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# Chapter 7 – Long-Term Protection of the State's Water Resources, Agricultural Resources and Natural Resources

The Region H Water Planning Group balanced meeting water needs with good stewardship of the water, agricultural and natural resources within the region. The RHWPG recommended water conservation as the first strategy applied to meet every projected shortage. In the strategy selection process, the yield and environmental impact of projects were given greater consideration than the unit cost of water.

In this plan, existing in-basin supplies are fully utilized prior to recommending new water supply projects or interbasin transfers. In the new interbasin transfer strategies, only the minimum amount of water supply required to meet the projected demands is recommended. Wastewater reuse is a recommended strategy in Harris County as an alternative to the importation of additional water supplies.

The RHWPG believes that local groundwater conservation districts are best-suited to manage groundwater resources in which the individual districts have the responsibility to regulate. This plan recommends using groundwater up to the local sustainable yield or to the restrictive limit established under subsidence district regulations, to meet local demands, but does not recommend the exportation of groundwater from its county of origin.

The affects of the recommended water management strategies on specific resources are discussed in further detail within this chapter.

## 7.1 Water Resources within Region H

Water resources available by basin within Region H are discussed in further detail below.

### 7.1.1 Neches-Trinity Coastal Basin

The Neches-Trinity Coastal Basin has numerous creeks and bayous which flow into East Bay. Many of these creeks and bayous provide water for irrigation and it is expected that this irrigation use will continue. Additional supplies are transferred into the Neches-Trinity Basin by the Lower Neches Valley Authority (water from the Sam Rayburn Reservoir – B.A. Steinhagen Lake System) and by the Chambers-Liberty Counties Navigation District (CLCND) (water from the Trinity River). This plan recommends the reallocation of existing supplies before increasing the transfer of water from the Trinity to meet the projected demands. Additional supplies from the Trinity are not recommended, which will affect the return flows location within Galveston Bay. No other impacts by these strategies are foreseen.

Groundwater supplies within the Neches-Trinity Basin come from the Gulf Coast Aquifer. The plan reflects using but not exceeding the sustainable yield of the aquifer in this basin.

### 7.1.2 Trinity River Basin

The Trinity River serves both Regions C and H. Within Region H, the Lake Livingston-Wallisville Saltwater Barrier System represents one half of the available surface water supply. This plan recommends using approximately 95% of the firm yield of this system, in addition to the full use of all

water rights below the Lake. Achieving the full yield of Lake Livingston is dependent upon return flows from the upper basin. Region C is recommending wastewater reuse as a water management strategy (WMS) in the upper basin, which will limit these flows, but is also recommending the import of new supplies into the upper basin. As discussed in *Chapter 3* and *Appendix 3C*, return flows from the upper basin are projected to decrease from 2020 to 2040 due to increased reuse. As demands in the upper basin increase in 2050 and 2060, return flows are projected to rise. In combination, the upper basin additional supply and reuse strategies should have a long-term neutral effect on the Lake Livingston supply.

This plan recommends transferring much of the Trinity River supply west into the adjacent coastal basin and the San Jacinto Basin. This will result in decreased flows in the lower Trinity Basin during drought periods. Senior water rights below Lake Livingston are protected by the Lake's operating rules. Return flows from these transfers will still reach Galveston Bay, but will return via the San Jacinto Basin.

Groundwater in the lower Trinity Basin predominantly comes from the Gulf Coast Aquifer as well as from the Carrizo-Wilcox, the Sparta, the Queen City and the Yegua-Jackson Aquifers. The plan reflects using but not exceeding the sustainable yield of the Gulf Coast Aquifer in this area. In addition, the other aquifers are only used to meet local demands. The export of groundwater from its source county is not recommended in this plan.

### 7.1.3 Trinity-San Jacinto Coastal Basin

The Trinity-San Jacinto Coastal Basin is relatively small, with Cedar Creek being the most significant stream. There are several surface water rights for irrigation within the basin along with a substantial saline water right for cooling water from Galveston Bay. Both of these uses are expected to continue throughout the planning period. This plan recommends the reallocation of existing supplies before increasing the transfer of water from the Trinity River to meet the projected demands, which will affect the return flows location within Galveston Bay. No other impacts from the transfers are foreseen.

The groundwater supply source within this basin is the Gulf Coast Aquifer. The plan reflects using but not exceeding the sustainable yield of the aquifer in this basin. In Harris County, the Harris-Galveston Subsidence District regulations further restrict the use of groundwater to address land subsidence. These groundwater pumpage restrictions are reflected in the plan.

