# *Trinity River Basin Master Plan*

Trinity River Authority of Texas
2012





Trinity River Survey Crew, Corps of Engineers 1899

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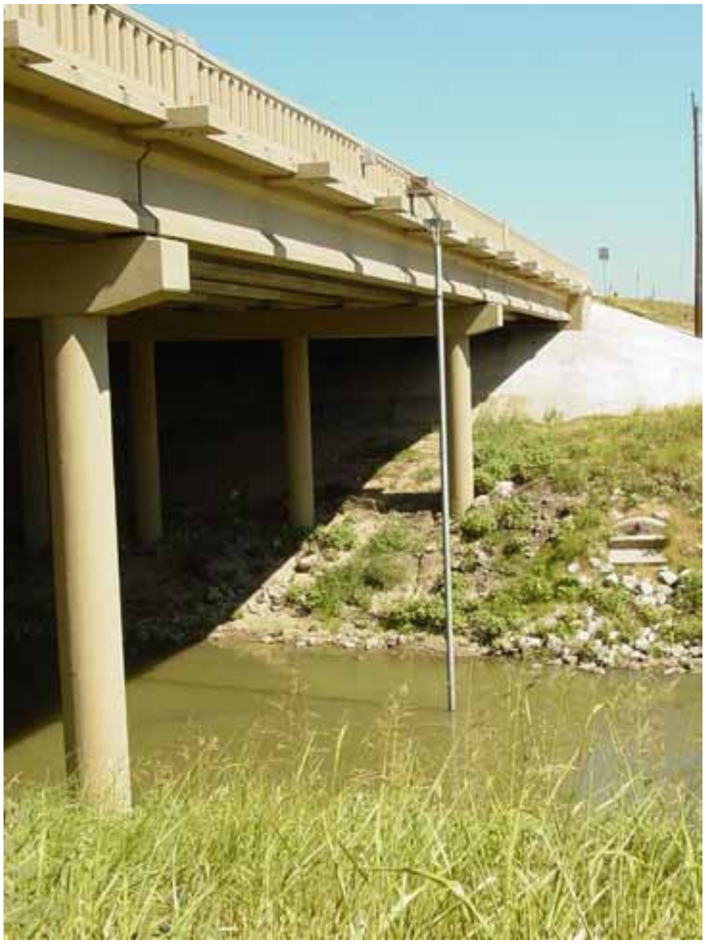

USGS Gage Station Trinity River at Grand Prairie

Soap Creek in Ellis County

Ten Mile Creek Outfall in Dallas County

Lower Trinity River in Chambers County

# Trinity River Authority of Texas

## Basin Master Plan

## Foreword

### Message from the General Manager

The 54th Texas Legislature created the Trinity River Authority of Texas in 1955 as a conservation and reclamation district, requiring that TRA prepare a master plan for responsible water use and reclamation that would ensure a healthy river basin. TRA completed the first master plan in 1958 after a series of public meetings throughout its statutory boundaries – since then, it has been revised and amended on a regular basis to keep up with dynamic technical, legal, environmental and economic changes.

While TRA is a leader in basin planning, the Authority does not control permitting or water rights issues — those duties are fulfilled by various state agencies. Instead, TRA coordinates with other entities, mostly municipalities, to implement water-related programs that serve the needs of Texas residents. When requested, TRA has served as a facilitator to help federal, state, regional and local entities develop projects based on the needs of their populations. To that end, the master plan does not advocate specific projects; instead, the master plan establishes basin-wide objectives designed to benefit the population of the entire basin, regardless of the implementing agency.

J. Kevin Ward, General Manager
Trinity River Authority of Texas

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## Trinity River Basin Master Plan Documents

| | |
|---|---|
| Report on Master Plan of the Trinity River and Tributaries, Texas, adopted by the Board of Directors of the Trinity River Authority | April 18, 1958 |
| Report on Soil Conservation and Upstream Flood Prevention of the Trinity River and Tributaries, Texas approved by the Texas State Conservation Board | January 7, 1959 |
| Supplemental Report on Master Plan of the Trinity River and Tributaries, Texas, adopted by the Board of Directors of the Trinity River Authority | October 21, 1960 |

Trinity River Basin Master Plan, revisions adopted:

| | | | |
|---|---|---|---|
| February 22, 1977 | February 22, 1989 | February 26, 1997 | February 28, 2007 |
| June 27, 1984 | February 24, 1993 | February 28, 2001 | February 22, 2011 |
| | | April 23, 2003 | April 25, 2012 |

# Trinity River Authority of Texas

# Basin Master Plan

## Introduction

### Objectives

These are the objectives for the Trinity River basin regardless of the implementing agency. Jurisdictional, financial, or engineering details are not a part of the plan and may vary without changing it. TRA Board of Directors may review or revise this Master Plan at any time. The order in which these objectives are listed is not intended to establish priorities.

- **Access**

  Provide public access and facilities for water-oriented recreation and recognize the need for maintenance dredging for the existing channel to Liberty.
- **Conservation**

  Support efforts and programs designed to conserve water, land, and soil resources and riverine and estuarine systems.
- **Education**

  Promote human, environmental, and economic well-being through education and information programs that foster an understanding of the complex water-related issues throughout the Trinity basin and Trinity Bay.
- **Flood Protection**

  Support efforts to reduce damages caused by flooding.
- **New Reservoirs**

  The thirteen remaining reservoirs identified in the 1958 Master Plan may be implemented as needed for water supplies: Tennessee Colony Lake, Tehuacana, Upper Keechi, Big Elkhart, Hurricane Bayou, Lower Keechi, Bedias, Nelsons, Harmon, Gail, Mustang, Caney, and Long King.
- **Reuse**

  Highly treated wastewater should be reused for beneficial purposes.
- **Wastewater Treatment Plants**

  Wastewater treatment plants should be expanded and upgraded as needed. Whenever feasible, regional wastewater treatment should be implemented.
- **Water Management Policy**

  Support water management policies that balance the values of both the Trinity River and Trinity Bay and promote the most efficient use of water resources for all beneficial purposes.
- **Water Quality**

  Continue to maintain and improve the water quality of the Trinity River.

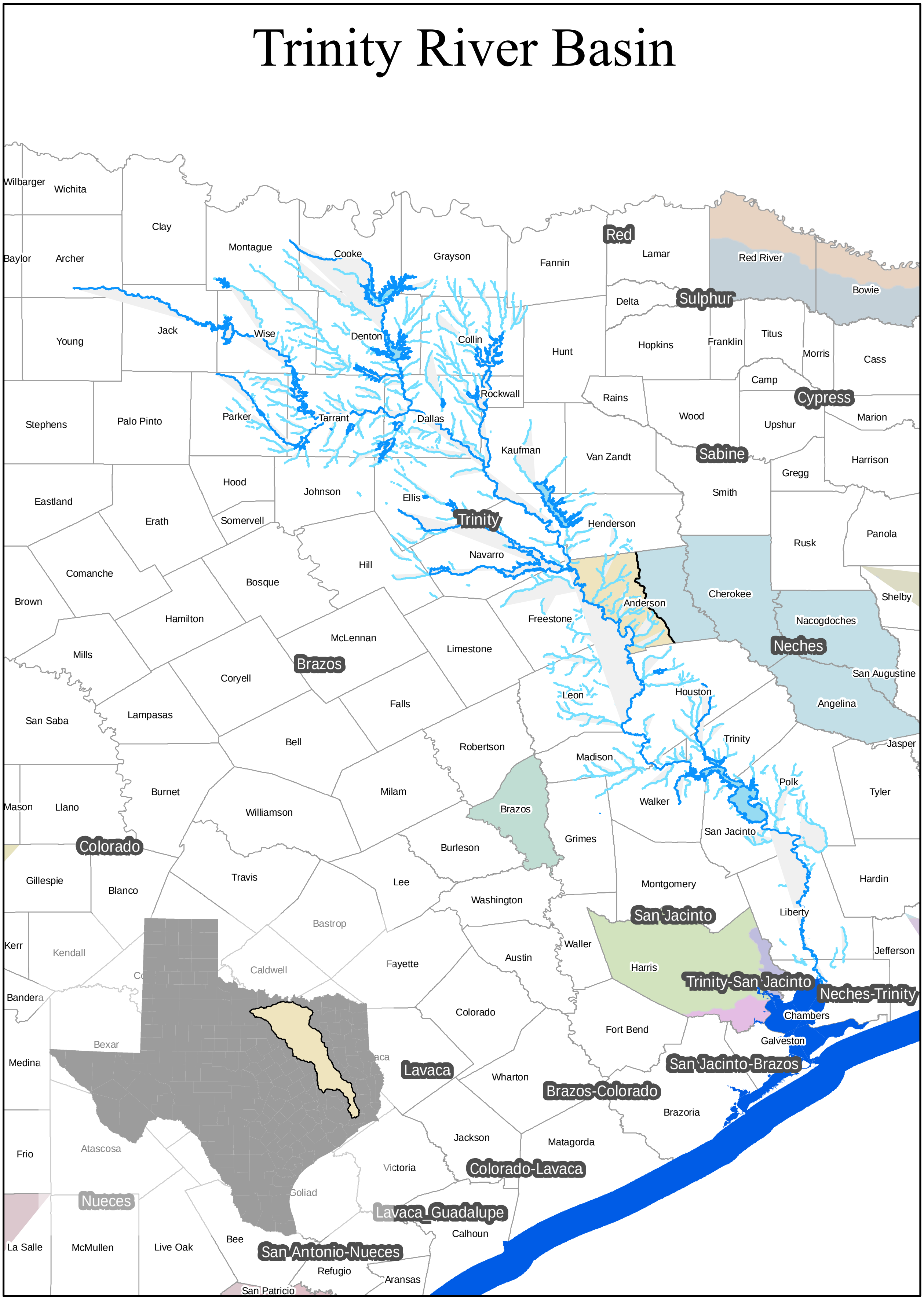



Fig. 1a. Trinity River Basin.

## The Trinity River Authority Overview

The Trinity River Authority (TRA) was created in 1955 as a conservation and reclamation district by House Bill No. 20, an Act of the 54th Legislature[1]. TRA is governed by a twenty-five member board of directors that are appointed by the governor with the approval of the senate. Unless the board member is "at large," he/she must live and own taxable property within the area from which he/she is appointed. The political boundary of TRA is divided into seventeen areas and includes all or part of seventeen counties.

Table 1a. TRA Board of Directors Allotments.

| Area | County | No. of Directors |
|---|---|---|
| 1 | Tarrant | 3 |
| 2 | Dallas | 4 |
| 3 | Kaufman | 1 |
| 4 | Henderson | 1 |
| 5 | Ellis | 1 |
| 6 | Navarro | 1 |
| 7 | Anderson | 1 |
| 8 | Freestone | 1 |
| 9 | Leon | 1 |
| 10 | Houston | 1 |
| 11 | Trinity | 1 |
| 12 | Madison | 1 |
| 13 | Walker | 1 |
| 14 | San Jacinto | 1 |
| 15 | Polk | 1 |
| 16 | Liberty | 1 |
| 17 | Chambers | 1 |
| 18 | "At Large" | 3 |


Fig. 1b. TRA Political Boundary.

By statute, Trinity River Authority is charged with:

1. Maintaining a master plan for the Trinity River basin;
2. Acting as local sponsor for federal water projects; and
3. Providing services authorized by the Texas Legislature within the Authority's territory.

The Trinity River Authority has the legislative authority to tax, but has never done so. Instead, the Authority generally provides a service to entities that wish to partner with TRA to create wastewater and water supply projects. TRA was originally tasked with overseeing the creation of a navigable waterway from Liberty to the Dallas/Fort Worth Metroplex. By the 1970's, the U.S. Army Corps of Engineers' cost vs. benefit analysis concluded that the navigation project should be postponed indefinitely. About this time, TRA began to focus its efforts towards creating and operating regional wastewater collection and treatment systems. These systems were huge improvements to the existing septic systems, small, inefficient package plants, and municipal plants, which were not functioning efficiently.

House Bill 20 also authorized TRA to construct, own, and operate reservoirs and to supply and sell water. To help the City of Houston satisfy its water demand, TRA completed construction on Lake Livingston in 1969. Currently, Lake Livingston alone accounts for approximately 75% of Houston's surface water supplies. TRA funded the construction of Livingston by sales of revenue bonds that were redeemed with income from the sale of water.

In addition, TRA acts as a local sponsor for major water supply projects. TRA has served as a local sponsor for four major U.S. Army Corps of Engineers multiple-purpose water resource projects: Bardwell Lake, Joe Pool Lake, Navarro Mills Lake, and the Wallisville Saltwater Barrier.

House Bill No. 20 granted TRA certain powers but did not mandate, nor fund, these powers. TRA *is not a permitting entity* and does not control permitting or water rights issues within the basin. Those functions are handled by various state agencies. TRA's primary function is to work and coordinate with other entities, mostly municipalities, to implement water related programs that serve the needs of Texas residents.

[1] *See appendix for an in-depth explanation of the Role of the Trinity River Authority.*

## Trinity River Basin Overview

The Trinity River begins in the Four Forks region in the northern portion of the basin. Just south of the DFW Metroplex, the Clear Fork, West Fork, Elm Fork and East Fork merge to form the Main Stem of the Trinity River. The Trinity River is 715 miles long and drains nearly 18,000 mi² of Texas. The climate and land type vary greatly across the basin. The watershed's character transforms from rolling West Texas plains with 29 inches of annual precipitation, through the Central Texas prairies, into the East Texas piney woods, and into the Gulf Coastal prairies which receive 53 inches of annual precipitation.

The Trinity River basin is the largest river basin in Texas that begins and ends within the state. The Trinity River provides water to over half of the population of Texas and serves two major population centers: Dallas/Fort Worth in the north and Houston to the south (fig. 1b). In addition, it is important to recognize that both major population centers drain into the Galveston Bay and estuary system, one of the most productive ecosystems and commercial fisheries in the United States.

Because of the scarcity of groundwater availability, residents of the Trinity River basin rely on surface waters to fulfill water demand. The Trinity River contains 28 water supply reservoirs with over 5,000 acre feet of storage. Surface water comprises over 550 mi², or 3.2%, of the watershed's landcover. Because of the importance of surface water to both the upper and lower portions of the basin, water quality is a major consideration throughout the Trinity River basin.

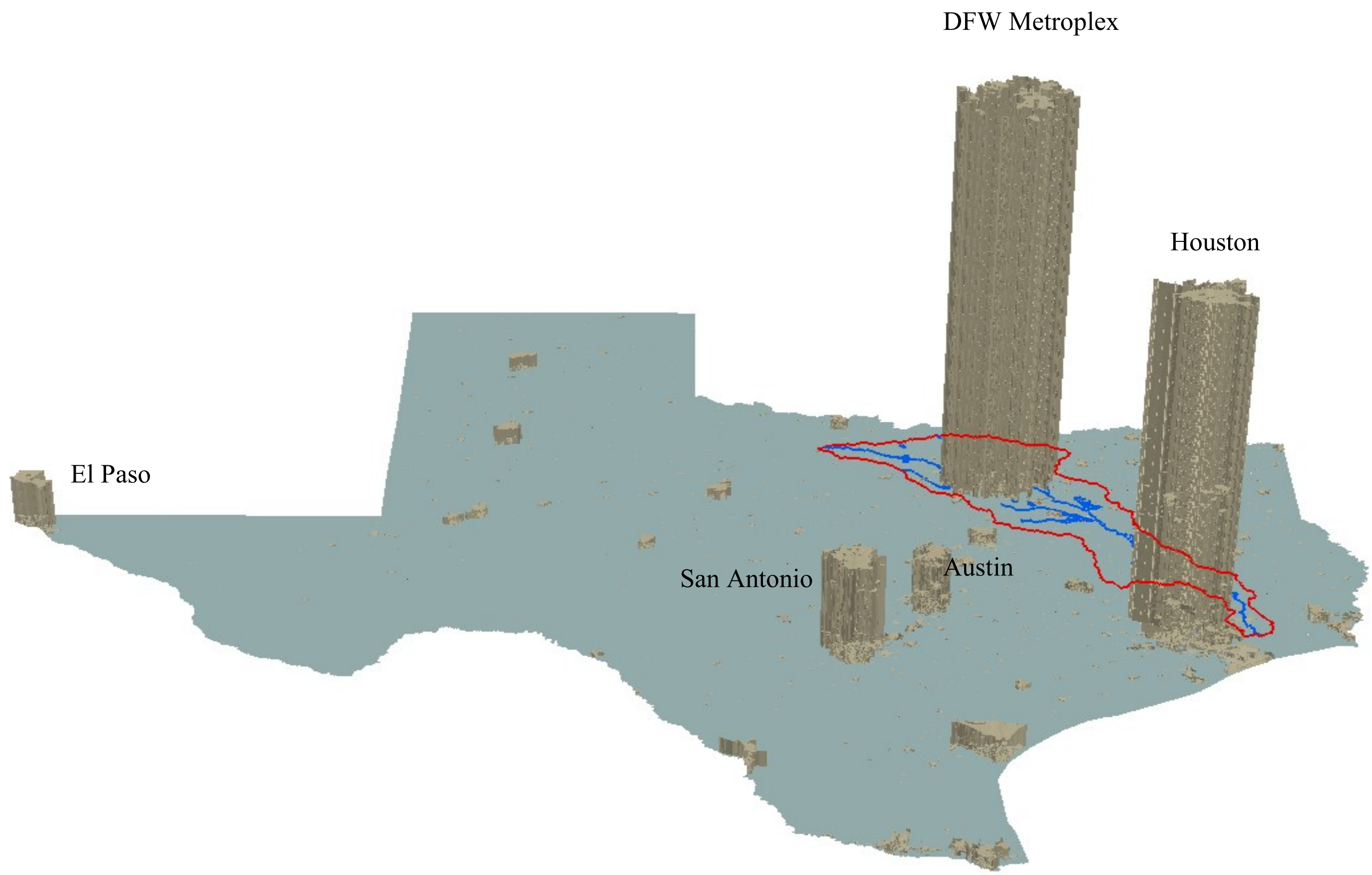



Fig. 1c. Population of Texas cities. Height of city polygons are proportional to their population.

## Future Review Procedures

The Master Plan may be reviewed and revised by the Board of Directors of the Trinity River Authority at any time. This revised plan has been formulated in terms of objective, without great detail, so that only major developments would require a change in the plan. However, when such developments occur, they will be promptly incorporated into the plan. Annually, the Board of Directors will receive and review a report on the status of implementation of the plan and consider any revisions that might be indicated at that time. An annual status report has been submitted to the Board every year since 1977. Periodically there should be a comprehensive review of the plan. The most recent significant revision to the Master Plan occurred in 2007 when it was converted to a full color document and the sections on Senate Bill 3 and Regional Water Planning efforts were added.

# Trinity River Authority of Texas

# Basin Master Plan

## Water Supply

### Background

Fig. 2a. Bardwell Lake in Ellis County.

To mitigate the effects of future droughts, the state created the Texas Water Development Board (TWDB) in 1957. In 1997, the TWDB, in cooperation with Texas Parks and Wildlife Department, Texas Natural Resource Commission (now Texas Commission of Environmental Quality or TCEQ), and numerous stakeholder groups, produced the last water plan *developed at the state level*. Since 1997, state water planning has been a regional and local effort that is compiled into the state water plan.

### Texas Water Planning

To mitigate the challenges met during the creation of the 1997 State Water Plan, the Texas Legislature passed Senate Bill 1 in 1997. Senate Bill 1 directed the Texas Water Development Board (TWDB) to designate regional water planning entities. Some of the factors used to delineate the 16 regional water planning entities included: river basin and aquifer delineations, water utility development patterns, socioeconomic characteristics, existing regional water planning areas, political subdivision boundaries, and public comment. Each of the 16 regions create and submit a water plan to the TWDB who approves each plan and combines all regional plans into a single state water plan. The most recent state water plan, *Water for Texas 2012*, was adopted by the TWDB on December 15, 2011 and forecasts planning efforts through 2060. Each of the 16 regions is comprised of a planning group that was required by Senate Bill 1 to include representatives from the public, counties, municipalities, industries, agriculture, environmental groups, small business, electric-generating utilities, river authorities, water districts, and water utilities. Once comprised, each planning group added other members as appropriate. The Regions were required to:

- describe the regional water planning area;
- quantify current and projected population and water demand;
- evaluate and quantify current water supply;
- identify surpluses and needs;
- evaluate water management strategies and prepare plans to meet needs;
- recommend regulatory, administrative, and legislative changes; and
- adopt the plan, including the required level of public participation.

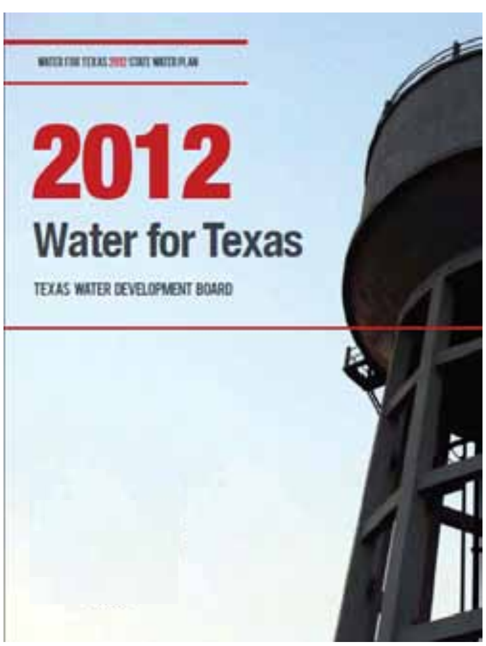



Fig. 2b. Texas State Water Plan Available at http://www.twdb.state.tx.us.

The planning groups were created to be transparent and conduct all functions at open meetings. In addition, public meetings were held while developing the scope of work. Additional hearings took place prior to the adoption of the regional plans. Consensus building within the planning groups was crucial to ensure sufficient support for adoption of the plan.

Not everyone agrees with the outcomes of the Regions' planning recommendations, and it is important to list some of the questions/concerns raised during the public comment period:

- Additional reservoirs are expensive, unnecessary, and destroy wildlife habitat;
- Land is acquired to build reservoirs in locations to serve the water needs of far away populations;
- Supplies do not take into account both bay/estuary and in-stream environmental flow requirements; and
- Existing reservoirs are not interconnected or used to their full potential.

Although there are many legitimate concerns about how to increase the current water supply to meet future demands, there is little disagreement that water shortages will become a reality if new supplies are not accessed.

## Regional Planning

The vast majority (81%) of the Trinity River basin falls into Region C or Region H. The Trinity River basin comprises 80% of Region C and includes Dallas/Fort Worth and the upper portion of the basin. Further to the south, the Trinity basin makes up only 28% of Region H, but accounts for the majority of Region H's surface water supplies. By 2060, regional planning estimates project that 53% of Texas' population will live within Regions C and H. Both regions' plans were approved by the Texas Water Development Board in 2010 and overviews of the plans are included below. The entire Water for Texas 2011 report is available online from the Texas Water Development Board.

Planning for the 2015 Water Plan is currently underway.

