soils are again healthy with soil organic matter increased back on a trajectory to achieve historic levels (an average of about 5% by dry weight) and plant communities have commensurate native plant community composition (native plant diversity and percent cover) as is currently found in reference natural areas of each representative ecological community of CPC. For purposes of estimating this accrued ecosystem value under restoration, a thirty-year time line has been used to approximate the time when all lands will be successfully restored in CPC.

Restored Ecological Communities

The annualized cost projections to restore or enhance ecological communities in the four restoration scenarios are presented in Table 9 and Figure 6 (also see Appendices 5-7, 5-8, 5-9, and 5-10). These estimates are the projected actual costs. Costs and values are presented in 2017 dollars. Neither discounting nor escalators have been added to account for future costs. In like fashion, we did not discount to account for increasing future values. Cost escalation and discounting might be appropriate in future financing studies.

Table 9. Annual Cost to Restore Ecological Communities Under Scenarios 2-5.

Enhancement/ Restoration Action	Annual Rest. Cost ($/ac)	Scenario 2 Convert w/in 20,000-ac AOI (Annual Cost for 5yrs)	Scenario 3 Convert w/in 30,000-ac AOI (Annual Cost for 5yrs)	Scenario 4 Convert w/in 50,000-ac AOI (Annual Cost for 5yrs)	Scenario 5 Convert w/in 101,000-ac AOI (Annual Cost for 5yrs)
Pasture to Restored Prairie	$461	$3,138,949	$4,839,117	$9,972,813	$20,156,303
Upland Crop to Restored Prairie	$409	$449,082	$668,715	$1,357,471	$3,711,675
Prairie Enhancement	$385	$1,454,145	$2,007,775	$2,915,220	$4,668,510
Rice Crop to Restored Wet Grassland	$417	$376,968	$378,636	$763,944	$1,114,641
Wet Grassland Enhancement	$799	$3,875,150	$5,726,433	$6,910,551	$12,582,652
Riparian Woodland Enhancement	$825	$949,575	$1,302,675	$1,471,800	$2,932,875
Upland Woodland Enhancement	$825	$770,550	$1,054,350	$1,724,250	$4,158,825
TOTAL		**$11,014,419**	**$15,977,701**	**$25,116,049**	**$49,325,481**

Figure 6. Annual Cost Per Acre to Restore Ecological Communities Under Scenarios 2-5

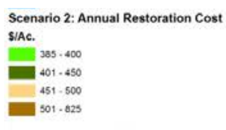
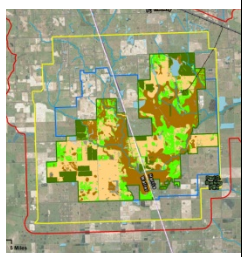
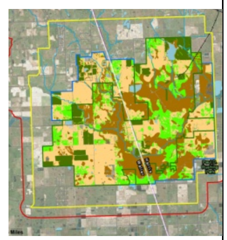
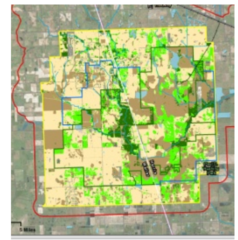
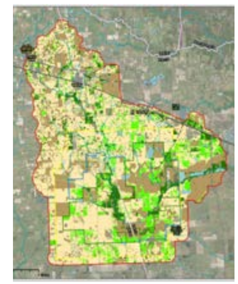
				
Annual Restoration Cost	**Scenario 2:** Conversion of lands within 20k AOI Annual Restoration Cost	**Scenario 3:** Conversion of lands within 30k AOI Annual Restoration Cost	**Scenario 4:** Conversion of lands within 50k AOI Annual Restoration Cost	**Scenario 5:** Conversion of lands within 101k AOI Annual Restoration Cost

Table 10 depicts changes ecosystem service values through restoration and enhancement. The 30-year accrued ecosystem service value (not including flood mitigation) of just protecting and enhancing natural areas ranges from $52,393 to $74,130/acre. The 30-year net value following restoration of these natural areas ranges from $56,388 to $78,256/acre. This contrasts with preserved agricultural land over 30 years with a preserved service value that ranges from -$811 to $29,279/acre; and a restored value that ranges from $54,482/acre to $56,822/acre. The increase in value of ecological services over 30 years for converting agricultural lands is significantly higher than the value of restoring existing natural communities (prairie, woodland and wetland). In short, there are opportunities to increase ecological service values provided by CPC lands through restoration of degraded ecosystem types for identifiable annual costs per acre in order to realize substantial increases in net accrued 30-year values, based on 2017 dollars without the addition of financing net present value discounting or cost escalation for the reasons cited above.

Table 10. Comparison of Change in Ecosystem Service Values Resulting from Transitioning Degraded Ecological Communities from Existing to Restored Conditions.

			ADDITIVE METHOD		
Community	**Existing annual value of services**	**Annual cost to enhance or restore community**	**Existing annual value plus annual restoration cost**	**Accrued Value Existing over 30 Years**	**Net Accrued Value over 30 Years following Restoration**
Wet Grassland Enhancement	$ 1,746	$ 799	$ 2,545	$ 52,393	$ 56,388
Prairie Enhancement	$ 1,902	$ 385	$ 2,287	$ 57,068	$ 58,993
Woodland Enhancement	$ 2,471	$ 825	$ 3,296	$ 74,131	$ 78,256
Pasture-Shrub to Restored Prairie	$ 194	$ 461	$ 655	$ 5,818	$ 55,587
Pasture-Grass to Restored Prairie	$ (27)	$ 461	$ 434	$ (811)	$ 54,482
Upland Crop to Restored Prairie	$ 493	$ 409	$ 902	$ 14,789	$ 56,822
Rice Crop to Restored Wet Grassland	$ 976	$ 417	$ 1,393	$ 29,279	$ 54,992

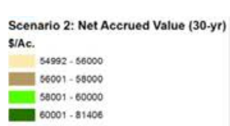
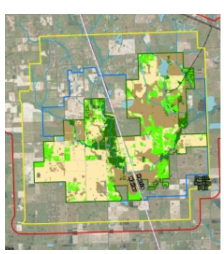
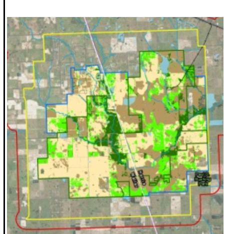
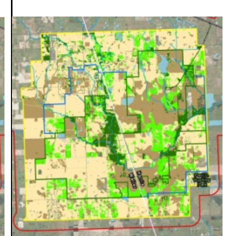
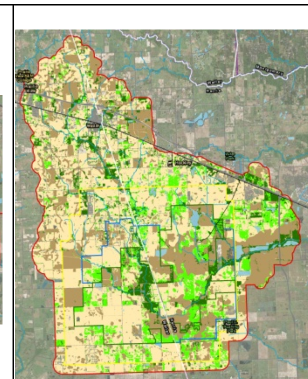
Ecosystem service values are rolled-up and tabulated as net values after 30 years of successful ecosystem restoration in Table 11 below (also in Appendix 2-7). The summed values for the 20,000 acres of existing CPC lands under the conversions in Scenario 2 suggest a net accrued value of $1.15 billion, or an annualized value of over $38 million, or approximately $1,900 per acre annually. These net accrued values are mapped in Figure 7 (below and in Appendices 5-11 through 5-14).

Table 11. Net 30-Year Accrued Ecosystem Service Values Following Restoration for Each Ecological Community and Each Scenario

Enhancement / Restoration Action	Net Accrued Value over 30-Yrs ($/ac)	Scenario 2 Net Accrued Value over 30-Yrs (Total $)	Scenario 3 Net Accrued Value over 30-Yrs (Total $)	Scenario 4 Net Accrued Value over 30-Yrs (Total $)	Scenario 5 Net Accrued Value over 30-Yrs (Total $)
Impervious	$0	$0	$0	N/A	N/A
Turf	$0	$0	$0	N/A	N/A
Pasture to Restored Prairie	$55,587	$378,492,675	$583,498,099	$1,202,516,374	$2,430,436,066
Prairie Enhancement	$58,993	$222,816,561	$307,648,495	$446,694,996	$715,349,118
Rice Crop to Restored Wet Grassland	$54,992	$49,712,768	$49,932,736	$100,745,344	$146,993,616
Upland Crop to Restored Prairie	$56,822	$62,390,556	$92,903,970	$188,592,218	$515,659,650
Wet Grassland Enhancement	$56,388	$273,481,800	$404,132,796	$487,699,812	$887,998,224
Woodland Enhancement	$78,256	$163,162,772	$223,576,038	$303,161,907	$672,684,501
TOTAL		**$1,150,057,222**	**$1,661,692,133**	**$2,729,410,651**	**$5,369,121,174**

The current value is projected under the existing condition scenario.

Figure 7. 30-Year Net Accrued Values of Restored Ecological Communities Under Scenarios 2-5

				
Net Accrued (30-Yr)	**Scenario 2:** Conversion of lands within 20k AOI Net Accrued (30-Yr)	**Scenario 3:** Conversion of lands within 30k AOI Net Accrued (30-Yr)	**Scenario 4:** Conversion of lands within 50k AOI Net Accrued (30-Yr)	**Scenario 5:** Conversion of lands w/in 101k AOI Net Accrued (30-Yr)

V. FLOOD DAMAGE REDUCTION AND ECOSYSTEM SERVICES VALUATION

Flood Damage Evaluation Methods

The volume, duration, and timing of runoff water from each pixel of each land cover type were quantified by Dr. Bedient's hydrologists (Bedient 2017) using the existing and future restored land cover mapping presented in Chapter IV. The engineering hydrology and hydraulic modeling is highly dependent on land cover (vegetation, bare ground, and impervious cover), slope of the land, and obstructions or controls on water flow (e.g., roads, ditches, culverts, and vegetation resisting the flow of water). Other factors such as design-storm rainfall distributions, antecedent conditions of soil moisture, and depressional storage free-board, were also accounted for in the hydraulic model.

The results from this analysis of reduced flood water runoff volumes provide the basis for valuing the economic benefits of protecting and restoring Katy Prairie ecosystem land with respect to hydrological services. This valuation follows the computations of the reduced runoff volumes for each design storm. The flood reduction benefits of each of the five scenarios (20,000, 30,000, 50,000, and 101,000 acres) were evaluated under the existing land cover types. Scenario 1 included only existing CPC protected lands and provided the baseline measurement. The four other scenarios modeled the potential benefits of increased acreage of land converted through restoration and conservation/protection. For each scenario, modeling was performed for six design storm events and their associated rainfall (Table 12). All design storms were Type II, 24-hour rainfall distributions typically used in watershed modeling to evaluate reasonable steady rainfall distribution over time and space in a watershed.

Table 12. Storm Event Definitions by Rainfall Totals

Design Storm Event (recurrence intervals of years)	Rainfall (inches)
2	4.1
5	5.8
10	7.1
25	9.0
50	10.6
100	12.4

Flood Damage Evaluation Analysis

Table 13 and Figure 8 depict the predicted stormwater runoff and infiltration water volumes for each of the five modeled scenarios (Scenario 1 represents existing conditions and Scenarios 2-5 reflect increased acreages of neighboring lands that theoretically will be protected and restored like CPC lands.) Scenario 1 serves as the baseline measure for comparison. The bar graphs (Figure 8) show precipitation and runoff/infiltration in acre-feet (ac-ft) for each design storm event with the modeled effects of increasing restored land protection and acreages. The reduction in stormwater runoff contributed by the infiltration rate improvements alone, resulting from the restoration of degraded ecosystems (e.g., row crop agricultural land restored to upland prairie; and former lower wetter rice production land restored to wet grasslands) are shown as a superimposed line over the histogram plots.

Stormwater runoff reductions increase noticeably over Scenario 1 (baseline existing conditions) and Scenario 2 (20,000 restored/protected acres) during a 10-year storm design event occurring in Scenario 3 (30,000 restored/protected acres). The 25-year storm event shows an even steeper increase in the runoff volume reduction for Scenario 3. Precipitation was balanced by stormwater runoff reductions for a 10-year storm event in Scenario 5, a 25-year storm event in Scenarios 4 and 5, and a 50-year storm event in Scenario 5. During a 100-year storm event, reductions in stormwater runoff were minimal in Scenario 5. Modeling predicts that the largest reductions in stormwater runoff, will occur in a 25-year storm event under all land restoration/land conservation scenarios but some volume reduction occurs across all modeled scenarios.

The hydraulic modeling demonstrates that land restoration conversions in the upper watershed area have the greatest benefit of reducing runoff for mid-frequency storm events (i.e., 10-, 25- and 50-year storm events). Larger storm events (i.e., 100-year and greater) resulted in less volume reductions as compared to the increased volumes produced, and this result was regardless of predicted changes in land uses. For the smaller, most frequent events (2-year) modeling suggests generated runoff may be managed reasonably well without restoration of any additional lands.

Based on this analysis, only using improvements in storm water infiltration rates, the 25-year and 50-year events are shown to provide significant reductions in runoff compared to a developed urban/suburban landscape with poor infiltration rates. When a 100-year design storm is compared to the existing conditions of the ecosystems in the watershed, minimum reductions in runoff volumes are measured, even with restoration.

Table 13: Modeled Effects on Stormwater Runoff (Volume and Infiltration) by Scenario and Storm Design Event

100-year Storm

		Soil Depth = Real Data			
Scenario	Converted Acres	Rainfall Vol (ac-ft)	Infiltration Vol (ac-ft)	Run-off Vol (ac-ft)	Runoff Volume Reduction (ac-ft)
1	0	76212	38844	37368	0
2	7828	76212	38905	37307	61
3	11635	76212	38966	37246	123
4	21214	76212	39028	37184	184
5	44325	76212	39212	37000	369

50-year Storm

		Soil Depth = Real Data			
Scenario	Converted Acres	Rainfall Vol (ac-ft)	Infiltration Vol (ac-ft)	Run-off Vol (ac-ft)	Runoff Volume Reduction (ac-ft)
1	0	65149	37123	28026	0
2	7828	65149	37246	27903	123
3	11635	65149	37430	27719	307
4	21214	65149	38045	27104	922
5	44325	65149	38721	26428	1598

25-year Storm

		Soil Depth = Real Data			
Scenario	Converted Acres	Rainfall Vol (ac-ft)	Infiltration Vol (ac-ft)	Run-off Vol (ac-ft)	Runoff Volume Reduction (ac-ft)
1	0	55315	34480	20835	0
2	7828	55315	34726	20590	246
3	11635	55315	34971	20344	492
4	21214	55315	35832	19483	1352
5	44325	55315	37246	18070	2766

10-year Storm

		Soil Depth = Real Data			
Scenario	Converted Acres	Rainfall Vol (ac-ft)	Infiltration Vol (ac-ft)	Run-off Vol (ac-ft)	Runoff Volume Reduction (ac-ft)
1	0	43638	30055	13583	0
2	7828	43638	30239	13399	184
3	11635	43638	30362	13276	307
4	21214	43638	30731	12907	676
5	44325	43638	31407	12231	1352