### 7.1.4 San Jacinto River Basin

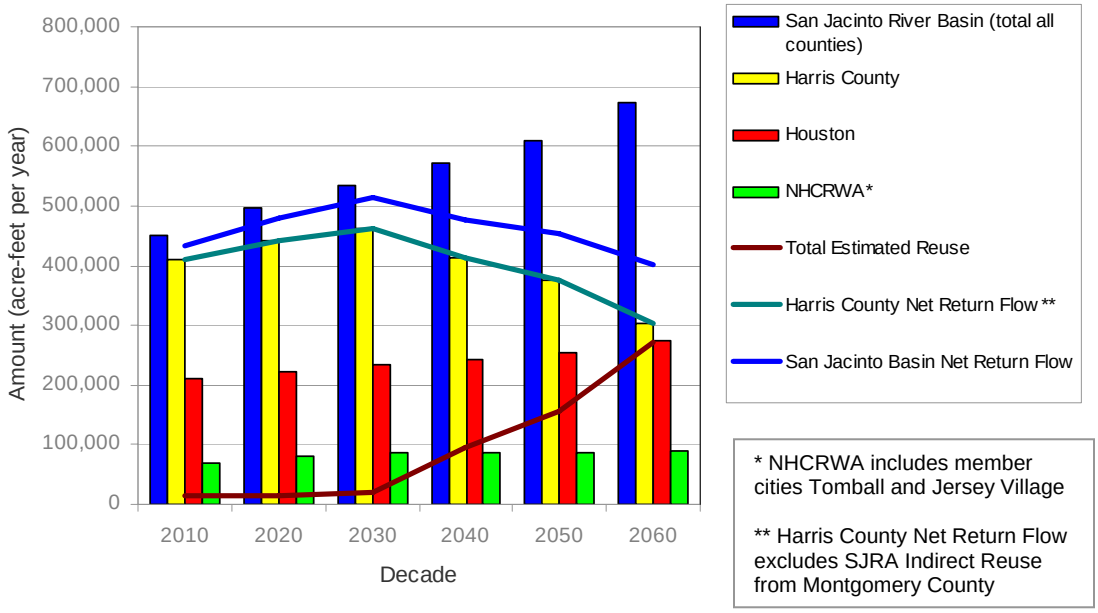
The San Jacinto River Basin contains Lakes Houston and Conroe. These reservoirs make up approximately one tenth of the total surface water available in the region. This plan recommends fully utilizing the yield of these reservoirs and other surface water rights within the San Jacinto Basin. In addition, the plan calls for the interbasin transfer of supply from the Trinity River to meet projected demands. Full use of the existing water rights will reduce stream flows during drought conditions. However, this will be mitigated by increased return flows and return flows from imported supply.

Wastewater reuse is a recommended water management strategy in Harris County. An estimate of municipal return flows throughout the planning period is shown in *Figure 7-1*, below, and detailed in *Appendix 7D*. Wastewater Reuse for Industry is recommended to begin by year 2060. The impact of initially diverting this reuse supply may be mitigated by tidal effects in the stream segment where the water is currently discharged. The brine produced by the additional treatment process will be discharged into the Houston Ship Channel, impacting the salinity in the brackish zone. Further investigation will be required to determine the full environmental impacts of the brine discharge. Reuse projects associated with local Groundwater Reduction Plans (GRPs) are expected to begin as early as 2010. Municipal Non-potable Reuse is recommended by 2030. Houston and NHCRWA Indirect Wastewater Reuse strategies are recommended to begin as early as year 2040. Municipal water demand in Harris County is expected to almost double during the planning period, and the

recommended reuse volume from the San Jacinto Basin is projected to be approximately 40% of the potential available municipal discharge. This indirect reuse is not expected to be implemented all at once, but rather as a series of small projects over several decades. Therefore, no shock effect of a new large diversion will be realized, and return flows in the San Jacinto Basin will remain near the year 2010 levels.

**Figure 7-1**

**Estimated Municipal Return Flows and Reuse**




The groundwater supply source in the San Jacinto Basin is the Gulf Coast Aquifer. The current regional water plan reflects using but not exceeding the sustainable yield of the aquifer in this basin. In Harris County, the Harris-Galveston Subsidence District regulations further restrict the use of groundwater to address land subsidence. These groundwater pumpage restrictions are reflected in the plan.

## 7.1.5 San Jacinto-Brazos Coastal Basin

The San Jacinto-Brazos Coastal Basin encompasses all of Galveston County, most of Brazoria County, and portions of Harris and Fort Bend Counties. The coastal basin contains numerous streams and bayous which flow into Galveston Bay and West Bay. Major bayous contributing to Galveston Bay include Clear Creek, Dickinson Bayou and Chocolate Bayou. Bastrop Bayou, located at the western edge of the basin, flows into Christmas Bay. There are numerous surface water rights for irrigation, mining and manufacturing within the basin and these uses are expected to continue throughout the planning period. Water from the Brazos River is transferred into the coastal basin to meet current demands. The Gulf Coast Water Authority (GCWA) maintains and operates canals and off-channel reservoirs within the coastal basin.

This plan recommends increasing the transfer of water from the Brazos to meet the projected growth in demands of Brazoria and Galveston Counties, which will increase the return flows to Galveston Bay. The GCWA Off-channel Reservoir, which would be located in Brazoria County, is a recommended strategy, and would store water from the existing GCWA canal systems. The reservoir will not require a new water right permit and will add efficiency to the GCWA canal system. The

project would likely have a minimal impact on seasonal low flows in the Brazos River, since diversions from the Brazos would be limited by existing permits. The Fort Bend County Off-channel Reservoir and the Brazoria County Off-channel Reservoir are recommended to meet demands in Brazoria, Fort Bend and Galveston counties beginning in 2030. The projects would divert peak flows reducing the net flow through the basin but will have limited impact on seasonal low flows.

Finally, seawater desalination is included as a recommended strategy to meet manufacturing demands in Brazoria County. This strategy will meet a portion of the demands and will potentially increase stream flows, since the return flows from desalination are not associated with a diversion from the source streams. No other surface water impacts are foreseen.