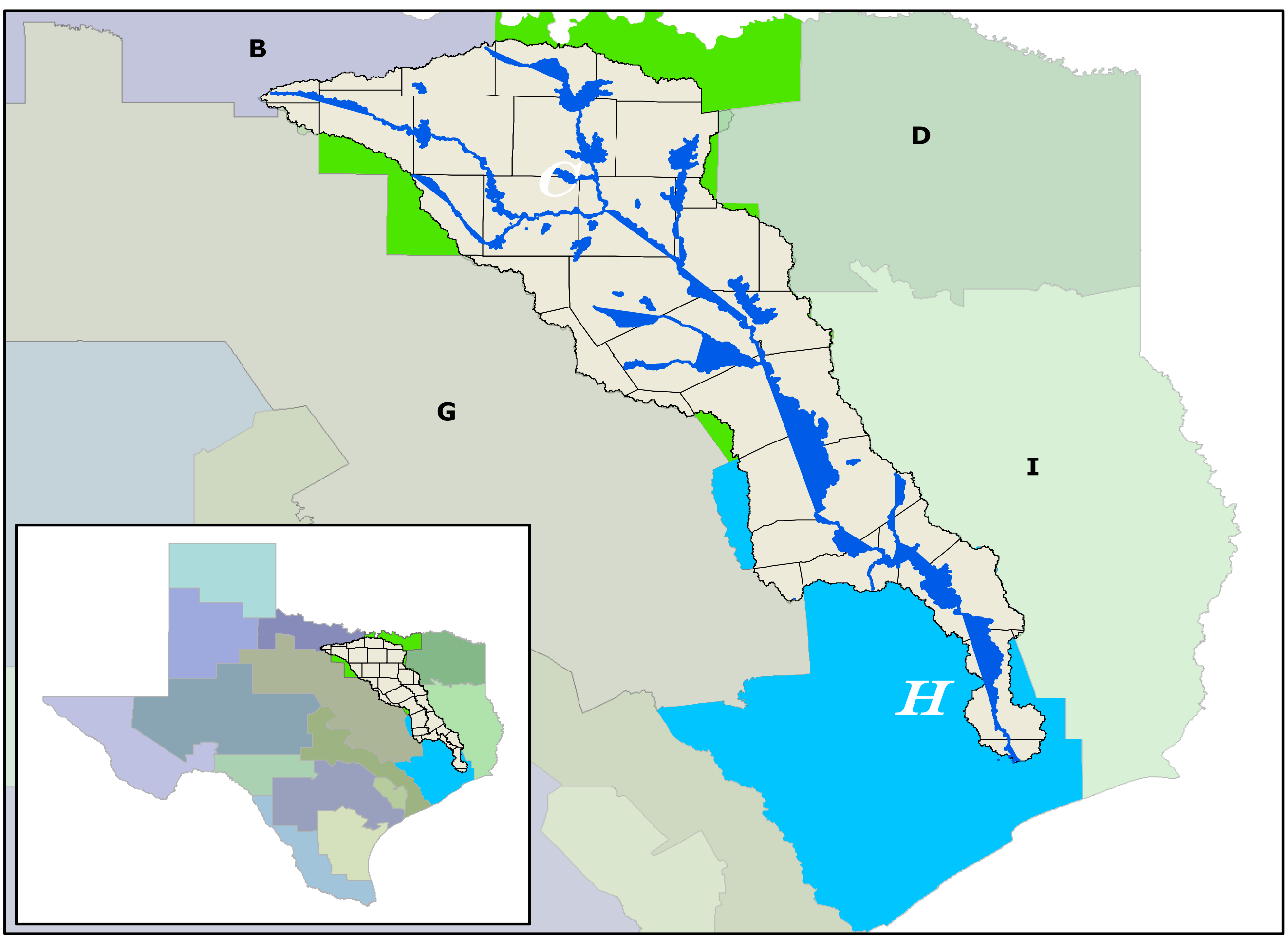



Fig. 2c. Regional Water Planning Entities.

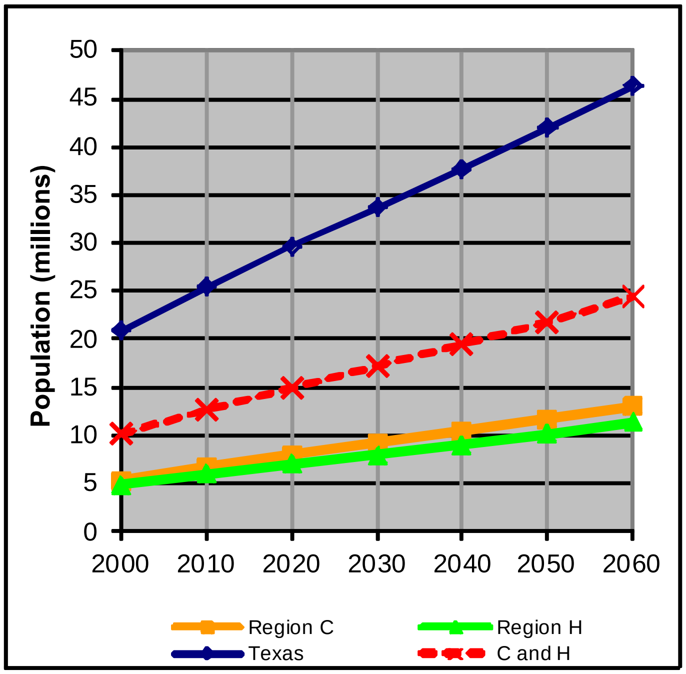



Fig. 2d. Population Estimates from Water for Texas 2012 for Region C, Region H, and Texas.

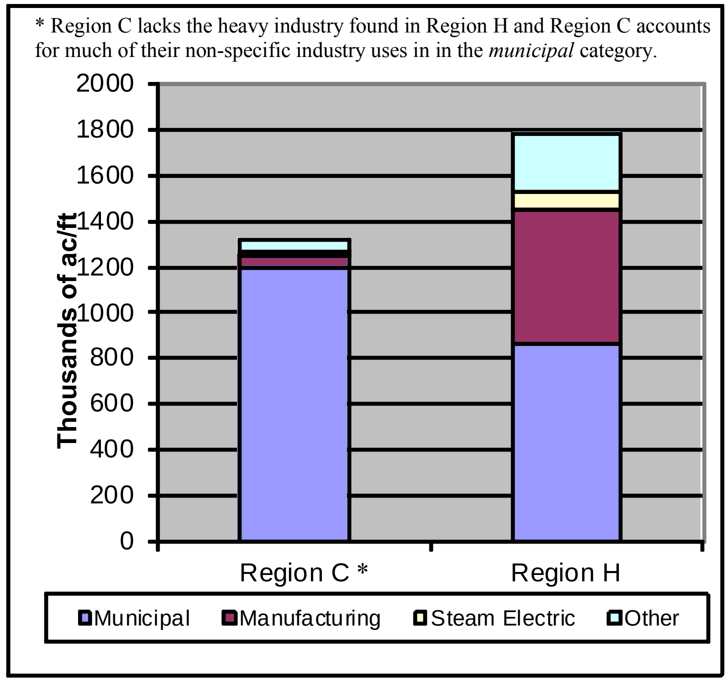



Fig. 2e. 2007 Demand for Regions C and H (By Category).

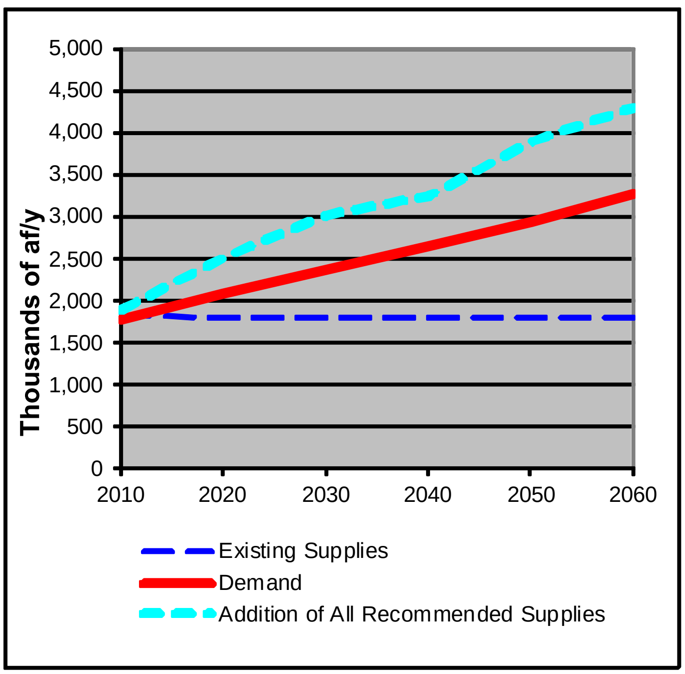



Fig. 2f. Region C Projected Water Supply, Demand, and Recommended Supplies.

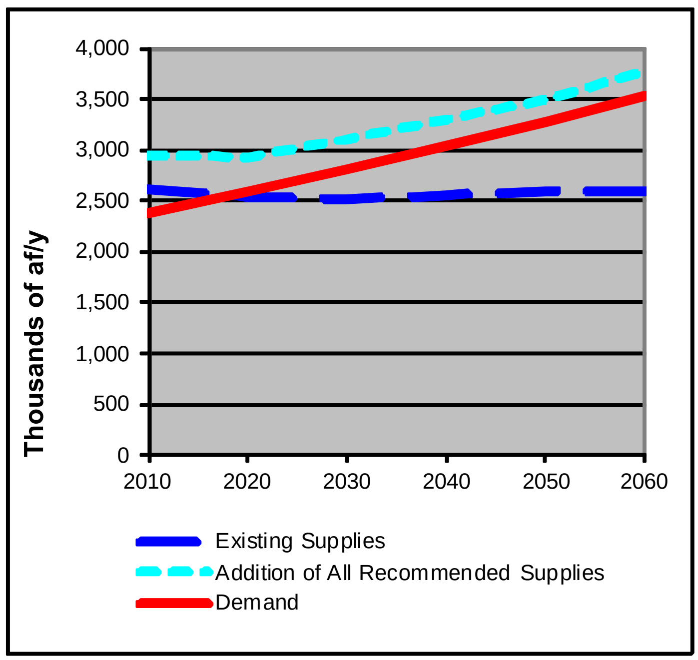



Fig. 2g. Region H Projected Water Supply, Demand, and Recommended Supplies.

**Access more Region C information at:**

**http://www.regioncwater.org/index.cfm**

**Access more Region H information at:**

**http://regionhwater.org/downloads/planningdocs.html**

# Summary of 2011 Regional Water Plans for Regions C and H

## *Region C (16 counties):*

**Population:** 6.7 million people (27% of Texas' population) were estimated to be living in Region C in 2010. That number is set to almost double to slightly more than 13 million by 2060 (fig. 2d).

**Water Demand**: Region C planners estimate that water use in 2006 was 1,404,535 af/y. This demand is predicted to rise to 2.4 million af/y by 2030 and 3.3 million af/y by 2060; an increase of 135% over 2006 demand. Municipal use makes up over 90% of the region's water demand (fig 2e).

**Water Supplies**: Water supplies for Region C are projected to remain relatively constant at around 1.8 million acre feet/year, as loss in storage capacity is offset by reuse, conservation and other factors. By contrast, demand is expected to increase to approximately 3.3 million af/y by 2060 (fig. 2f). This will result in a deficit of 1.5 million af/y if new supplies are not developed (fig. 2f). To offset this demand, the Region C Water Plan has identified and recommended projects that would make available 2.36 million af/y. If all of those strategies were implemented, the region would have a total supply of 4.14 million af/y; more than enough to offset the increased 2060 demand.

**Water Sources**: Over 90% of the water supply for Region C is surface water, almost all of which originates from reservoirs. Although constituting less than 10% of Region C supplies, groundwater is still an important source of water, especially in rural areas. Because the majority of municipal water used in Region C is discharged as return flows from wastewater treatment plants, reuse will be a major component of future water supplies for Region C, accounting for 1.2 million af/y (when combined with conservation) by 2060. Conservation is also an important component of the plan, directly reducing the deficit that will need to be overcome and thereby "accounting" for 12% of future supplies, which by 2060 will total over 270,000 af/y.

Interbasin transfers, already a significant source of water for the region, are projected to become even more important. Although less prominent than has historically been the case, new reservoirs will be important in meeting the projected future supply deficit. Three new reservoirs are recommended in the plan and an additional one may be recommended in the future to replace Lake Fastrill which was removed from the 2006 plan. Selected major strategies are listed in Table 2a. The estimated cost to implement all of these strategies is $21.5 billion.

## *Region H (15 counties):*

**Population:** 6 million people (24% of Texas' population) were estimated to be living in Region H in 2010. Like Region C, that number is expected to almost double to 11.3 million by 2060 (fig. 2d).

**Water Demand:** Region H planners estimate that current water demand will increase from 2.038 million af/y in 2010 to 3.5 million af/y in 2060. As of 2006, municipal uses made up 48% of demand, manufacturing 33%, irrigation 13%, steam and electric generation 5%. All other uses made up only 1% of demand. The median daily water use per capita in the 2011 plan was estimated to be 135 gallons.

**Water Supplies:** Current water sources for Region H are predicted to decline by approximately 4% from 3.5 million af/y in 2010 to 3.14 million af/y in 2060 (fig. 2g) as reservoirs lose storage through sedimentation and groundwater pumping is curtailed. If no additional supply is created, the TWDB projects a shortage of about 1,069,469 af/y in 2060 (fig 2g). This is significantly higher than the estimated shortage predicted in the previous Region H plan due to the recognition that water supplies do not always coincide with where they are needed. Looking at shortages county-by-county provides a more accurate description of shortages than does looking at the region as a whole.

**Water Sources:** In 2010, approximately 70% of water supply for Region H was from surface water with groundwater making up the remaining 30%. Because of subsidence concerns, existing groundwater supply resources are expected to decline by 27% (208,484 af/y) from 2010 to 2060. The reduction in groundwater availability will result in the increased need for surface water sources both in and out-of-basin. Region H planners recommended the construction of 5 new major reservoirs: Allens Creek, Dow Off-Channel, Gulf Coast Water Authority Off-Channel, Brazoria Off-Channel and Fort Bend Off-Channel.

Reuse is expected to become a significant source of supply for Region H accounting for by estimate 14,866 af/y by 2060. For additional information on reuse, see chapter four.

Conservation: Conservation strategies are anticipated to reduce future demand by approximately 183,933 af/y.

Selected major strategies are listed in Table 2a. The estimated cost to implement all of these strategies is $12 billion.

## Table 2a. Major Water Supply Strategies in 2011 Regional Plans

Region C

| Strategy | Sponsor | Supply (Acre-ft/yr) | Type |
|---|---|---|---|
| Toledo Bend Reservoir | NTMWD/TRWD | 400,000 | IBT** |
| Marvin Nichols | NTMWD/TRWD/UTRWD | 489,840 | New Reservoir |
| Integrated Pipeline | TRWD | 179,000 | Existing Supply |
| Lower Bois d'Arc Creek | NTMWD | 123,000 | New Reservoir |
| Oklahoma Water | NTMWD/TRWD/Irving/UTRWD | 140,000 | IBT |
| Lake Palestine | DWU | 107,347 | IBT |
| New Lake Texoma | NTMWD | 113,000 | IBT |
| Wright Patman - Flood Pool | DWU | 112,100 | Unpermitted IBT |
| TRWD Wetlands | TRWD | 105,500 | Reuse |
| Tawakoni Pipeline | DWU | 69,128 | IBT |
| Lake Ralph Hall and Reuse | UTRWD | 52,437 | New Reservoir |
| Main Stem Trinity River Pump Station | DWU/NTMWD | 41,029 | Reuse |

Region H

| Strategy | Sponsor | Supply (Acre-ft/yr) | Type |
|---|---|---|---|
| Allens Creek Reservoir | BRA/Houston | 99,650 | New Reservoir/IBT |
| Millican Reservoir | BRA | 120,994 | New Reservoir/IBT |
| Expanded Use of Groundwater | | 91,400 | Groundwater |
| Luce Bayou Transfer | Houston | 450,000 | IBT |
| TRA to Houston | TRA/Houston | 123,524 | IBT |
| TRA to SJRA | TRA/SJRA | 76,476 | IBT |
| Houston Indirect Reuse | Houston | 128,801 | Reuse |
| NHCRWA Indirect Reuse | NHCRWA | 16,300 | Reuse |
| Reuse for Industry | Houston | 67,200 | Reuse |
| Brazoria Interruptible-irrigation | GCWA | 104,977 | Inter-basin Transfer |

*Major water supply strategies are defined here as those that supply more than 60,000 ac-ft/yr. * Represents maximum amount of water to be provided by a given strategy through 2060. **IBT*—Inter-basin Transfer

### Reservoirs

The vast majority of water supplies in the Trinity River basin are from surface water reservoirs. Since 1911, 31 major reservoirs have been constructed within the Trinity River basin (Table 2b). In addition, seven reservoirs located outside the Trinity basin are either supplying or are under contract to supply water to Trinity basin users. As of 2010, the firm yield of existing reservoirs and the currently permitted inter-basin water transfer amount shows that there will be approximately 2,994 MGD of reservoir water supply for the Trinity River basin.

Reservoirs also serve an important economic and recreation function for their communities. Major resort and residential developments adjacent to water supply reservoirs can bring tremendous increase to a city's sales revenue, tax base, and jobs. According to the Town of Flower Mound, located just north of Dallas/Fort Worth, the Gaylord Texas resort hotel, built on the shores of Lake Grapevine, employs almost 1,700 people and has an annual economic impact of more than $450 million dollars in the region.

Fig. 2h. TRWD Water Supply Intake Structure at Benbrook Lake in Tarrant County.

Fig. 2i. Recreation at Lake Livingston in Polk County.

Recreation on and around water supply reservoirs provides an important source of revenue and jobs for local residents. Anglers, boaters, campers, and day visitors support local marinas, campgrounds, hotels, and restaurants. According to a report from the Texas Coalition for Conservation and Texas Parks and Wildlife Department, state parks can significantly contribute to surrounding economies: In 2004,

- Cedar Hill State Park, located on Lake Joe Pool in Dallas & Ellis County, contributed $6.4 million, 114 jobs, and $32,000 in sales tax to local economies;
- Fairfield Lake State Park, located on Fairfield Lake in Freestone County, contributed $0.87 million, 18 jobs, and $4,300 in sales tax to local economies; and
- Lake Livingston State Park, located on Lake Livingston in Polk County, contributed $5.1 million, 108 jobs, and $25,700 in sales tax to local economies.

To meet the needs of Regions C and H through 2060, the state water plan recommends constructing additional out-of-basin reservoirs (Table 2a). The creation of new reservoirs are physically, politically, and administratively challenging. The Trinity River Authority will continue to work with all parties to find solutions to these issues.

## Groundwater

The laws governing the pumping of groundwater stand in stark contrast to those of surface water. In 1904, the Texas Supreme Court cemented the idea of "absolute ownership" of groundwater by the landowner in Houston & T.C. Railway Co. v. East. The Court decided that landowners had the "right of capture" to groundwater in part because the "existence, origin, movement, and course of such waters, and the causes which govern and direct their movements, are so secret, occult, and concealed that an attempt to administer any set of legal rules in respect to them would be involved in hopeless uncertainty, and would, therefore, be practically impossible."

Groundwater may be used for any beneficial use but may not be: wasted, intentionally contaminated, maliciously pumped for the sole purpose of hurting adjoining landowners, or pumped to the point of causing land subsidence. As the scarcity of water increases, more focus is being placed on the efficient uses of groundwater. Parts of Texas are creating Groundwater Conservation Districts (GCD) whose goals are to: provide the most efficient use of groundwater, prevent waste, control and prevent subsidence, address conjunctive sur-

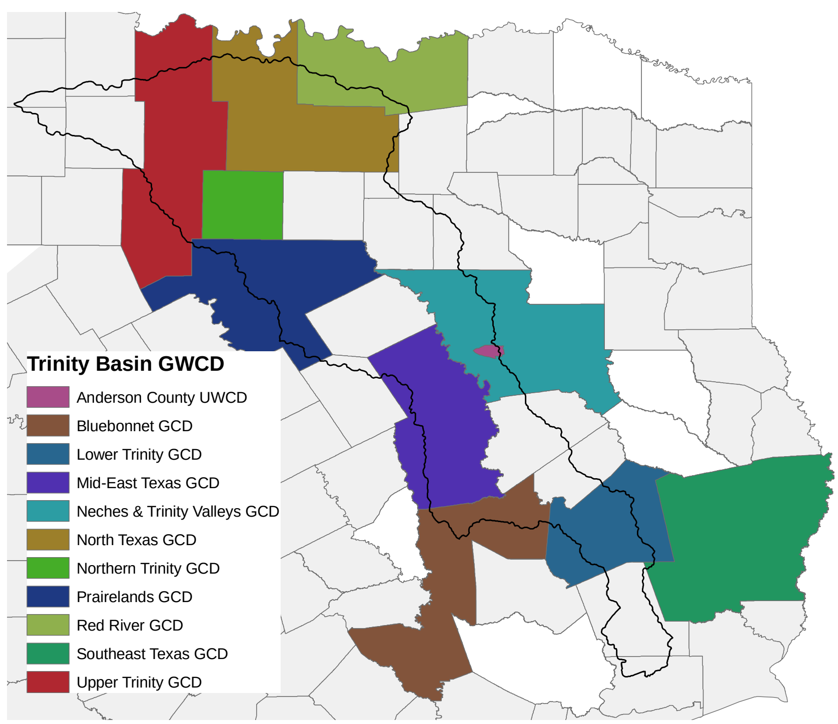



Fig. 2j. Trinity Basin Groundwater Conservation Districts.

face water and drought issues, and address conservation, recharge enhancement, brush control, and rainwater harvesting. According to the TWDB, GCD's are the "state's preferred method of groundwater management." GCD's are created by the legislature or TCEQ and have the authority to regulate the spacing of water wells and/or the production of water from wells. The Trinity River basin crosses the boundaries of eleven confirmed Groundwater Conservation Districts (fig. 2j ).

Eighty-six percent of the Trinity River basin lies over either a major (80%) aquifer, minor (59%) aquifer, or both. Aquifers are dynamic systems and are not constant across space or time and are dependent on surface water infiltration for recharge. In some cases, water is being pumped faster than the aquifer can recharge resulting in wells having to be extended, higher pumping costs, and land subsidence. The Trinity River basin overlays three major aquifers (fig. 2k).