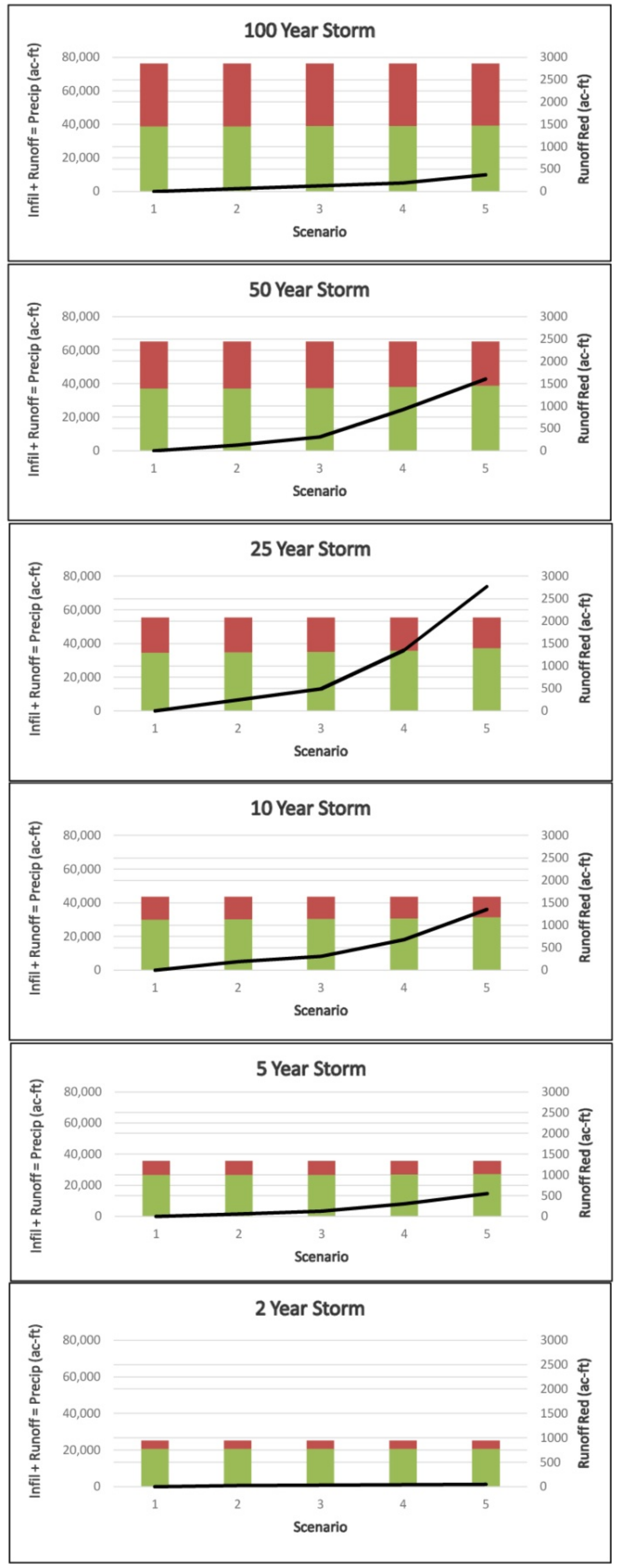
5-year Storm

		Soil Depth = Real Data			
Scenario	Converted Acres	Rainfall Vol (ac-ft)	Infiltration Vol (ac-ft)	Run-off Vol (ac-ft)	Runoff Volume Reduction (ac-ft)
1	0	35648	26674	8973	0
2	7828	35648	26736	8912	61
3	11635	35648	26797	8850	123
4	21214	35648	26982	8666	307
5	44325	35648	27227	8420	553

2-year Storm

		Soil Depth = Real Data			
Scenario	Converted Acres	Rainfall Vol (ac-ft)	Infiltration Vol (ac-ft)	Run-off Vol (ac-ft)	Runoff Volume Reduction (ac-ft)
1	0	25199	20651	4548	0
2	7828	25199	20678	4521	27
3	11635	25199	20680	4519	29
4	21214	25199	20691	4508	40
5	44325	25199	20697	4502	46

Figure 8: Graphical Depiction of Modeling Effects on Stormwater Runoff (Volume and Infiltration) by Scenario and Storm Design Event



Flood Damage Reduction Valuation

Two methods of flood damage reduction valuation were used:

- Method 1: Reduction in Runoff Volume
- Method 2: Improved Infiltration and Reduced Runoff Volumes Compared to Urban Development Build-out.

Method 1 is used to estimate benefits by comparing existing conditions to those expected from a projected restored land condition.

Method 2 is used to estimate existing and projected runoff volumes compared to conventional regional suburban and urban developments. This method uses projections based on the measured soil infiltration rates in proximate developments in the same soil types in "greenspace" in developments present just east of CPC lands. This second method is used to provide a reference point to allow a comparison with the flood water volume reductions and potential reduced detention storage costs that might otherwise be associated with nearby developments. We describe these methods in greater detail along with our findings below.

Method 1. Reduction in Runoff Volume

The first method uses the stormwater runoff volume reductions (Table 13 and Figure 8) for each design storm and for the existing land condition and the restored future conditions to generate projected reductions in the volume of stormwater runoff. The existing and projected reductions in flood water volumes for each scenario then are valued using unit costs to create the equivalent storage in a hypothetical reservoir. This estimate can be considered as a one-time cost (2017-dollar values) to design, permit, construct, operate, and maintain new or enhanced reservoirs at $10,100/ac-ft of storage. It can also be considered as the basis for a cost structure if a stormwater utility was established on Coastal Prairie Conservancy land or expanded to other lands within each projected scenario area. The comparison of the on-going maintenance costs for a flood control reservoir compared to a protected prairie suggests a several order of magnitude lower cost per acre annually in maintaining protected prairie. It is very challenging to obtain local flood control reservoir operations and maintenance budgets. But, annual prairie maintenance budgets typically cost $50-100 dollars/acre per year or less. Estimates of reservoir operations and maintenance costs suggest costs of $1,500-5,000/acre per year.

We estimated the underlying land purchase price using an approximate average cost of $25,000 per acre (see Appendix 4-1). This cost estimate included the land area needed to create a 5-foot depth reservoir with adequate buffer acreages around the reservoir to support the construction and management and operations of the reservoir. When these costs are combined, the all-in one-time costs for a reservoir are estimated at $16,577/ac-ft, exclusive of the on-going annual operations and maintenance costs once the reservoir is constructed. This estimate was used as a multiplier to determine the cost and the corresponding ecosystem service value of reduced runoff volumes. To ensure use of consistent units, we made the "ecologically-based" assumption that the reservoir would involve an average 5-foot of depth created by excavation below the ground surface elevation. This depth was chosen because of its potential to create seasonal wetlands that can provide conservation value. This depth also maximizes storage capacity by remaining above the shallow regional ground water which would otherwise occupy valuable storage volume in a reservoir with a deeper excavated depth.

Using the estimated runoff volume reductions (Table 13) and the estimated total cost of constructing a reservoir that would accommodate those volumes, we calculated the ecosystem service values that the Katy Prairie lands could contribute to mitigating flood impacts under all scenarios and design storm events. This was accomplished by multiplying the reservoir storage needs by the all-in cost of $16,577 per ac-ft of storage, as a one-time cost, by the modeled ac-ft of reduced runoff volumes (Tables 13 and 14).

Table 14: Valuation of the Reduced Stormwater Runoff by AOI Scenario and Design Storm Event

AOI Scenario	Design Storm Event (year intervals)											
	2		5		10		25		50		100	
	ac-ft	Dollar Value	ac-ft	Dollar Value	ac-ft	Dollar Value	ac-ft	Dollar Value	ac-ft	Dollar Value	ac-ft	Dollar Value
1	0	0	0	0	0	0	0	0	0	0	0	0
2 (20,000 AOI)	27	$447,579	61	$1,011,197	184	$3,050,168	246	$4,077,942	123	$2,038,971	61	$1,011,197
3 (30,000 AOI)	29	$480,733	123	$2,038,971	367	$6,083,759	492	$8,155,884	307	$5,089,139	123	$2,038,971
4 (50,000 AOI)	40	$663,080	307	$5,089,139	676	$11,206,052	1352	$22,912,104	922	$15,283,994	184	$3,050,168
5 (101,000 AOI)	45	$745,965	553	$9,167,081	1352	$22,412,104	2766	$45,851,982	1598	$26,490,046	369	$6,116,913

Summarizing the findings presented in Table 14:

a) The values of flood water management on Scenario 2 (20,000-acre AOI) across all design storm events ranged from minimum to maximum runoff volumes of 27 to 246 ac-ft, with corresponding economic values of $447,579 to $4,077,942.

b) The values of flood water management on Scenario 3 (30,000-acre AOI) across all design storm events ranged from minimum to maximum runoff volumes of 29 to 492 ac-ft, with corresponding economic values of $480,733 to $8,155,884.

c) The values of flood water management on Scenario 4 (50,000-acre AOI) across all design storm events ranged from minimum to maximum runoff volumes of 40 to 1352 ac-ft, with corresponding economic values of $663,080 to $22,912,104.

d) The values of flood water management on Scenario 5 (101,000-acre AOI) across all design storm events ranged from minimum to maximum runoff volumes of 45 to 2766 ac-ft, with corresponding economic values of $745,965 to $45,851,982.

In all the cases above, the lowest reductions in runoff volumes were associated with the 2-year design storm event and the highest were associated with the 25-year design storm event. Greater reductions occurred when the AOI's were expanded in size and when more Katy Prairie ecosystem land was restored, progressing from Scenario 1 through 5.

This valuation method predicts that the reduction in flood water generated as an ecosystem service value depends on acreage of protected/restored land and the magnitude of the design storm event. Based on the range modeled, a minimum estimate of $447,579 to a maximum of $45,851,982 (Scenario 5, 25-year design storm event) is documented. These dollars represent a savings from money that would otherwise need to be invested in stormwater management infrastructure if CPC lands and other lands under each AOI scenario were not protected and restored.

Method 2. Improved Infiltration and Reduced Runoff Volumes Compared to Urban Development Build-out

We based a second method of valuing the flood mitigation benefits of restoration on comparisons of the improved and increased infiltration on Katy Prairie restored and protected lands with measured impaired infiltration rates from the green space of nearby urban/suburban (built-out) lands. With this method, we compared the modeled infiltration volumes on CPC lands to the urban/suburban lands where infiltration rates were measured at essentially zero.

Infiltration measurements in nearly all tested representative green space suburban/urban land cover type locations (e.g., mowed lawns, park space, and vegetated rights-of-ways) had a value of zero (Bedient 2017). As a conservative estimate, this approach used the modeled infiltration volumes rather than the total rainfall volumes which would theoretically run off if zero infiltration occurred. By using only the actual modeled infiltration volumes, we have arbitrarily applied a conservative discount factor of 30-60% to the runoff for this approach. By assuming that only the modeled infiltration under each scenario and design storm would become runoff if the lands were in a fully developed condition, we calculated an estimated flood water reduction benefit of land protection and ecosystem restoration compared to land development changes in the future.

The estimated zero infiltration rate is based on in situ infiltration measurements at nine suburban/urban open space locations suggested by Harris County Flood Control staff. They were sampled under average antecedent moisture conditions. While we expected greater variability in measured infiltration rates, the consistent measured rate of zero inches/hour lent support to this being a useful reference for this comparison method. Comparison of these urban/suburban infiltration measurement areas to infiltration on CPC lands was ensured by selecting equivalent soil types in both settings.

Using this approach, if future development occurs on undeveloped land in the Katy Prairie landscape, a worse case increase in stormwater runoff volume would be similar to the total volume of stormwater generated by each design storm. Using Method 2, the range of increased runoff assuming the lands were to be developed, is 20,000 to 39,000 ac-ft for the 2- and 100-year event storms, respectively. The increased runoff would increase for larger storm events and as AOI is increased.

Using Method 2, the estimated ecosystem service value of protecting and restoring Katy Prairie ecosystem, expressed as the equivalent cost for building traditional reservoir storage, ranges from $331.5 to $646.5 million (2017 dollars) across all design storms and AOI sizes.

In summary, compared to a developed land scenario, protected and restored Katy Prairie ecosystem lands provide a valuable flood water management function equivalent to $646.5 million, using a one-time cost to pay for the equivalent 39,000 ac-ft of storage of a traditional reservoir plus the additional cost for annual operations and maintenance of the flood control reservoir. If the Katy Prairie ecosystem land were established as a stormwater management utility, then rather than a one-time cost, this could be presented as a range of value for the annual services provided for the 2 to 100-year design storms that could be managed with the Katy Prairie ecosystem lands and the annual operational and maintenance costs of the prairie are believed to be one to two orders of magnitude lower than a flood control reservoir.. This approach has been used at several locations in the United States, including New York City, Chicago region, Milwaukee, and elsewhere.

Caveats for Hydrological Ecosystem Service Valuation

Following accepted engineering standards and procedures, traditional models used for estimating floodwater volumes and rates employ assumed and generalized values. In recent years, due to improved remote and field measurement capabilities, landscape-specific measured variables and data sets can be used in models in place of assumed values. This approach, using more sophisticated models with site-specific measured data, allow for more accurate predictions of storm and flood metrics, and thus improved valuations.

As new modeling tools and software become available, these models can benefit from new technological devices used to measure ecological and land-performance variables. For example, for this evaluation, the latest automated, dual head infiltrometers (SATURO, by Meter Environment) were used to conduct standardized infiltration measurements in the primary soil types within the area of the hydrologic model (Bedient 2017). Additional ecological measurements (Table 15, below) could also be used for further refinement of the hydrologic model. Such measurements would result in improved predictions that better model the relationships between land use, ecological conditions, and stormwater management. The hydrological modeling reported in this study has not directly considered the integration of these factors. <u>As such, we view the valuations of stormwater management derived from CPC land to be very conservative, that is to say, undervalued.</u>

Additionally, current hydrologic modeling and valuation estimates are <u>conservative</u> because of the anticipated hydrological changes that will occur over time in response to ecosystem changes resulting from restoring the land. For example, <u>soil carbon levels will improve as grassland restoration progresses</u>, improved grazing occurs, or reduced tillage agriculture is implemented in the Katy Prairie ecosystem lands. Increases in soil carbon will almost certainly further alter the hydrology of the landscape. Vegetation system restoration will improve infiltration capacity as the plant roots develop vertical piping routes, especially noticeable in the heavier soils, and as other soil-inhabiting organisms expand or recolonize in recovering soils.

One of the major changes documented during restoration of farmland to prairie, is the rebuilding of soil organic carbon (SOC). Over a period of 15–25 years, SOC levels are anticipated to increase from a low of between 0.7–1.2%, the estimated levels now present in CPC land based on reconnaissance sampling. This equals approximately 75–120 tonnes (metric tons) of carbon per acre. If the accrual rate is 0.4–0.8 tonnes of additional soil organic carbon/acre-yr. (under improved grazing and land restoration practices on CPC land), soil organic carbon would be expected to increase about 0.8–1.6% annually (at 1 tonne/ha-yr. and 100 tonnes/ha stocks), until about year 10, and then start to level off. This suggests the soil carbon stocks on CPC lands may increase to approximately 6–8%. Based on soil carbon and water retainage studies (Kimble et al. 2007) <u>for every 1% increase in SOC, water holding capacity increases by 12,000 to 15,000 gallons per acre. In short, the water-holding and water-infiltration capacity is expected to increase substantially over time as Katy Prairie lands are restored.</u>

Table 15. Hydrology variables not assessed in the hydrology/hydraulic modeling or this valuation.

Water Management Functional Element	Documented Benefits in Other Regions	Citations
Interception of rainfall by prairie vegetation that results in zero runoff or increase in soil moisture	In NE, IL, and MN, as much as one-inch Type II storm events have been documented to be completely intercepted during a storm by the standing stems/foliage of prairie vegetation. Typically (Weaver 1929) evaporation of the intercepted rainfall occurred within one to several hours after the rainfall stopped. (A Type II storm provides rainfall over an even temporal distribution during the 24-hour design storm). Intercepted water lands on plant leaves and evaporates and never mobilizes and does not contribute to storm water runoff.	• Weaver 1935, 1954, 1968 • Apfelbaum, Eppich and Solstad 2014.
Increased soil surface/plant material resistance to water flow with restoration and enhancement	Increased Manning's coefficients of 20 to 50% are typical with restoration of prairie/wetlands. This equates to a commensurate reduction in the rate at which water leaves landscape, leading to increased time of concentration, increased hydrograph lag time and desynchronization of flood peaks from tributary watersheds.	• USDA- NRCS standards. Red River of the North Technical Science Team, MN
Microdepressional water storage improvements with restoration	Restoration increases soil surface irregularity (i.e., roughness) by as much as 10-12 inches vertically within a decade or less. The hummocks formed around bunch grasses, and accumulation of biomass and underlying soil carbon create a corrugated landscape that holds significant water in microdepressional storage. This can be measured with high resolution LIDAR to measure the additional storage created. It is estimated that microdepressional storage can increase more than 10% over a graded flat landscape.	• Based on ecological experience and judgement. as no good examples are available in publications
Soil organic carbon improvements with prairie restoration increases soil moisture holding capacity of the soils	Restoration of deep-rooted warm season prairie vegetation builds up substantial soil carbon levels at rates of 3-5 tonnes C/ha-yr. that can be increased under regenerative grazing practices and prescribed burning management. Documented improvements in soil moisture holding capacity include 12,000 to 15,000 gallons per acre with an increase of 1% in soil organic carbon.	• Kimble et al.2007. • West & Six, Dept. of Interior,10.1007/s10584-006-9173-8, 2007)

VI. CONCLUSION

When non-hydrological related ecosystem services values are projected over 30 years for just the existing CPC land (Scenario 1, 20,000 acres), the total cumulative value is estimated at $950 million. This works out to $31.4 million/year, or an annual value of approximately $1,568/acre. Rolled-up values of projected ecosystem services over a 30-year period for the increasing acreages of Scenarios 2, 3, 4 and 5 (20,000, 30,000, 50,000, and 101,000 acres, respectively) approximated $1.15, $1.66, $2.73, and $5.37 billion dollars or annual per acre values of $1,963, $1,959, $1,941, and $1,947.