The groundwater supply source in the San Jacinto Basin is the Gulf Coast Aquifer. The plan reflects using, but not exceeding the sustainable yield of the aquifer in this basin. In Fort Bend, Galveston and Harris Counties, regulations enacted by the Fort Bend Subsidence District and the Harris-Galveston Subsidence District further restrict the use of groundwater to address land subsidence. These groundwater pumpage regulations are reflected in the plan.

### 7.1.6 Brazos River Basin

The Brazos River Basin is the second largest basin in the state (after the Rio Grande), primarily serving Regions O, G and H. The Brazos River Authority operates a system of reservoirs within the middle and upper basin, which provide a portion of the lower basin supply. There are also numerous water rights on the Brazos River and its tributaries which provide water for municipal, manufacturing, irrigation, mining and steam electric power uses. This plan recommends full use of the existing water rights in the lower basin as well as developing new sources of supply.

The Brazos River Authority has identified additional yield that can be realized by operating their reservoirs as a system. This strategy would allow the Brazos River Authority to divert interruptible flows to meet customer needs when these flows are available in lieu of releasing water from reservoir storage. During drought periods, more stored water would then be available, thus increasing the total yield of the Brazos River Authority system. This WMS will reduce the peak flows in the lower Brazos due to the increase in diversions. However, when base flows are below the median value, the BRA would release flows to meet customer demands. This would result in increased flows in the river segments above the customer diversion points, and should have no effect below those diversions.

Four new off-channel reservoirs are included in the 2011 Plan as recommended water management strategies. The recommended strategies include Allens Creek, located in Austin County, the Brazoria County Off-channel Reservoir, the Fort Bend County Off-channel Reservoir and the Dow Off-channel Reservoir. The Dow Off-channel Reservoir will store water diverted using Dow Chemical's existing water rights and will be used to meet manufacturing demands in Brazoria County. The three remaining off-channel reservoirs will divert peak flows in the Brazos Basin. The Little River Off-channel Reservoir, located in Milam County, would divert flows from the Little River in the Brazos Basin. This off-channel reservoir is an alternative strategy in the 2011 RWP. The Little River Off-channel Reservoir would divert peak flows when the source stream is above a set base flow. This will reduce the net flow within the basin, but the impacts during drought or seasonal low flow periods would be limited.

As discussed in the San Jacinto-Brazos coastal basin description above, seawater desalination is included in the plan as a recommended strategy in Brazoria County. This would meet a portion of the manufacturing demands within the lower basin, and may be expanded in the future to meet increased demands. The increase in return flows from this source will mitigate, but not remedy, the reduction in base flows due to full use of water rights in the basin.

To protect water quality in the lower Brazos Basin, particularly at the diversion points serving the southwestern portion of Brazoria County, the construction of a saltwater barrier is recommended.

The Brazos River is the only river basin in Region H not protected from the seasonal tidal influence of saltwater by a saltwater barrier or other impoundment structure. Basin salinity modeling performed by the TWDB has shown that the saltwater influence will move further upstream under full use of water rights. This project will mitigate that effect and still allow flows to pass into the small Brazos River estuary.

Groundwater within this basin predominantly comes from the Gulf Coast Aquifer, as well as the Carrizo-Wilcox, the Brazos Alluvium, the Sparta and the Queen City Aquifers. The plan reflects using but not exceeding the sustainable yield of the Gulf Coast and Brazos Alluvium Aquifers in this area. The Carrizo-Wilcox, the Sparta and the Queen City Aquifers are only used to meet local demands. The export of groundwater from its source county is not recommended in this plan. In Fort Bend County, regulations enacted by the Fort Bend Subsidence District further restrict the use of groundwater from the Gulf Coast Aquifer to address land subsidence. These regulations are reflected in the plan.

### 7.1.7 Brazos-Colorado Coastal Basin

The Brazos-Colorado Coastal Basin contains the San Bernard River and its tributary streams. There are several surface water rights along the San Bernard River for manufacturing and irrigation uses. Both of these uses are expected to continue. However, there is a surplus in manufacturing water available. This plan recommends allocating a portion of the manufacturing surplus to meet the mining demand within the coastal basin. The remaining surplus of manufacturing water will remain with the water right holder. Municipal demands are supplied surface water from the Brazos River. No net change to basin flows is expected.

The groundwater supply source in San Jacinto Basin is the Gulf Coast Aquifer. The plan reflects using but not exceeding the sustainable yield of the aquifer in this basin.

## 7.2 Agricultural Resources within Region H

Region H has approximately 4,000,000 acres of land in farms, with about one third of that land in production during any given year. Although this has remained constant over the past two decades, the crops and water usage within those farms has changed. Sugar Land is no longer surrounded by its namesake cane fields, and the Imperial Sugar Mill in that town closed its doors in 2004.

Data from the USDA Census of Agriculture is provided in *Appendix 7A*. The data shows that since 1987, irrigated acreage within Region H has declined by 45%. This decline is driven by economic factors, but the cost of water is among them. Rice, which is the most water-intensive crop raised in the region, has declined in price in recent years. Therefore, the rice price reduction has driven the reduction in irrigation. A rise in price could easily halt the decline in the irrigation demand.

Additionally, the region has approximately 1.55 million acres of productive timberland. This has declined by approximately 36,000 acres over the past decade. Rural land data obtained from the Texas Cooperative Extension at Texas A&M University is also provided in *Appendix 7A*. It indicates that rural land use is increasing in the northern portion of the region, while decreasing in Montgomery and the southern counties due to urbanization. In many counties, native rangeland is being converted to improved, non-irrigated pasture.