*Trinity Aquifer*

- 10,625 mi² outcrop
- 21,308 mi² in subsurface
- 2010 availability: 205,799 af/y
- Water is generally fresh but very hard
- Some of the states largest water level declines (350 ft to >1,000 ft)

*Carrizo-Wilcox*

- 11,186 mi² outcrop
- 25,409 mi² in subsurface
- 2010 availability: 1,014,753 af/y
- Water is generally fresh but very hard
- Desalination of brackish water and developing new wells are possibilities

*Gulf Coast*

- 41,879 mi² area
- 2010 availability: 1,825,976 af/y
- Water quality varies across and with depth (TDS varies: 500 – 10,000 mg/L)
- Some wells show high level of radionuclides
- Water level declines of up to 350 ft have led to subsidence problems

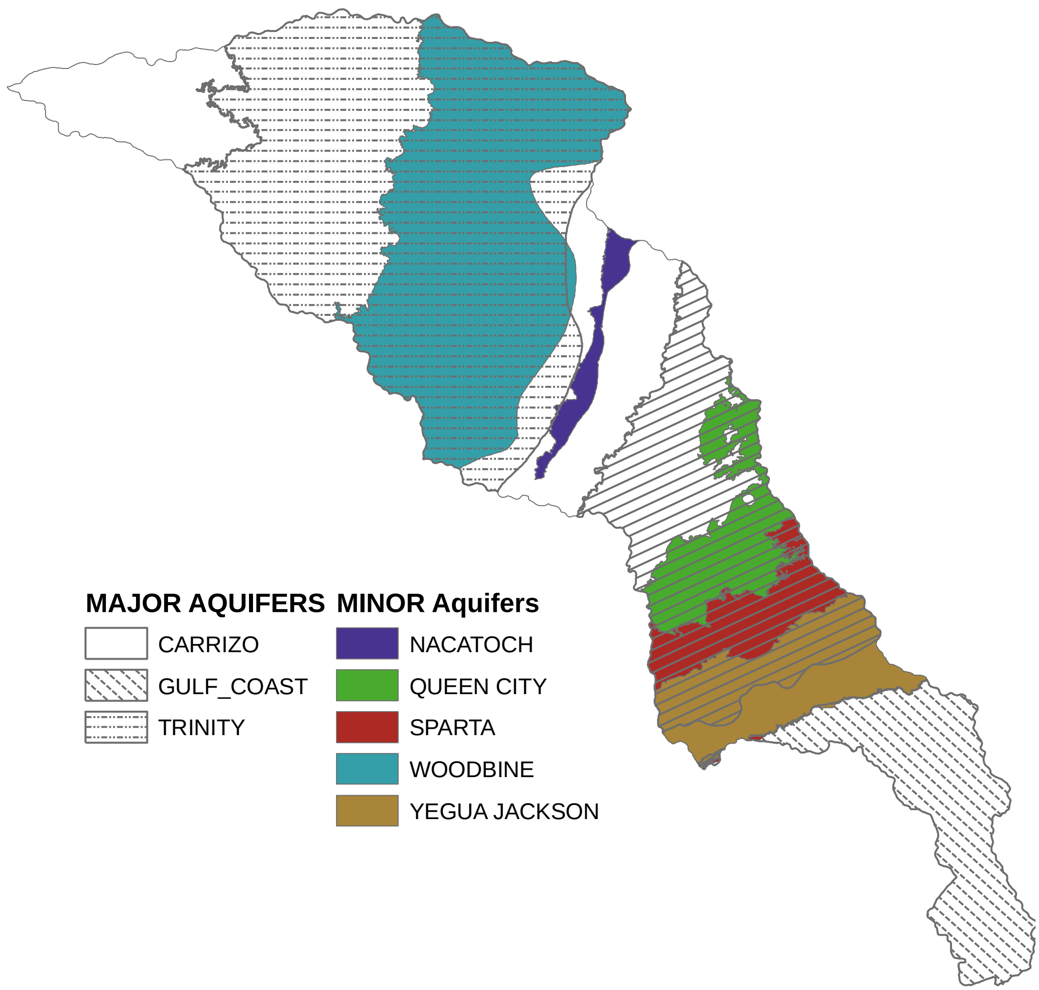
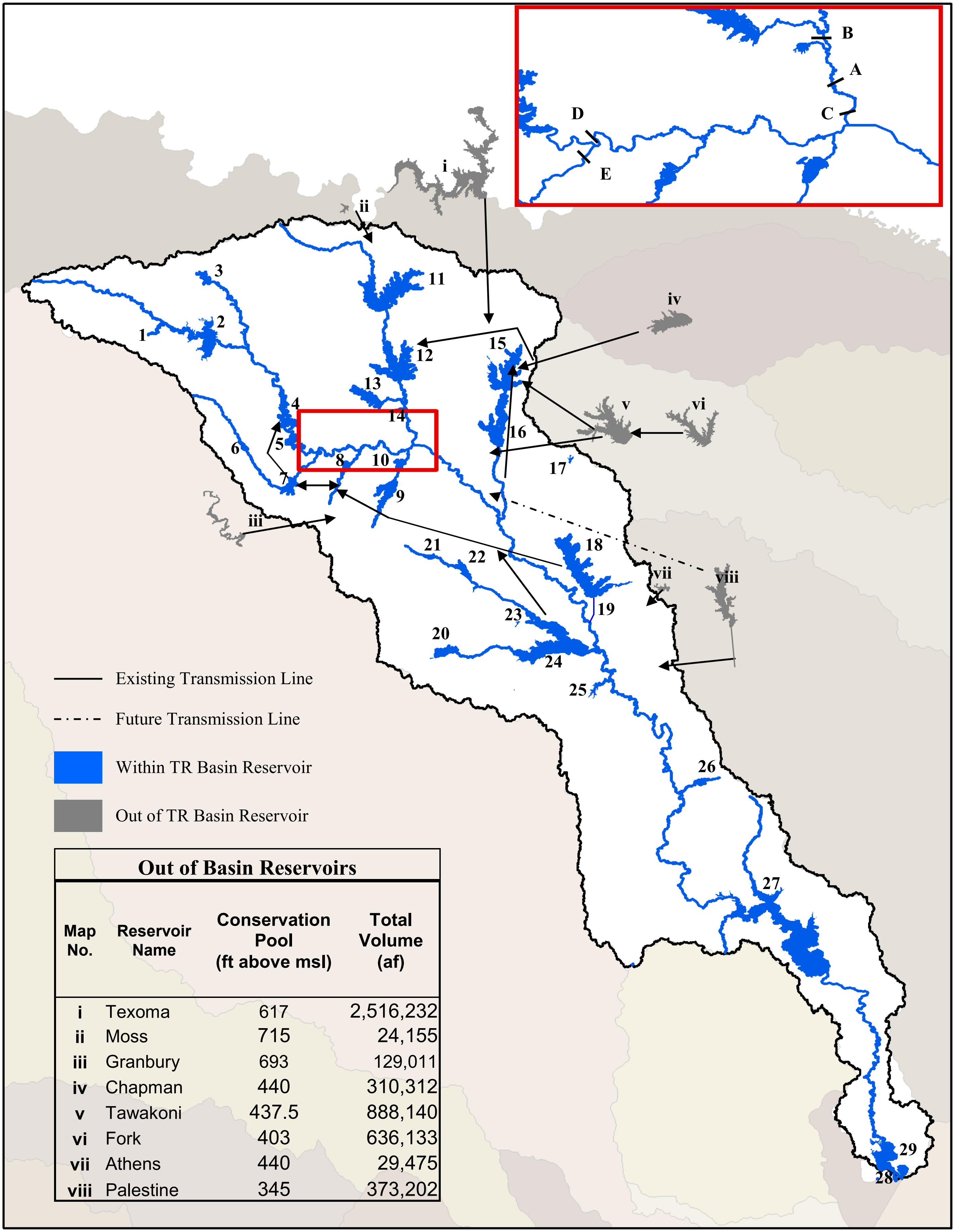



Fig. 2k Trinity Basin Aquifers




**Out of Basin Reservoirs**

| Map No. | Reservoir Name | Conservation Pool (ft above msl) | Total Volume (af) |
|---|---|---|---|
| i | Texoma | 617 | 2,516,232 |
| ii | Moss | 715 | 24,155 |
| iii | Granbury | 693 | 129,011 |
| iv | Chapman | 440 | 310,312 |
| v | Tawakoni | 437.5 | 888,140 |
| vi | Fork | 403 | 636,133 |
| vii | Athens | 440 | 29,475 |
| viii | Palestine | 345 | 373,202 |

Fig. 21. Trinity Basin Major Water Supply Reservoirs (In/Out-of-Basin) and Channel Dams as of 2010.

Table 2b. Trinity Basin Major Water Supply Reservoirs and Channel Dams as of 2010. (References available on next page.)

# 2010 Major Trinity Basin Water Supply Reservoirs

| Map No. | Reservoir Name | 1st Im-pound ment Date | Uncontrolled Watershed ($m^2$) | Normal Pool (ac) | Normal Pool (af) | Owner/ Oper-ator | Yield [a] (mgd) | Primary Uses | Water Rights Permit Holder |
|---|---|---|---|---|---|---|---|---|---|
| 1 | JACKSBORO & | 1950 | 26 | 143 | 2,129 | Jacksboro | 1 | WSm | Jacksboro |
| | LOST CREEK | 1990 | 4 | 367 | 11,961 | Jacksboro | 1 | WSm | Jacksboro |
| 2 | BRIDGEPORT | 1932 | 1,082 | 12,900 | 374,836 | TRWD | b | WSm | TRWD |
| 3 | AMON G. CARTER | 1956 | 106 | 1,848 | 28,589 | Bowie | 2.3 | WSm | Bowie |
| 4 | EAGLE MOUNTAIN | 1934 | 753 | 6,480 | 177,520 | TRWD | 70 | Wsme | TRWD |
| 5 | WORTH | 1912 | 94 | 3,560 | 37,775 | Fort Worth | b | WSm | Fort Worth |
| 6 | WEATHERFORD | 1951 | 109 | 1,091 | 16,298 | Weatherford | 2 | Wsme | Weatherford |
| 7 | BENBROOK | 1952 | 320 | 3,770 | 88,250 | COE | 6 | WSm,FC | TRWD |
| 8 | ARLINGTON | 1957 | 143 | 1,939 | 38,785 | Arlington | 4.3 | Wsme | Arlington, TU |
| 9 | JOE POOL | 1986 | 232 | 7,470 | 176,900 | COE | 14 | WSm,FC | TRA |
| 10 | MOUNTAIN CREEK | 1937 | 63 | 2,710 | 22,840 | TU | 13.4 | Wse | TU |
| 11 | RAY ROBERTS | 1986 | 676 | 29,350 | 799,600 | COE | c | WSm,FC | Dallas, Denton |
| 12 | LEWISVILLE | 1954 | 968 | 29,170 | 571,926 | COE | 165 | WSm,FC | Dallas, Denton |
| 13 | GRAPEVINE | 1952 | 695 | 7,380 | 181,100 | COE | 19.1 | WSm,FC | Park Cities MUD, Dallas, Grapevine |
| 14 | NORTH | 1957 | 3 | 800 | 17,000 | TU | 0.4 | Wse | TU |
| 15 | LAVON | 1953 | 770 | 21,400 | 456,500 | COE | 93 | WSm,FC | NTMWD |
| 16 | RAY HUBBARD | 1968 | 304 | 21,683 | 413,526 | Dallas | 50 | Wsme | Dallas |
| 17 | NEW TERRELL | 1955 | 14 | 830 | 8,712 | Terrell | 0.7 | WSm | Terrell |
| 18 | CEDAR CREEK | 1965 | 940 | 32,623 | 637,180 | TRWD | 156 | WSm | TRWD |
| 19 | TRINIDAD | 1925 | 1 | 740 | 7,450 | TU | 2 | WSe | TU |
| 20 | NAVARRO MILLS | 1963 | 320 | 5,070 | 56,960 | COE | 14.7 | WSm,FC | TRA |
| 21 | WAXAHACHIE | 1956 | 30 | 690 | 13,500 | ECWCID | 2.4 | WSm | Ellis County WCID 1 |
| 22 | BARDWELL | 1965 | 148 | 3,528 | 45,347 | COE | 9.8 | WSm,FC | TRA |
| 23 | HALBERT | 1921 | 12 | 650 | 7,420 | Corsicana | 0.5 | WSm | Corsicana |
| 24 | RICHLAND CHAM-BERS | 1987 | 1,432 | 41,356 | 1,136,600 | TRWD | 187 | WSm | TRWD |
| 25 | FAIRFIELD | 1969 | 34 | 2,350 | 50,600 | TU | 6.9 | Wse | TU |
| 26 | HOUSTON CO. (Little Elk Heart) | 1966 | 44 | 1,282 | 19,500 | HCWCID | 6.3 | WSm | Houston County WCID #1 |
| 27 | LIVINGSTON | 1969 | 6,764 | 83,277 | 1,741,867 | TRA | 1120 | WSmia | Houston, TRA |
| 28 | WALLISVILLE | 1998 | 968 | 0 | 0 | COE | 80 | Wsmia | Houston, TRA |
| 29 | ANAHUAC | 1914 | 199 | 5,300 | 35,300 | CLCND | 21.7 | Wsam | CLCND |
| **Channel Dams Affecting Major Water Rights and/or Water Supply Systems** | | | | | | | | | |
| A | CALIFORNIA CROSSING | 1912 | 68 | 180 | 990 | Dallas | d | WSm | Dallas |
| B | CARROLTON | 1912 | 104 | 89 | 666 | Dallas | d | WSm | Dallas |
| C | FRAISER | 1928 | 50 | 72 | 434 | Dallas | 18 | WSm | Dallas |
| D | NUTT | 1910 | 33 | 96 | 673 | TRWD | 1 | WSe | TRWD |
| E | CLEAR FORK | 1882 | 89 | 43 | 259 | Fort Worth | 2 | WSm | Fort Worth |

# Water Supply Lakes and Lakes
# > 5,000 af in the Trinity River Basin

Notes from Table on Previous Page

Primary published sources:

TWDB. 73. Dams & reservoirs in Texas.
Turner Collie & Braden. 89. Dallas long range water supply plan.
Freese & Nichols. 90. TCWCID regional water supply plan.
TWC. 80-4. Final determinations of all claims of water rights in the Trinity River Basin.
USGS. several years. Water resources data – Texas.
Freese & Nichols/Forrest & Cotton. 74. North Central Texas water supply study.
Forrest & Cotton. 58. Trinity River Basin master plan.
TWDB. 94-5. Sediment resurveys of Arlington, Cedar Creek, White Rock.
BuRec. 91. Livingston sediment resurvey.
COE. 89. Reallocation & sedimentation resurvey report Bardwell.
COE. 89. Water resources development in Texas.
COE. 92. Lower Trinity River Basin reconnaissance report.
COE. 81. Wallisville post-authorization change report.
TBWE. 57. Transcript of hearing on app. 1990 by Southern Canal Co.
Bolding & Bolding. 81. Origin & growth of the Dallas water utilities.
Freese & Sizemore. 94. A century in the making.
COE. 49. Definite project report on Fort Worth floodway.
KSA Engineers. 96. Wortham water supply alternatives.

Yields:

a. Where source documentation provides a basis for yield estimates for future years, estimates closest to 2010 conditions are used.
b. Bridgeport yield is included in the yield shown for Eagle Mountain.
c. Ray Roberts yield is included in the yield shown for Lewisville.
d. Carrollton and California Crossing yields are included in the yield shown for Fraiser. These are three within-banks impoundments on the lower Elm Fork which are used as diversion points for water released from larger lakes upstream. They have their own yield as shown, based on very senior rights in connection with the City of Dallas' early water supply facilities on the Elm Fork.

Primary Uses:

WS = water supply for:

m = municipal, which includes all uses in a municipal water supply system.
e = electrical power generation (condenser cooling)
I = industry
a = agriculture (irrigation)

FC = flood control

R = recreation (All the lakes are used for recreation). This notation is used only for those three lakes in the table which are used solely for recreation. White Rock was originally built and used for water supply and is now used only for recreation. Kiowa was built solely for recreation. Alvarado was built and permitted for water supply but to date has been used only for recreation

Fig. 2m. Notes from Water Supply Lakes Map.

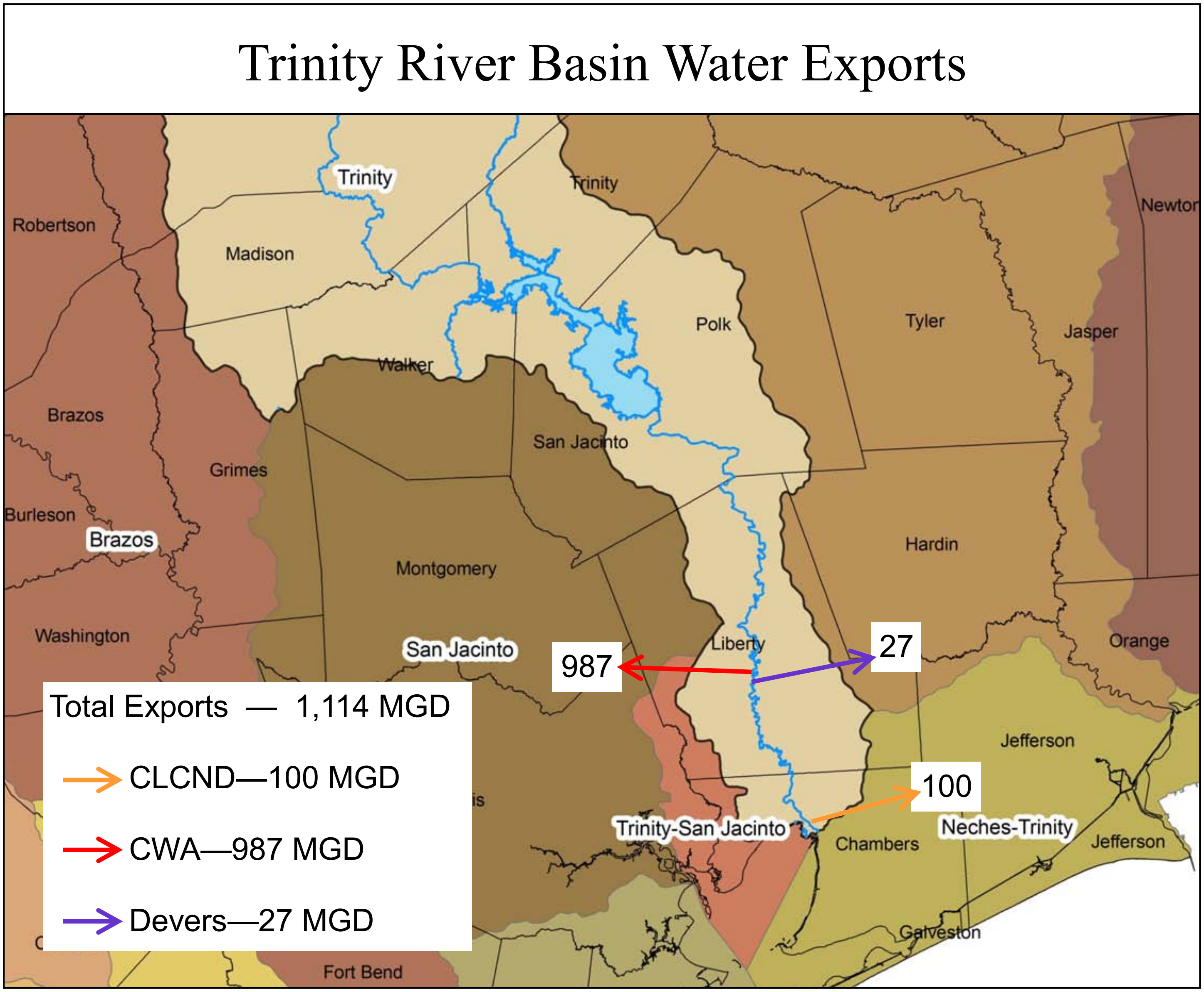



Fig. 2n. Trinity Basin Water Exports.

## Water Rights

Water has been a source of life, prosperity, and conflict since settlement began in Texas. Because of the importance of water on the Texas plains, colonizers sought to secure legal water rights. Texas water law has evolved from a mixture of Riparian Doctrine and Prior Appropriation Doctrine into what it is today.

Texas water law is based on the principle of "first in time, first in right." In other words, senior water rights holders have the authority to take their allotted portion of water before a junior water rights holder. It has been said that water does not flow downhill, it flows towards priority dates. If a senior water right holder is downstream of a junior water rights holder, the junior holder must allow the water to flow through to the senior rights holder. During a drought, the decision to shut off water pumping is made by a Texas Watermaster. Currently, only three areas operate under a Watermaster Program: Rio Grande, Concho River, and South Texas. Should water demand increase as expected, a Watermaster will eventually be appointed for the Trinity River basin to ensure the "first in time" laws are followed.

*Water Rights Adjudication* – The adjudication of the Trinity River Basin water rights was completed in the 1980's. It has upheld in full almost all rights which had been granted under permits and certified filings. Of the many small claims which had been based upon riparian or other rights, only a minority were acceptable under the various legal and factual tests which were applied. All water rights and priorities are now completely defined. Each water right was given a priority date that essentially sets the holders place for the "first in time" line. The earliest priority date in the basin is 1906 and the earliest in Texas is 1731.

*Large Run-of-River Water Rights* - In the Lower Trinity basin, there are several canal systems which supply water primarily to rice farmers, with lesser quantities supplied for municipal and industrial needs. Three of these systems entered into written agreements with the co-sponsors of the Livingston and Wallisville projects to ensure that a fixed amount of water would be made available. These agreements became known as the "Fixed Rights Agreements." Releases of water stored in Lake Livingston, together with available streamflow originating downstream of Lake Livingston, are to be provided to each system in amounts shown in the table entitled "Summary of Fixed Rights Agreement."

The water rights of the "Fixed Rights" parties have been modified significantly since 1995. The San Jacinto River Authority purchased from the Devers system the rights to 56,000 acre feet per year for use in Montgomery County in the San Jacinto River basin. That water is no longer intended for irrigation use in the Trinity basin, as was the case when the fixed rights agreements were made, and does not retain the claim on Lake Livingston stored water that was indicated in those agreements. The City of Houston has purchased the Dayton Canal System and is seeking water rights permit amendments to allow that water to be used in the San Jacinto River basin. Also, the Chambers-Liberty Counties Navigation District and the San Jacinto River Authority have agreed to convey 30,000 acre feet per year of the District's water to the River Authority for use in Montgomery County. In addition to the "Fixed Rights Agreement," the City of Houston holds permits totaling 40.2 MGD (45,000 acre feet per year) on the Trinity River below Lake Livingston which were formerly held by the Southern Canal Company. The trend of water rights shifting away from irrigation and towards municipal uses is expected to continue.

*Small Run-of-River Water Rights* – There are numerous relatively small diversions with little or no storage to firm up the supply during low flows. For a complete list of lower Trinity water rights see Appendix 5. Most of these rights are for irrigation and other agricultural purposes.

## Table 2c. Summary of Historic, Lower Trinity Water Rights

| Original System Name | Current Owner | Amount of Rights<br>*Acre Feet/Year* | | Priority Date |
|---|---|---|---|---|
| Chambers-Liberty Counties | CLCND* | 58,820 | | 1936, 1971 |
| Navigation District | SJRA | 30,000 | | 1914 |
| | | | 88,820 | |
| Devers Canal System | Devers* | 30,000 | | 1929, 1959 |
| | SJRA | 56,000 | | 1917, -26, -29, -36 |
| | | | 86,000 | |
| Dayton (formerly Richmond) | Houston | 33,000 | | 1913, 1969 |
| | | | 33,000 | |
| Southern Canal Company | Houston | 45,000 | | 1913 |
| | | | 45,000 | |

** Guaranteed by fixed rights agreements with TRA and the City of Houston. If there is insufficient flow in the river to meet these senior rights, TRA will release water from Livingston storage.*

# Trinity River Authority of Texas

# Basin Master Plan

## Water Quality

### Background

On a Federal level, the Clean Water Act (CWA) of 1972 established the basic structure for regulating discharges of pollutants into water bodies. The Act gave the Environmental Protection Agency (EPA) authority to implement pollution control programs such as setting wastewater standards, water quality standards, and point and nonpoint source discharge permits. For the Trinity River basin, the CWA of 1972 does not tell the whole story.

Fig. 3a. TRA's Central Regional Wastewater System, 2005.

In 1846, during his reconnaissance of Texas, A.W. Moore described the Trinity River as a "little narrow deep stinking affair." Historically, many of the major tributaries, and sometimes the main stem, of the Trinity River would dry up during the long, hot summer months and periods of drought. As settlement increased, people relied heavily on the Trinity for water supply and waste removal. Drinking water was pumped directly from the main stem for Dallas' water supply until 1896 when Record Crossing was built on the Elm Fork so that a cleaner, more reliable water supply was available. The Trinity River received large amounts of untreated and partially treated sewage from sources including small, inefficient wastewater treatment facilities, dysfunctional septic systems, and direct discharges from citizens and industry. Consequently, in 1925, Texas Department of Health characterized the Trinity River as a "mythological river of death" because of the number of people that died from typhoid fever, a bacteria associated with polluted water sources.

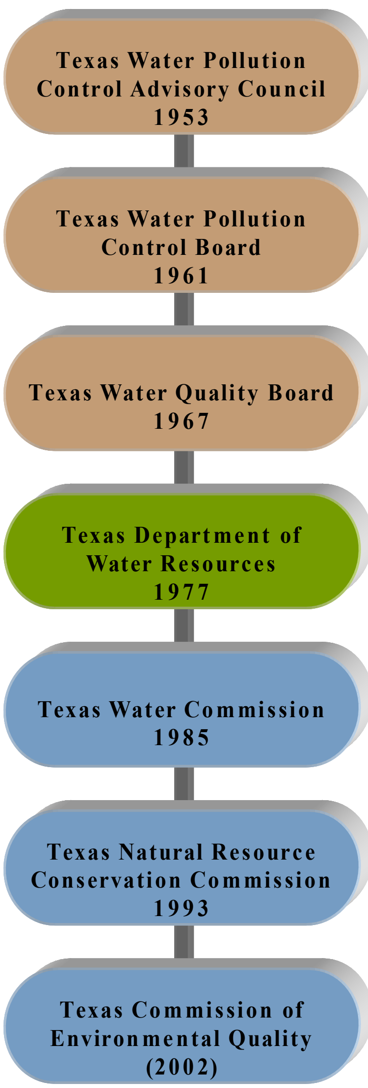



Fig. 3b. Evolution of TCEQ.

In the 1950's, the legislature granted the Trinity River Authority the authority to construct and operate regional wastewater treatment and collection systems. The first of these was TRA's Central Regional Wastewater System (CRWS). The legal groundwork and this idea of "cooperation" between municipalities, entities, and the State, helped to create a blueprint that other regions of Texas soon followed.

Prior to 1967, the Texas Department of Health (TDH) reviewed wastewater treatment plant designs. TDH had few resources allocated to wastewater and no comprehensive permit system for wastewater dischargers existed. The Texas Water Quality Board was created in 1967 around the same time this concept of cooperation among dischargers (which later evolved into the "The Compact") developed. The major dischargers and their consultants met with the Texas Water Quality Board and committed to using the best technology, that was proven to work, for large scale plants. In addition, prior to the Clean Water Act of 1972, permits written by the Texas Water Quality Board included permit levels of 10 mg/L biochemical oxygen demand (BOD) and 10 mg/L total suspended solids (TSS). The science and administrative base for the creation of these "10/10" permits by the Trinity River basin entities became the groundwork for other permitting issues throughout Texas.

Improvements in water quality since the 1950s has been quite dramatic. Permit levels have greatly reduced loadings from point sources and increased wastewater quality such that it has become a commodity. For decades, the Trinity River Authority has been integral to improving water quality in the Trinity basin, and that commitment continues today.