We concluded that the hydrological ecosystem services of 101,000 acres of protected and restored Katy Prairie ecosystem lands had a projected highest value of $45 million for a 25-year event storm. This reflects the benefits of reducing downstream floodwaters – floodwaters that otherwise would have to be managed in a constructed reservoir. For consistency however, we added the hydrologic-related ecosystem service value to the same Scenario 1, 20,000-acre existing conditions as above, resulting in over $4M additional savings per 25-year storm event, a significant savings anticipated to occur on a more frequent basis.

In contrast, at the full restoration scale (101,000 acres, Scenario 5), the total estimated value equivalency of the reduced contribution to downstream flood waters due to infiltration alone ranges from $376 to $691 million, or per acre values of $3,727 to $6,846 as an annual on-going contribution to reduced floodwaters. If the Katy Prairie ecosystem lands were to be established as a stormwater management utility as has been done in several locations in the United States, rather than representing a one-time cost equivalency for hypothetical reservoir storage, this would represent a likely value range for the services provided during real storms that occur during any given year.

Combining the non-hydrological and hydrological estimates and conservatively, the ecosystem service values that were measured, estimated and projected in this project have per acre values ranging from $5,627 to $8,341 depending on the total protected and restored acreage and the percent composition of each ecosystem type. Thus, again, during any given year, the ecosystem services provided by existing CPC lands under a restoration scenario return approximately $112.5 M to $166.8 M to the Greater Houston region.

In general, we suspect that most of these valuations of ecosystem and hydrological services are conservative, or undervalued, in nature. We expect increases in values will follow from improved modeling approaches that better integrate more accurate and site-specific remote and field measurements that in turn follow from improved software and technological devices. Based on ecological work on this landscape and other locations, we also predict enhanced functionality and thus value will proceed from the many interrelated benefits from the progression of ecosystem restoration. Soil carbon stands as proxy for many of the system changes that will translate over time to increased ecosystem services values. But regardless, this study provides the economic foundations for a regional model to better support further protection and restoration of the historic Katy Prairie.

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(Bold numerals in parentheses following a citation indicate use in the Valuation Table)

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APPENDICES

APPENDIX 1: VALUATION REFERENCES

APPENDIX 1-1. PRIMARY REFERENCES USED IN ECOSYSTEM SERVICES VALUATION

REFERENCE	MATRIX NUMBER Red = Houston area and mid TX coast Green = Gulf states Black = Other	LOCATION
The Conservation Fund, 2012 Houston-Galveston Green Infrastructure and Ecosystem Services Assessment. The Conservation Fund. Arlington, VA.	2	Houston Area
SSPEED Center, Rice University 2014 prepared by Hale, C., A. Gori & J. Blackburn. Ecosystem services of the mid-Texas coast. Texas Coastal Exchange.	3	Mid-TX coast
Thibodeau, F.R. & B.D. Ostro. 1981. An Economic Analysis of Wetland Preservation. Journal of Environmental Management, 12:19-30 (cited In: http://www.environment.nsw.gov.au/envalueapp/studydetail.asp?id_study=334)	4	MA
Costanza, R. O. Perez-Maqueo, M. Luisa Martinez, P. Sutton, S. Anderson & K. Mulder. 2008. The value of coastal wetlands for hurricane protection. Ambio 37(4):241-248	5	US (Atlantic / Gulf coasts)
The Conservation Fund. 2014. Ecosystem Services Literature Review: For valuation of ecosystem services provided by the natural resources included in the Chicago Wilderness Green Infrastructure Vision. Prepared for Chicago Metropolitan Agency for Planning. CMAP Contract #C14-0041	6	IL (Chicago)
USEPA. Wetlands functions and values. (Accessed June 2017) https://www.epa.gov/sites/production/files/2016-02/documents/wetlandfunctionsvalues.pdf	7	US
Ko, J-Y. 2007. The economic value of ecosystem services provided by the Galveston Bay/estuary system. Texas Commission on Environmental Quality, Galveston Bay Estuary Program, Webster, TX.	8	Mid-TX coast
U.S. Environmental Protection Agency (EPA). 2006. Wetlands: protecting life and property from flooding. EPA843-F-06-001.	9	US
DeGroot, R., M. Stuip, M. Finlayson & N. Davidson. 2006. Valuing wetlands: Guidance for valuing the benefits derived from wetland ecosystem services. Ramsar Technical Report No. 3, CBD Technical Series No. 27. Ramsar Convention Secretariat, Gland, Switzerland.	10	Global
Weber, T. 2007. Ecosystem services in Cecil County's Green Infrastructure: Technical Report for the Cecil County Green Infrastructure Plan. The Conservation Fund, Annapolis, MD.	11 (see 24 who uses this)	MD
Feagin, R. A, M. L Martinez, G. Mendoza-Gonzalez & R. Costanza. 2010. "Salt Marsh Zonal Migration and Ecosystem Service Change in Response to Global Sea Level Rise: A Case Study from an Urban Region." (Appendix) Ecology and Society 15, no. 4: 14.	12	TX
Woodward, R. T. & Y.S. Wui. 2001. The economic value of wetland services: a meta-analysis. Ecological. Economics, 37(2), 257–270. doi:10.1016/S0921-8009(00)00276-7.	13	N. Am.
Houston Wilderness. 2014. Houston Wilderness Ecosystem Services Reference Sheet. Citing: Tilley, D., E. Campbell, T. Weber, P. May & C. Streb. 2011. Ecosystem based approach to developing, simulating and testing a Maryland ecological investment corporation that pays forest stewards to provide ecosystem services: Final Report. Department of Environmental Science and Technology, University of Maryland, College Park, MD	14	TX (Houston)
Houston Wilderness. 2016. The Ecosystem Services Primer. Accessed May 2017. http://houstonwilderness.org/ecosystem-services/	1	TX (Houston)
Batker, D., M. Kocian, B. Lovell & J. Harrison-Cox. 2010. Flood protection and ecosystem services in the Chehalis River Basin. Earth Economics, Tacoma, WA.	15	WA
Klapproth, J. C. & J. E. Johnson. 2001. Understanding the science behind riparian forest buffers: benefits to communities and landowners. Virginia Cooperative Extension. Publication Number 420-153.	16	VA

Appendix 1 – Valuation References

REFERENCE	MATRIX NUMBER Red = Houston area and mid TX coast Green = Gulf states Black = Other	LOCATION
Texas Coastal Exchange. 2014. Ecosystem services of the mid-Texas coast. Prepared for the SSPEED Center.	22	Mid-TX Coast
Costanza, R., R. D'Arge, R. DeGoot, S. Farber, M. Grasso, B. Hannon, K. Limburg, S. Naheem, R. O'Neill, J. Paruelo, R. Raskin, P. Sutton, & M. Van Den Belt. 1997. The value of the world's ecosystems and natural capital. Nature 387: 253-260.	23	Global
Kauffman, G., A. Homsey, E. McVey, S. Mack & S. Chatterson. 2011. Socioeconomic value of the Chesapeake Bay Watershed in Delaware. Water Resource Agency/Institute for Public Administration. University of Delaware, DE.	24	DE
Klimas, C., A. Williams, M. Hoff, B. Lawrence, J. Thompson & J. Montgomery. 2016. Valuing ecosystem services and disservices across heterogeneous green spaces. Sustainability 8, 853; doi:10.3390/su8090853.	25	N. Am.
Paul, A. 2011. The economic benefits of natural goods and services: A report for the Piedmont Environmental Council. Berkley Scholars Environmental Program and The Piedmont Environmental Council. Warrenton, VA	26	Valuation for Piedmont, VA. Pasture lumped.
Jenkins, W. A., B.C. Murray, R.A. Kramer & S.P. Faulkner. 2010. Valuing ecosystem services from wetlands restoration in the Mississippi Alluvial Valley. Ecological Economics 69:1051-1061 *(Replacement of wetland cropland by forested wetland. Negative values for rice.)*	27	SE US (Mississippi River Alluvial Valley)
Kroeger, T. 2005. The economic value of ecosystem services in four counties in northeastern Florida. Conservation Economics Working Paper #2. Defenders of Wildlife.	28	Data from Costanza 1997.
Troy, A. 2012. Valuing Maine's natural capital. Report for Manomet Center for Conservation Science. Prepared by Spatial Informatics Group LLC	29	ME
Foundation for Sustainable Development. TEEB Valuation Database. https://www.es-partnership.org/services/data-knowledge-sharing/ecosystem-service-valuation-database/ (accessed May 2017)	30	Variable, US and global
Van der Ploeg, S., R.S. De Groot & Y. Wang. 2010. The TEEB Valuation Database: overview of structure, data and results. Foundation for Sustainable Development, Wageningen, the Netherlands.	31	Variable, US and global
TEEB database. https://www.es-partnership.org/services/data-knowledge-sharing/ecosystem-service-valuation-database/	32	US and Canada
Wilson, S.J. 2008. Lake Simcoe's Basin's Natural Capital. Friends of the Greenbelt Foundation Occasional Papers Series. Produced for David Suzuki Foundation, Friends of the Greenbelt Foundation & Lake Simcoe Region Conservation Authority *(Good example ESV study for a landscape.)*	33	Canada, Ont. (south central)
Aisbett, E. & M. Kragt. 2010. Valuing ecosystem services to agricultural production to inform policy design: an introduction. Environmental Economics Research Hub, Research Report 73. Crawford School of Economics and Government, Australian National University, Canberra, Australia *(Approaches the subject from what services ag provides, not what benefit ag receives from natural land. includes values to pasture from shelterbelts of trees.)*	34	Global, New Zealand.
Sanhu, H.S., S.D. Wratten, R. Cullen & B. Case. 2008. The future of farming: the value of ecosystem services in conventional and organic arable land. National Centre for Advanced Bio-Protection Technologies, Lincoln University, Canterbury, New Zealand	35	New Zealand
United States Department of Agriculture (USDA). 2015. Land Values Summary. ISSN: 1949-1867. National Agricultural Statistics Service.	36	TX
United States Department of Agriculture (USDA). 2016. Texas Rice. National Agricultural Statistics Service.	37	TX

Appendix 1 – Valuation References

REFERENCE	MATRIX NUMBER Red = Houston area and mid TX coast Green = Gulf states Black = Other	LOCATION
Clucas, B., S. Rabotyagov & J.M. Marzluff. 2015. How much is that birdie in my backyard? A cross-continental economic valuation of native urban songbirds. Urban Ecosystems 18:251-266.	42	US
Texas Parks and Wildlife. 2017. Potential Income for Texas Landowners. Website. https://tpwd.texas.gov/publications/pwdpubs/media/pwd_br_w7000_1037.pdf	43	TX
Xiao, Y., G. Xie, C. Lu, X. Ding & Y. Lu. 2005. The value of gas exchange as a service by rice paddies in suburban Shanghai, PR China. Agriculture, Ecosystems and Environment 109:273-283.	44	China
Dwyer, J.F., E. G. McPherson, H.W. Shroeder & R.A. Rowantree. 1992. Assessing the benefits and costs of the urban forest. Journal of Arboriculture 18(5):227-234	45	WI (Madison)
Kroodsma, D.A. & C.B. Field. 2006. Carbon sequestration in California agriculture, 1980-2000. Ecological Applications 16(5): 1975-1985	46	CA
Barth, B. 2016. Farmers are capitalizing on carbon sequestration: How much is your carbon-rich soil worth? Modern Farmer. Accessed online June 13, 2017 http://modernfarmer.com/2016/04/carbon-sequestration/	47	US
Texas Almanac. 2017. Forest Resources http://texasalmanac.com/topics/environment/forest-resources	48	East TX
ThinkProgress web report. "This program will make cutting carbon emissions lucrative for farmers. https://thinkprogress.org/this-program-will-make-cutting-carbon-emissions-lucrative-for-farmers-6273a0f8512e	49	AR
Texas Living Waters Project: Unit Cost ($/acre-feet) of Texas Water Supply Options (2014) http://texaslivingwaters.org/image-1/	50	TX
Texas Environmental Almanac. http://www.texascenter.org/almanac/Land/SOILCH5P1.HTML#CONDITIONS Accessed June 15, 2017	51	TX
iTree, Design (Accessed June 2017) https://design.itreetools.org/ (calculated values for watersheds encompassing the project area)	52	TX (project area)
Pimentel, D., D. Harvey, P. Resosudarmo, K. Sinclair, D. Kurz, M. McNair, S. Crist, L. Shpritz, L. Fitton, R. Saffouri & R. Blair. Environmental and economic costs of soil erosion and conservation benefits. Science, New Series, 267 (5201): 1117-1123.	53	US
ASFMRA (American Society of Farm Managers and Rural Appraisers). 2015. Texas Rural Land Value Trends. Lands Magazine, CoStar Group Publications, Austin, TX	54	TX, Houston area

APPENDIX 2: ECOSYSTEM SERVICES VALUATION WORKSHEETS

APPENDIX 2-1. AES SUMMARY COSTS FOR RESTORATION AND ENHANCEMENT

Task	Unit	Unit Price*	Comments	5 yr	Ea Yr
PRAIRIE - ENHANCE					
Supplemental seeding	Acre	$ 600			
Weed management - 5 Years	Acre	$ 1,250	assumes $250/year/ac		
Prescribed Burn	Acre	$ 75	per burn	$ 1,925	$ 385
PASTURE TO PRAIRIE					
Herbicide	Acre	$ 120	Assumes 2 times		
Soil prep	Acre	$ 60	Assumes 1 time		
Seeding	Acre	$ 800			
Weed management - 5 Years	Acre	$ 1,250	assumes $250/year/ac		
Prescribed Burn	Acre	$ 75	per burn	$ 2,305	$ 461
WETLAND - ENHANCE					
Spot herbicide	Acre	$ 120	assumes 1 application		
Supplemental seeding	Acre	$ 800			
Supplemental planting	Acre	$ 1,750	Assumes 500 each (typical 32/38 ct. flat plugs)		
Weed management - 5 Years	Acre	$ 1,250	assumes $250/year/ac		
Prescribed Burn	Acre	$ 75	per burn	$ 3,995	$ 799
RIPARIAN WOODLAND - ENHANCE					
Selective woody brush removal	Acre	$ 2,000	highly dependent on density		
Supplemental seeding	Acre	$ 800			
Weed management - 5 Years	Acre	$ 1,250	assumes $250/year/ac		
Prescribed Burn	Acre	$ 75	per burn	$ 4,125	$ 825
UPLAND WOODLAND - ENHANCE					
Selective woody brush removal	Acre	$ 2,000	highly dependent on density		
Supplemental seeding	Acre	$ 800			
Weed management - 5 Years	Acre	$ 1,250	assumes $250/year/ac		
Prescribed Burn	Acre	$ 75	per burn	$ 4,125	$ 825
ROW CROP (UPLAND) TO PRAIRIE					
Herbicide	Acre	$ 60	Assumes 1 time		
Soil prep	Acre	$ 60	Assumes 1 time		
Seeding	Acre	$ 600			
Weed management - 5 Years	Acre	$ 1,250	assumes $250/year		
Prescribed Burn	Acre	$ 75	per burn	$ 2,045	$ 409
RICE FIELDS (LOWLAND) TO WETLAND					
Herbicide	Acre	$ 80	Assumes 1 time		
Soil prep	Acre	$ 80	Assumes 1 time		
Seeding	Acre	$ 600			
Weed management - 5 Years	Acre	$ 1,250	assumes $250/year		
Prescribed Burn	Acre	$ 75	per burn	$ 2,085	$ 417