This plan holds the projected irrigation demand fairly constant over the planning period, declining from 450,175 acre-feet per year in 2010 to 430,930 acre-feet per year in 2060 (a change of under 5 percent, and consistent with the observed development patterns in the southern half of the region). Region H is able to meet those demands from a combination of existing supplies, and recommended interruptible supplies from existing sources, conservation, Allens Creek Reservoir and off channel reservoir projects in Fort Bend and Brazoria counties. The need for financial assistance to realize the conservation goal is addressed in *Chapter 8* under legislative recommendations. Providing

interruptible water is expected to preserve local agricultural resources by providing irrigators with water at a cheaper rate when surface water supplies are available. Many irrigators in Region H, specifically those in Brazoria County, contract water on a year-to-year basis. The water provided under these contracts is generally less expensive than contracts for firm water supplies. To reflect the economics of irrigation water supplies in Brazoria County, an interruptible water supply strategy was developed to meet irrigation demands that typically contract irrigation water on a year-to-year basis.

## 7.3 Natural Resources within Region H

Region H contains many natural resources, and the WMS recommended in this plan are intended to protect those resources while still meeting the projected water needs of the region. The impacts of recommended strategies on specific resources are discussed below.

### 7.3.1 Threatened and Endangered Species

Region H has abundant habitat areas within the Sam Houston National Forest, the Big Thicket Nature Preserve, several National Wildlife Refuges, and significant undeveloped areas. Numerous native and migratory species live within these habitats, including over ten threatened and endangered aquatic species (listed in *Appendix 7B*).

The water management strategies (WMS) recommended in this water plan will have some impacts upon wetlands habitats. In the 2006 Region H Water Plan, two reservoir projects were recommended. The Little River Off-channel Reservoir, located within the Little River watershed, and Allens Creek Reservoir, both with the potential to impact wetlands habitat. However, the potential impacts at these proposed sites are less than on the main stem of a river. In the current plan, the Fort Bend and Brazoria Off-channel Reservoirs have replaced the Little River Off-channel Reservoir to increase the future surface water supply in the Brazos. The Little River Off-channel Reservoir is still included in the plan as an alternative strategy. At the Allens Creek site in Austin County, habitats for the White-faced Ibis, Wood Stork and Houston Toad may be inundated and require mitigation. It should be pointed out that the Allens Creek project was modified by the project sponsor to avoid impacting Alligator Hole, a wetland segment adjacent to the project site. The current plan includes the Allens Creek Reservoir as a recommended water management strategy. Although the Brazoria and Fort Bend Off-channel reservoir sites have not been defined, it is anticipated that these strategies may inundate wetland and endangered species habitats requiring mitigation.

The transfer of supply from Lake Livingston into the San Jacinto Basin is recommended in this plan. While the recommended amount is less than the full yield of the reservoir, it will still impact the lake level during dry periods as well as wetlands along the periphery of the reservoir. Habitats for the Wood Stork and Alligator Snapping Turtle may be affected during drought periods, but no permanent impacts to these habitats are foreseen.

The recommended conveyance from the Trinity to the San Jacinto Basin is the Luce Bayou Transfer. This project includes a pump station, pipeline, 23.6 miles of canal and an outfall into Lake Houston. The current alignment will disturb undeveloped forest areas near the Trinity River, farm lands, and more developed areas near Lake Houston. By limiting the use of bed and banks conveyance, the current Luce Bayou strategy attempts to minimize impacts on wetlands and avoid them wherever possible.

Texas Parks and Wildlife Department Resource Protection Division prepared an evaluation of the WMS considered in the 2001 Region H Plan. That assessment, which is the most recent available, addresses terrestrial species as well as the aquatic species addressed above, and is included as *Appendix 7C*.

### 7.3.2 Parks and Public Lands

As described in *Chapter 1*, Region H contains over 325,000 acres of state and national forests, over 107,000 acres of coastal wildlife refuges, and over 12,000 acres of Texas wildlife management areas. The RHWPG was fortunate that none of the recommended strategies required water supply projects within or conveyances through these areas. The transfer of supply from Lake Livingston into the San Jacinto basin has the potential to reduce flows through the Trinity River National Wildlife Refuge during drought periods. The transfer may also include an interbasin pipeline route potentially impacting lands in the Sam Houston National Forest (SHNF) increasing possible environmental impacts from construction and maintenance activities.

### 7.3.3 Impacts of Water Management Strategies on Unique Stream Segments

Region H recommended eight stream segments for designation as unique in the 2006 Water Plan. The streams recommended were:

- Armand Bayou in Harris County
- Austin Bayou in Brazoria County
- Bastrop Bayou in Brazoria County
- Big Creek in Fort Bend County
- Big Creek in San Jacinto County
- Cedar Lake Creek in Brazoria County
- Menard Creek in Polk and Liberty Counties
- Oyster Bayou in Chambers County

All of these segments occur within riparian conservation areas, and there are no water management strategies that divert additional water from or above these streams. Additionally, terrestrial strategies such as brush control or salt cedar removal are not recommended within Region H, so the riparian habitats should not be affected. Finally, there is some concern that overuse of groundwater would impact spring flows within the Sam Houston National Forest. Region H does not recommend the export of groundwater from any county, and encourages the formation of groundwater conservation districts to actively manage these resources. The western portion of the National Forest lies in Walker and Montgomery Counties, which both have active groundwater conservation districts. The southern portion of the National Forest is in San Jacinto and Liberty Counties, which are currently working towards forming a groundwater conservation district.