## The Trinity River Basin

The natural flow in the great majority of streams in the Trinity River basin is highly variable. Most of the Trinity's flow is rainfall runoff. In the summer, flow is quite low—sometimes dry. To combat the intermittent nature of the Trinity River, reservoirs were built throughout the basin to solidify a water supply for a growing population. The characteristics of the streams have changed over time and at present there are four distinct water body types:

- Effluent Dominated Streams
- Reservoir Release Dominated Streams
- Intermittent Streams
- Perennial Streams
- Reservoirs

### *Effluent Dominated Streams*

Wherever there is a wastewater treatment plant discharging into a stream, the flow from that plant during dry periods constitutes a majority, sometimes all, of the flow. That situation is considered an effluent dominated stream, and it exists for some distance downstream from most wastewater plants in the basin. It is a result of the natural characteristics of the land.

Effluent dominated streams exist in all sizes from small discharges into small streams or large discharges into large streams. During dry periods, river beds upstream of discharges may be dry and the discharge could evaporate or soak into the bed and banks downstream leaving a dry channel.

The biggest effluent dominated reach is the main stem from the DFW Region to Lake Livingston. In dry weather, the flow is almost entirely wastewater effluent. Since improvements in wastewater treatment technologies and facility upgrades, the water quality in these reaches has greatly improved, even as the population has increased. Figure 3c shows how average annual dissolved oxygen, one of the many water quality indicators, has increased even though the population has doubled since 1970.

Dissolved oxygen (DO) in natural waters is necessary for fish and other aquatic life. The Texas Commission of Environmental Quality (TCEQ) sets the standard for high aquatic life use at 5 mg/L. In pure water, the concentration of dissolved oxygen will reach an equilibrium with the oxygen in the air at its *saturation* (100%) point. Figure 3d shows in 1971, the average saturation was about 44%, but by 2003, it averaged about 100%.

With all organisms, there is a constant competition for resources. Wastewater provides nutrients for algal growth which produces oxygen. Yet, wastewater also contains bacteria and certain other chemicals that consume oxygen. When consumption is greater than available oxygen, fish kills may occur.

Biochemical oxygen demand (BOD) is another measure of water quality. Due to improving technologies, wastewater discharge permit levels have been reduced from 30, to 10, and currently to 5 mg/L. It is interesting to note the inverse relationship between BOD and increased flow from wastewater treatment plants (fig. 3e).

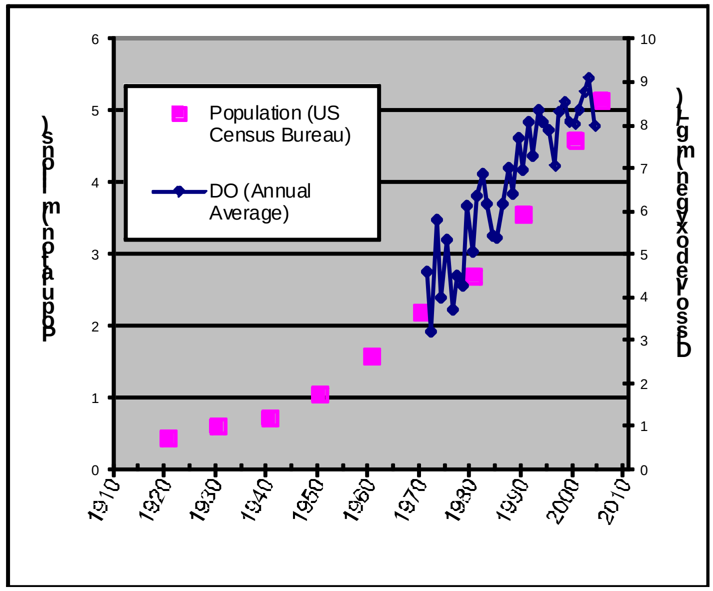



Fig. 3c. Population of Dallas, Tarrant, Ellis, and Navarro Counties Plotted Against DO Values at the Rosser Gage.

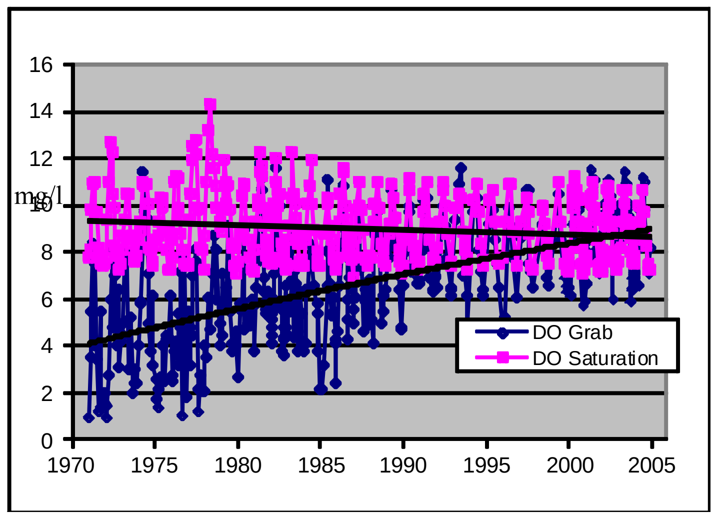



Fig. 3d. Dissolved Oxygen Plotted Against Saturation at the Rosser Gage.

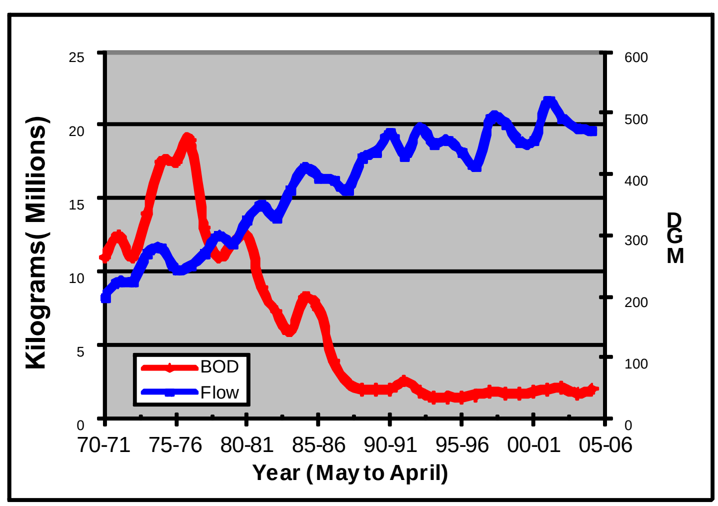



Fig. 3e. BOD vs. Flow for Major Region C Dischargers.

### *Reservoir Release Dominated Streams*

Because of the extensive reservoir network, the majority of water in the Trinity basin is reservoir water, was reservoir water, or is going to be reservoir water. With all of the physical, chemical, and biological forces at work, reservoirs do an excellent job of cleaning water. When runoff or stream flow moves through a reservoir system, the water slows down allowing suspended sediment to settle out, nutrients to be used, and pollutants to sorb to particulates. Released water generally provides clean baseflow for streams. In general, these reaches are saturated with dissolved oxygen and have only isolated, infrequent pollution problems. There are five reaches of stream in the basin that are commonly supported at baseflow with releases from reservoirs (fig. 3f) and these segments are monitored closely by the agencies using them for water supply.


Fig. 3f. Map of Reservoir Supported Base Flow Segments.

### *Intermittent Streams*

Intermittent streams throughout the basin are generally characterized by the runoff characteristics of their watersheds. Some small urban watersheds may have poor water quality during dry periods and during the "first flush" of a rain event. In addition, dissolved oxygen is occasionally low and bacteria are often high. Suspended and attached algae sometimes produce scums and odors and cloud the water. Notwithstanding these problems, fish such as shad and sunfish are often seen in numbers and recreational uses are intensive in park areas along such streams.

Fig. 3g. Release from Lake Livingston.

Intermittent streams with larger and less developed watersheds generally have turbid but otherwise good quality water following a rain, decreasing turbidity as the runoff decreases, standing pools which may remain clean or slowly stagnate after the flow ceases, and finally a dry channel. It is not uncommon for these streams to stay dry for months at a time. Although the data is limited, water quality parameters, other than suspended solids, are generally good. In some streams, occasional elevated levels of total dissolved solids, chlorides, or bacteria are noted at times of rising or peak runoff, apparently due to non-point sources.

### *Perennial Streams*

In the eastern portion of the basin from around Cedar Creek Reservoir to Liberty, a number of the Trinity's tributaries receive some of their baseflow from groundwater. Menard and Big Creeks in the lower basin and Catfish Creek in Anderson County are examples. These waters are clear, have a high water quality, and retain a constant baseflow even during periods of drought. The hydrograph in figure 3h shows that groundwater influenced Menard Creek retains a fairly patterned flow regime and no instances of zero flow during the period of record.

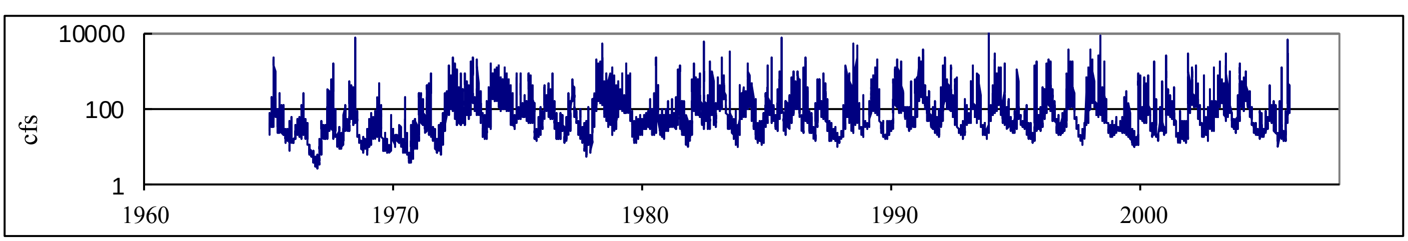



Fig. 3h. USGS Daily Flow Data at Menard Creek (Lower Basin) and Hwy 146.

Fig. 3i. Benbrook Lake.

***Reservoirs***

The reservoirs in the basin are fed mainly by intermittent streams. The main exception is Lake Livingston on the lower main stem. The water quality in the main pool of these lakes is generally acceptable for its intended uses. Some of the smaller urban lakes show elevated levels of toxics and are listed as impaired on the USEPA's 303d list. Lake Livingston, along with other basin reservoirs, occasionally has pH values above the 8.5 standard or taste and odor problems in raw water supplies. In most cases these problems are not extreme and while they may represent eutrophic pressures in some lakes, there may be natural causes in others.

Water quality in the basin's reservoirs is a major concern for TRA and other controlling entities. Residential subdivisions, boat launches, marinas, and parks adjacent to lakes are capable of generating sizable amounts of domestic sewage and other wastes. Along with devising best management practices (BMPs) at Lake Livingston, TRA provides services for a fee in the operation of some sewage treatment plants, chemical analysis of treatment plant discharges, and the operation of a vacuum truck. In addition, TRA requires that on-site sewage facilities and excavation and/or construction projects be permitted through TRA's Lake Livingston Project. It is clear that a reservoir's owner/operator must take the lead in the control of lakeshore pollution.

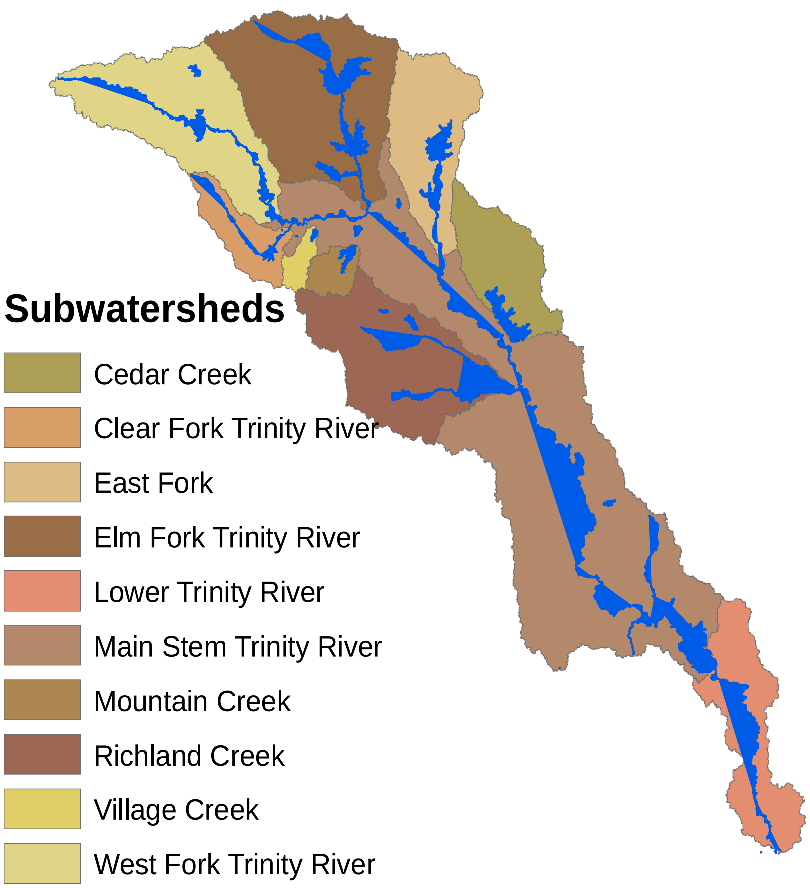



Fig. 3j. Trinity River Subwatersheds.

## Watersheds

Wastewater discharge permits and standards have greatly improved water quality within the basin. Although it is no small task to regulate these point discharges, non-point sources present an even greater challenge. The Trinity River watershed is nearly 18,000 $m^2$ and has been divided into ten major subwatersheds (fig. 3j) ranging in size from 143 to 6,788 $m^2$. A river segment typically shares the characteristics of its watershed. For example, segments in the Upper Main Stem tend to be quite turbid which is characteristic of the prairie soils found in the subwatershed. Whatever happens in a watershed can have an impact on the water quality of that segment, as well as any downstream river segment.

In the Trinity River basin, the constituents that contribute to non-point source pollution include: oxygen demanding material, nutrients, dissolved and suspended solids including sediments, heavy metals, pesticides, complex compounds, bacteria, PAH's, litter, and floatables. Other potential sources of pollutants include wastewater overflows, septic system leakage, leachate from solid waste facilities, construction activities, and agricultural operations. Materials which may be contributed from agricultural sources include pesticides, nutrients, salts, and sediments in runoff and return flows. Non-point pollutants have been associated with low dissolved oxygen concentrations, algae blooms, periodic toxicity to aquatic life, and sediment accumulations of toxic and organic substances.

To aid in controlling pollutants entering waterways throughout the United States, the EPA has initiated a stormwater permitting program for cities with populations exceeding 100,000 residents. At present, the major cities in the Dallas-Fort Worth area have joined in a cooperative approach to the stormwater permitting process. The North Central Texas Council of Governments (NCTCOG) coordinates these efforts. The cities, NCTCOG, and their consultants are working on a watershed-based approach to classifying the *instream water quality* during wet weather, "first flush" events. This instream sampling method is quite a shift from the previous "end of pipe" sampling required in the past.


Fig. 3k. Intersection of Park Row and Fielder in Arlington, TX. (Note how urbanization has changed the watershed).

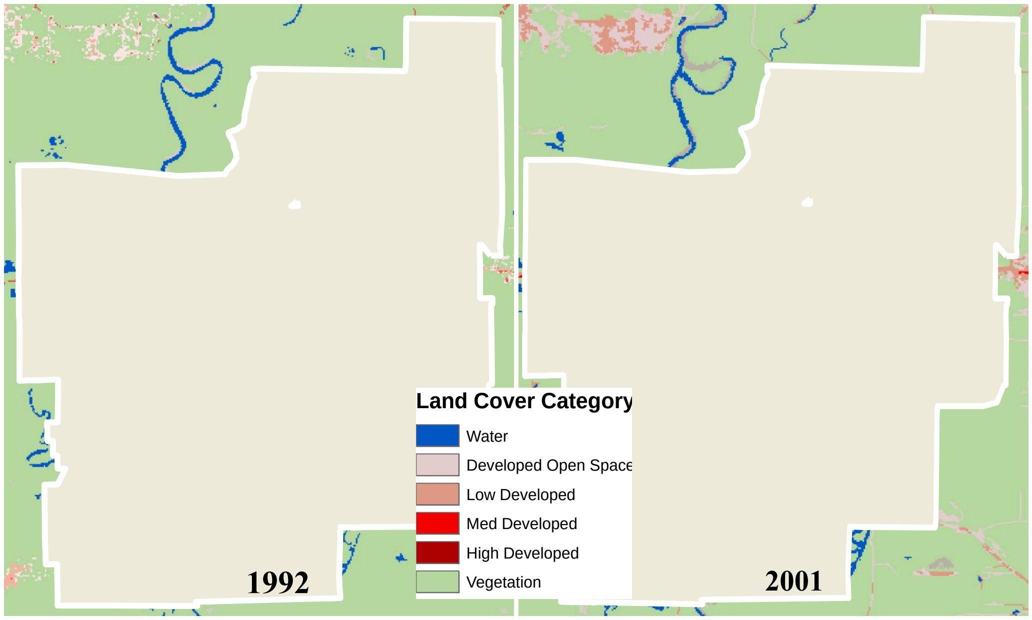



Fig. 3l. City of Liberty, TX Land Cover Change (USGS).

In the Dallas/Fort Worth area, subdivisions and mobile home parks have grown along the leading fringes of the rapid urban expansion. These developments are beyond the economic range of existing collection systems and are frequently beyond any city limits or extraterritorial jurisdictions. They provide sewage treatment with either septic tanks or small package plants. Maintenance, operations, and system designs are often not very good. There is concern and interest on the part of the water supply agencies to begin taking reasonable and prudent steps toward good wastewater management as these areas grow. Of greatest interest are the geographic areas within about ten miles of the regions major water supply lakes: Arlington, Benbrook, Eagle Mountain, Worth, Grapevine, Lewisville, Lavon, Ray Hubbard, and Joe Pool. Although the scale is smaller, the lower basin is facing some of the same issues as development and population increase (fig. 3l).

Dallas, Fort Worth, Mansfield, Arlington, along with the Trinity River Authority, the Tarrant Regional Water District and the North Texas Municipal Water District have been studying, separately and together, ways to encourage and assist with water quality management in these areas. The most likely approach is to make quality wastewater services available, such as are now provided by the Trinity River Authority around Lake Livingston and the North Texas Municipal Water District in the East Fork watershed, and to urge their use. When justified by the amount of development in an area, eventual connection to a regional system would be encouraged.

The TRA Denton Creek Regional Wastewater System is an example of this approach. It serves an area of northern Tarrant County and southern Denton County at the upstream end of Grapevine Lake. In its service area are a growing residential population, Alliance Airport, and The Texas Motor Speedway. The TRA Mountain Creek Regional Wastewater System came online in 2004 and was developed to serve the expanding populations of Midlothian, Grand Prairie, and Venus.

## Water Quality Planning and Assessments

As the commitment to improving water quality picked up speed throughout the 1960s, it was apparent that a system of collecting organizing, and analyzing water quality data was needed. Entities throughout the basin began stream and reservoir sampling programs that ranged in size from single event sampling to systematic basin-wide collection efforts. Every aspect of the water business has evolved. On the political side, agencies are constantly changing their priorities and goals. On the science side, technological improvements are re-shaping how samples are collected and analyzed. In addition, the importance of database creation and management cannot be overstated.

From the 1950s to the 1990s, entities throughout the basin collected water quality data with some oversight from and coordination with various state agencies. The Texas Legislature created the Clean Rivers Program (CRP) in 1991 in response to concerns that water resource issues were not being addressed in a holistic manner. The CRP is funded by fees paid by wastewater dischargers and the program is implemented by TCEQ contracting with 15 partner agencies. Because of its basin-wide scope, TRA was selected to implement the CRP for the Trinity River basin.

TRA partners with several other cities and regional entities to collect quality-assured water quality data that is used in the biannual state surface water assessment. The CRP promotes coordination and communication so that a comprehensive sampling program can ensure the highest quality data with little overlap and/or duplicated effort. The Clean Rivers Program has become an essential source of routine water quality data.

## Water Quality Reports

Many water quality reports are completed in and on the Trinity River basin each year and the scale and scope of these reports varies drastically. Taken as a whole, the reports indicate that the three major water quality topics in the Trinity River basin are legacy pollutants, bacteria, and nutrients.

Every two years, the state completes a water quality assessment that is submitted and approved by the EPA. This assessment separates sections of the river basin into assessment units and uses water quality data to determine if that section's water quality meets the predetermined standard. For example, it is determined that segment X should be able to support a great deal of aquatic life, aka "High Aquatic Life Use." The quantative standard associated with that qualitative designation is 5mg/L of dissolved oxygen. If the data shows that the samples meet that criteria, then the designated assessment unit is determined to be supporting its use.

Although this process seems straightforward, care must be taken when reviewing the state report. All segments that have not been specifically studied are assigned a default "High Aquatic Life Use." In reality, some of these streams may be slow moving, shaded, and full of organic debris. The natural conditions suggest that it should not be held to the same standard and may become listed inappropriately. Efforts are currently underway at both the state and regional level to address this issue of inappropriate standards. In addition, TCEQ is focusing on creating designated assessment units with site specific water quality criteria. The shift to this assessment unit approach represents an evolution of water quality monitoring programs and demonstrates a commitment to constantly improving the water quality of the basin.

### Legacy Pollutants

Pollutants that have been banned for decades, yet are still found in the environment in concentrations deemed to be detrimental for humans. The sources of these are typically unknown or contaminated sediment that, were it to be removed, could cause greater harm.

### Bacteria

Samples continue to show high levels in highly urbanized portions of the basin (fig. 3m).

### Nutrients

Aquatic organisms need nutrients to survive. However, in some segments of the basin, excess nutrients may contribute to algal blooms that could lead to low DO levels and fish kills.

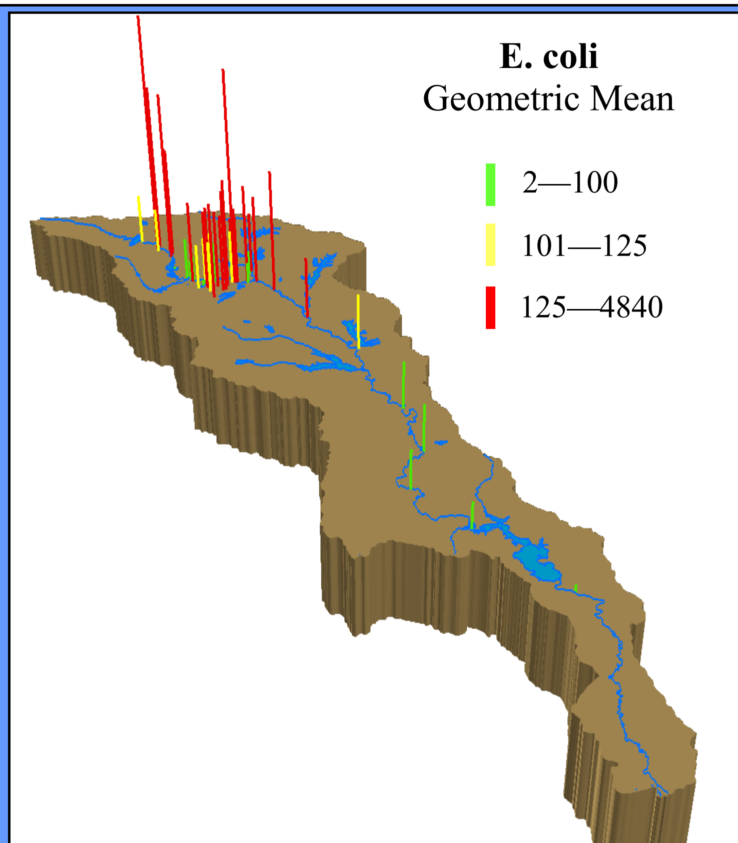



Fig. 3m. E. coli. Values .

## Discussion

*Water Quality Assessment under the Clean Rivers Act* – The 1992 assessment, though performed within three months, was able to review the water quality indicators which have been studied for years and also to examine more recent data. Most important among the latter are toxics and non-point sources, excerpted from the assessment report below. Since 1993, TRA has further investigated these topics and performed relevant special studies and pilot projects.

*Toxics* – Toxic substances are receiving increased attention in the Trinity Basin, especially in the upper main stem. Throughout the Trinity Basin, wastewater discharges, urban runoff, and agricultural runoff have been identified as potential contributors of toxics. Diazinon has been identified as causing biomonitoring compliance problems in wastewater effluents. Measured levels of chlordane in fish tissue have caused fishing bans to be imposed in several urban segments.