*based on 250-acre units

APPENDIX 2-2. PRIMARY AND SECONDARY ECOSYSTEM SERVICES PROVIDED BY ECOLOGICAL COMMUNITIES

		Wet Grassland	Prairie	Woodland	Pasture - Shrub	Pasture - Grass	Upland Crop	Rice Crop	Turf (Park Land)
Service	Air Quality	Secondary		Primary					Secondary
	C Sequestration	Primary	Primary	Secondary					
	Soil Stability / Health		Primary	Secondary	Secondary				
	Water Quality	Primary	Primary	Secondary	Secondary				
	Water Supply		Primary	Secondary	Secondary				
	Regulate Water Flow	Secondary	Secondary	Secondary					
	Habitat	Primary	Primary	Primary	Secondary		Secondary	Secondary	Secondary
	Climate Moderation	Secondary	Secondary	Primary					Secondary
Direct Product	Commodities			Secondary	Primary	Secondary	Primary	Primary	
	Mitigation	Primary							
	Hunt / Fish	Primary	Primary	Primary	Secondary	Secondary	Secondary	Secondary	
Secondary Product	Recreation and Tourism	Primary	Primary	Primary					Primary
	Property Values	Primary	Primary	Primary	Secondary	Secondary	Secondary	Secondary	Primary

Legend	
(blue)	Primary Service
(green)	Secondary Service
(white)	No Service

APPENDIX 2-3. VALUATION METHODS REPORTED IN SCIENTIFIC LITERATURE FOR THE ECOSYSTEM SERVICES PROVIDED BY EACH ECOLOGICAL COMMUNITY

		Wet Grassland	Prairie	Woodland	Pasture - Shrub	Pasture - Grass	Upland Crop	Rice Crop	Turf (Park Land)
Service	Air Quality	Replacement Cost		Avoided Cost					Replacement Cost
	C Sequestration	Avoided Cost	Direct Market Pricing	Avoided Cost					
	Soil Stability / Health		Avoided Cost	Avoided Cost	Avoided Cost	Avoided Cost (negative values)	Avoided Cost (negative values)	Avoided Cost (negative values)	
	Water Quality	Replacement Cost	Replacement Cost	Replacement Cost	Replacement Cost				
	Water Supply		Measured Values and Direct Market Pricing	Replacement Cost	Replacement Cost				
	Regulate Water Flow	Replacement Cost	Not Stated	Replacement Cost					
	Habitat	No relevant data	No relevant data	No relevant data	No relevant data		No relevant data	No relevant data	
	Climate Moderation	No relevant data	No relevant data	Avoided Cost					Avoided Cost
Direct Product	Commodities			Direct Market Pricing	Direct Market Pricing	Direct Market Pricing	Direct Market Pricing	Direct Market Pricing	
	Mitigation	Direct Market Pricing							
	Hunt / Fish	Direct Market Pricing	Direct Market Pricing	Direct Market Pricing	Direct Market Pricing	Direct Market Pricing	Direct Market Pricing	Direct Market Pricing	
Secondary Product	Recreation and Tourism	User Cost	User Cost	User Cost					
	Property Values								

Legend	
	Primary Service
	Secondary Service
	No Service

APPENDIX 2-4. SUMMARY OF THE ANNUAL VALUE OF ECOLOGICAL SERVICES PROVIDED BY ECOLOGICAL COMMUNITIES

		Wet Grassland	Prairie	Woodland	Pasture - Shrub	Pasture - Grass	Upland Crop	Rice Crop	Turf (Park Land)
Service	Air Quality	$ 107	$ 3	$ 312	$ 3				$ 21
	C Sequestration	$ 152	$ 150	$ 67	$ 0				
	Soil Stability / Health		$ -	$ -	$ -	$ (119)	$ (119)	$ (119)	
	Water Quality	$ 1,100	$ 35	$ 820	$ 22				
	Water Supply		$ 1,370	$ 200	$ 1				
	Regulate Water Flow	$ 12	$ 1	$ 500					
	Habitat								
	Climate Moderation		$ -	$ 36					
Direct Product	Commodities			$ 17	$ 152	$ 76	$ 596	$ 1,079	
	Mitigation								
	Hunt / Fish	$ 48	$ 16	$ 33	$ 16	$ 16	$ 16	$ 16	
Secondary Product	Recreation and Tourism	$ 327	$ 327	$ 486					
	Property Values								
Value per Acre		$ 1,746	$ 1,902	$ 2,471	$ 194	$ (27)	$ 493	$ 976	$ 21

Legend	
(blue)	Primary Service
(green)	Secondary Service
(white)	No Service

APPENDIX 2-5. ANNUAL COSTS TO RESTORE ECOLOGICAL COMMUNITIES UNDER SCENARIOS 2-5

Enhancement/ Restoration Action	Annual Rest. Cost ($/ac)	Scenario 2 Convert w/in 20,000-ac AOI (Annual Cost for 5yrs)	Scenario 3 Convert w/in 30,000-ac AOI (Annual Cost for 5yrs)	Scenario 4 Convert w/in 50,000-ac AOI (Annual Cost for 5yrs)	Scenario 5 Convert w/in 101,000-ac AOI (Annual Cost for 5yrs)
Pasture to Restored Prairie	$461	$3,138,949	$4,839,117	$9,972,813	$20,156,303
Upland Crop to Restored Prairie	$409	$449,082	$668,715	$1,357,471	$3,711,675
Prairie Enhancement	$385	$1,454,145	$2,007,775	$2,915,220	$4,668,510
Rice Crop to Restored Wet Grassland	$417	$376,968	$378,636	$763,944	$1,114,641
Wet Grassland Enhancement	$799	$3,875,150	$5,726,433	$6,910,551	$12,582,652
Riparian Woodland Enhancement	$825	$949,575	$1,302,675	$1,471,800	$2,932,875
Upland Woodland Enhancement	$825	$770,550	$1,054,350	$1,724,250	$4,158,825
TOTAL		**$11,014,419**	**$15,977,701**	**$25,116,049**	**$49,325,481**

APPENDIX 2-6. COMPARISON OF CHANGE IN ECOSYSTEM SERVICES VALUE RESULTING FROM TRANSITIONING DEGRADED ECOLOGICAL COMMUNITIES TO RESTORED COMMUNITIES.

			ADDITIVE METHOD		
Community	**Existing annual value of services**	**Annual cost to enhance or restore community**	**Existing annual value plus annual restoration cost**	**Accrued Value Existing over 30 Years**	**Net Accrued Value over 30 Years following Restoration**
Wet Grassland Enhancement	$ 1,746	$ 799	$ 2,545	$ 52,393	$ 56,388
Prairie Enhancement	$ 1,902	$ 385	$ 2,287	$ 57,068	$ 58,993
Woodland Enhancement	$ 2,471	$ 825	$ 3,401	$ 77,281	$ 81,406
Pasture-Shrub to Restored Prairie	$ 194	$ 461	$ 655	$ 5,818	$ 55,587
Pasture-Grass to Restored Prairie	$ (27)	$ 461	$ 434	$ (811)	$ 54,482
Upland Crop to Restored Prairie	$ 493	$ 409	$ 902	$ 14,789	$ 56,822
Rice Crop to Restored Wet Grassland	$ 976	$ 417	$ 1,393	$ 29,279	$ 54,992

APPENDIX 2-7. NET 30-YEAR ACCRUED ECOSYSTEM SERVICE VALUES FOLLOWING RESTORATION FOR EACH ECOLOGICAL COMMUNITY AND EACH SCENARIO

Enhancement / Restoration Action	Net Accrued Value over 30-Yrs ($/ac)	Scenario 2 Net Accrued Value over 30-Yrs (Total $)	Scenario 3 Net Accrued Value over 30-Yrs (Total $)	Scenario 4 Net Accrued Value over 30-Yrs (Total $)	Scenario 5 Net Accrued Value over 30-Yrs (Total $)
Impervious	$0	$0	$0	N/A	N/A
Turf	$0	$0	$0	N/A	N/A
Pasture to Restored Prairie	$55,587	$378,492,675	$583,498,099	$1,202,516,374	$2,430,436,066
Prairie Enhancement	$58,993	$222,816,561	$307,648,495	$446,694,996	$715,349,118
Rice Crop to Restored Wet Grassland	$54,992	$49,712,768	$49,932,736	$100,745,344	$146,993,616
Upland Crop to Restored Prairie	$56,822	$62,390,556	$92,903,970	$188,592,218	$515,659,650
Wet Grassland Enhancement	$56,388	$273,481,800	$404,132,796	$487,699,812	$887,998,224
Woodland Enhancement	$78,256	$163,162,772	$223,576,038	$303,161,907	$672,684,501
TOTAL		$1,150,057,222	$1,661,692,133	$2,729,410,651	$5,369,121,174

APPENDIX 3: CPC ECOSYSTEM SERVICES VALUES BASED ON LOCAL DATA AND CONTRACTS

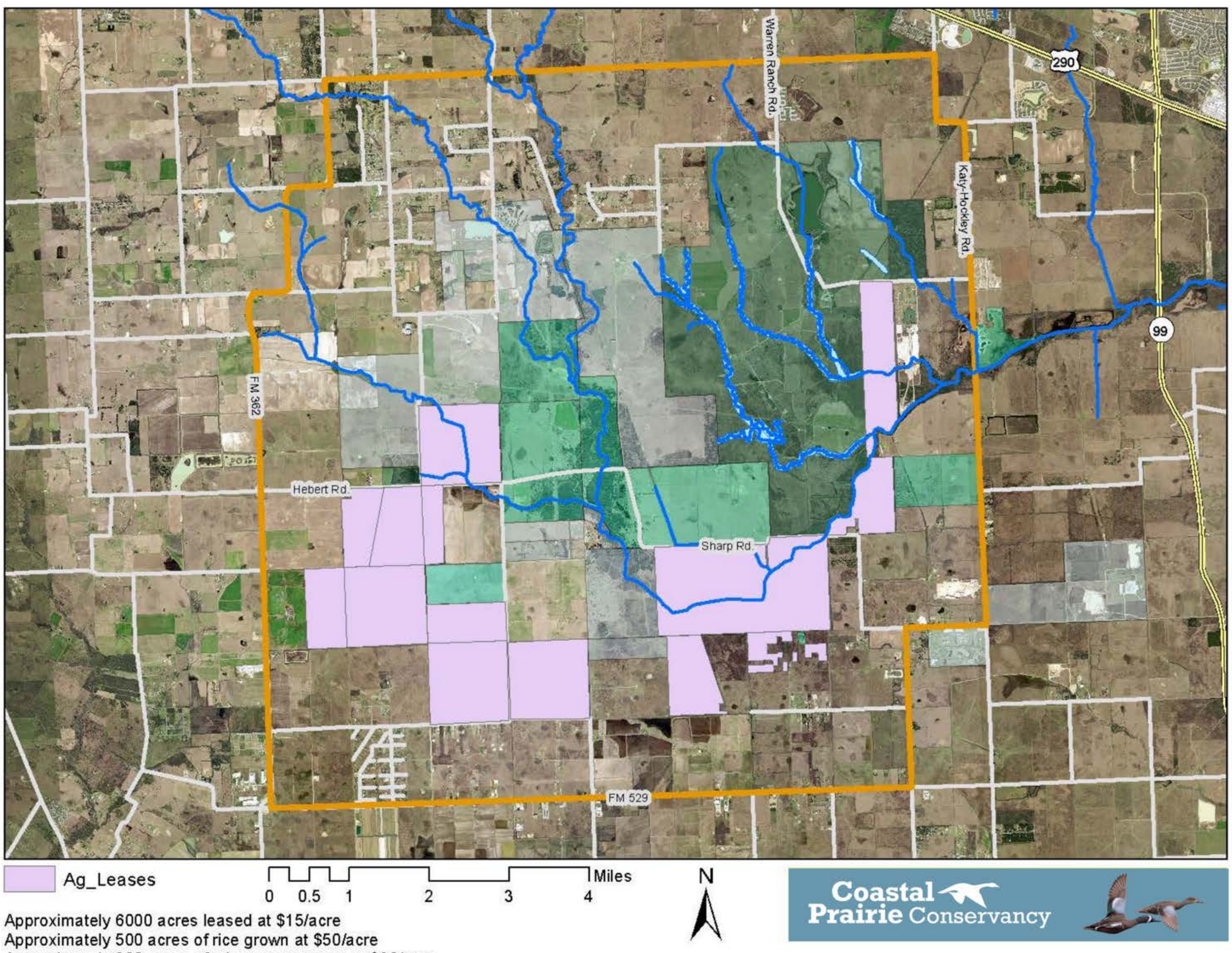
APPENDIX 3-1. CPC BACKGROUND DATA ON AGRICULTURAL LEASE REVENUE

Agricultural Leases

CPC Agricultural leases
All agricultural leases are structured on an annual lease basis with automatic renewal. The leases roll over every year unless either party terminates or changes the terms; 2017 values were utilized

Warren Ranch Agricultural leases
Current (2017) Warren Ranch leases were utilized.
All grazing leases are renewed on an annual basis.

Warren Ranch Cattle Income
Approximately 4,900 acres are utilized for cattle grazing on the ranch for an annual revenue of approximately $180,000 (approx. $36.73/acre).



Approximately 6000 acres leased at $15/acre
Approximately 500 acres of rice grown at $50/acre
Approximately 320 acres of other crops grown at $30/acre

APPENDIX 3-2. CPC BACKGROUND DATA ON HUNTING LEASE REVENUE

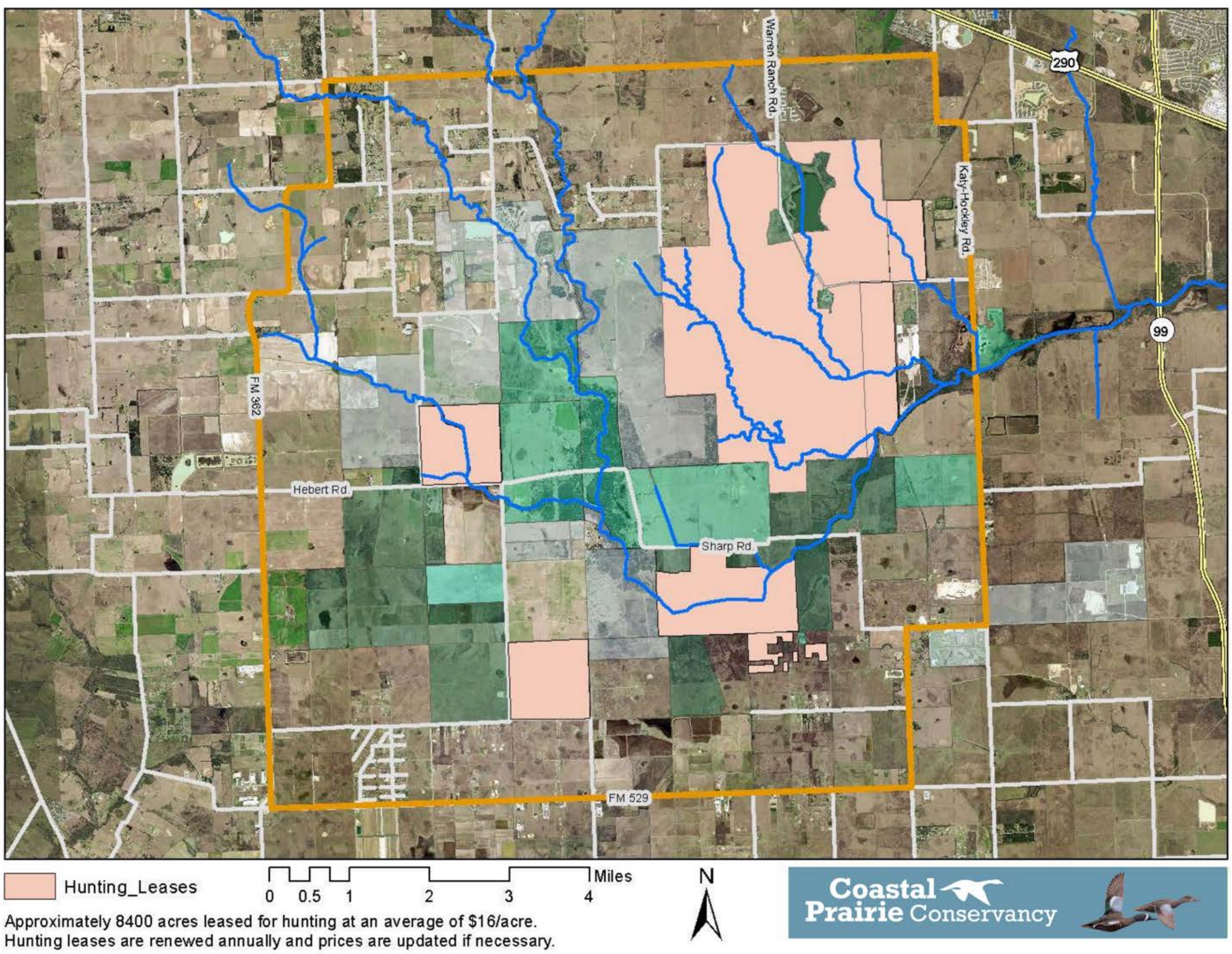
Hunting Leases

CPC Hunting leases

Approximately 2,900 acres of the Katy Prairie Preserve are leased for hunting providing income of $37,900 (approx. $13/acre on average) (Attached map shows total acreage, or 8,400 acres, leased for hunting which includes CPC's Preserves and Warren Ranch.)
All hunting leases are renewed on an annual basis.