The current unique stream segments and an analysis of all proposed stream segments is provided in *Chapter 8*.

### 7.3.4 Impacts of Water Management Strategies on Galveston Bay

The Galveston Bay estuary is arguably the most significant natural resource within Region H, providing habitat for a rich diversity of permanent and migratory species, recreational and tourism use, employment for fisherman and the tourism industry, and serves as the gateway to the second busiest port in the U.S.

As discussed in *Chapter 4*, Galveston Bay is affected by the water plans for both Region C (in the Upper Trinity River Basin) and for Region H (in the Lower Trinity and San Jacinto River Basins. The Galveston Bay Freshwater Inflows Group has defined target frequencies for inflows to the estuary, based upon salinity and harvest models developed by the TCEQ and TPWD. In 2008, the Region H

Planning Group authorized a study to analyze the impact of individual strategies on Bay and Estuary (B&E) inflows from individual water management strategies. The study analyzed the impacts on inflows to Galveston Bay and instream flows to identify the impacts from future strategies. The effects of the 2006 Regional Water Plans on the Bay are summarized in *Table 7-1*below. While the table indicates that the combined plans will maintain overall flows into Galveston Bay, it does not reflect the change in inflow locations. The transfer of water from the Trinity River Basin into the San Jacinto basin will relocate return flows from Trinity Bay to Upper Galveston Bay. This may have some impact on the oyster beds located within Trinity Bay. The increase of flows into Upper Galveston Bay should be less of a concern, because that flow will occur in the Houston Ship Channel (a dredged channel that is significantly deeper than the rest of the estuary). As a continuation of the environmental flows investigation performed in 2008, the impact of water management strategies on bay and estuary inflows was analyzed on a decadal basis. The decadal environmental flows investigation is presented in *Chapter 4*.

**Table 7-1**

**Overall Frequencies of Meeting Monthly Inflow Targets**

| Inflow Target | Max H | Min Q | Min Q-Sal |
|---|---|---|---|
| Historical Frequency | 66% | 78% | 82% |
| GBFIG Target Frequency | 50% | 60% | 75% |
| Naturalized Flow | 68% | 67% | 83% |
| Existing Diversions with Full Return Flows | 63% | 58% | 79% |
| Full Authorized Diversions with Return Flows | 59% | 53% | 75% |
| Full Authorized Diversions with no Return Flows | 43% | 43% | 56% |
| Future 2060 Conditions with Return Flows and all Recommended WMS | 62% | 59% | 77% |

### 7.3.5 Energy Reserves

Oil, gas and other energy reserves are considered natural resources of the state. While Region H is home to a large portion of the nation's petrochemical industry, the amount of actual oil and gas mining within Region H is small compared to other portions of the state. In this plan, Region H was able to identify reliable supplies to meet all projected mining and manufacturing demands throughout the planning period. No adverse affect on this resource is foreseen.

# Agricultural Census Data

The Data presented on the following tables was obtained from the U.S. Department of Agriculture, National Agricultural Statistics Service.

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# Threatened and Endangered Species within Region H

Listed below are the state- and federally-listed aquatic threatened and endangered aquatic species within Region H, by county. A description of each threatened and endangered species is listed on the following pages.

| Species | County | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Austin County | Brazoria County | Chambers County | Fort Bend County | Galveston County | Harris County | Leon County | Liberty County | Madison County | Montgomery County | Polk County | San Jacinto County | Trinity County | Walker County | Waller County |
| **Alligator Snapping Turtle** | X | X | X | X | X | X | X | X | X | X | X | X | | X | X |
| **American Peregrine Falcon** | X | X | X | | X | X | X | X | X | X | X | X | X | X | X |
| **Artic Peregrin Falcon** | X | X | X | | X | X | X | X | X | X | X | X | | X | X |
| **Atlantic Hawksbill Sea Turtle** | | X | X | | X | X | | | | | | | | | |
| **Bald Eagle** | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X |
| **Black Rail** | | X | | | X | X | | | | | | | | | |
| **Brown Pelican*** | | X | X | | X | X | | | | | | | | | |
| **Corkwood** | | X | X | X | | | | | | | | | | | |
| **Correll's false dragon-head** | | | | | X | | | | | X | | | | | |
| **Creek Chubsucker** | | | | | | | | X | | X | X | X | X | X | X |
| **Green Sea Turtle** | | X | X | | X | X | | | | | | | | | |
| **Houston Toad** | X | | | | | X | X | X | X | | | | | | |
| **Interior Least Tern** | X | | X | | | | X | | X | | | | | | X |
| **Kemps Ridley Sea Turtle** | | X | X | | X | X | | | | | | | | | |
| **Leatherback Sea Turtle** | | X | X | | X | X | | | | | | | | | |
| **Loggerhead Sea Turtle** | | X | X | | X | X | | | | | | | | | |
| **Paddlefish** | | | | | | | X | X | X | X | X | X | X | X | |
| **Piping Plover** | | X | X | | X | | | X | | X | X | | X | X | |
| **Reddish Egret** | | X | X | | X | | | | | | | | | | |
| **Sharpnose shiner** | | X | | | | | | | | | | | | | X |
| **Swallow-tailed Kite** | | X | X | | X | | | X | | | X | X | | X | |
| **Timber/Canebrake Rattlesnake** | | | X | X | X | X | X | X | | X | X | X | | X | X |
| **West Indian manatee** | | X | | | | | | | | | | | | | |
| **White-faced Ibis** | X | X | X | X | X | X | | X | | X | | | X | | X |
| **Wood Stork** | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X |