In recent years, numerous studies have been carried out in the Trinity River Basin, particularly in the Dallas-Fort Worth area. These studies have been performed by the TCEQ, TRA, consultants and universities. The following toxic chemicals have been documented to exceed water quality criteria levels: cadmium, chlordane, chromium, copper, dieldrin, endrin, heptachlor, lead, lindane, and PCB's. Other toxics which have caused concern because of elevated levels in water and sediments include: aldrin, arsenic, DDT, hexachlorocyclopentadiene, mercury, selenium, silver and zinc. It is important to note that the water quality criteria are used only as a point of comparison. If a parameter exceeds a water quality criteria, it does not mean that the value is in violation of a water quality standard. Oftentimes, the value is measured at a location where the water quality standard does not strictly apply, such as in the hypolimnion of a reservoir, an intermittent, non-designated tributary, or a high flow condition.

Fig. 3n. TRAD Trash Clean Up.

Fig. 3o. Trinity Clean Up.

*Non-point sources* – Non-point sources from urban and non-urban areas contribute dissolved and suspended materials to the Trinity River Basin. These materials include oxygen-demanding material, nutrients, dissolved and suspended solids including sediments, heavy metals, pesticides, complex organic compounds, bacteria and litter. Other potential sources of non-point pollutants include overflows from wastewater collection systems, septic system leakage, leachate from solid waste facilities, construction activities, and agricultural operations. Materials which may be contributed from agricultural sources include pesticides, nutrients, salts, and sediments in runoff and return flows. Non-point pollutants have been associated with low dissolved oxygen concentrations, algae blooms, periodic toxicity to aquatic life, and sediment accumulations of toxic and organic substances.

To aid in controlling pollutants entering waterways throughout the United States, the EPA has initiated a stormwater permitting program for cities with populations exceeding 100,000 persons and for many industries. At the present time, the major cities in the Dallas-Fort Worth area have joined in a cooperative approach to the stormwater permitting process. NCTCOG is coordinating these efforts. The cities, NCTCOG and their consultants, and the USGS have established wet-weather monitoring stations in residential, commercial and industrial areas of Dallas, Fort Worth, Arlington, Irving, Garland, Mesquite and Plano for stormwater sampling of seven storm events at each site. NCTCOG expects that approximately 300 runoff events will be sampled by the time the program is complete. Once the pollutant-generating mechanisms have been characterized, Best Management Practices will be developed for control of stormwater pollution.

*Bay and Estuary Inflow Quality* – Inflows to bays and estuaries are important in establishing a salinity gradient and in providing nutrients to the biological systems of bays and estuaries. However, the natural quantity and quality of inflow is highly variable, and there is not a consensus regarding the exact amounts which are necessary for the bays and which changes would make a difference.

*Water Quality Goals in Effluent Dominated Reaches* – The federal Clean Water Act required that all waters in the United States be suitable for fish and wildlife and for recreation in or on the waters by 1983. Even though these criteria do not include provisions for drinking water for human consumption, they are in many respects more stringent, inasmuch as the requirements for fish, wildlife, and recreation must be high enough to exclude toxic conditions or disease-bearing organisms even without any treatment of the water. Fortunately, as noted above, most of the waters in the Trinity River Basin satisfy these criteria.

The effluent dominated reaches, described above, do not entirely satisfy the federal criteria. While it is desirable to pursue the prescribed conditions of high water quality, they are extremely difficult, if not impossible, to achieve so long as dry weather flow consists entirely of wastewater effluent. Moreover, the river is affected by runoff and other factors quite removed from the wastewater treatment plants. The better the wastewater treatment, the more radically the river quality will be affected by rises from storm events. Such changes are very damaging to stable and desirable communities of fish and other wildlife.

As described above, the emphasis of regulatory agencies is now on finding and regulating toxicity in wastewater plant effluents. However, the runoff or rise condition is the limiting factor in the quality of receiving waters, and no improvements have occurred in that area. In order to reduce such problems, the Environmental Protection Agency has required all cities over 100,000 population to obtain permits governing the quality of stormwater in those cities. At present, stormwater is being analyzed to determine existing contaminants. Then steps will be devised by EPA and the permittees to control the contaminants. Concurrently, under the Clean Rivers Act, methods are being developed to include runoff in the calculations which are presently used by regulatory agencies to determine permit limits for point sources.

Also, in the Fort Worth-Dallas area there are several park areas being developed next to the rivers and streams which will bring people into contact with the river in unprecedented numbers. Fort Worth is expanding its parks from the Clear Fork through the West Fork. Arlington has opened a large park on an effluent dominated section of the West Fork. Dallas has one park in the floodway of the river, and voters have approved funds for additional parks in the floodway. These are definite, and some additional developments are planned. The idea of a continuous park, or “Greenbelt,” along the river between Fort Worth and Dallas has been promoted for many years. The idea was incorporated into a specific plan as part of the Trinity River Project in the early 1970s. The idea is now being discussed in coordinating committees of the North Central Texas Council of Governments.

Because of the increasing recreational opportunities along the Trinity River, public safety regarding infectious organisms is an important issue. This problem is made more difficult by the dechlorination requirements of wastewater effluents.

*Lakeshore Water Pollution Control* – Certain activities which are common near lake shores may cause pollution in the adjacent part of the lake. Residential subdivisions, boat launches, marinas, and parks are capable of generating sizable amounts of domestic sewage and other wastes. The TCEQ is the primary state agency with jurisdiction and enforcement power in water quality matters. Other governmental entities have some legal powers, but their staff and other resources are much more limited.

When Lake Livingston was being constructed, it was apparent that there would be extensive residential and other development around the lake. Much of the initial facilities to handle wastewater would be septic tanks and drainfields. Much of the soil around the lake is clay and is poorly suited for drainfields. The Authority provides services, for a fee, in the operation of some sewage treatment plants, the chemical analysis of treatment plant discharges, and the operation of a vacuum truck. The Authority, through the Livingston Recreation Fund, owns and operates a sewage treatment plant to serve Wolf Creek Park, on the lake’s shore. A long-range plan for sewering most of the developed shoreline of Lake Livingston was prepared in 1974 and updated in 1978.

The lakes owned and operated by the Tarrant Regional Water District (TRWD), especially Cedar Creek Lake, and the city of Dallas’ Lake Ray Hubbard, are similar to Lake Livingston regarding shoreside development. Similar steps have been taken to protect water quality.

In conclusion, it is clear that the owner/operator of a lake must take a strong role in the control of lake shore pollution problems. The TCEQ can provide support in enforcement. Still, the owner/operator is often best suited, especially on a large lake, to take the lead in organization, planning and in technical services.

*Water Supply Lake Watershed Management* – In the past few years the rate of development in the watersheds of the water supply lakes of the Dallas-Fort Worth area has accelerated greatly. This is development over and above that which has occurred in the immediate shoreline area of these lakes. It consists generally of subdivisions and mobile home parks in the leading fringe of suburban growth. These developments are beyond the economic range of existing collection systems and are frequently beyond any city limits or extra-territorial jurisdictions. They provide sewage treatment with either septic tanks or small package plants. Maintenance, operation and design of these systems are often insufficient to assure continuous, high-quality treatment.

The lakes of interest at present are Arlington, Benbrook, Eagle Mountain, Worth, Grapevine, Lewisville, Lavon, Ray Hubbard, and Joe Pool. The quality of water in these lakes is quite adequate at present, but there is a concern and interest on the part of the water supply agencies to begin taking reasonable, prudent steps toward good wastewater management as these areas grow. The geographic area of greatest interest is within five to ten miles of the lake shores.

A historical case study is that of Lake Arlington. About 1970, there were about a dozen medium-to-small wastewater plants in the watershed. The quality of operation was fair to poor. The City of Arlington tried to have all of those discharges diverted, treated, and discharged outside the lake watershed. It extended necessary collection mains and exercised what legal power and persuasion was available to it and largely succeeded by about 1974. The city was pleased with certain improvements in algae concentrations and taste-and-odor problems in the lake water. The actions taken in the Lake Arlington watershed are not necessarily feasible in other cases, and even now some new development is occurring beyond the presently sewered areas.

The cities of Dallas, Fort Worth, Mansfield and Arlington, along with the Trinity River Authority, the Tarrant Regional Water District and the North Texas Municipal Water District have been studying, separately and together, ways to encourage and assist with water quality management in these areas. The most likely approach at present is to make quality operating services available, such as are now provided by the Trinity River Authority around Lake Livingston and the North Texas Municipal Water District in the East Fork watershed, and to urge their use. When justified by the amount of development in an area, eventual connection to a regional system would be encouraged.

TRA's Denton Creek Regional Wastewater System (DCRWS), located at the upstream end of Grapevine Lake, is one example of this approach. DCRWS serves one of the fastest growing residential populations in Texas (fig. 3p).

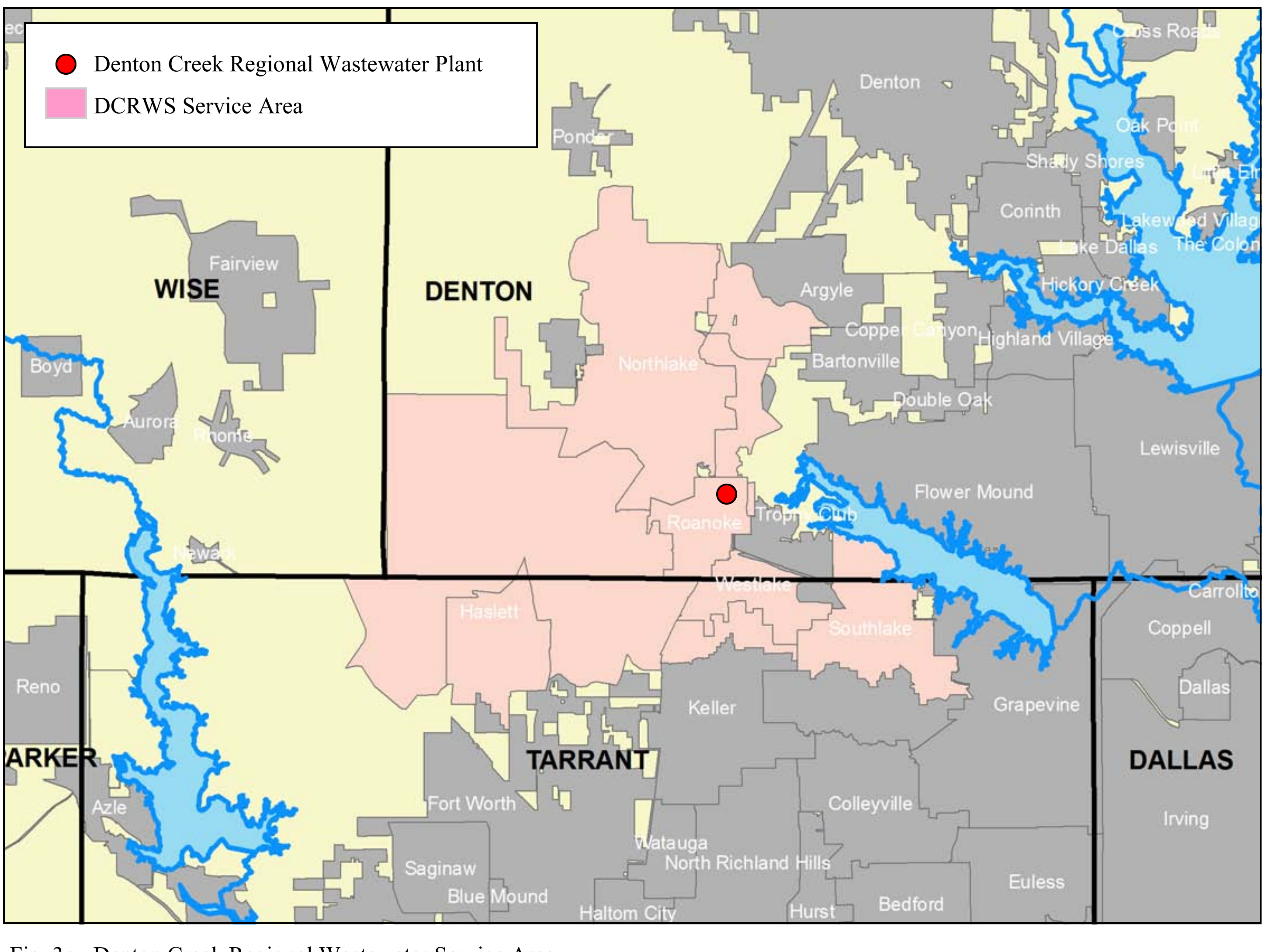



Fig. 3p. Denton Creek Regional Wastewater Service Area.

# Trinity River Authority of Texas

# Basin Master Plan

## Water Reuse

### Background

When reuse was considered after the drought of the late 1950s, the standard for municipal wastewater treatment was called "secondary" treatment. It was designed to produce water with a biochemical oxygen demand (BOD) and total suspended solids (TSS) of approximately 30 mg/l each. The quality was suitable for some irrigation purposes, but very little of it was used that way in the Trinity basin. Almost all of it was discharged to streams, where in most cases it produced a distinct reduction in dissolved oxygen and some toxicity due to ammonia and chlorine residuals. Moreover, a lack of enforcement and public interest resulted in many plants not performing as well as designed.

The environmental movement in the mid-1960s changed everything. Under the Texas Water Quality Act (1967) the major permit limits in the Dallas-Fort Worth area were lowered to 10 mg/l for BOD and 12 mg/l for TSS. The new standards required improved biological treatment and sand filters. The federal Clean Water Act (1972) adopted those requirements and, over time, continued to require more improvements. BOD limits were lowered further and ammonia limits were added, requiring complete nitrification. Treatment to remove chlorine residuals were added. Moreover, since the permit limits are the limits of what is legally allowed, the plants must perform even better than those limits almost all the time in order to still meet them under the most adverse conditions. The result is consistently high water quality.

The Trinity River Basin has moderate rainfall and runoff on average but it is notoriously erratic: floods at times and drought at other times. Even a normal year has much of the rain and streamflow in the late spring followed by very hot dry weather from mid-June through August. Population growth and economic activity in the Trinity basin has necessitated extensive development of water supplies to get through the dry periods. On average, about 60-65% of the water supplied in a municipal system is subsequently discharged into the wastewater system. The return flow is fairly constant, a characteristic that is essential for water supply (fig. 4a). However, the quality of treated wastewater for many years was not of sufficient quality for most forms of reuse. It was discharged to a stream and natural processes gradually purified and diluted it. In many cases, the water entered and supplemented another water supply downstream. It was not done intentionally to supplement a water supply, but as a practical matter it was *de facto* reuse.

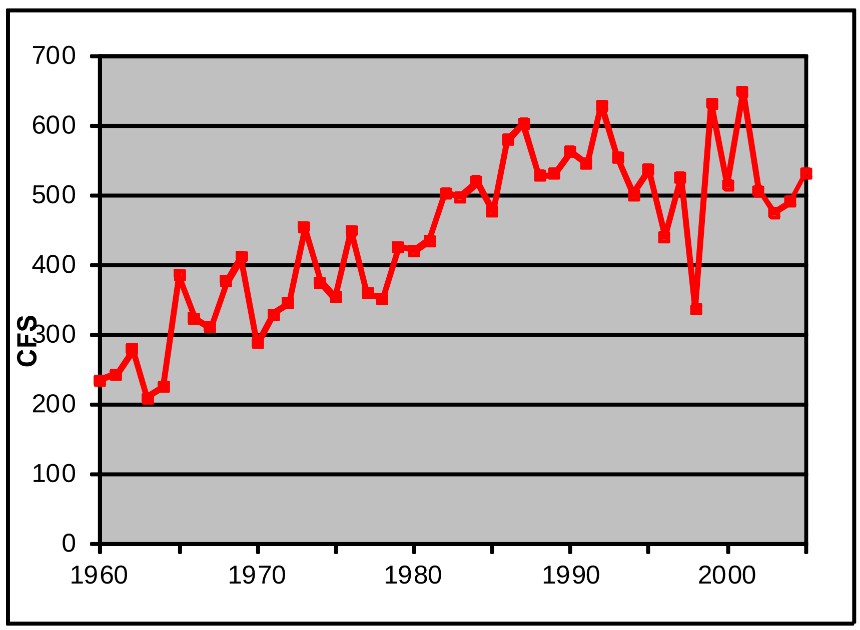



Fig. 4a. Minimum 7-Day Flow at Trinity River Below Dallas.

It does not appear that it will ever be possible or desirable to reuse all reclaimed water. Some flows need to remain in the stream to support the natural environment and to protect downstream water rights and supplies. Moreover, repeated cycles of reuse become progressively more difficult and expensive. Reuse will be an important part of water supplies, but there will be limits.

### Reuse Explained

What is Reuse? In the Trinity River basin, the same parcel of water is reused several times over before being discharged into Trinity Bay. For example, runoff collects in Lake Lewisville, is then pulled out of Lake Lewisville and pumped north to be used by the City of Denton. Denton treats the water and discharges the water back into Lake Lewisville. The same water could then be pumped out of Lewisville and used as Dallas water supply. Dallas treats the water and discharges it back into the Trinity River. Continuing south, the same water could be pumped out by the City of Huntsville, cleaned, and discharged into Lake Livingston. Once in Lake

Livingston, the water could be pulled out by Houston and used again. Finally, Trinity River water could be discharged from Houston into the San Jacinto River and arrive in Galveston Bay from a different river basin altogether.

Two types of reuse exist: direct reuse and indirect reuse. Direct reuse is using water that is pumped directly from a treatment plant to another location without ever entering a receiving surface water stream. Currently, direct reuse does not require a water rights permit because the original user still controls the water. Indirect reuse is using treated water after it has been discharged into a receiving stream. For example, a treatment plant discharges water into the stream and that water is later pumped from the stream to irrigate a golf course. Because the water is being diverted from Texas surface waters, the golf course must own a bed and banks permit. Currently, the legal intricacies are still being debated.

## Past and Present Issues

*Reclaimed Water* – In 1959, the quality of treated wastewater did not make it attractive for reuse. Over the next four decades, improvements in wastewater treatment by all parties in the basin have made it very feasible. New treatment technologies increase the possibilities every year. The word "wastewater," as applied to water produced by a wastewater treatment plant, is now out-of-date in several respects:

- It is not "waste" in the sense of "poor quality." It is good quality and getting better. Most "waste" has been removed.
- It is not "waste" in the sense of "unusable." It is suitable for many uses and there is an increasing demand for it.
- It is not "waste" in the sense of "cheap." A large amount of money has been spent to remove the waste.
- It is not "waste" in the sense of "without value." There is a market of buyers willing to pay a price for it.

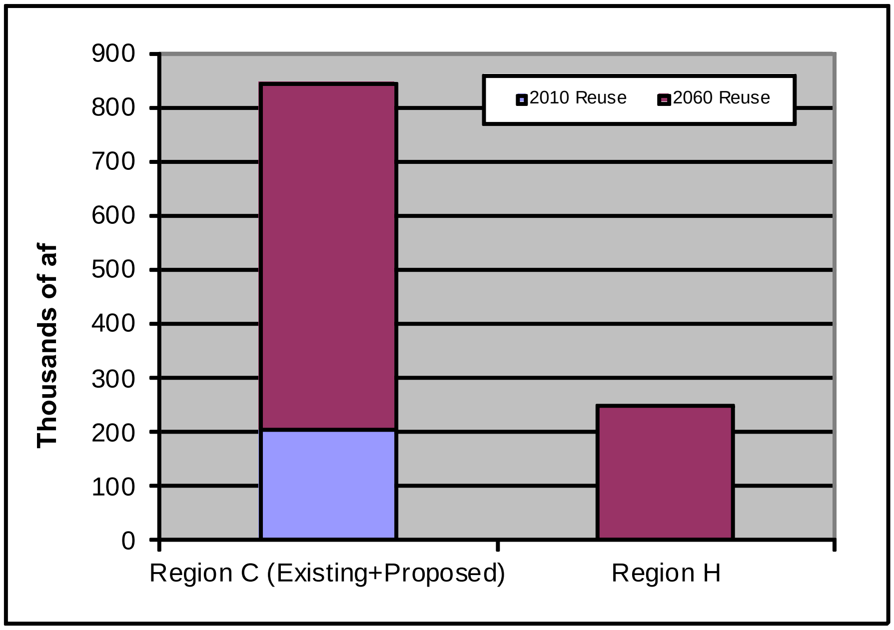


Fig. 4b. 2010 and 2060 Reuse Estimates for Regions C and H.

Today a more appropriate term is "reclaimed" water. It may be wastewater when it enters the plant and what happens there may be considered wastewater treatment. But after treatment, it is no longer "waste" water. Even "treated wastewater" is ambiguous and fails to convey the radical transformation that has occurred.


Fig. 4c. Effluent from TRA's Denton Creek Outfall.

*Quantity of Reclaimed Water* - The great majority of reclaimed water in the Trinity basin comes from municipal plants (approximately 95%). According to 2011 Region C Water Plan, Region C anticipates that the reuse portion of the water supply will increase 209% from 205,911 af in 2010 to 636,656 af in 2060. In addition, reuse is projected to make up 26% of all 2060 total water supplies from recommended strategies. Currently, Region H has no reuse. By 2060, that number is expected to increase to 250,239 af and make up 21% of projected water supplies from recommended strategies (fig. 4b).

*New Treatment Technologies* – A number of treatment technologies have advanced dramatically in recent years. For example, membrane technology has been known for over twenty years. Until recently, however, it was not cost effective except in the most extreme circumstances. Now, however, there are a variety of types of reliable membranes which can produce almost any desired level of purity, including the removal of all cysts, bacteria, viruses, organics, metals and inorganics. Membrane treatment is rapidly increasing in both wastewater treatment and drinking water treatment. Other technologies are also be-

Carbon is widely used to remove organics, disinfection byproducts, and tastes and odors. In addition, many treatment plants are using ultraviolet light or ozone instead of chemicals to sterilize effluent.

*New Regulations that May Require New Treatment Technology* - State and federal regulatory agencies are developing new regulations for both drinking water and wastewater treatment which will likely require one or more of the new technologies discussed above. For example, the Enhanced Surface Water Treatment Rule under the Safe Drinking Water Act focuses on the removal of the smallest solid particles in order to exclude infectious organisms, such as *Cryptosporidium* that are resistant to disinfection, or to reduce organic substances that can form carcinogens during disinfection. Such requirements apply regardless of any reuse that may be involved, but may result in the requirement of membrane technology, which in turn addresses a wide range of contaminants and constitutes a broad barrier to contamination. The Disinfectants / Disinfection-Byproduct Rule and the Total Trihalomethane MCL, which address mainly potential carcinogens, and the Arsenic MCL, among others, may also require membrane or carbon treatment. Also, under the Clean Water Act, the Environmental Protection Agency is currently requiring all states to develop new numeric stream standards for nutrients. Numerical nutrient criteria are currently undetermined, but initial proposals would require many wastewater treatment plants to add nutrient removal processes.

*"Emerging Concerns" that May Require New Treatment Technology* – There is concern about various pharmaceuticals that are taken by people, excreted, and make it through the wastewater treatment plant. Antibiotics in the receiving stream might create an environment that selects and propagates new antibiotic-resistant pathogens. Hormones such as estrogen might affect fish or water supplies downstream. These are possibilities that are being studied by scientists at present, but if they are determined to be a real problem, advanced treatment of the type discussed above would be called for. Advancements in detection technologies have allowed scientists to study these emerging contaminants and it is anticipated that the next decade will bring better understanding of their importance.

*Reclaimed Water as a Commodity with Several Stakeholders* – The steady, reliable flow of reclaimed water, its high quality, the cost of producing it, and increasing demand make reclaimed water a commodity. At the same time, it is a resource in which several stakeholders have an interest, especially in the upper basin (fig. 4d). The ratepayers of the utilities have paid for both the water supply and wastewater treatment and they have an interest in how it is reused. There are environmental needs and requirements to maintain flow in the stream. Prior water rights need to be protected. Reuse will have to be implemented in ways that are consistent with its characteristics as both a commodity and a public resource.