Warren Ranch Hunting leases

Approximately 5500 acres leased for hunting totaling income of $97,000 (approx. $17.63/acre on average) (Attached map shows total acreage, or 8,400 acres, leased for hunting which includes CPC's Preserves and Warren Ranch.)
All hunting leases are renewed on an annual basis.



Recreational Value

As identified in the text, recreational values for rural passive activities are not well documented but the following data points were utilized:

https://tpwd.texas.gov/newsmedia/releases/?req=20080226g (2008 data)

APPENDIX 4: HOUSTON REGION ECOSYSTEM SERVICE VALUES FOR FLOODWATER REDUCTION

APPENDIX 4-1. SUMMARY COSTS FOR CONVENTIONAL WETLAND STORAGE PONDS

	Wetland Acreage		
	10	**100**	**1,000**
1. Soil Preparation	$2,000	$20,000	$150,000
2. Planting	$30,000	$210,000	$1,075,000
3. Management (during establishment)	$6,500	$65,000	$430,000
4. Maintenance (after establishment)	$11,000	$110,000	$565,000
5. Monitoring (after establishment)	$60,000	$600,000	$2,750,000
Establishment, O&M, and Monitoring Sub-Total	**$109,500**	**$1,005,000**	**$4,970,000**
	Required Parcel Size (ac)		
6. Land Purchase Costs	**15**	**125**	**1,100**
$25,000/ac average costs	$375,000	$3,125,000	$27,500,000
7. Engineering + Permitting Costs			
3 foot deep depressional wetland	$60,499	$604,986	$6,049,860
4 foot deep depressional wetland	$80,665	$806,648	$8,066,480
5 foot deep depressional wetland	$100,831	$1,008,310	$10,083,100
8. Excavation Costs			
3 foot deep depressional wetland	$242,000	$2,420,000	$24,200,000
4 foot deep depressional wetland	$322,667	$3,226,667	$32,266,667
5 foot deep depressional wetland	$403,333	$4,033,333	$40,333,333
Project Total - 3ft deep	**$786,999**	**$7,154,986**	**$62,719,860**
Ac-ft storage	30	300	3,000
Cost/ac-ft storage	$26,233	$23,850	$20,907
Project Total - 4ft deep	**$887,831**	**$8,163,315**	**$72,803,147**
Ac-ft storage	40	400	4,000
Cost/ac-ft storage	$22,196	$20,408	$18,201
Project Total - 5ft deep	**$988,664**	**$9,171,643**	**$82,886,433**
Ac-ft storage	50	500	5,000
Cost/ac-ft storage	$19,773	$18,343	$16,577

APPENDIX 4-2. CONSTRUCTION COSTS FOR CONVENTIONAL WETLAND STORAGE PONDS

EXCAVATION VOLUME CALCULATION	Soils Excavation cy/ac	Topsoil Excavation & Replacement cy/ac	WETLAND SIZE Soil & Topsoil Excavation Volume (cy) 10	100	1,000
3 foot deep depressional wetland	3,227	1,613	48,400	484,000	4,840,000
4 foot deep depressional wetland	4,840	1,613	64,533	645,333	6,453,333
5 foot deep depressional wetland	6,453	1,613	80,667	806,667	8,066,667
ENGINEERING + PERMITTING COSTS		**Engineering & Permitting ($2,016.62/ac-ft)**		**Total Engineering & Permitting**	
3 foot deep depressional wetland			$60,499	$604,986	$6,049,860
4 foot deep depressional wetland			$80,665	$806,648	$8,066,480
5 foot deep depressional wetland			$100,831	$1,008,310	$10,083,100
EXCAVATION COSTS		**Excavation Cost ($5/cy)**		**Total Excavation**	
3 foot deep depressional wetland			$242,000	$2,420,000	$24,200,000
4 foot deep depressional wetland			$322,667	$3,226,667	$32,266,667
5 foot deep depressional wetland			$403,333	$4,033,333	$40,333,333
ACRE-FOOT OF WATER STORAGE				**Water Storage (ac-ft)**	
3 foot deep depressional wetland			30	300	3,000
4 foot deep depressional wetland			40	400	4,000
5 foot deep depressional wetland			50	500	5,000
LAND VALUE COSTS				**parcel size (acres)**	
Unit Cost ($/ac)			**15**	**125**	**1,100**
$25,000			$375,000	$3,125,000	$27,500,000

Assumptions:

1	12 inch topsoil excavation, stockpile and replacement		
2	wetland located in depressional area which can be bermed to provide a 1 foot depressional depth		
3	wetland depths (3-5 feet) will be constructed using 1 foot berm and remaining depth through excavation		
4	engineering + permitting costs ($/ac-ft)		
	average	$	2,016.62
5	excavation		soils & topsoil
	unit costs		$/cy
	low	$	3.00
	average	$	5.00
	high	$	7.00

APPENDIX 4-3. ESTABLISHMENT, O&M, AND MONITORING COSTS FOR CONVENTIONAL WETLAND STORAGE PONDS

			Wetland Acreage		
	10-100ac ($/acre)	1,000ac ($/acre)	10	100	1,000
1. Soil Preparation (1st yr)	**$200**	**$150**	**$2,000**	**$20,000**	**$150,000**
Herbicide existing vegetation & discing	$200	$150	$2,000	$20,000	$150,000
2. Planting (1st yr)	**$16,500**	**$16,000**	**$30,000**	**$210,000**	**$1,075,000**
Emergent or wet grassland vegetation	$1,500	$1,000	$15,000	$150,000	$1,000,000
Slope, outlet, and inlet bioengineering	$15,000	$15,000	$15,000	$60,000	$75,000
3. Management (during establishment) (1st yr)	**$650**	**$430**	**$6,500**	**$65,000**	**$430,000**
Initial mowing	$50	$30	$500	$5,000	$30,000
Wick herbicide management	$200	$125	$2,000	$20,000	$125,000
Spot herbicide application	$150	$100	$1,500	$15,000	$100,000
Remedial Planting	$250	$175	$2,500	$25,000	$175,000
4. Maintenance (after establishment) (5 yrs)	**$1,100**	**$565**	**$11,000**	**$110,000**	**$565,000**
Spot herbicide spraying (5 yrs)	$750	$375	$7,500	$75,000	$375,000
Mowing (3 yrs)	$150	$90	$1,500	$15,000	$90,000
Prescribed burning (2 yrs)	$200	$100	$2,000	$20,000	$100,000
5. Monitoring (after establishment) (5 yrs)	**$6,000**	**$2,750**	**$60,000**	**$600,000**	**$2,750,000**
Hydrology (5 yrs)	$1,750	$750	$17,500	$175,000	$750,000
Vegetation (5 yrs)	$1,750	$750	$17,500	$175,000	$750,000
Wildlife (Birds & Herpetofauna) (5 yrs)	$2,500	$1,250	$25,000	$250,000	$1,250,000
			$109,500	**$1,005,000**	**$4,970,000**

Appendix 4-4. CPC Background Data on Houston Costs for Detention/Retention Ponds

Detention/Retention Pond Estimates

Introduction

Detention/retention pond estimates were initiated by evaluating and summarizing the range and average one-time costs to construct detention ponds (reservoirs) in Houston. Separate from construction and land costs, operational and maintenance (O and M) annual costs also need to be understood. However, no useful discerning costs data was available for our evaluation to understand these on-going annual costs. In the large regional reservoir projects, annual O and M costs were often confused in annual operating budgets (or federal appropriate budgets) that include bond payments, among many other cost elements that did not support a head to head comparison with the annual costs to maintain protected Coastal Prairie Conservancy prairie lands.

Assumptions

The detention pond estimates for this report are based on a number of assumptions and estimations given to CPC by various engineers in the local community. The goal of this analysis is to provide a range and average of costs to construct a detention pond. The costs estimates determined in this analysis will be used to scale up and down for modeling. Please note that these costs assume that the land is already owned; it does *not* include lands costs.

Although not directly tied to costs, it should be noted that site specific locations have different water detention requirements. In general, without a detailed analysis 0.55–0.65 acre-feet (ac-ft) of water detention per acre of impervious cover is a good rule of thumb in most locations, while locations within the Cypress Creek and Addicks/Barker Reservoir must include an additional 0.2 ac-ft of retention.

The following calculations and assumptions are used for this analysis:

- $3–$7 dollars per cubic yard
- 1-acre foot = 1,613.30 cubic yards
- Engineering and Permitting cost add an additional 25% to the overall cost of the project

Cost Summary

Low Cost: @ $3 per cubic yard X 1,613.30 = $4,840 per 1 ac-ft

- Engineer and Permitting Cost = $1,210 per 1 ac-ft
- Total development costs – $6,050 per 1 ac-ft

Average Cost: @ $5 per cubic yard X 1,613.30 = $8,067 per 1 acre/foot

- Engineer and Permitting Cost = $2,017 per 1ac-ft
- Total development costs = $10,084 per 1 ac-ft

High Cost: @ $7 per cubic yard X 1,613.30 = $11,293 per 1 acre/foot

- Engineer and Permitting Cost = \$2,823 per 1 ac-ft
- Total development costs = \$14,116 per 1 ac-ft

LOW COST: Cost Summary per 100 acres of impervious cover @ \$3 per cubic yard

Low Cost: @ \$3 per cubic yard X 1,613.30 = \$4,840 per 1 ac-ft
- Engineer and Permitting Cost = \$1,210 per 1 ac-ft
- Total development costs = \$6,050 per 1 ac-ft

100 acres at 0.65 acres detention per acre of impervious

100 acres X 0.65 = 65-acre feet of detention

- 65 acres X \$6,050 total development cost = \$393,250

100 acres at 0.65 acres detention plus 0.2 acres retention per acre of impervious

100 acres X 0.65 = 65-acre feet of detention

100 acres X 0.20 = 20-acre feet of retention ------ 85-acre feet total (detention+retention)

- 85-acre feet X \$6,050 total development cost = \$514,250

AVERAGE COST: Cost Summary per 100 acres of impervious cover at \$5 per cubic yard

Average Cost: @ \$5 per cubic yard X 1,613.30 = \$8,067 per 1 acre/foot
- Engineer and Permitting Cost = \$2,017 per 1ac-ft
- Total development costs = \$10,084 per 1 ac-ft

100 acres at 0.65 acres detention per acre of impervious

100 acres X 0.65 = 65-acre feet of detention

- 65 acres X \$10,084 total development cost = \$655,460

100 acres at 0.65 acres detention plus 0.2 acres retention per acre of impervious cover

100 acres X 0.65 = 65-acre feet of detention

100 acres X 0.20 = 20-acre feet of retention ------ 85-acre feet total (detention+retention)

- 85-acre feet X \$10,084 total development cost = \$857,140

HIGH COST: Cost summery per 100 acres of impervious cover at \$7 per cubic yard

High Cost: @ \$7 per cubic yard X 1,613.3 = \$11,293 per 1 acre/foot
- Engineer and Permitting Cost = \$2,823 per 1 ac-ft
- Total development costs = \$14,116 per 1 ac-ft

100 acres at 0.65 acres detention per acre of impervious

100 acres X 0.65 = 65-acre feet of detention

- 65 acres X \$14,116 total development cost = \$917,40

100 acres at 0.65 acres detention plus 0.2 acres retention per acre of impervious cover

100 acres X 0.65 = 65-acre feet of detention

100 acres X 0.20 = 20-acre feet of retention ------ 85-acre feet total (detention+retention)

- 85-acre feet X $14,116 total development cost = <u>$1,199,860</u>

APPENDIX 4-5. CPC LAND DATA ON HOUSTON COSTS FOR DETENTION/RETENTION PONDS

INFORMATION FOR ECONOMIC IMPACT STUDY

Land Values

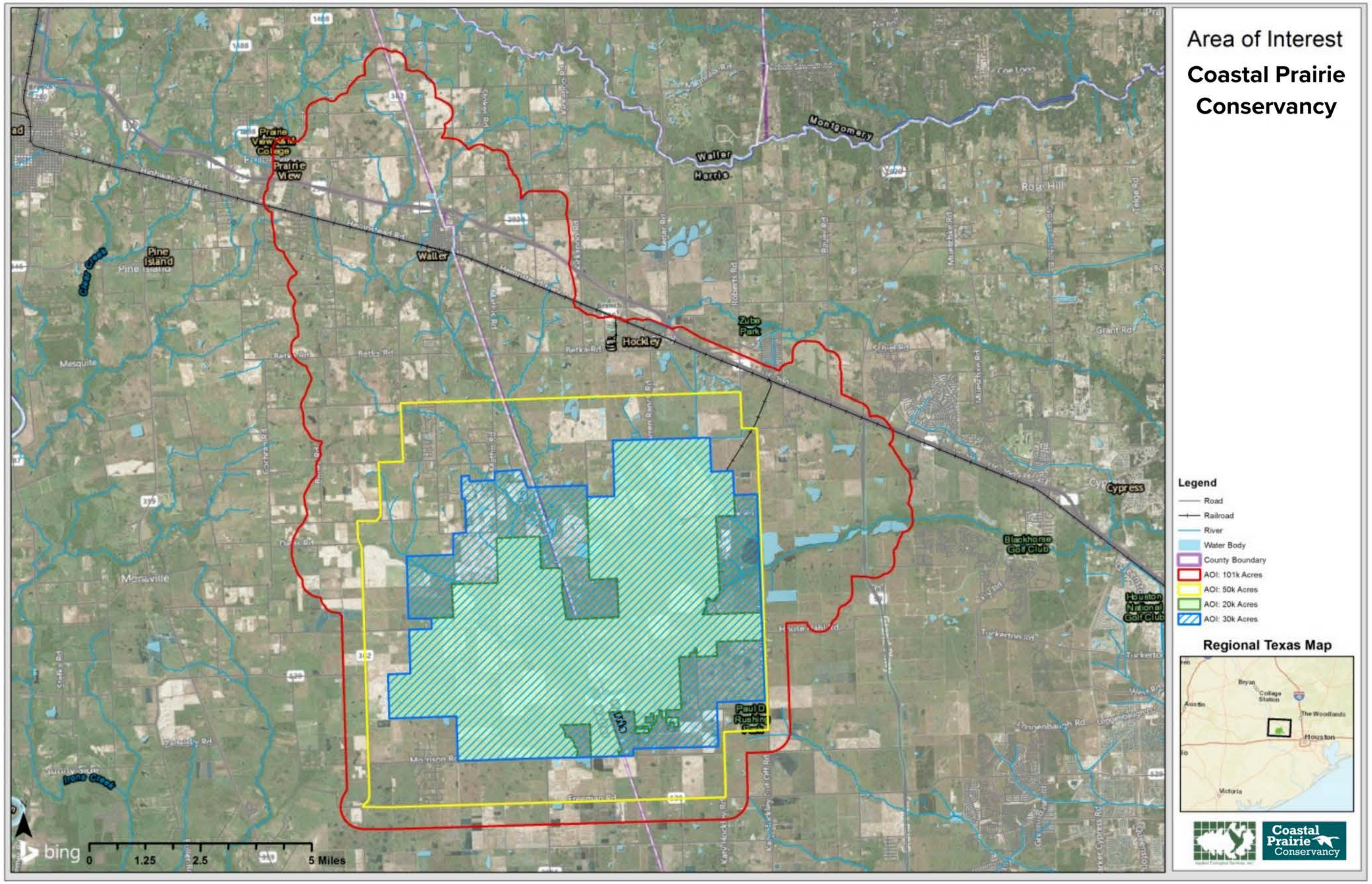
Appraisal District Values for CPC Lands – Harris CAD, Waller CAD, and Ft. Bend CAD are the appraisal districts that tax the Katy Prairie Preserve holdings. We have identified all property tax records which show that CPC's appraisal district values total more than $82M. It is estimated that CPC's land values, if not protected as conservation lands, could easily total at least twice that amount. Appraised values per acre range from $800 to more than $53,500 per acre. To determine the average value, the outliers of the low $800 and the high of $53,500 were removed to get $6,200 an acre. (See map of CPC's lands with identifying numbers that match appraisal district values.)