* Delisted in November, 2009 by United States Fish and Wildlife Service

## Description of Threatened and Endangered Species

**Alligator Snapping Turtle (*Macrochelys temminckii*)** - deep water of rivers, canals, lakes, and oxbows; also swamps, bayous, and ponds near deep running water; sometimes enters brackish coastal waters; usually in water with mud bottom and abundant aquatic vegetation; may migrate several miles along rivers; active March-October; breeds April-October

**American Peregrine Falcon *(Falco peregrinus anatum)***- year-round resident and local breeder in west Texas, nests in tall cliff eyries; also, migrant across state from more northern breeding areas in US and Canada, winters along coast and farther south; occupies wide range of habitats during migration, including urban, concentrations along coast and barrier islands; low-altitude migrant, stopovers at leading landscape edges such as lake shores, coastlines, and barrier islands

**Artic Peregrin Falcon *(Falco peregrinus tundrius)***- migrant throughout state from subspecies' far northern breeding range, winters along coast and farther south; occupies wide range of habitats during migration, including urban, concentrations along coast and barrier islands; low-altitude migrant, stopovers at leading landscape edges such as lake shores, coastlines, and barrier islands

**Atlantic Hawksbill Sea Turtle *(Eretmochelys imbricate)-*** Gulf and bay system, warm shallow waters especially in rocky marine environments, such as coral reefs and jetties, juveniles found in floating mats of sea plants; feed on sponges, jellyfish, sea urchins, mollusks, and crustaceans, nests April through November

**Bald Eagle (*Haliaeetus leucocephalus*)** - found primarily near seacoasts, rivers, and large lakes; nests in tall trees or on cliffs near water; communally roosts, especially in winter; hunts live prey, scavenges, and pirates food from other birds

**Black Rail (*Laterallus jamaicensis*)** - salt, brackish, and freshwater marshes, pond borders, wet meadows, and grassy swamps; nests in or along edge of marsh, sometimes on damp ground, but usually on mat of previous year's dead grasses; nest usually hidden in marsh grass or at base of Salicornia

**Corkwood (*Leitneria floridana*)** – small, sparingly-branched, dioecious, deciduous shrub or small tree; forms thickets of stick-like erect stems, the diameter of each at base rarely to 12 or 13 cm; found in narrow zone between brackish marsh and contiguous coastal pine-hardwood; brackish or freshwater swamps or thickets; flowers in spring

**Correll's false dragon-head (*Physostegia correllii*)** – wet soils including roadside ditches and irrigation channels; flowering June-July

**Creek Chubsucker (*Erimyzon oblongus*)** - small rivers and creeks of various types; seldom in impoundments; prefers headwaters, but seldom occurs in springs; young typically in headwater rivulets or marshes; spawns in river mouths or pools, riffles, lake outlets, upstream creeks

**Green Sea Turtle *(Chelonia mydas)* -** Gulf and bay system; shallow water seagrass beds, open water between feeding and nesting areas, barrier island beaches; adults are herbivorous feeding on sea grass and seaweed; juveniles are omnivorous feeding initially on marine invertebrates, then increasingly on sea grasses and seaweeds; nesting behavior extends from March to October, with peak activity in May and June

**Houston Toad (Bufo houstonensis)** - endemic; species sandy substrate, water in pools, ephemeral pools, stock tanks; breeds in spring especially after rains; burrows in soil when inactive; breeds February-June

**Interior Least Tern (*Sterna antillarum athalassos*) –** this subspecies is listed only when inland (more than 50 miles from a coastline); nests along sand and gravel bars within braided streams, rivers; also know to nest on man-made structures (inland beaches, wastewater treatment plants, gravel mines, etc); eats small fish and crustaceans, when breeding forages within a few hundred feet of colony

**Kemps Ridley Sea Turtle *(Lepidochelys kempii)-*** Gulf and bay system, adults stay within the shallow waters of the Gulf of Mexico; feed primarily on crabs, but also snails, clams, other crustaceans and plants, juveniles feed on sargassum and its associated fauna; nests April through August

**Leatherback Sea Turtle *(Dermochelys coriacea)-*** Gulf and bay systems, and wide-ranging open water sea turtle; omnivorous, shows a preference for jellyfish; nests from November to February, but not known to nest in Gulf of Mexico, just forages

**Loggerhead Sea Turtle *(Caretta caretta)-*** Gulf and bay system primarily for juveniles, adults are most pelagic of the sea turtles; omnivorous, shows a preference for mollusks, crustaceans, and coral; nests from April through November

**Paddlefish (*Polyodon spathula*)** - prefers large, free-flowing rivers, but will frequent impoundments with access to spawning sites; spawns in fast, shallow water over gravel bars; larvae may drift from reservoir to reservoir

**Piping Plover *(Charadrius melodus)*** - wintering migrant along the Texas Gulf Coast; beaches and bayside mud or salt flats