*Existing Markets and Uses for Reclaimed Water* – Various reuse markets and uses have developed in the last few years. TRA implemented a reuse project with the Las Colinas development in Irving in 1985. Reclaimed water is purchased by Las Colinas to maintain the level of scenic lakes, irrigate landscaping, and water several golf courses. A number of sales of reclaimed water have been made in the Trinity basin, and elsewhere in Texas, for cooling water for commercial electric generating plants and for watering golf courses. The North Texas Municipal Water District located a major new wastewater treatment plant so that its discharge would supplement the District's water

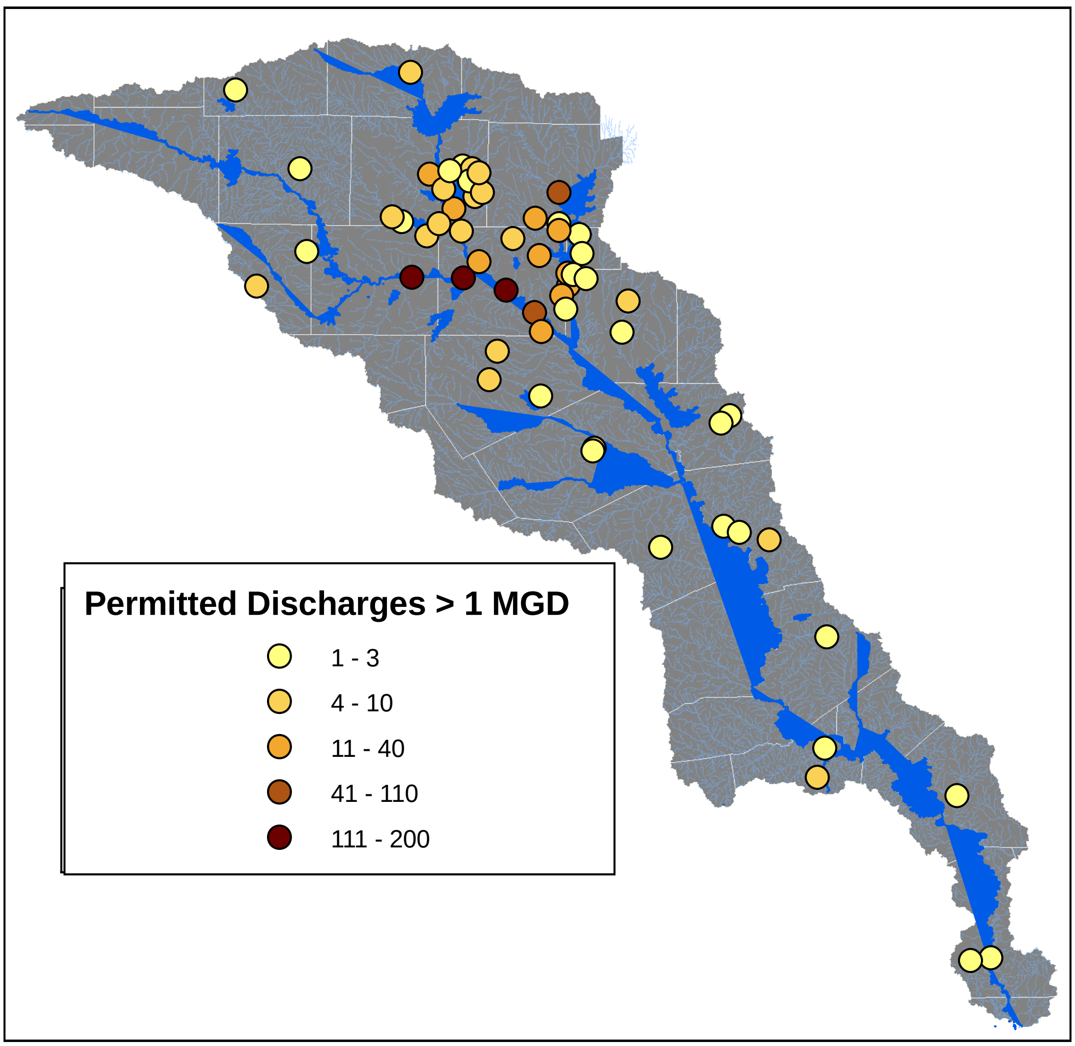



Fig. 4d. Dischargers Permitted Above 1 MGD.

supply. That supplement has now grown to 32 MGD. In addition, there are numerous pending proposals to purchase or trade reclaimed water.

The Tarrant Regional Water District (TRWD) has created a reuse project that will divert Trinity River water into constructed wetlands. The wetlands serve a cleaning function and then deliver the water into the Richland–Chambers or Cedar Creek Reservoir. The North Texas Municipal Water District (NTMWD) operates a similar system south of Lake Ray Hubbard on the East Fork. NTMWD captures some of its return flows and pumps them back into Lake Lavon. Dallas is also planning to reuse some of their reclaimed water in Ray Hubbard and Lewisville reservoirs.

Fig. 4e. Aerial photo of Las Colinas Reuse Project.

*Reuse and Lake Livingston* – At the time of TRA's founding in 1955, there were already many *de facto* cases of reuse, but it was not called reuse and the amounts of water were relatively small. However, it was a time of historic change. TRA's enabling statute empowered TRA to do many things as circumstances permitted but only absolutely required TRA to do one thing: prepare a Master Plan for the water resources of the basin. It was the climax of the 1950-57 drought. All water suppliers were seeking new sources, near-term and long-term. The Legislature's purpose in requiring a Master Plan was to combine all the separate plans with an overview and to reconcile differences.

The most controversial proposal was for a large lake on the lower Trinity River to supply the Houston area. TRA and its Master Plan became the vehicle of the Trinity basin interests to ensure that the lake did not damage their interests in the river. As a result, TRA became a partner with the city of Houston in the development of the lake, which became Lake Livingston. Many assurances were incorporated into Livingston's operation to provide water to the mid- and lower-Trinity basin and protect upstream supplies as well. During the development of Lake Livingston, the unusual step was taken in the process of acquiring water rights for the lake to specifically recognize that wastewater discharges from upstream made a significant portion of the drought period inflow, firm yield, and resulting appropriation. An engineering report in 1959 noted that, "Although the two principal cities in the Upper Basin so far do not seem to contemplate the reuse of Trinity waters, the Trinity River Authority does consider that possibility." Consequently, the Lake Livingston water rights recognized a right of reuse of upstream water.

Fig. 4f. Lake Livingston Spillway.

## Legal Issues

*Water Rights Permits Involving Reclaimed Water* – Several permits have been issued for water rights involving reclaimed water since 2000. They are all quite different from each other as to physical scheme and legal

**For more information about water reuse, visit the Water Reuse Association at:**

**www.watereuse.org**

basis. They include the Tarrant Regional Water District for 195,000 af/y, the Trinity River Authority for the reclaimed water from its four wastewater treatment plants, the city of Dallas for all but 114,000 af/y from its two wastewater treatment plants and two additional wastewater treatment plants, the Upper Trinity Regional Water District for reclaimed water associated with water imported from the Sulphur River basin, and the city of Irving for reclaimed water associated with water imported from the Sulphur River basin. As of early 2007, a major permit for the North Texas Municipal Water District is pending.

*Sequential Ownership and Control in Regional Systems* – Many small cities and districts in rural areas own and operate their entire water supply and wastewater systems. In such cases the city or district can design and implement a reuse project in whatever way is most efficient for them without concern about ownership or control because they own the entire cycle. Regional systems, however, which provide almost all service in urban areas and even some rural areas, are completely different. There are eight steps through which water passes in a water supply and wastewater system: raw water, raw water transmission, drinking water treatment, distribution system, users' homes and workplaces, primary collection system, secondary collection system and wastewater treatment. The water and facilities at each step may be owned and controlled by a different party. Moreover, each owner may acquire water from more than one entity at the prior step and convey it to more than one entity at the next step. In fact, the water utilities of the Dallas-Fort Worth Metroplex are made up of many networks of this type. Notwithstanding the complexity, it works and adapts efficiently to the constantly changing requirements of the area.

*Wastewater Plants as Key Locations for Reuse Decisions* – In the above-described sequence through which water passes, the wastewater plant is the focal point for decisions regarding reuse. Prior to the retail users, reuse is not relevant because the water has not even been used the first time. Afterward it is too dirty to reuse until it is reclaimed. At the wastewater plant, when treatment is complete, the water is of known, consistent quality and quantity. If it needs further treatment to be suitable for a certain potential reuse, or transport to reach the point of reuse, it is at the wastewater plant that the fullest range of options exists, from which the best alternative can be chosen. Among the options are further treatment at the plant, or treatment at the point of use; it can be transported by pipeline or discharge downstream.

*Water Rights* – Many different doctrines, guidelines, and legal theories have been advocated and applied regarding water rights involving treated water from wastewater plants. Historically, most calculations of yields and water rights have not included wastewater flows, but some have, and for some, the records do not show whether they were considered or not. Wastewater is a small fraction of the total appropriation in some cases, but in some it is large. In some cases the wastewater source is specifically acknowledged, and in others not. There are distinctions and debates about "direct" and "indirect" reuse, the "four corners" of water rights, "bed and banks" permits, the "seniority" of reuse, "reclaimed," "developed," and "surplus" water, "return flows" and other matters.

There is no settled and consistent approach to water rights involving reuse that adequately comprehends 1) the great variety of arrangements regarding water ownership and liabilities among municipalities, users, and regional water utilities, 2) the developing markets and competition for water supplies, 3) the requirement by law of progressively more advanced treatment by both wastewater and drinking water treatment plants, 4) the advanced treatment technologies which enable the production of extremely purified water at progressively lower costs, and 5) the state's need to manage and monitor the use of its water.

## Conclusion

Reuse will steadily grow into an important component of water supply in the Trinity basin. It is important that certain criteria and principles be followed:

- Develop reuse in ways that can adapt to new technologies and markets
- Develop projects that are efficient in their use of resources
- Negotiate equitable arrangements among stakeholders
- Treat reclaimed water as a commodity with value
- Wastewater treatment plants are focal points for planning reuse systems
- Maintain the health and safety of water supplies
- Protect existing water rights and supplies
- Protect the natural environment

## Trinity River Authority of Texas

## Basin Master Plan

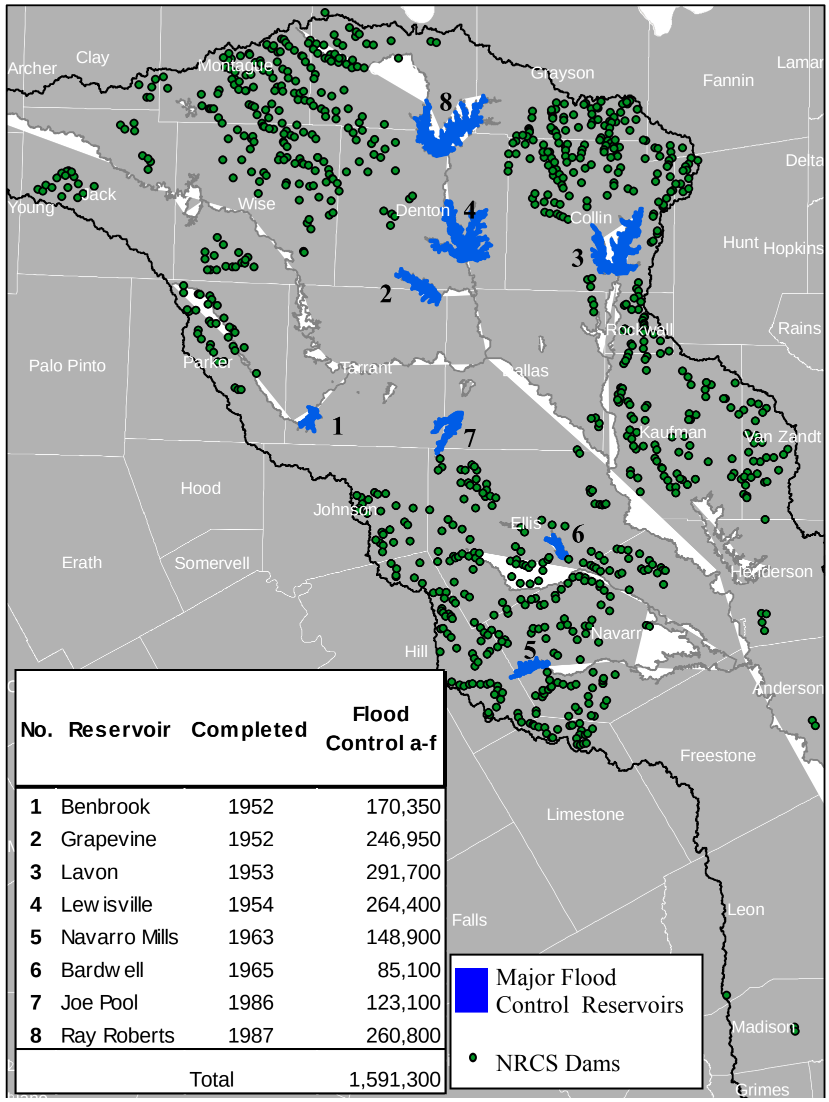
# Flooding

### Background

*Role of the Trinity River Authority in Flood Control* – The original Master Plan dealt only lightly with the problem of flood control throughout the basin. The federal government assumed the primary role in flood control planning for the watershed when the Corps of Engineers prepared its Comprehensive Survey Report of the Trinity River Basin in the early 1960s.

*Major Flood Control Reservoirs* – Since 1950 the Corps of Engineers has completed eight major reservoirs, all of which have incorporated flood control as a primary purpose (fig. 5a).

*Soil Conservation Service Program of Floodwater Retarding Structures* – Under the Flood Control Act of 1944 and PL 83-566, the Soil Conservation Service prepared plans for numerous small floodwater retarding reservoirs to control flooding problems in upstream areas. The geographical extent of the SCS program begins in the upper reaches of the West, Elm and East Forks, and ceases for all practical purposes at U.S. Highway 79-84 in the mid-basin. The SCS program presently calls for the construction of 1,074 such floodwater retarding reservoirs (a reduction from earlier plans for over 1,300 structures), of which 933 have been constructed (fig. 5a). SCS plans also included the construction of 503 miles of channel improvements, of which 91 miles have been completed. Some 300 miles of the planned 503 miles will be deleted from SCS plans. The following table summarizes the SCS program for floodwater retarding structures in the Trinity River Basin.




| No. | Reservoir | Completed | Flood Control a-f |
|---|---|---|---|
| 1 | Benbrook | 1952 | 170,350 |
| 2 | Grapevine | 1952 | 246,950 |
| 3 | Lavon | 1953 | 291,700 |
| 4 | Lewisville | 1954 | 264,400 |
| 5 | Navarro Mills | 1963 | 148,900 |
| 6 | Bardwell | 1965 | 85,100 |
| 7 | Joe Pool | 1986 | 123,100 |
| 8 | Ray Roberts | 1987 | 260,800 |
| | | Total | 1,591,300 |

Fig. 5a. Major Flood Control Reservoirs and NRCS Dams Since 1950.

*Levee Districts* – There are 38 water districts, levee districts, or floodwater districts in the Trinity River Basin which have been involved in levee construction and improvements. Twenty-two of these are situated at least partially in the floodplain of the Trinity River. These levee and floodway districts provide varying degrees of protection for more than 134,000 acres of land along the Trinity River. Between Dallas and the proposed Tennessee Colony Lake site, about 80 percent of the river has a levee on at least one side, and about 63 percent has a levee on both sides. Between the proposed Tennessee Colony damsite and Lake Livingston, about 25 percent of the river has a levee on at least one side.

Table 5a. NRCS Structures.

**NRCS Program for Floodwater Retarding Structures**

| | Planned | Constructed |
|---|---|---|
| Floodwater Retention (Acre-Feet) | 751,817 | 534,326 |
| Drainage Area Controlled (Square Miles) | 2,741 | 1,958 |
| Total Sediment Storage (Acre-Feet) | 175,636 | 126,949 |
| Beneficial Use (Acre-Feet) | 24,311 | 14,587 |

**Dallas Trinity River Corridor Project & Floodway Extension**

This part of the Trinity River project was found "feasible" in the Corps of Engineers 1979 reports. While the Corps proceeded with more detailed designs, the City of Dallas assumed the local obligations for the project, consisting primarily of land, relocations, and maintenance for the project. The city has subsequently made this project part of a comprehensive *Trinity Corridor Project*, along with recreational and aesthetic development of the existing floodway through downtown Dallas, a new tollway paralleling the river, and other planning and zoning adjacent to the river. Currently, the U.S. Army Corps of Engineers is working on projects to restore 800 year flood protection to downtown Dallas and the populated areas downstream. When complete, the project will be made up of the 5.5 mile Cadillac Heights and Lamar Levees, 270 acre wetland chain, and a river realignment at I-45. In addition, several choke points along the river are being cleared and/or modified to help floodwaters move downstream.

Fig. 5b. Trinity River Flooding at Mockingbird in Dallas.

**More information on the entire Trinity River Corridor Project can be found at http://www.trinityrivercorridor.org/**

**Fort Worth Trinity River Vision**

The Trinity River Vision Master Plan was adopted by the Fort Worth City Council in 2003. The plan addresses issues such as the environment, ecosystems, recreation, access to the waterfront, preserving green space, urban revitalization, and flood protection. The levee system protecting the downtown Fort Worth area was built in the 1950s to serve the needs of the 1960's population. Because of the increased runoff from urbanization, Fort Worth wants to increase its level of protection. In 1990, The U.S. Army Corps of Engineers found that potential flooding risks were present in the Fort Worth Floodway. The flood control portion of the project plans to raise the level of protection back to the 800-year flood level of 120,000 cfs.

The project involves creating an oxbow lake just west of downtown Fort Worth that is protected by levees from flooding in the West Fork. The plan is expected to allow for substantial greenspace and both residential and commercial development.

Fig. 5c. Lake Worth in Fort Worth.

**More information on the entire Trinity River Vision can be found at http://www.trinityrivervision.org/**

**Successes and Failures of Existing Flood Control Measures**

To the credit of the existing flood control measures, several statements may be made. Completion of the major flood control reservoirs has reduced the catastrophic damages to downstream interests, particularly in the reaches immediately downstream from the flood control reservoirs. Second, no failure of a major urban levee has occurred.

Environmental and cost-sharing rules have made federal flood control projects extremely difficult to implement. The Elm Fork Floodway, which was authorized in 1965, became impossible to implement because of such rules and a lack of agreement among local cities. However, since the late 1970s, large parts of the project have been built by private parties. Their designs have been similar to the Corps' design, particularly regarding flood capacity. The West Fork Floodway, which was a part of the Trinity River Project, but was found "economically unfeasible" by the Corps in 1979, may follow a course similar to the Elm Fork Floodway. Private levee projects in Irving, Fort Worth, and Grand Prairie are examples.

**Multiple-purpose Channel to Liberty**

This is also a part of the Trinity River Project which was reported favorably by the Corps in 1979. The Trinity River Authority has asked local interests in Liberty and Chambers Counties to determine their ability to provide the local obligations for this project. A commitment has not yet been made, and further work by the Corps is on hold.

**Non-Structural Flood Control Measures**

These measures usually include one or more of the following three procedures. Floodplain acquisition is the purchase in fee simple by some public agency, or agencies, of land known to be subject to flooding. The second is the purchase of a flood easement on such flood-prone lands by some public agency or agencies. The third is the imposition of land use controls, such as local zoning ordinances and/or building codes. These alternatives simply provide governmental entities with different degrees of control regarding the use of flood-prone lands. Once the control is obtained, the possibility of flood losses on such lands is reduced by reducing the presence of things of value which can be damaged by floods in the area. While plans have been drawn for non-structural measures in various situations around the country, few have been implemented. One instance in the Trinity River basin has been action by the City of Dallas to purchase homes in flood-prone residential areas adjacent to urban streams rather than implement structural measures such as channelization or levees. Federal law specifically requires the Corps of Engineers and other federal agencies to include an assessment of non-structural measures in the planning of all flood control projects.

## Discussion

*The Federal Flood Insurance Act*

The Flood Disaster Protection Act of 1973 requires all communities containing flood-prone areas establish a program which will limit any types of construction which would be damaged by flooding. Residents of flood-prone communities cannot purchase federal flood insurance unless the community has established such a program. Furthermore, federally regulated banks and savings and loan associations are not permitted to make mortgages on property located in flood-prone areas unless the community has enacted suitable regulations.

The federal act does not categorically prohibit flood control measures, nor does it prohibit the construction of habitable or other dwellings in the floodplain so long as such dwellings are built in such a way as to minimize their susceptibility to damages for flooding. Under appropriate circumstances, levees, flood control reservoirs, or other structural flood control measures can be implemented. The federal flood insurance program is, therefore, compatible with both structural and non-structural flood control measures, and it gives local communities the discretion to decide which of the two methods to use.

*Corps of Engineers Section 404 Regional Impact Study*

Section 404 of the federal Clean Water Act requires that a permit be obtained from the Corps of Engineers for a wide range of construction activities in or around rivers. Several years ago the Corps received several applications for permits for major developments along the West Fork between Fort Worth and Dallas and decided to evaluate their impact together rather than separately. The result was a study of possible development impacts along the West Fork between Fort Worth and Dallas, the Elm Fork from Lewisville Dam to the confluence with the West Fork, and the main stem from the confluence of the West and Elm Forks to south Dallas. The study concluded that certain future development scenarios could make the existing floodways in downtown Fort Worth and Dallas insufficient to contain a maximum flood. In response local interests requested an additional investigation to refine the flood analysis. Congress in 1988 directed the Corps to conduct such an investigation, and it is now underway. Throughout the Corps' work, the North Central Texas Council of Governments has attempted to evaluate the results and try to develop local policies on the subjects involved. That effort is still going on.

For more information about major flood control projects, visit:

**http://www.usace.army.mil/**

Flood control projects in the Trinity Basin have been very valuable and successful. In recent years, however, they have become much more difficult to develop because of their costs, environmental conflicts, and other factors. This has especially affected levee and channel-type projects which do not have multiple purposes to help share the cost. The Trinity River Authority has served as local sponsor for most federal projects in its territory since it was created, and it remains willing to do so. However, the higher cost-sharing and other requirements now make it more important than ever for any local sponsor to be sure it can perform before formal commitments can be made to the federal government.

Recent major levee projects have been implemented by private and local parties. Even in these cases, the federal role has been of value in providing a high-quality unified design. Such an approach may be useful along the West Fork and along the mid-Trinity River. The deferral of Tennessee Colony Lake leaves that area for which flood protection has been a high priority without a unified plan. There are a number of local levees for protection of agricultural land along the mid-Trinity River. However, it is not possible to have many such projects without major conflicts unless they are designed by common standards and methods. Future consideration will be given to the development of a unified design, within which local implementation could occur. This should not preclude or interfere with future development of a Tennessee Colony Reservoir.

## Drought

The months between January and December of 2011 saw the driest twelve-month period on record for the state of Texas. The lack of rainfall was accompanied by exceptionally-high temperatures that set a record for the hottest three-month period (June through August). This led to dangerous conditions that resulted in devastating wildfires in some areas of the state. In the Bastrop Fire Complex that raged to the south and west of Austin, over 1,600 homes were destroyed, costing an estimated $325 million in insured property damage. Fortunately, the Trinity basin was spared from the fires, and spring rains in the upper basin in early 2011 meant that Trinity water suppliers entered the drought with full reservoirs. However, as both evaporation and water use increased with higher temperatures, the combination of drought and record heat created a multiplicative problem. Reservoirs have large surfaces which can evaporate tremendous amounts of water when conditions are right. It has been estimated that Lake Livingston lost over 440,000 acre feet of water in 2011 due to evaporation; approximately 16% more than losses the previous year.

The drought not only affected water supplies for municipalities, but also for agriculture. Statewide, agricultural losses for 2011 have been estimated by the Texas AgriLife extension Service at $7.62 billion: $3.5 billion higher than the previous most-costly one-year drought. That drought occurred in 2006 and was broken by flooding the next year. In similar fashion, rains in late 2011 and early 2012 replenished water-supply reservoirs and brought soil-moisture levels back up for the eastern half of the state. Unfortunately drought conditions persisted into 2012 for much of West Texas.

Figure 5d shows a comparison of precipitation and temperatures from 1956 – considered one of the worst years of the drought of record— to the drought of 2011. The values shown in the graph are average values from five different weather stations around Lake Livingston. In 1956, the total average precipitation at those stations was 34 inches; well short of an historical average of around 50 inches. Precipitation in 2011 at the same locations was only 23 inches.