Appraiser Comps –The relevant data came from land sales along US 290 just west of Katy Hockley Road. Land sales ranged from $16,288 – $24,735. In addition, sales were shown along Katy Hockley that ranged from $22,000 to $35,174.

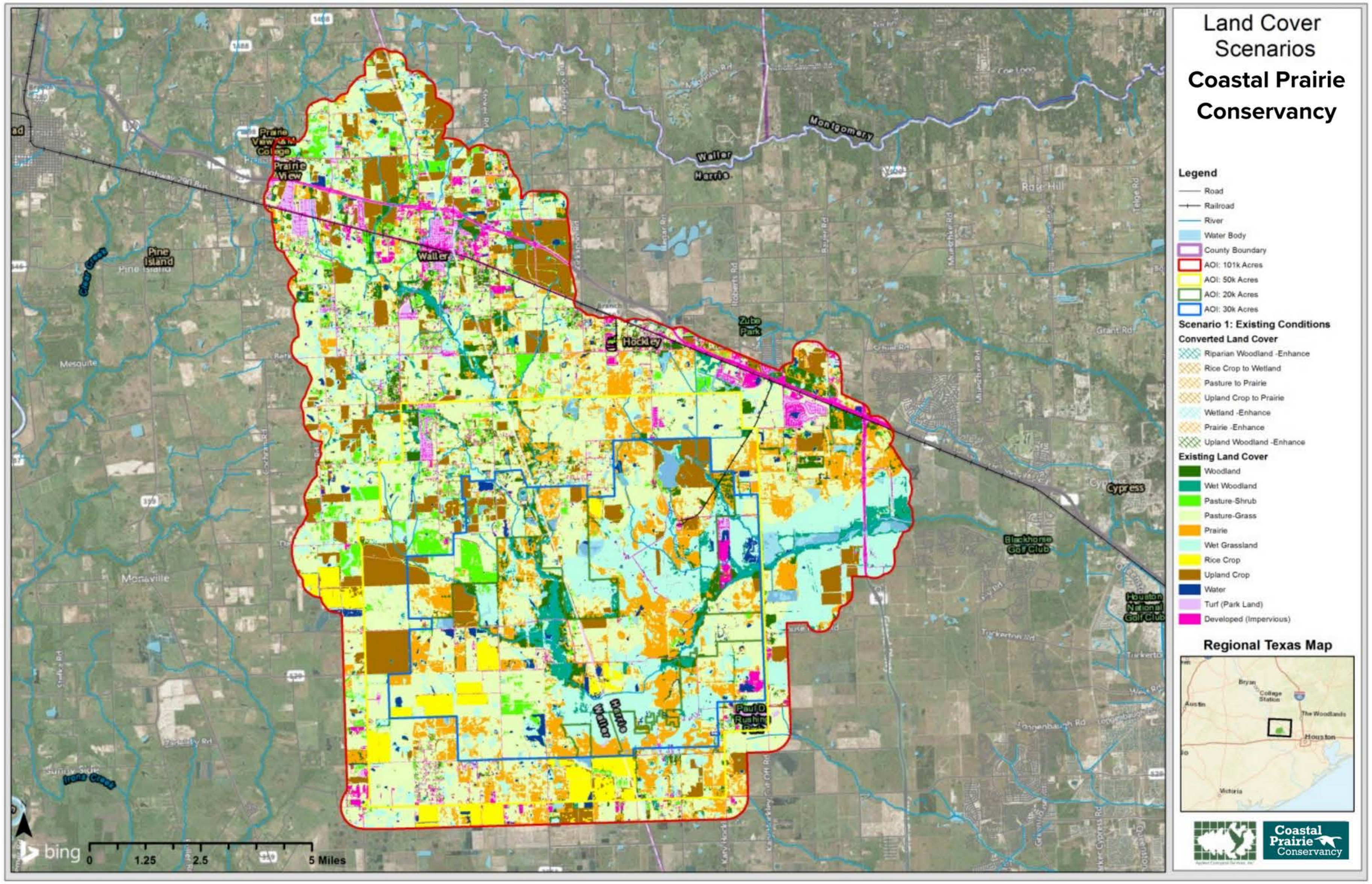
Harris County Flood Control District Cypress Creek Management Study – The study team analyzed land sales data and came up with general sales data for the Cypress Creek Overflow area, an area roughly encompassing some of the AOI studied. In general land values were between $22,500 to $30,000 an acre for land not already under CPC's protection. It should be noted that in determining overall costs for the overflow project, the District estimated that land already conserved by the Coastal Prairie Conservancy should be valued at $12,500 an acre for the purposes of flood damage reduction. (See Cypress Creek Overflow Plan found at the Harris County Flood Control District website).

APPENDIX 5: REMOTE SENSING AND LAND COVER CLASSIFICATION

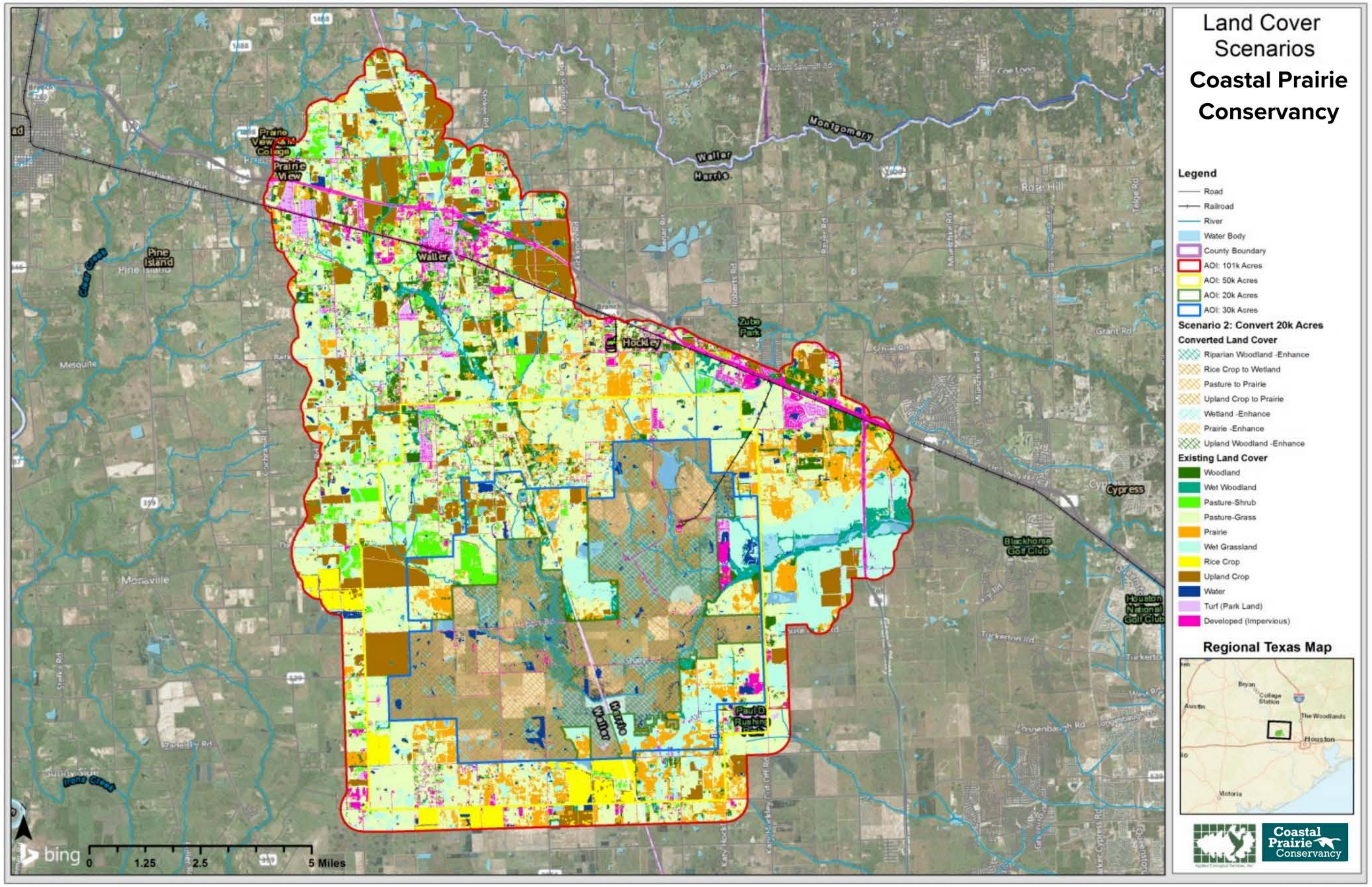
APPENDIX 5-1. COASTAL PRAIRIE CONSERVANCY AREA OF INTEREST (AOI)



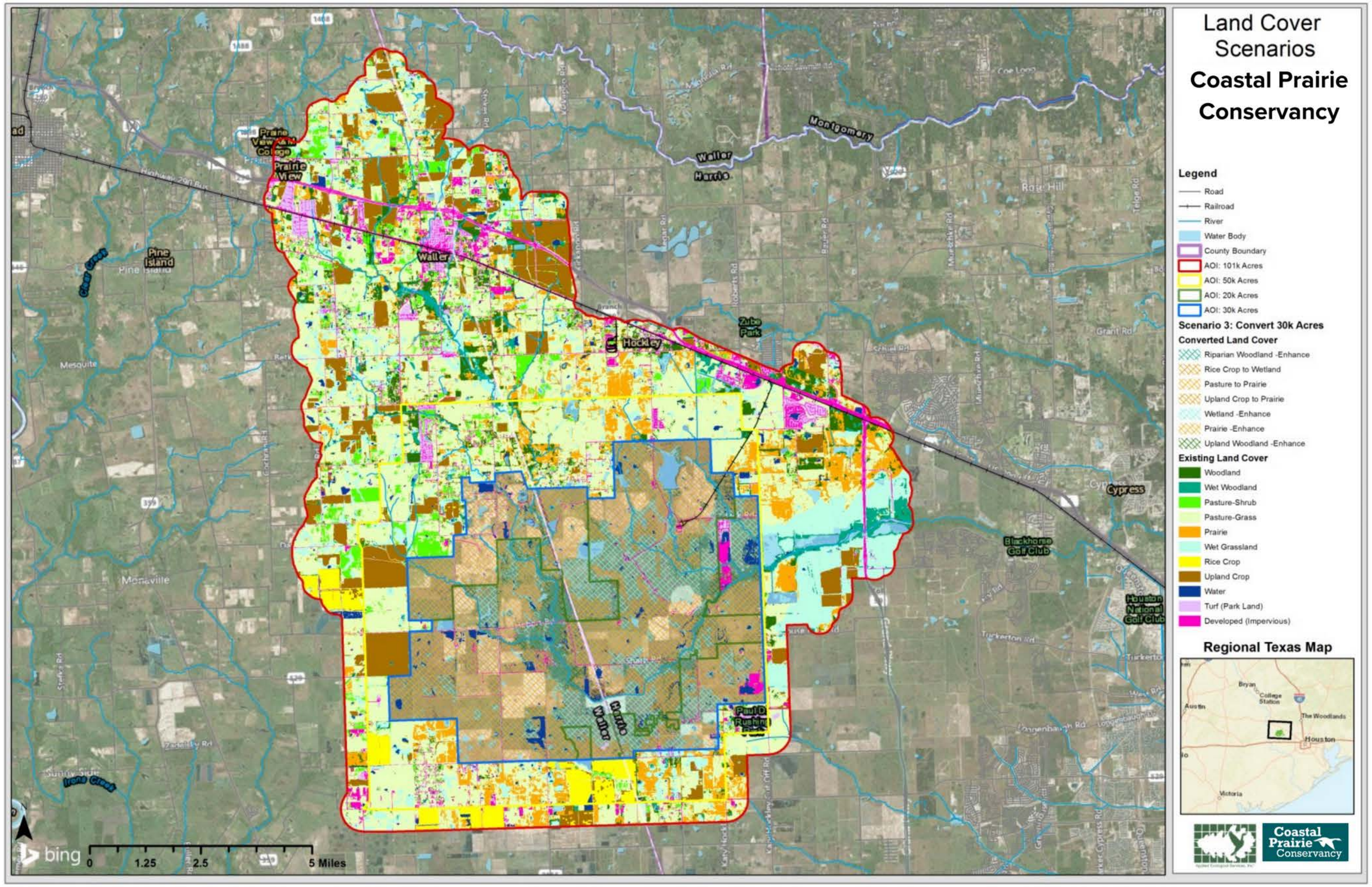
APPENDIX 5-2. SCENARIO 1: EXISTING ECOLOGICAL COMMUNITIES (EXISTING CONDITIONS)