**Reddish Egret *(Egretta rufescens)* -** resident of the Texas Gulf Coast; brackish marshes and shallow salt ponds and tidal flats; nests on ground or in trees or bushes, on dry coastal islands in brushy thickets of yucca and prickly pear

**Sharpnose shiner *(Notropis Oxyrhynchus)***- endemic to Brazos River drainage; also, apparently introduced into adjacent Colorado River drainage; large turbid river, with bottom a combination of sand, gravel, and clay-mud

**Swallow-tailed Kite (*Elanoides forficatus*)** - lowland forested regions, especially swampy areas, ranging into open woodland; marshes, along rivers, lakes, and ponds; nests high in tall tree in clearing or on forest woodland edge, usually in pine, cypress, or various deciduous trees

**Timber/Canebrake Rattlesnake *(Crotalus horridus)-*** swamps, floodplains, upland pine and deciduous woodlands, riparian zones, abandoned farmland; limestone bluffs, sandy soil or black clay; prefers dense ground cover, i.e. grapevines or palmetto

**West Indian manatee *(Trichechus manatus)-*** Gulf and bay system; opportunistic, aquatic herbivore

**White-faced Ibis (*Plegadis chihi*)** - prefers freshwater marshes, sloughs, and irrigated rice fields, but will attend brackish and saltwater habitats; nests in marshes, in low trees, on the ground in bulrushes or reeds, or on floating mats

**Wood Stork (*Mycteria americana*)** - forages in prairie ponds, flooded pastures or fields, ditches, and other shallow standing water, including salt-water; usually roosts communally in tall snags, sometimes in association with other wading birds (i.e. active heronries); breeds in Mexico and birds move into Gulf States in search of mud flats and other wetlands, even those associated with forested areas; formerly nested in Texas, but no breeding records since 1960

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# Texas Parks and Wildlife Department

## Analysis of Water Management Strategies

## Recommended in the 2001 Region H Water Plan

The Resource Protection Division of the Texas Parks and Wildlife Department prepared the attached document: Region H Strategies – Preliminary Assessment, Internal Working Memorandum, 2001.

The following changes between the 2001 Region H Plan and this update to the plan should be noted:

- The final impoundment plan for Allens Creek Reservoir, as submitted and approved in the water right application, was changed from the outline included in the 2001 Region H Water Plan. The project footprint was reduced to avoid Alligator Hole.

- Bedias Creek Reservoir and the related Interbasin Transfer from Bedias to Lake Conroe is not a recommended strategy in the 2006 Plan or the 2011 update to the Region H plan.

- Little River Reservoir has been replaced in the 2006 update to the Region H Plan with an off-channel reservoir in the Little River Basin. The Little River Off-channel Reservoir was replaced in the 2011 update to the Region H Plan with off-channel reservoirs in Brazoria and Fort Bend Counties. The Little River Off-channel Reservoir is included in the 2011 Plan as an Alternative Water Management Strategy.

- The SJRA/Lake Livingston Diversion was not a recommended strategy in the 2001 and 2006 Region H Plan.

- The Sabine to Region H Interbasin Transfer was not a recommended strategy in the 2001 and 2006 Region H Plan, nor is it recommended in the 2011 update. It is however, listed as an alternative strategy.

- The COH/GCWA transfer strategy was recommended in the 2006 Region H Water Plan, but is not included in the 2011 Plan Update as a recommended or alternative water management strategy.

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# Estimated Municipal Return Flows and Reuse

To evaluate the effects of recommended reuse strategies on stream-flows, current and future municipal return flows were estimated. Currently, 60% of municipal water supply returns to streams and bayous via wastewater treatment plants. As water saving fixtures reduce in-home use, that return percentage was assumed to decline to 50%. As can be seen in the table, the total municipal wastewater return flow is expected to increase from 605,000 ac-ft/yr in the year 2010 to 922,000 ac-ft/yr in the year 2060. In Harris County and the surrounding areas, these municipal return flows are a significant portion of the in-stream freshwater flow, and for some streams the only source of flows during drought periods.

Wastewater reuse is permitted for the San Jacinto River Authority in Montgomery County, and is recommended in Harris County for industry, the City of Houston, the North Harris County Regional Water Authority, and in smaller volumes for several additional WUGs. Total reuse supplied from return flows in the San Jacinto basin should increase from 14,944 ac-ft/yr in 2010 to 272,582 ac-ft/yr in 2060.

*Table 7D-1* shows the estimated municipal return flows for each county, and for Houston and the NHCRWA, which are recommended for significant future reuse. As can be seen, the net return flow from Harris County will decline as reuse projects come on-line, but not below 70% of the current county return flow. The San Jacinto Basin overall will also see declines in net return flow as reuse projects come on-line, but is not projected to drop below 90% of the current return flow levels.