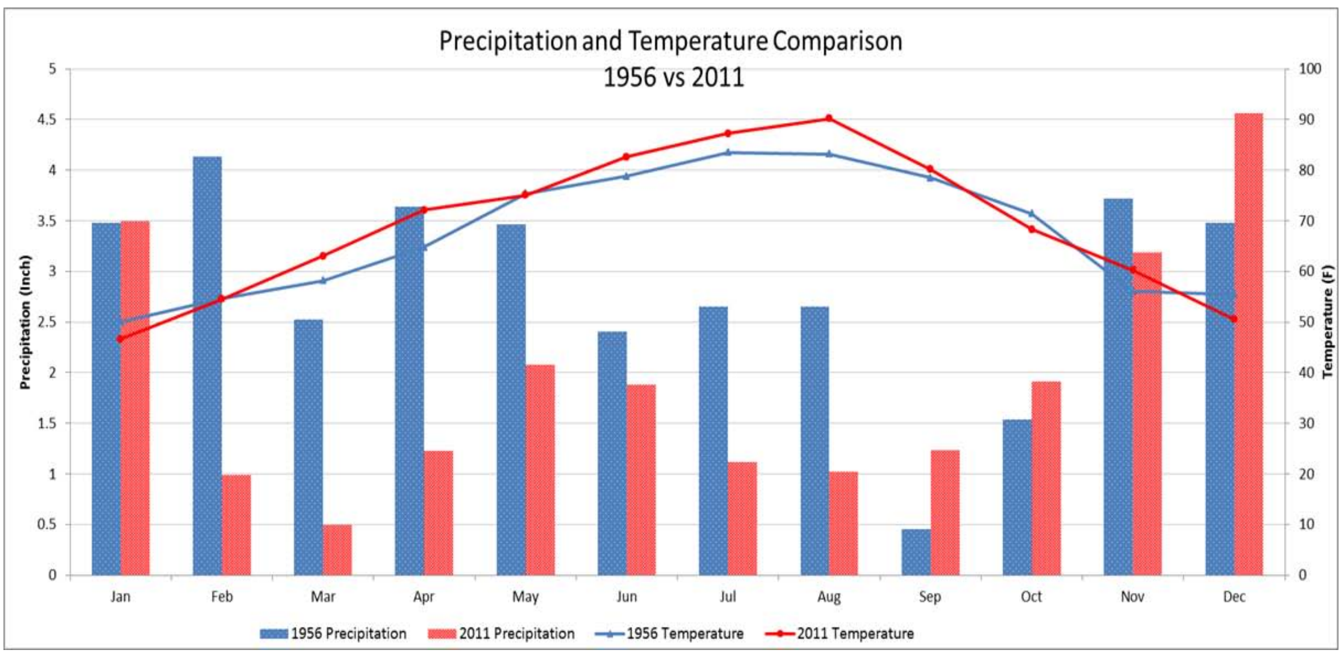



Figure 5d. Average precipitation and temperature from five weather stations around Lake Livingston around Lake Livingston.

The experience of the 2011 drought reinforces how important water planning is for critical periods and the variability of weather in Texas. In order to determine if a water supply is vulnerable to extreme drought, water supply planners compare it to the drought of the 1950s. Through this process, a quantity of water known as the firm yield is determined. This is the amount of water that would be available under a given set of conditions if the hydrology of the 1950s were to be repeated. The Trinity River Authority is currently embarking upon initial efforts to evaluate the drought of the 1950s to determine if it is still an appropriate benchmark for testing water supplies under drought conditions.

Extreme drought conditions can stress water supply infrastructure not only through high peak demands, but also by causing water main breaks when drying soil cracks and shifts.

Figure 5e

## Conservation and Preservation

### Background

*Need for Water Conservation* – Most of the more desirable sites for surface water development have been, or soon will be, utilized to meet the intra-basin and extra-basin water supply needs. This fact, in addition to the increasing expense of providing water from sources located far distances from needs, places a practical limit upon the availability of surface water. In addition, even existing water supplies are gradually reduced by sedimentation in reservoirs.

Moreover, various amounts of water are wasted beyond the point of providing for basic needs. At home, lawns are watered to the point of overflowing the gutter, a faucet is left running in the kitchen or bathroom. At work and business, there are other instances of waste, sometimes enormous. When a drought strikes, these excessive uses can be stopped, and often are, by stringent restrictions and by a common awareness of the crisis. In other times, however, the tendency is not only to waste some water, but even to increase per capita consumption of water. Planning for water supplies generally attempts to provide adequate water for the minimal rates of use, plus a considerable safety factor resulting in plans for larger reservoirs at points more remote from their use.

The transportation of water over a considerable distance can become much more expensive than the construction of a reservoir to provide water. The construction of the Coastal Water Authority system to transport water from the lower Trinity River to Houston cost approximately twice as much as the construction of Lake Livingston, which provides the water to be moved.

*Methods* – Among the more common methods of water conservation are to meter water uses and adjust rate structures. The metering program of the Devers Canal System provided an example of the former method. Prior to the implementation of the metering program, water was delivered and sold to the irrigation farmers on the basis of acreage to be irrigated. Under the metering program, the farmers used much less water per acre.

A second method of achieving water conservation is through modification of rate structure. The common and current practice is to encourage consumption of water through rate structures which allow the larger user to pay for water at lower rates. A level or reversed rate structure would discourage wasteful consumption of water. The City of Dallas uses such a rate in order to lower peak water demands (which occur during summertime lawn watering), compared to average demands. It not only saves water, it saves capital expenses for treatment and transmission facilities.


Fig. 6a. Earth Day at The University of Texas at Arlington.

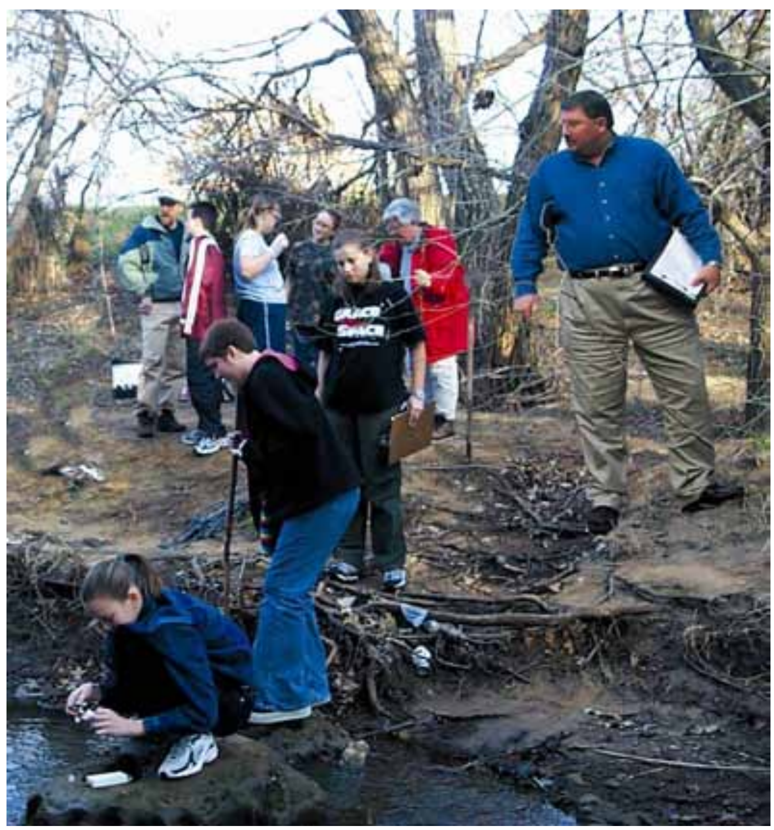


Fig. 6b. Texas Watch Volunteers Collecting Samples.

Recent state legislation requires any applicant for financial assistance from loan funds administered by the Texas Water Development Board to have, or to prepare, a conservation plan.


Fig. 6c. Soil Conservation Structure: Padera Lake in Ellis Co.

**Soil and Water Conservation**

The programs of the soil and water conservation districts of the basin include land management programs which are designed to control soil erosion and water runoff, the construction of small reservoirs (fig. 5a) for soil and floodwater retention (fig. 6c & 6d,) and, in the Trinity basin, a small amount of stream channelization. The land management programs of the districts are the essence of conservation, as they are designed to make best use of water which comes as rain on the ground where it falls. Even the programs which involve structural changes in streams and waterways, the floodwater retarding structures and stream channelization, are designed for the local watershed requirements, and they also require application of conservation techniques in the watershed in advance.

Soil and water conservation programs are broadly supported. This plan recognizes the responsibility of the soil and water conservation districts and the State Soil and Water Conservation Board to provide the master plan for their programs in the basin. Their plans are recognized and included by reference in this Master Plan for the Trinity River Basin.


Fig. 6d. NRCS Structure Padera Lake in Ellis Co. (Note Broken Pipe and Erosion).

**Preservation**

It is desirable to preserve areas of unusual beauty and/or scientific value. When water is an important part of such areas, as it often is, it is appropriate to include them in the Master Plan.

The acquisition and protection of such areas is a function closely related to recreation, and both produce little or no revenue. However, it is sometimes possible to fund acquisitions in connection with a specific water project and sometimes there are general tax funds available. In connection with water projects, sometimes natural areas are required to be preserved as mitigation for wildlife habitat lost in the construction of the project. In these cases, preservation and management are paid for by water rates.

The acquisition, protection, and management of natural areas is looked on favorably by the public, but it is not generally considered among the highest priorities for public expenditures. Certainly no governmental entity is able to do all that might be desired. Successful acquisition programs are often a matter of being alert for favorable opportunities and acting quickly when such opportunities arise. The Nature Conservancy is a private organization designed precisely for such timely acquisitions, obtaining properties and then, usually, holding them only until an appropriate governmental entity can obtain appropriations necessary to purchase the property at cost. The Conservancy's operation illustrates two characteristics of successful preservation programs: taking advantage of opportunity, and cooperation between organizations. Acquisitions in the Trinity River basin have had these characteristics. Many entities are involved: cities, counties, special districts, state and federal agencies, and private individuals and organizations. Cooperation has been, and must continue to be, the key to further success.

**Discussion**

To a large degree water is supplied for consumption at a direct rate to the consumer, approximating the actual cost of the water, treatment, and delivery. As new water supplies are required, at increasing cost, a cost-oriented rate structure is an appropriate and effective instrument for conservation. Other methods, especially for use in drought conditions, may be best implemented by each municipality or other retail supplier.

## Galveston Bay System and Environmental Flows

### Background

The Trinity-Galveston Bay system supports an important sport and commercial fishery. Almost 10 million pounds of commercial finfish and shellfish, valued at over $600 million, have been taken from the system in recent years. Over the past several years, annual finfish catches ranging in wholesale value from $640,000 to $1.5 million have been taken from the Trinity-Galveston Bay system. Similarly, oyster harvests from public reefs in Galveston Bay have ranged in value from $1.25 million to over $2.1 million, representing from 70 percent to 90 percent of the total harvest along the Texas coast. Harvesting of shrimp and crab likewise represents a valuable and important resource.

The sports fishery provided by the Trinity-Galveston Bay system is significant. On the order of a million pounds of finfish are caught annually, consisting primarily of Atlantic croaker, sand trout, black drum, gafftopsail catfish, and others. Recreational oystering accounts for an unknown portion of the overall oyster harvest, occurring primarily along shallow-water reefs where oysters can be readily gathered by hand. The sport fishery for crabs exists primarily in areas where the public is provided access to saltwater.

Marshes and estuaries are an integral part of the Galveston-Trinity Bay ecosystem. They provide a necessary environment in the life cycles of several important sport and commercial species. The salinity gradient in the bay is important in the life of oyster reefs. The quantity, quality, and timing of inflows to the Trinity-Galveston Bay System are factors in all the above.

Among the natural factors, there are wide variations over time – every season and year are different. Some specific relationships (the salinities at which oysters and their parasites grow) are known, but there are many important relationships which are known only in general, particularly as their relationship to natural, annual variations between wet and dry years. There have been numerous studies of these subjects by universities and government agencies and more are planned. Each study sheds new light on its subject, but the complexity of this system, with the number and range of variables involved, is expected to take many more years to fully understand.

### Environmental Flows

*Freshwater Inflow*

As early as 1985, the Texas Legislature enacted laws directing the Texas Parks and Wildlife Department and the Texas Water Development Board to jointly maintain a data collection and analytical study program focused on determining the needs for freshwater inflows to the state's bays and estuaries. Bays and estuaries are some of the most productive areas on earth, and Galveston Bay is the most productive bay in Texas and the second most productive bay in the nation. Five river basins feed Galveston Bay. The Trinity River accounted for about 54% of the total inflow of 10, 041,209 af/y between 1941 and 1990 (fig. 7a).

The initial findings were questioned by many interested stakeholders and the State's methodology is currently being studied further. The methodology generally looks at historic data from the TPWD and various sources of inflow data to model how much freshwater is needed to support a productive commercial and recreational fishery. Bays and estuaries are so complex that it is difficult to place a number on what constitutes enough flow. In addition to the scientific aspects, the political and regulatory questions are difficult and must be answered before creating the regulations.

*Senate Bill 2—Instream Flows*

In 2001, the Texas Legislature enacted Senate Bill 2, which established a partnership between The Texas Water Development Board, Texas Parks and Wildlife, and The Texas Commission on Environmental Quality to "determine flow conditions in the state's rivers and streams necessary to support a sound ecological environment." The group created a work plan and scope that includes peer review, oversight from the National Academy of Sciences and stakeholder input. The Draft Technical Overview was revised in 2006 and several stakeholder meetings took place throughout the state. The study is now expected to be completed sometime after 2016.

Instream flows are defined as a flow regime adequate to maintain an ecologically sound environment in streams, rivers, riparian areas, and floodplains. The flows must able to support the diversity and productivity of ecologically characteristic fish and wildlife and the living resources on which they depend. Instream flow may also be defined as those flows needed to support economically and aesthetically important activities, such as water-oriented recreation and navigation. The goal of an instream flow study is to determine an appropriate flow regime (quantity and timing of water in a stream or river) that conserves fish and wildlife resources while providing sustained benefits for other human uses of water resources. Determining adequate instream flow is quite difficult as river ecosystems are complex due to the interactions of many biological, chemical, and physical processes. The Trinity River (middle subbasin) has been designated as a priority for an instream flow study. The initial phases of the SB 2 work on the Trinity are underway. TRA personnel are engaged in this process. In addition, information collected during TRA CRP river surveys of 2010 and 2011 have proven extremely valuable in the planning stages. Sampling is scheduled to begin in the summer of 2013 and continue through 2016.

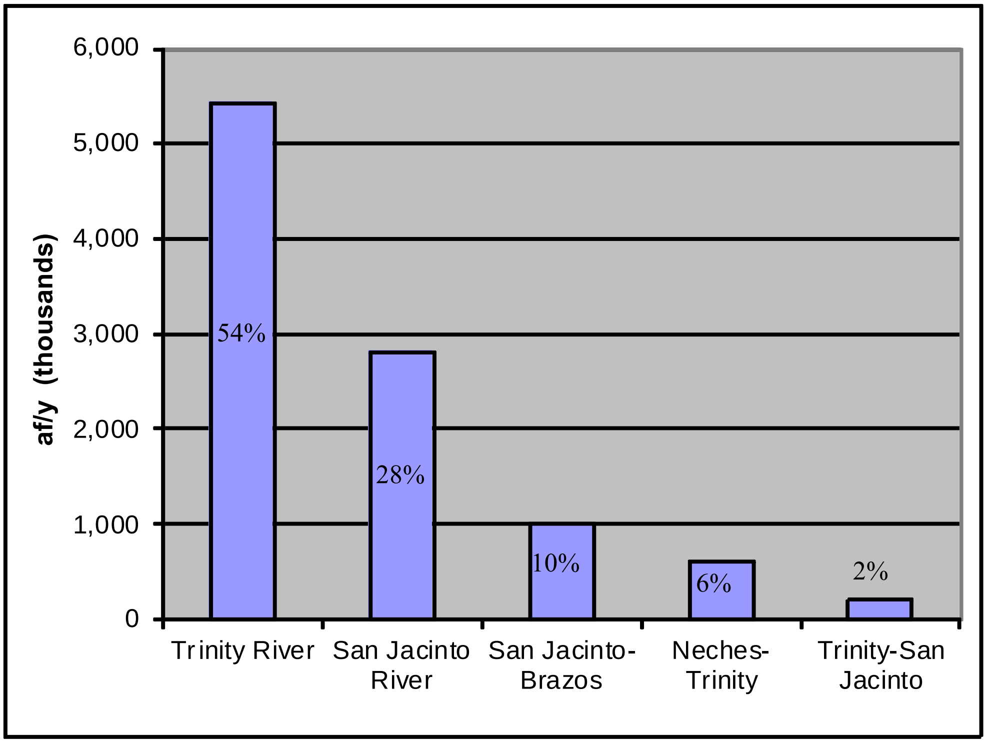



Fig. 7a. Average Inputs Into Galveston Bay per River Basin (1941—1990 ) as Calculat-

*Senate Bill 3—Environmental Flow Standards*

In 2007, the 80th Legislature passed Senate Bill 3 (SB-3), an omnibus water bill related to the development, management, and preservation of the water resources of the state. It was the first broad water legislation to be passed since 1997. It addressed environmental flows, designation of unique reservoir sites, establishment of the Study Commission on Region C Water Supply, implementation of various water conservation efforts including authorizing a Statewide Water Conservation Public Awareness Program, and creation of an eight member Legislative Joint Interim Committee tasked with studying water infrastructure needs, costs, and funding issues. SB-3 created several committees and a schedule of actions culminating in the Texas Commission on Environmental Quality (TCEQ) establishing flow standards for each major river basin and bay complex in the state. Environmental Flow standards are composed of a set of flow conditions (flow regime) deemed necessary to maintain ecologically-healthy aquatic systems. Standards are set for both rivers and bay/estuary systems. In river systems, the amount of flow required is referred to as an instream flow regime and is typically composed of low (subsistence and base) flows and high (peak or pulse) flows. Bay and estuary requirements differ from rivers in that the total volume of freshwater entering the system is paramount, rather than the instantaneous amount coming in at any one point in time. Freshwater inflows to bays keep the salinity in balance; if flows are too low for too long, the bay risks becoming overly salty.

Because flows naturally change throughout the year, increasing during wet periods such as the spring and winter months, and de-

Fig. 7b. Old Fork Anahuac Park in Trinity Bay.

Fig. 7c. Gatorfest near Trinity Bay.

creasing in the drier months, both river and bay flow requirements have seasonal components.

The process to derive flow standards was based largely upon the creation of two local stakeholder committees. One, the Basin and Bay-area Expert Science Team, is composed of subject-matter experts related to ecology, hydrology and other similar disciplines. This group is charged with determining the amount of flows necessary to maintain the ecological health of the Trinity and San Jacinto Rivers and Galveston Bay complex. The second committee, the Basin and Bay-area Stakeholders Committee, was charged with balancing the recommendations of the Expert Science Team pertaining strictly to ecological needs with the needs of man. In this fashion, consensus-based balanced flow standards were to be determined and recommended to the TCEQ for adoption. Due to a lack of data and understanding of how flows affect the ecological health of aquatic systems, a consensus was not reached. Two sets of recommendations were forwarded to the TCEQ. Although both were derived from statistical descriptions of historical flows, there were significant differences. One recommendation contained significantly more levels of flow requirements while the second set opted for a simpler set of standards with fewer control points (USGS gages) and levels of flow requirements.

In April of 2011, the Texas Commission on Environmental Quality adopted environmental flow standards for the Trinity and San Jacinto Rivers and the Galveston Bay complex. The standards consist of flow requirements as measured at four gages along the Trinity River and two gages on the San Jacinto River. The required flow values vary by season and have subsistence, base, and pulse flow components. Freshwater inflow requirements for Galveston Bay consist of annual and seasonal flow targets with achievement frequency goals. The actual flow standards for both the instream flow and freshwater inflow requirements are listed in appendix 6.

The Study Commission on Region C Water Supply consists of six members, three appointed each from Regions C and D. The Study Commission is required to review water supply alternatives available to Region C including groundwater options and additional supplies from existing and proposed reservoirs; analyze the socioeconomic impact on the area where the supply is located; determine if Region C demand reduction and reuse could postpone the need for additional supplies; study mitigation aspects of new reservoirs; and review methods of compensating affected landowners. This commission was established in response to opposition to the proposal to build Marvin Nichols Reservoir in Region D to supply Region C in the future. The members of the commission have been appointed and have had several meetings. The Study Commission divided the study into two phases. Phase I focused on an examination of existing studies and data gaps, with respect to five alternative water sources: Lake O' the Pines, Lake Texoma, Marvin Nichols Reservoir, Toledo Bend Reservoir and Lake Wright Patman. A draft report summarizing existing data, socioeconomic studies and data gaps related to the alternative water sources has been completed. Phase II of the Commission's efforts will continue the work of Phase I and more closely examine the potential alternative water supply strategies, with a deadline of October 2010 for completion of the Commission's work.

**Discussion**

Development of freshwater supplies and other activities affecting inflows to the bay and estuary system must consider the impact on the system and strive to avoid adverse impacts. The impact of various changes to inflow need to be understood accurately and reliably. More studies are desirable to make progress in that direction.

The health and productivity of the bay must be protected and maintained. Not only studies, but informed action based on sound science should be used in making the necessary decisions. Where there is uncertainty, decisions should be designed to keep impacts small and to provide the flexibility to adapt to new information.

This master plan gives high priority to maintaining the health and productivity of Trinity and Galveston Bays, and has since the twenty-two public hearings and master plan revisions of 1975-77. Both Trinity and Galveston Bays are valued statewide. It is part of the life and livelihood of the lower Trinity Basin counties, particularly Liberty and Chambers Counties. All of Trinity Bay and a large part of Galveston Bay are within the boundary of Chambers County and within Trinity River Authority territory. It is necessary for all interested parties to be informed and involved in this concern.

## Trinity River Authority of Texas

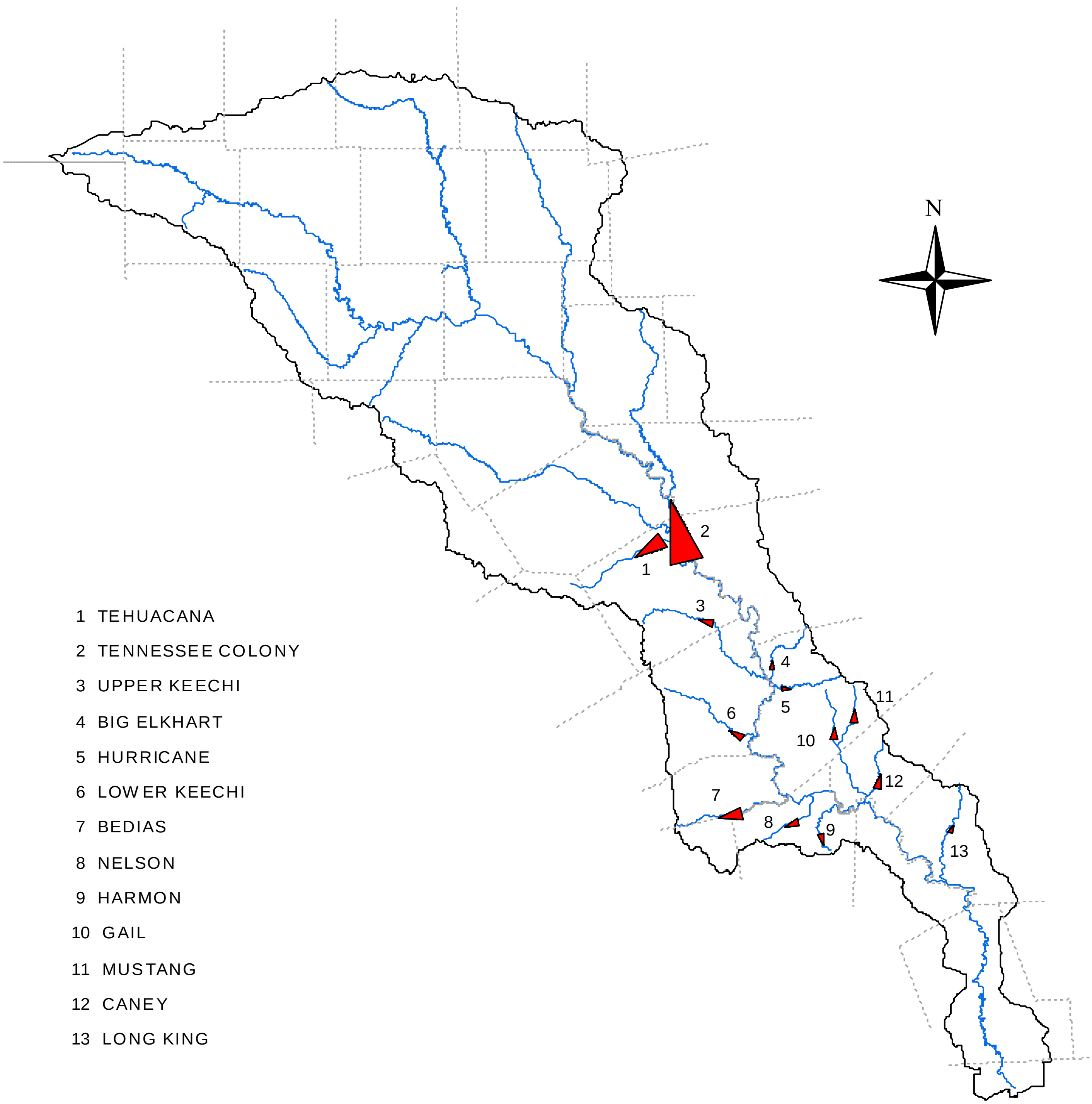
## Basin Master Plan

## Appendix

**Trinity River Authority of Texas**

**Appendix 1**

# Unbuilt Master Plan Reservoirs



# Trinity River Authority of Texas

# Appendix 2

## Description of the Trinity River Authority

**Legal Basis**. The Authority is a political subdivision and agency of the State of Texas created by the authority of Article XVI, Section 59 of the Texas Constitution by various acts codified as Article 8280-188, Revised Civil Statutes of Texas.