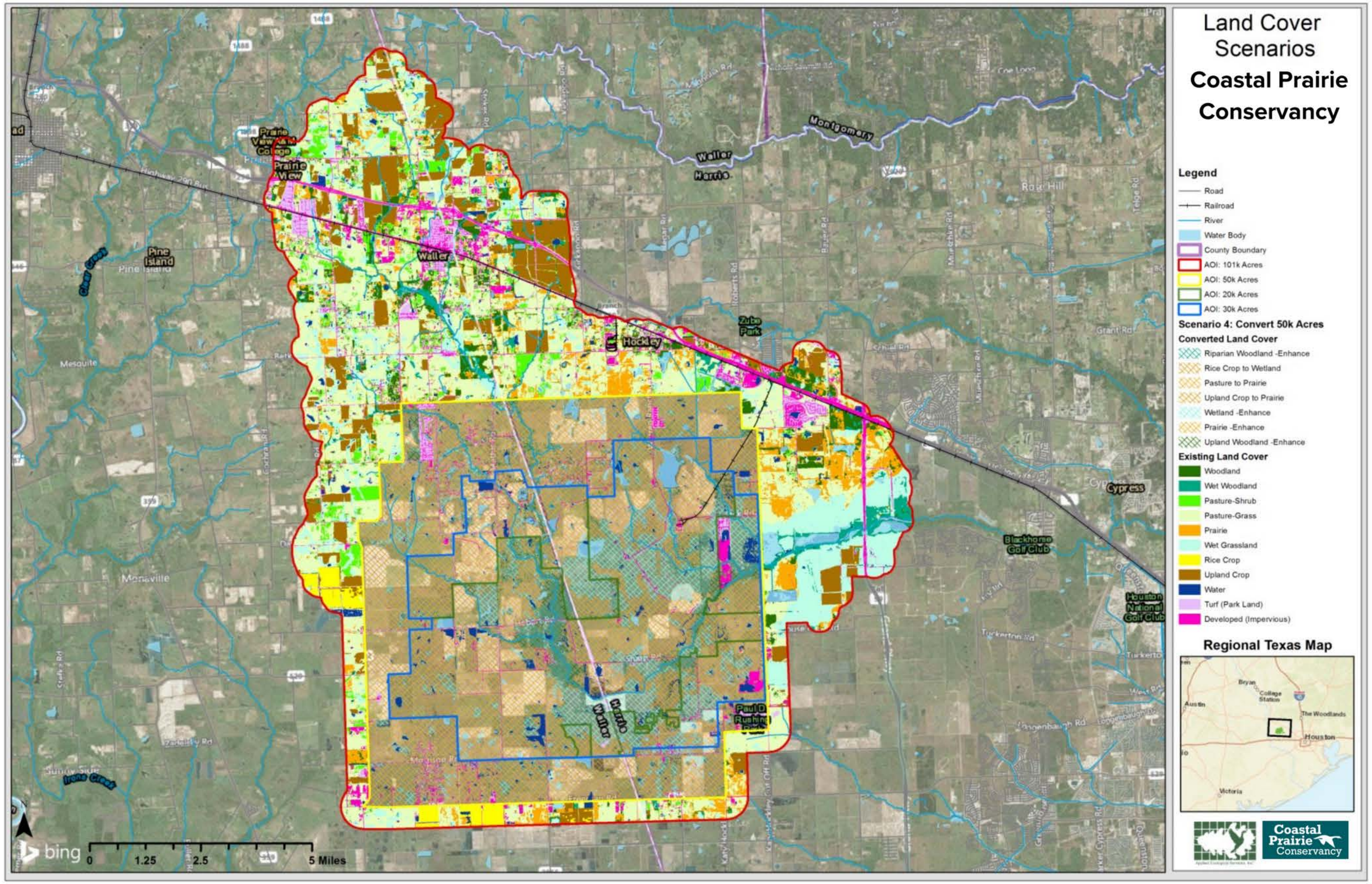
APPENDIX 5-3. SCENARIO 2: 20,000-ACRE CONVERSION MAP



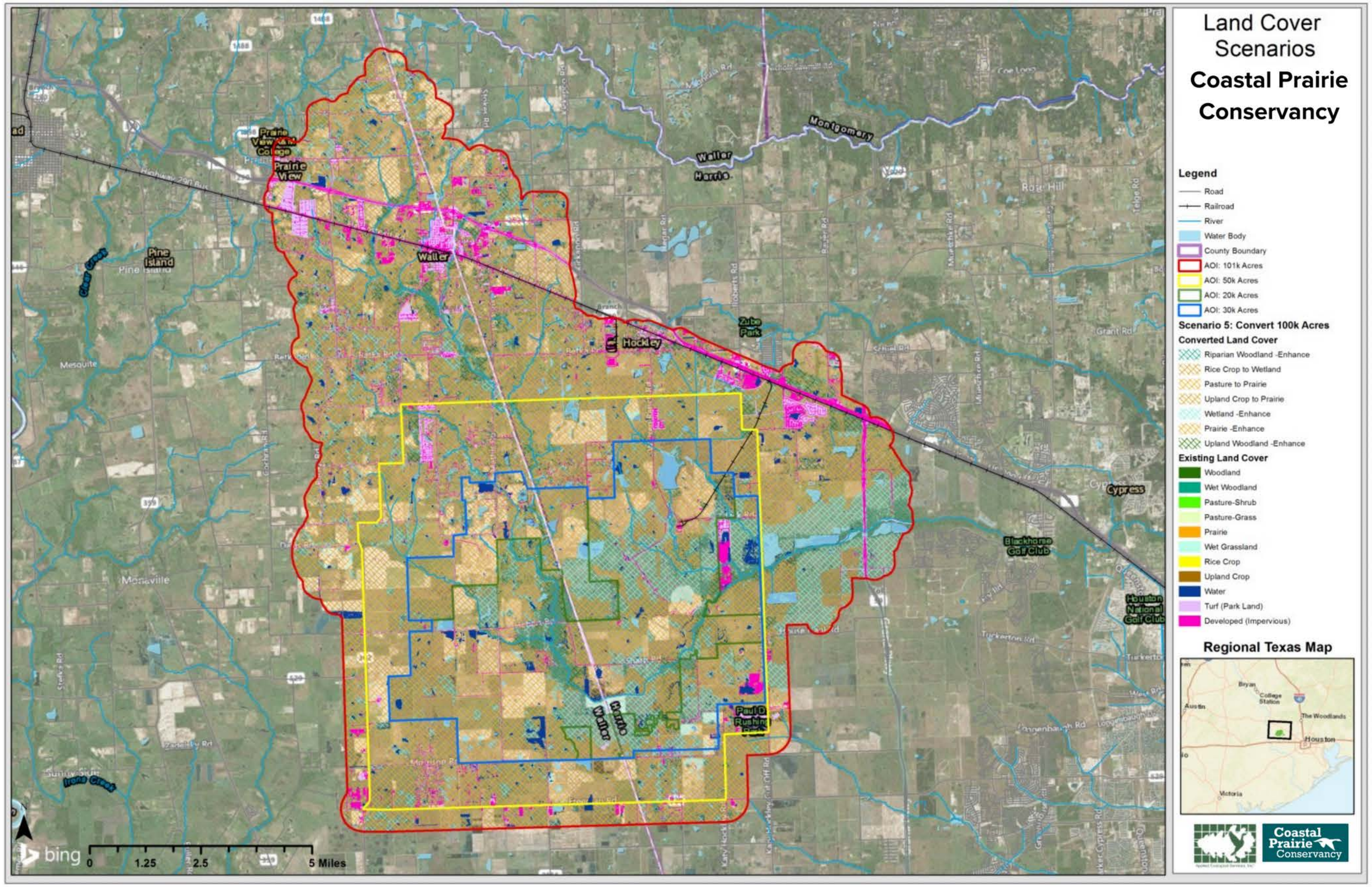
APPENDIX 5-4. SCENARIO 3: 30,000-ACRE CONVERSION MAP



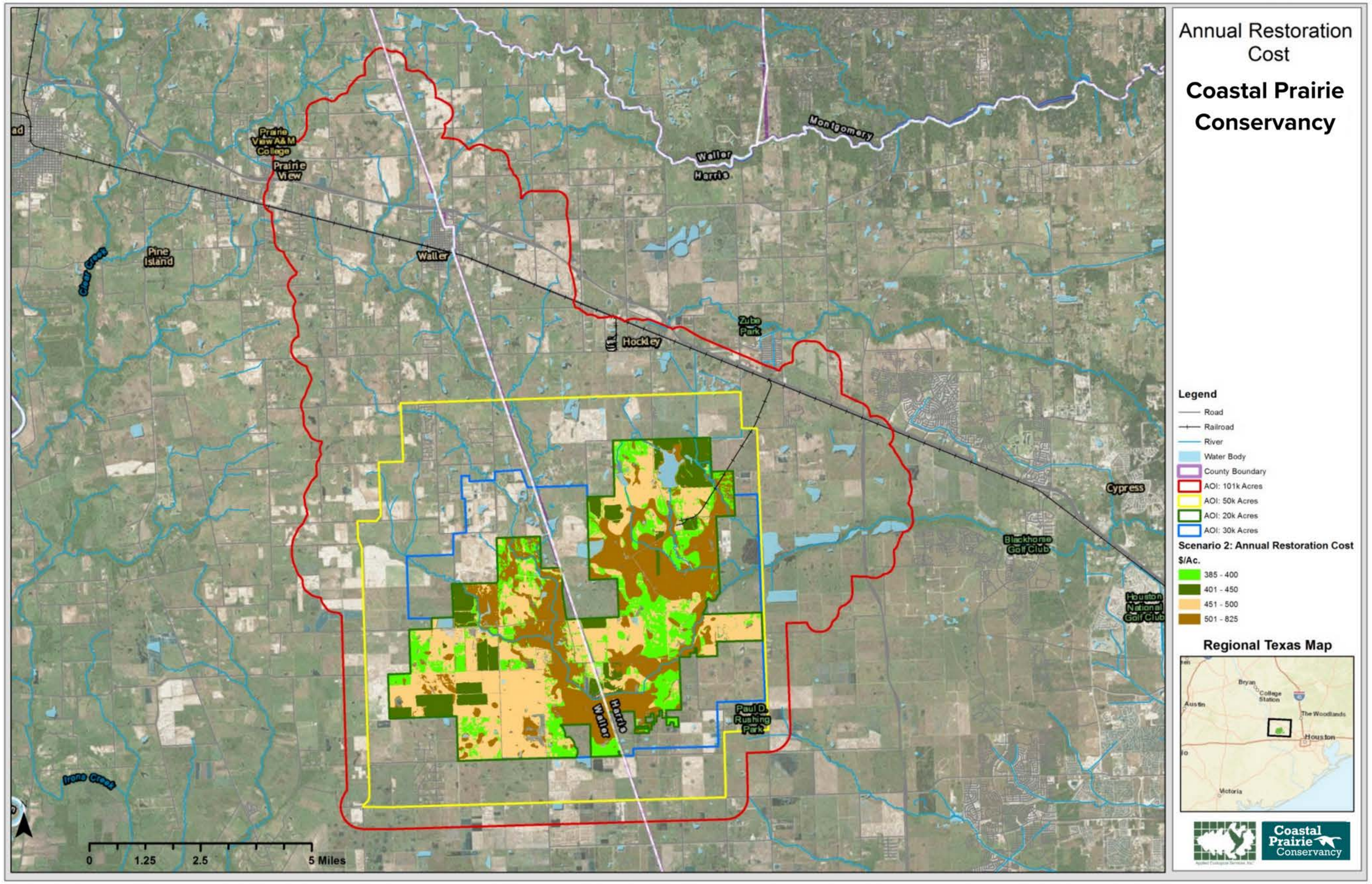
APPENDIX 5-5. SCENARIO 4: 50,000-ACRE CONVERSION MAP



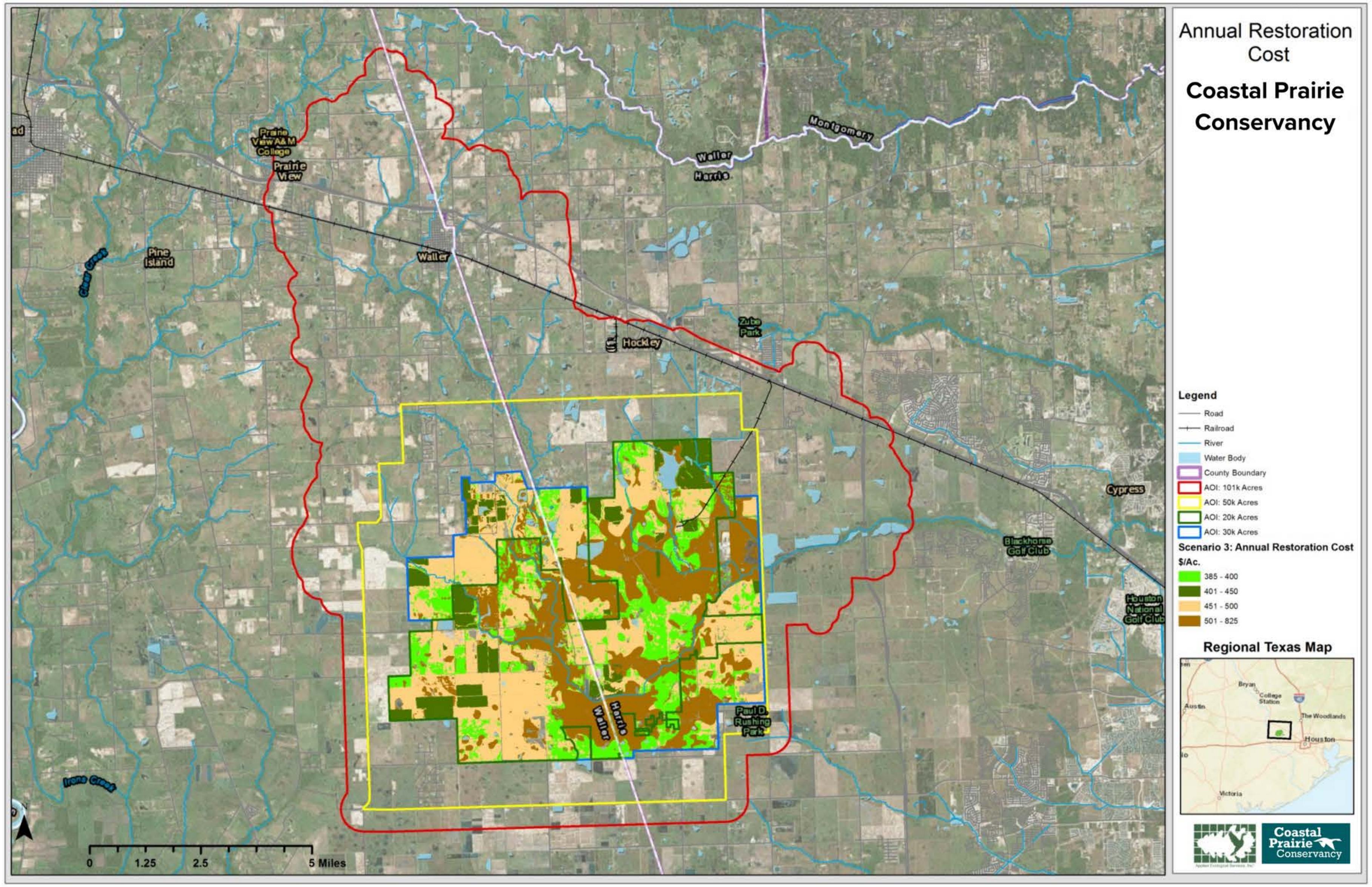
APPENDIX 5-6. SCENARIO 5: 101,000-ACRE CONVERSION MAP



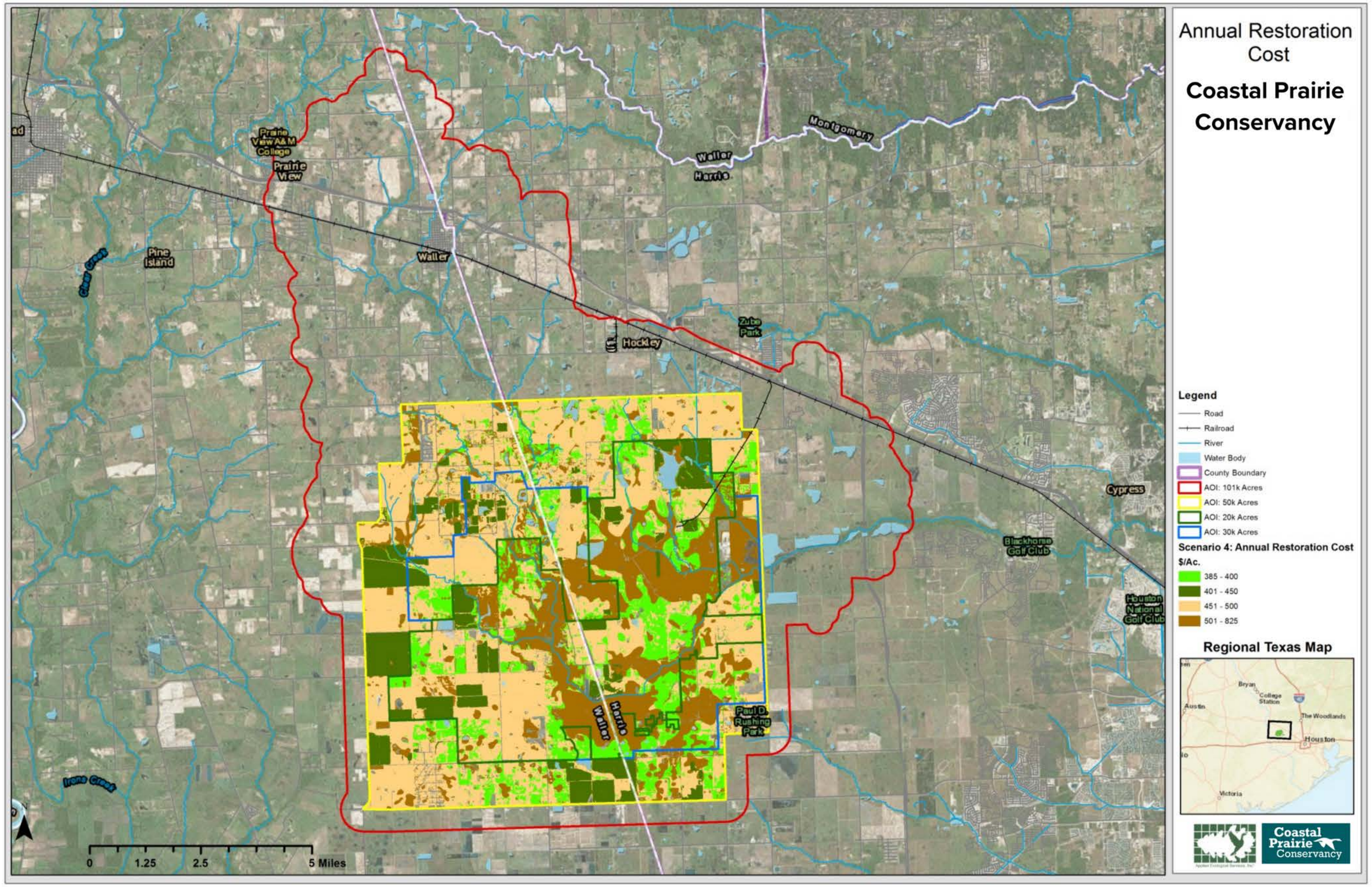
APPENDIX 5-7. SCENARIO 2: ANNUAL RESTORATION COSTS



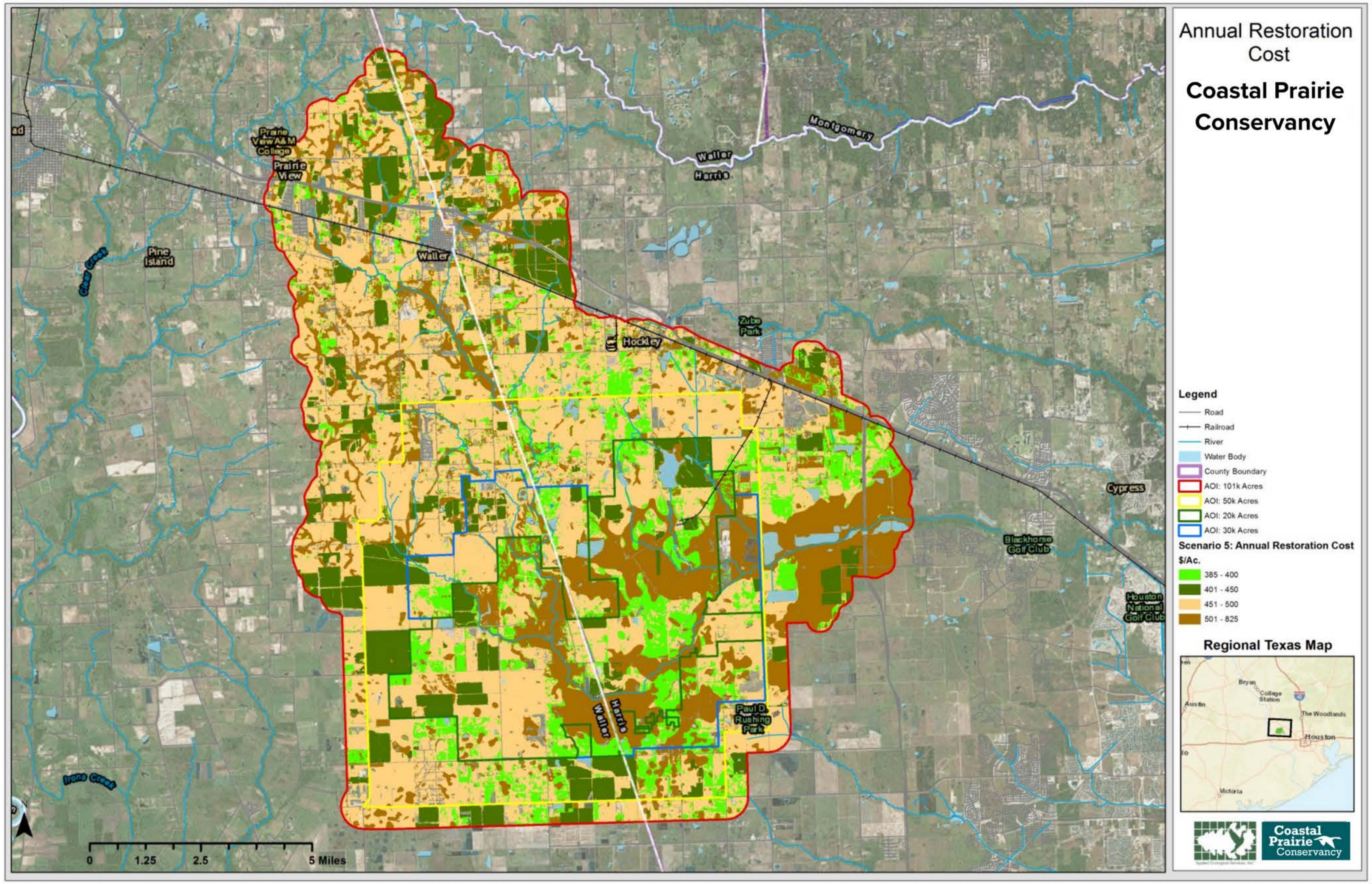