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| | Municipal Water Demand | | | | | | Estimated Municipal Return Flow | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **2010** | **2020** | **2030** | **2040** | **2050** | **2060** | **2010** | **2020** | **2030** | **2040** | **2050** | **2060** |
| | | | | | | | **58%** | **56%** | **54%** | **52%** | **50%** | **50%** |
| **Counties** | | | | | | | | | | | | |
| Austin | 4,123 | 4,658 | 5,027 | 5,191 | 5,278 | 5,446 | 2,391 | 2,608 | 2,715 | 2,699 | 2,639 | 2,723 |
| Brazoria | 47,184 | 53,523 | 59,656 | 65,134 | 71,567 | 78,598 | 27,367 | 29,973 | 32,214 | 33,870 | 35,784 | 39,299 |
| Chambers | 4,985 | 5,854 | 6,648 | 7,338 | 8,067 | 8,863 | 2,891 | 3,278 | 3,590 | 3,816 | 4,034 | 4,432 |
| Fort Bend | 109,869 | 143,023 | 174,552 | 208,691 | 251,533 | 300,689 | 63,724 | 80,093 | 94,258 | 108,519 | 125,767 | 150,345 |
| Galveston | 46,090 | 47,390 | 47,818 | 47,487 | 47,393 | 47,641 | 26,732 | 26,538 | 25,822 | 24,693 | 23,697 | 23,821 |
| Harris | 709,300 | 789,397 | 868,320 | 948,412 | 1,030,899 | 1,119,593 | 411,394 | 442,062 | 468,893 | 493,174 | 515,450 | 559,797 |
| Leon | 2,128 | 2,376 | 2,489 | 2,456 | 2,414 | 2,437 | 1,234 | 1,331 | 1,344 | 1,277 | 1,207 | 1,219 |
| Liberty | 10,470 | 11,759 | 12,980 | 14,211 | 15,629 | 17,362 | 6,073 | 6,585 | 7,009 | 7,390 | 7,815 | 8,681 |
| Madison | 1,793 | 1,867 | 1,921 | 1,954 | 2,010 | 2,075 | 1,040 | 1,046 | 1,037 | 1,016 | 1,005 | 1,038 |
| Montgomery | 74,871 | 98,947 | 122,197 | 146,984 | 180,292 | 219,432 | 43,425 | 55,410 | 65,986 | 76,432 | 90,146 | 109,716 |
| Polk | 5,062 | 5,632 | 6,046 | 6,335 | 6,693 | 7,088 | 2,936 | 3,154 | 3,265 | 3,294 | 3,347 | 3,544 |
| San Jacinto | 3,153 | 3,616 | 3,964 | 4,120 | 4,207 | 4,251 | 2,317 | 2,571 | 2,709 | 2,645 | 2,559 | 2,538 |
| Trinity | 1,203 | 1,260 | 1,255 | 1,206 | 1,145 | 1,102 | 698 | 706 | 678 | 627 | 573 | 551 |
| Walker | 16,920 | 16,607 | 17,244 | 16,240 | 16,042 | 15,786 | 9,814 | 9,300 | 9,312 | 8,445 | 8,021 | 7,893 |
| Waller | 5,713 | 7,003 | 8,469 | 10,084 | 12,093 | 14,454 | 3,314 | 3,922 | 4,573 | 5,244 | 6,047 | 7,227 |
| Total Estimated Return Flows | | | | | | | 605,349 | 668,577 | 723,405 | 773,141 | 828,087 | 922,821 |
| | | | | | | | | | | | | |
| WUGs with Reuse WMS greater than 50,000 afy | | | | | | | | | | | | |
| | | | | | | | | | | | | |
| HOUSTON | 389,082 | 429,218 | 467,036 | 506,047 | 547,787 | 593,096 | 225,668 | 240,362 | 252,199 | 263,144 | 273,894 | 296,548 |
| NHCRWA* | 116,062 | 136,903 | 152,789 | 161,456 | 164,968 | 169,178 | 67,316 | 76,666 | 82,506 | 83,957 | 82,484 | 84,589 |
| | | | | | | | | | | | | |
| San Jacinto River Basin | | | | | | | | | | | | |
| (total for all counties) | 774,979 | 885,100 | 991,261 | 1,100,192 | 1,217,947 | 1,347,121 | 449,488 | 495,656 | 535,281 | 572,100 | 608,974 | 673,561 |
| | | | | | | | | | | | | |
| Reuse WMS | | | | | | | | | | | | |
| Montgomery County GRP | | | | | | | 0 | 759 | 943 | 1015 | 1,017 | 1,018 |
| Municipal Non-potable Reuse*** | | | | | | | 0 | 0 | 5,488 | 11,480 | 18,207 | 25,302 |
| NHCRWA - Indirect Reuse | | | | | | | 0 | 0 | 0 | 18800 | 46000 | 89,000 |
| SJRA-Indirect | | | | | | | 14,944 | 14,944 | 14,944 | 14,944 | 14,944 | 14,944 |
| Wastewater Reuse for Industry | | | | | | | 0 | 0 | 0 | 0 | 0 | 67,200 |
| Houston - indirect Reuse | | | | | | | 0 | 0 | 0 | 48,290 | 75,118 | 75,118 |
| | | | | | | | | | | | | |
| **Total Estimated Reuse** | | | | | | | **14,944** | **15,703** | **21,375** | **94,529** | **155,286** | **272,582** |
| | | | | | | | | | | | | |
| Harris County Net Return Flow**** | | | | | | | 411,394 | 441,303 | 462,462 | 413,589 | 375,108 | 302,159 |
| San Jacinto Basin Net Return Flow | | | | | | | 434,544 | 479,953 | 513,906 | 477,571 | 453,688 | 400,979 |

* includes Jersey Village and Tomball (member cities)
** includes portions within San Jacinto Basin
*** includes portions within San Jacinto Basin
**** excludes SJRA indirect Resue from Montgomery County