APPENDIX 5-8. SCENARIO 3: ANNUAL RESTORATION COSTS



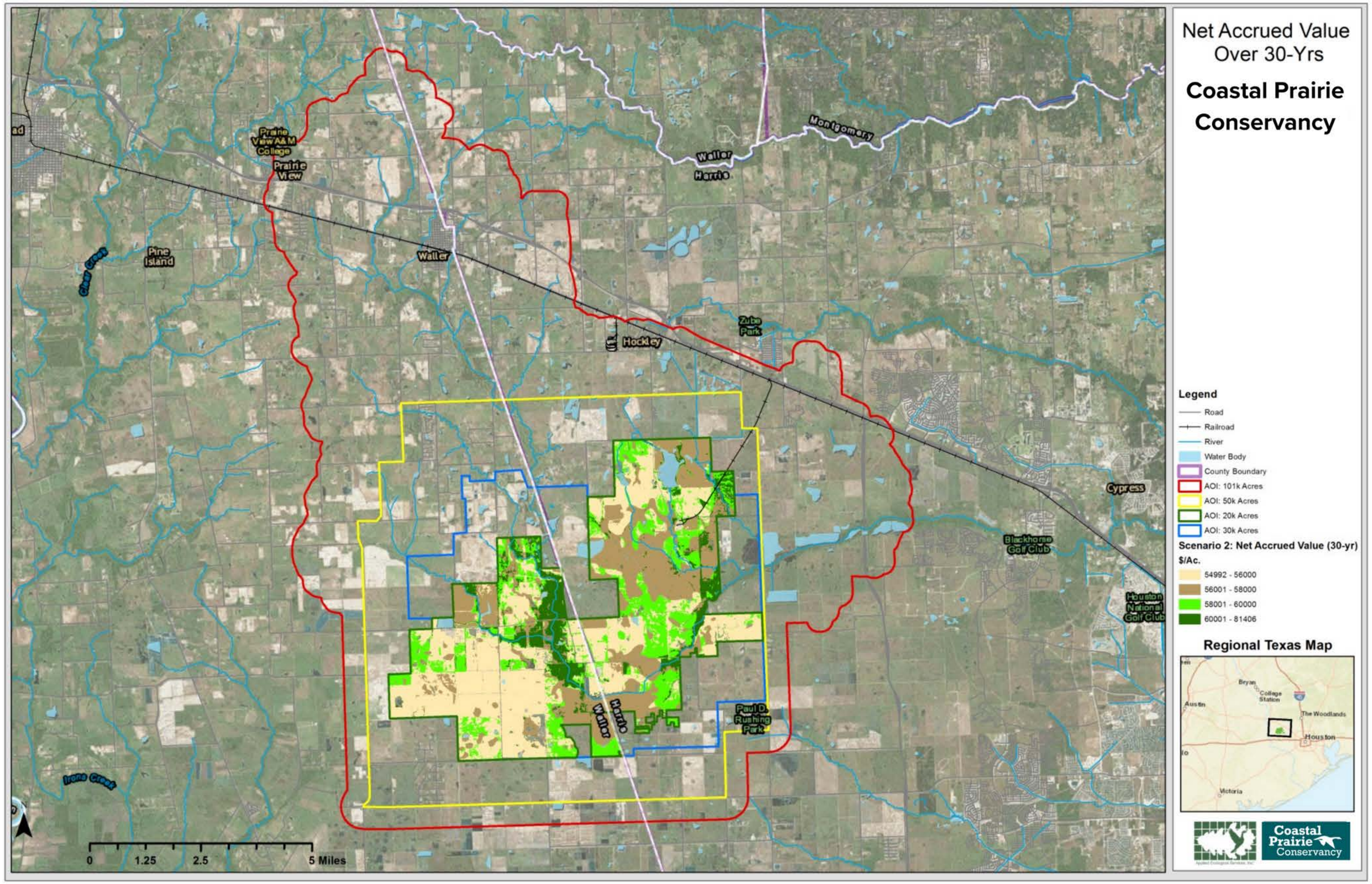
APPENDIX 5-9. SCENARIO 4: ANNUAL RESTORATION COSTS



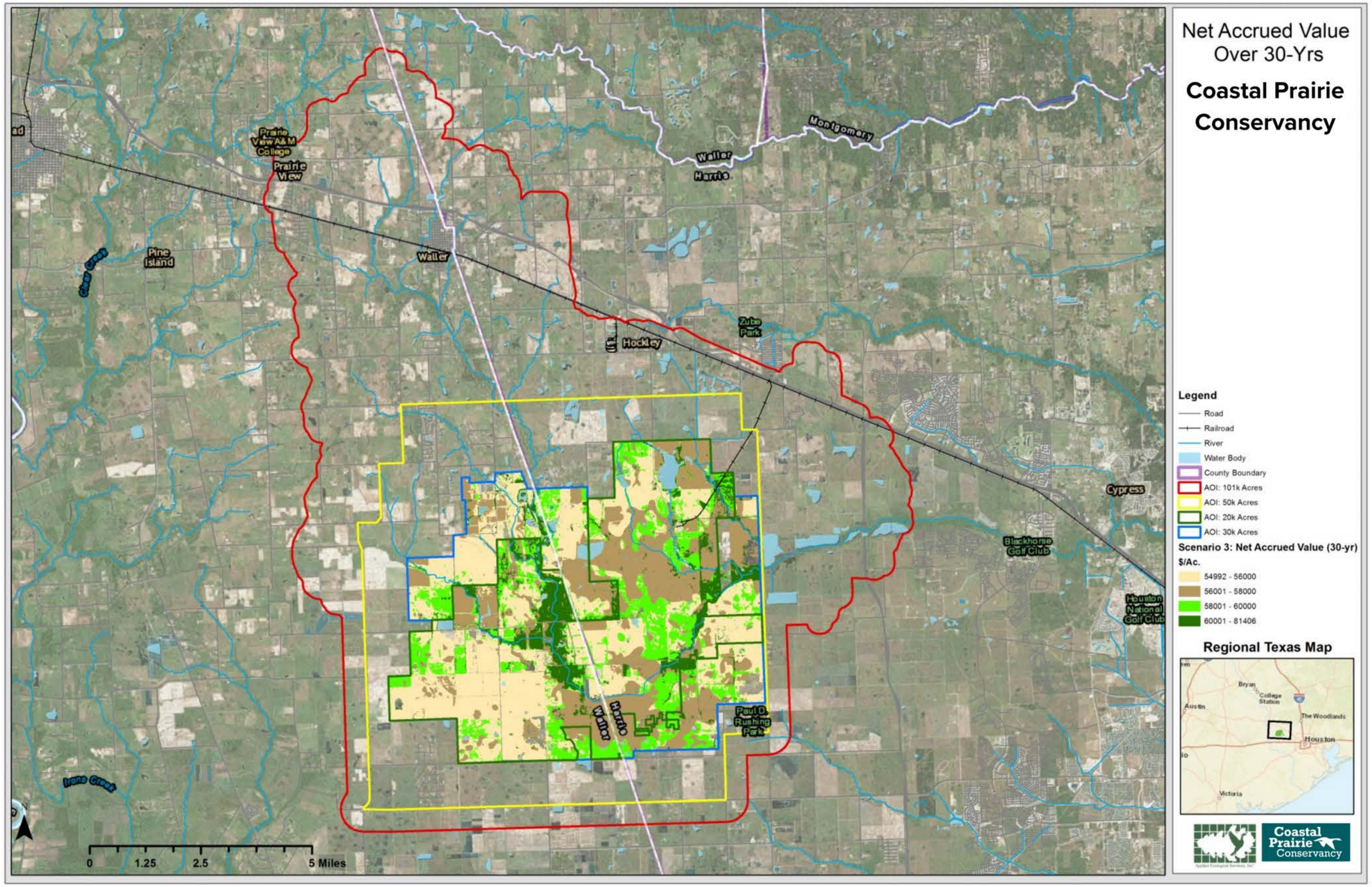
APPENDIX 5-10. SCENARIO 5: ANNUAL RESTORATION COSTS



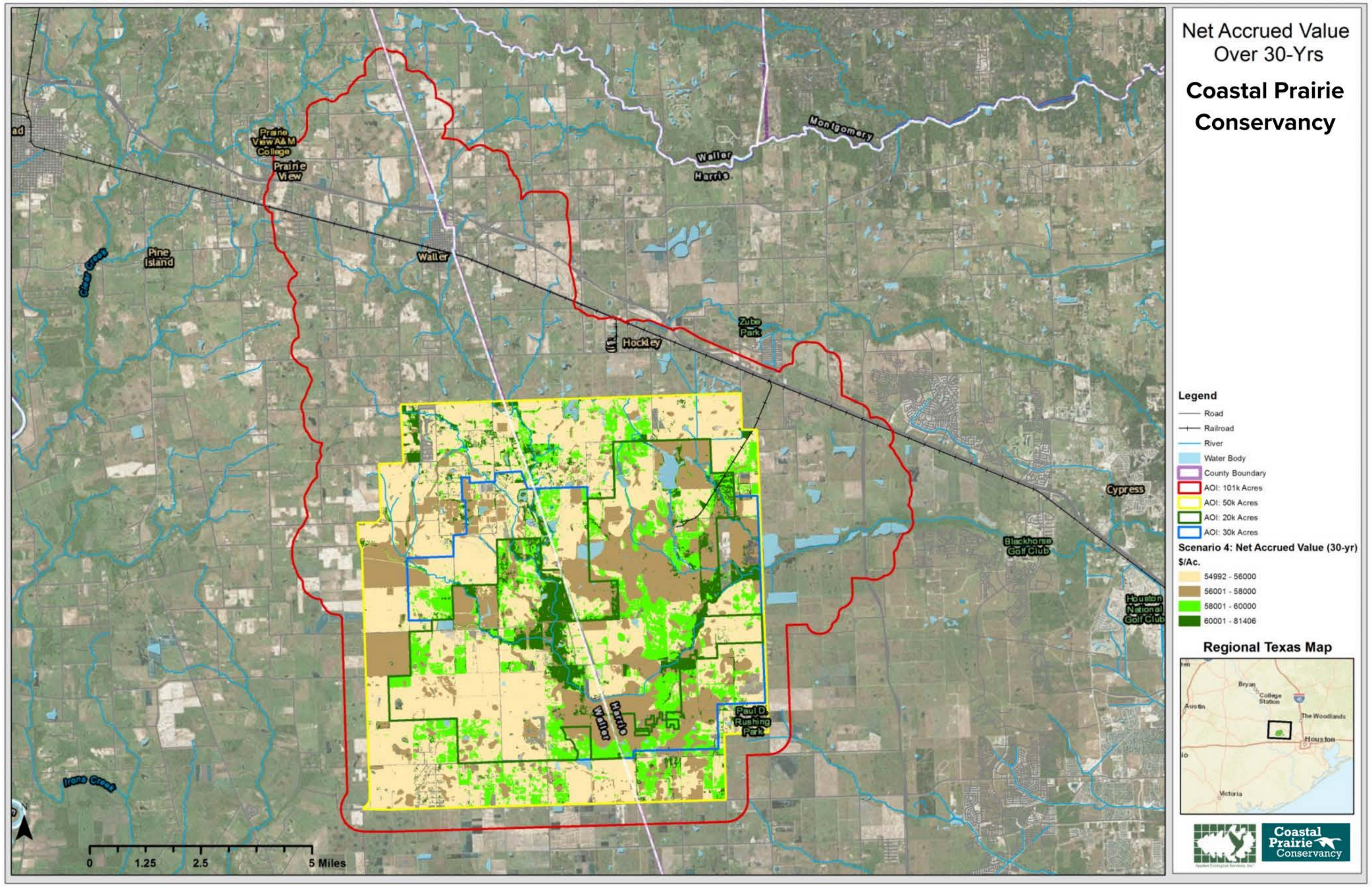
APPENDIX 5-11. SCENARIO 2: 30-YEAR ACCRUED ECOSYSTEM SERVICE VALUES



APPENDIX 5-12. SCENARIO 3: 30-YEAR ACCRUED ECOSYSTEM SERVICE VALUES



APPENDIX 5-13. SCENARIO 4: 30-YEAR ACCRUED ECOSYSTEM SERVICE VALUES



APPENDIX 5-14. SCENARIO 5: 30-YEAR ACCRUED ECOSYSTEM SERVICE VALUES