**Powers.**

In the acts creating and governing the Authority, the Texas Legislature has authorized the Authority to exercise fifteen powers to:

1. effectuate flood control;
2. store and conserve water;
3. supply and sell water;
4. conserve soils and other surface resources;
5. provide water for irrigation;
6. provide water for commerce and industry;
7. construct reservoirs, dams, water supply levees, and water purification and pumping facilities;
8. import water;
9. develop recreational facilities;
10. provide ingress and egress to lakes on the Trinity River;
11. preserve fish and wildlife;
12. provide for navigable water ways and ports;
13. provide sewage services;
14. prepare and maintain a master plan for the entire Trinity River watershed (basin);
15. generate electricity with hydropower facilities.

Through other acts, the Texas Legislature has authorized all river authorities, including the Trinity River Authority to:

1. provide water quality management services;
2. provide comprehensive regional plans for water quality management control and abatement of pollution;
3. provide financial services for water and air pollution control projects, and
4. provide solid waste disposal services.

Taxes cannot be levied by the Authority unless approved in an election held throughout the defined territory.

**Territory**. The Authority's defined territory includes all of Tarrant, Dallas, Ellis, Navarro, and Chambers Counties and parts of Kaufman, Henderson, Anderson, Freestone, Leon, Houston, Madison, Walker, Trinity, San Jacinto, Polk and Liberty Counties. The Authority's defined territory is shown on page 8.

**Governing Body**. The Authority is governed by a 25-member Board of Directors appointed by the Governor with the approval of the Senate. Three Directors must come from Tarrant County, four must come from Dallas County, one must come from each of those parts of the other 15 counties within the Authority, and two may come from anywhere within the defined territory.

# Trinity River Authority of Texas

# Appendix 3

## Natural Characteristics of the Trinity River Basin

The Trinity River Basin lies in the eastern half of Texas and has an overall length of 360 miles. It extends from a 130 mile wide headwater region, located generally along a northwest-southeast axis from Archer County to Chambers County, at Trinity Bay. The total area drained by the Trinity River and its tributaries is approximately 17,969 square miles.

Formed as primordial seas gradually withdrew to the present location of the Gulf of Mexico, the Trinity River serves as a major element of an extended coastal drainage system including such other Texas rivers as the Nueces, San Antonio, Guadalupe, Lavaca, Colorado, Brazos, San Jacinto, Neches, Sabine and Red.

Generally, stream flows in the Trinity River Basin follow the rainfall pattern of the area. In the Northcentral portion of Texas where the Trinity River rises, the annual average rainfall ranges from 27 inches in the west to about 33 inches in the east. Annual rainfall amounts increase progressively along the river's southeasterly course to 51 inches at Romayor, a short distance upstream from the tidal effect of the Gulf of Mexico. Of the average annual rainfall of 36.7 inches for the Trinity River Basin above Romayor, an average of 6.46 inches, less than 18 percent of the total, runs off and appears as flow in the stream at Romayor. The rainfall which does not appear as runoff is accounted for principally by evaporation and seepage into underground formations.

Stream flow records since 1925 at Romayor stream flow gauge show that the minimum annual runoff occurred in 1956 and the maximum flow occurred in 1945. During the drought year of 1956, only 1.00 inch of rainfall appeared in the stream, whereas in 1945, the year of greatest runoff, 13.39 inches of rainfall appeared as runoff.

The Trinity River rises in its East Fork, Elm Fork, West Fork and Clear Fork in Grayson, Montague, Archer and Parker counties, respectively. The main stream begins with the junction of the Elm and West Forks at Dallas and follows a meandering course for 500 river miles to its mouth at Trinity Bay on the Gulf of Mexico. The maximum elevation in the basin is 1,522 feet Mean Sea Level (MSL) in an area northwest of Fort Worth. From this area, which averages over 1,000 feet MSL, the land gradually slopes down to sea level along the southeasterly route of the river.

The mouth of the Trinity River is on Trinity Bay, an arm of Galveston Bay, the largest of the estuaries on the Gulf of Mexico between the Mississippi and Rio Grande Rivers. The Trinity River is the major source of freshwater inflow to Galveston Bay. Despite large volumes of pollution entering Galveston Bay from the Houston area, much of it, and particularly Trinity Bay, yields the largest commercial fish and shellfish catches of all Texas bays.

The trends in precipitation and vegetation, taken in conjunction with land slopes and some other factors, cause runoff in the upper basin to be rapid, but low in total volume. Runoff becomes progressively slower, but higher in total volume as one proceeds downstream. As a result, stream flows in the upper basin are more erratic and quite often zero. Most of the smaller streams in the basin cease to flow within a few days or weeks without rain, depending on the season and drainage area.

Several of the Trinity River's tributaries, and the river itself below Dallas, have a base or dry weather flow of sewage effluent discharged from wastewater treatment plants. Extensive sampling and monitoring have proven that more than 90 percent of the river's flow below Dallas in dry weather originates in the wastewater treatment plants of Fort Worth, Dallas, Garland and the Trinity River Authority. A limited number of smaller streams have a consistent base flow maintained by springs.

As a result of geological and climatic conditions, the Trinity River Basin is divided into eight distinctively different physical regions. These regions are discernible by their vegetation, animal life and the uses to which they have been put by man. The North Central Prairie comprises approximately seven percent of the basin. This region is characterized by the lightest average rainfall of the entire watershed, stony and steeply sloping ridges made up of dense, shallow soils, grasslands and large sections of shrubs, mesquite, noncommercial cedars and other native vegetation. Primary agricultural activities are cattle and the cultivation of limited amounts of grains, hay and feed crops.

The East and West Cross Timbers are soil groups formed during different periods of time, but are very similar in composition. The East Cross Timbers extend southward from the Red River through eastern Denton County and along the Dallas-Tarrant County boundary through Johnson County into Hill County. The West Cross Timbers is a much larger formation that extends south from the Red River through Clay, Montague, Jack, Wise and Parker Counties on to the Colorado River. The soils contained in these formations are adapted to fruit and vegetable crops; and as a result, much of these areas have been converted to croplands of significant economic value despite the moderate rainfall. Other agricultural activities include dairy and beef cattle, sheep and goats raised on improved grazing land.

The Grand Prairie region is a ten mile wide belt that separates the East and West Cross Timbers. It extends south from the Red River in an irregular band through Cooke, Montague, Wise, Denton, Tarrant, Parker, Hood and Johnson Counties. Sometimes called the Fort Worth Prairie, it has a primarily agricultural economy and largely rural population with no large cities except Fort Worth on its eastern boundary. The soil is predominantly limestone, but the terrain is generally rockier and steeper in the southern sections than in the gently rolling plains around Fort Worth. Generally treeless, this area is primarily used for livestock including beef and dairy cattle, sheep and poultry. The majority of the crops are grown for livestock feed with some cotton grown as a cash crop.

The Blackland Prairies include the largest part (38 percent) of the Trinity River Basin. Its rich rolling prairies developed rapidly as a farming cotton producing area of Texas. The region extends from the Rio Grande gradually widening as it runs north-east to the Red River. Because of its early agricultural development the Blackland Prairie is still the most populated physical region in the state, containing within it and along its borders many of the state's large and middle-sized cities, including Dallas. Primarily because of the early population concentrations, this belt has developed the most diversified manufacturing industry of the state. As a result of the fertile soil and adequate rainfall, agricultural activity abounds in this area with cotton serving as the principal crop.

The East Texas Timberlands, which cover 25 percent of the Trinity River Basin, may be divided into two distinct sections. The Post Oak Savannah is a transitionary region between the Blackland Prairie on the west and the true East Texas Timberlands or "Piney Woods" on the east. This area has characteristics of both regions that can be seen in its native grasses and trees. As a result of poor drainage and low organic content, the soil is not suited for extensive cultivation, but many areas have been improved for cattle grazing.

The East Texas Timberlands proper is the source of practically all of Texas' large commercial timber production and is characterized by fairly heavy rain and wider-spread, better-developed forest areas than the Post Oak Savannah. This region was settled early in Texas history and is an older farming area of the state. The area's soils and climate are adaptable to production of a variety of fruit and vegetable crops, but has experienced an increase in cattle production accompanied by the improvement of large sections of pasture land. In addition to lumber production, the area possesses large oil, clay, lignite and other mineral deposits with potential for development.

The Coast Prairie and Marsh can be seen in Chambers County and a portion of the Liberty County area of the basin and characterized by heavy rainfall and alluvial soil. The lower portion of the watershed is suited primarily for the production of rice and dense salt-tolerant grasses which provide excellent forage for cattle. The virtually featureless terrain of the area is poorly drained as a result of the dense soils and low elevations. Rice grown in this area of the watershed is almost totally dependent on the Trinity River for irrigation water. The lush grass grown along the Coastal Prairie supports the densest cattle population in the state. This physical region, which includes Houston, has experienced the most extensive industrial development in Texas history since World War II.

The Bottomland of the Trinity River Basin consists of the flood plain areas adjacent to the tributaries and main stream and primarily consists of alluvial soil washed from the Blackland Prairies upstream. While this region contains the most potentially productive soil resources of the basin, and possibly the state, farming is a gamble due to frequent flooding; and as a result, generally not attempted. Land on higher river terraces is routinely farmed and is notable for large-scale production of corn, cotton, feed crops, livestock and commercial hardwoods. The primary use of the river bottom area is stock grazing. The largest part of the flood plain is covered in native grasses and hardwoods similar to those found in the East Texas Timberlands.

**History to 1958**

One of the primary results of the distribution of the basin's physical regions was the concentration of the Trinity River basin's population in the Dallas/Fort Worth area, with smaller cities and rural populations distributed throughout the rest of the basin. While this concentration originally formed due to the feasibility of profitable agricultural activity, it has evolved and expanded since the mid 1800s to an economy dependent on transportation, fabrication, assembly, marketing, insurance, corporate and government administration and other activities.

In order to support and allow for the continued growth of the population concentration in the Dallas/Fort Worth area, which in effect is a semi-arid region devoid of natural lakes and groundwater of adequate quantity and quality, it became necessary to develop numerous impoundments along tributaries. Water for the population of the most rural areas of the basin is supplied primarily by groundwater resources and a limited number of impoundment. A notable exception to the use of Trinity River water within the basin is Lake Livingston which was constructed principally as a bulk supply of water for Houston.

# Trinity River Authority of Texas

# Appendix 4

## Evolution of the Master Plan

## 1958 Master Plan

The development of the original *Master Plan for the Trinity River and Tributaries* was authorized by the Trinity River Authority Board of Directors on March 2, 1956 in accordance with the 1955 legislative act creating and governing the Authority.

In 1956 and 1957 the Authority held 15 public hearings to collect citizen input on the types of projects that should be included in the Master Plan. During the public hearings, requests were made for the following projects:

Saltwater barrier
Lake Liberty (Capers Ridge Site)
Water supply for Livingston
Water supply for Huntsville
Water supply reservoir on Gail or White Rock Creek above FM 1280
Four reservoir projects on White Rock Creek in Trinity County for conservation purposes
Caney Creek development for conservation purposes
Hurricane Bayou Reservoir
Little Elkhart Creek Reservoir
Big Elkhart Creek Reservoir
Flood control dams on Bedias Creek
Reservoir for recreation on Boggy Creek
Reservoir on Beaver Creek
Reservoir on Two Mile Creek
Water supply for Fairfield
Flood control project on Cottonwood Creek in Freestone County
Water supply for Malakoff and Trinidad
Water and soil conservation project on Cedar Creek
Water supply and flood control reservoir on Cummings Creek in Navarro County
Channel rectification of Waxahachie and Chambers Creek
Extension of Fort Worth Floodway and levee system on Big Fossil
Reservoirs for water supply and/or flood control on Big Fossil Creek, Mary's Creek, Silver Creek, and the West Fork of the Trinity River near Boyd
Interior drainage improvements for the Fort Worth Floodway
Water supply reservoir project on Cedar, Richland, and Tehuacana Creeks and an increase in the conservation storage in Grapevine Reservoirs
Grade the existing Dallas Floodway
Extension of Dallas Floodway levees
Rehabilitate Dallas County Levee Improvement District No. 5 Northwest Levee to conform to design criteria for the Dallas Floodway Project
That a re-examination be made in light of 1957 floods of flood storage and spillway design requirements for reservoirs above Dallas and of interior drainage design criteria used for the Dallas Floodway project
White Rock Levee
Roanoke, Aubrey, Ray Roberts and Forney Reservoir projects for water supply
Ten Mile Creek sewage disposal plant and water supply system for seven small towns in Dallas County
Canalization of the Trinity River for barge navigation to Fort Worth

Based on the requests made during the public hearings, the firm of Forrest and Cotton, Consulting Engineers, prepared in consultation with the Authority's Directors a document entitled "Report on the Master Plan of the Trinity River and Tributaries, Texas." This report presented a plan of improvement that provided for development of the soil and water resources of the basin in an orderly and economical manner. A basic premise used in developing the Master Plan was that all of the runoff of the Trinity River and tributaries that could be regulated economically would be required in future years for watershed development. As a result, the plan called for a high degree of development of water resources by the construction of four water supply reservoirs on the main stem of the river and 13 water supply reservoirs on tributary streams in addition to reservoirs proposed by other agencies.

As required by the Act creating the Authority, the portion of the Master Plan relating to soil conservation and upstream flood prevention structures was prepared by the Soil Conservation Districts and approved by the State Soil Conservation Board. This portion of the Master Plan was coordinated with the soil conservation aspects of the overall plan and submitted in a separate volume to the State Board of Water Engineers.

The Master Plan incorporated existing plans of cities, counties, state and federal agencies.

Following completion of all related public hearings and investigations, the Trinity River Authority Board of Directors at its meeting on April 18, 1958 adopted the Master Plan.

## Events Since 1958

After the Master Plan was adopted in 1958 many of its elements were implemented as a result of the coordinated efforts of many local, state and federal agencies. Navarro Mills, Bardwell, Ray Hubbard, Cedar Creek, Little Elkhart, and Livingston reservoirs were built. Lake Lavon was enlarged. Construction of the Wallisville project was begun. Many small flood and silt control dams have been built in the rural areas of the Trinity watershed and substantial lands brought into soil conservation practices. Wastewater treatment systems were upgraded. Brine discharges from oil fields were virtually eliminated. Water quality management plans required by 1966 and 1972 federal laws were completed to insure that all local governments in the Trinity watershed were eligible for federal grants for the construction and enlargement or improvement of wastewater systems.

In addition to the projects that were completed, 11 projects, all consistent with the Trinity River Master Plan, received Congressional authorization. They were Tennessee Colony Lake, Lake Joe Pool, Ray Roberts Lake, Roanoke Lake, West Fork Floodway, Dallas Floodway Extension, Elm Fork Floodway, Liberty Local Protection, Water Conveyance Facility and Multiple-purpose Channel.

## 1977 Revision

The Trinity River Master Plan review began with the passage of a resolution on January 22, 1975 at a Special Meeting of the Trinity River Authority Board of Directors. This resolution summarized the legislative origins of the Authority, the specific legislative directive and resulting procedures that caused the creation of the original Master Plan as well as the progress that had been made in implementing various elements through the coordinated efforts of many local, state and federal agencies. It further summarized events and developments both in and out of the Basin that required a comprehensive review of the Master Plan and specified the method of accomplishing this goal.

To determine what revisions were desirable, a total of 20 public hearings and two conferences with state and federal agencies were held. Again, existing plans were incorporated. Many issues which were brought out repeatedly in the hearings were brought into the plan for the first time. The revised plan was adopted by the Board of Directors on February 22, 1977.

## 1984 Revision

In the late 1970s, and early 1980s, there were developments in water quality and water supply planning which necessitated revisions to the Master Plan. Improvements in wastewater plans, which had been under design and construction since as early as 1969, were completed and came on line. There were notable improvements in the quality of the Trinity River. The Corps of Engineers' general design memorandum and environmental impact statement on the Trinity River Project was published in 1979. Construction began on Lake Ray Roberts, Richland-Chambers Lake and Lake Joe Pool. The city of Dallas and the North Texas Municipal Water District made arrangements for new out-of-basin water sources. New thought was given to the role of the Trinity basin as a source of water for the greater Houston and Gulf Coast area. These developments resulted in revision, primarily to the Water Supply and Water Quality sections of the Master Plan, in June 1984.

## 1989 Revision

In 1989 further developments in water supply and water quality warranted revisions in the Master Plan. Improvement in water quality continued as dissolved oxygen levels in the Trinity River became more plentiful and oxygen demanding material from major wastewater treatment plants declined. Lake Joe Pool was completed in 1989, providing a water supply for southern Dallas County and northern Ellis County and creating recreational facilities for the Dallas/Fort Worth Metroplex.

## 1993 Revision

The Water Quality section was again updated to include information from the 1992 Water Quality Assessment under the Clean Rivers Act.

## 1997 Revision

The Water Supply section was updated to current development and planning.

### 2001 Revision

The Water Supply section was updated to reflect regional plans prepared pursuant to Senate Bill 1.

### 2003 Revision

A new section on Reuse of Reclaimed Water was added to cover the many interactions between this subject and both water supply and water quality, and also to outline principles for implementation of reuse.

### 2007 Revision

The Regional Planning section was updated with information from the most recent state water plan, *Water for Texas 2007.* Additionally, the format of the document was changed from black and white to full color with added photographs, maps, and graphs.

#### 2010 Revision

Goals and Action Plan was restated into nine objectives to reflect current Trinity basin needs and to better complement the regional water planning process.

#### 2012 Revisions

The Regional Planning section was updated with information from the most recent regional water plans and the state water plan, *Water for Texas 2011.* Additional information on water rights was added, including a new appendix, and a new section on drought was included. The section on environmental flows was also updated to describe the adoption of flow standards, which were detailed in a new appendix.

## Trinity River Authority of Texas

## Appendix 5

## Trinity Basin Run-of-River River Water Rights below Lake Livingston Dam

| WAM* Control Point | Water Right No. | Amount (af/yr) | USE /Priority Date | Permit ID | Owner | Stream Name |
|---|---|---|---|---|---|---|
| CPB4262A | 60804262301 | 0 | REC19691117 | | | |
| CPB4263A | 60804263301 | 0 | REC19790122 | | | |
| CPB4264A | 60804264301 | 0 | REC19781002 | | | |
| CPB5026P | 10805026301 | 0 | REC19851022 | | | |
| CPB4266A | 60804266301 | 0 | REC19750721 | | | |
| CPB4267A | 60804267301 | 0 | REC19690825 | | | |
| | 60804267302 | 0 | REC19691020 | | | |
| CPB3993P | 10803993401 | 0 | REC19830228 | | | |
| | 10803993004 | 0 | REC19830228 | | | |
| CPB4260P | 10804260301 | 0 | REC19851119 | | | |
| CPB4259P | 10804259301 | 0 | REC19850625 | | | |
| CPB3739P | 10803739301 | 0 | REC19791119 | | | |
| CPB4268A | 60804268301 | 0 | REC19660907 | | | |
| CPB4269A | 60804269001 | 1932 | IRR19691211 | 08-4269 | TRINITY PLANTATION INC ET AL | MENARD |
| CPB4270A | 60804270301 | 0 | REC19391231 | | | |
| | 60804270001 | 0 | REC19591231 | | | |
| CPB4271A | 60804271301 | 0 | REC19741216 | | | |
| CPB3858P | 10804036305 | 0 | REC19810928 | | | |
| CPB4272A | 60804272301 | 0 | REC19660705 | | | |
| CPB4272B | 60804272302 | 0 | REC19660705 | | | |
| CPB4273A | 60804273301 | 0 | DOM19790221 | | | |
| CPB4274A | 60804274301 | 0 | REC19800107 | | | |
| CPB4275A | 60804275301 | 0 | REC19790102 | | | |
| CPB4276A | 60804276301 | 0 | REC19681028 | | | |
| CPB4283A | 60804283001 | 640 | IRR19750218 | 08-4283 | A REESE BROWN | N FRK LONG ISLAND |
| CP579341 | 10805793001 | 1,050 | IRR20030113 | 08-5793 | WELDON ALDERS | LONG ISLAND BAYOU |
| CPB4261A | 60804261001 | 31,600 | IND19131230 | 08-4261 | CITY OF HOUSTON | TRINITY RIVER |
| | 60804261002 | 13,400 | IRR19131230 | 08-4261 | CITY OF HOUSTON | TRINITY RIVER |
| | 60804261004 | 444,000 | MUN19590923 | 08-4261 | CITY OF HOUSTON | TRINITY RIVER |
| | 60804261005 | 458,800 | IND19590923 | 08-4261 | CITY OF HOUSTON | TRINITY RIVER |
| | 60804261006 | 10,000 | MUN19590923 | 08-4261 | CITY OF HOUSTON | TRINITY RIVER |
| | 60804261007 | 28,000 | IND19590923 | 08-4261 | CITY OF HOUSTON | TRINITY RIVER |
| | 60804279009 | 30,000 | MUN19140626 | 08-4279 | SAN JACINTO RIVER AUTHORITY | TRINITY RIVER |
| | 10805271002 | 7,500 | IND19170226 | PM 5271B | SAN JACINTO RIVER AUTHORITY | TRINITY RIVER |
| | 10805271003 | 20,000 | IND19260908 | PM 5271B | SAN JACINTO RIVER AUTHORITY | TRINITY RIVER |
| | 10805271004 | 17,500 | IND19291212 | PM 5271B | SAN JACINTO RIVER AUTHORITY | TRINITY RIVER |
| | 10805271005 | 11,000 | IND19360924 | PM 5271B | SAN JACINTO RIVER AUTHORITY | TRINITY RIVER |

| WAM* Control Point | Water Right No. | Amount (af/yr) | USE /Priority Date | Permit ID | Owner | Stream Name |
|---|---|---|---|---|---|---|
| CPB4277A | 60804277001 | 33,000 | IRR19130702 | 08-4277 | CITY OF HOUSTON | TRINITY RIVER |
| CPB4277D | 60804277003 | 5,000 | IRR19690825 | 08-4277 | CITY OF HOUSTON | TRINITY RIVER |
| CPB4278A | 60804278302 | 0 | REC19800331 | | | |
| CPB5271P | 60804248003 | 27,500 | IRR19590923 | | | |
| | 10805271001 | 2,500 | LTIRR19291212 | PM 5271A | DEVERS CANAL RICE PRO ASSN INC | TRINITY RIVER |
| CPB4148P | 10804148301 | 0 | REC19840612 | | | |
| CPB4261C | 60804261003 | 0 | IRR19131230 | | | |
| CPB4261D | 60804279001 | 36,667 | IRR19060414 | 08-4279 | CHAMBERS-LIBERTY COS ND | TRINITY RIVER |
| | 60804279002 | 36,667 | IRR19140212 | 08-4279 | CHAMBERS-LIBERTY COS ND | TRINITY RIVER |
| CPB4284A | 60804284001 | 104 | IRR19490430 | 08-4284 | STEPHEN & LOUIS MECHE | WHITES |
| | 60804285001 | 440 | IRR19580109 | 08-4285 | CHARLES & PAUL HAIDUSEK | WHITES |
| CPB4286A | 60804286001 | 710 | IRR19670531 | 08-4286 | JETT HANKAMER & SONS | WHITES |
| CPB4280A | 60804280001 | 395 | IRR19600428 | 08-4280 | GEORGE W MAXWELL | COW ISLAND |
| CPB4281A | 60804281001 | 232 | IRR19470430 | 08-4281 | RAY STOESSER ET AL | COW ISLAND |
| CPB4282A | 60804282001 | 172.3 | IRR19670331 | 08-4282 | DONALD R MAXWELL ET AL | COW ISLAND |
| CPB4279C | 60804279003 | 0 | IRR19140623 | | | |
| | 60804279004 | 0 | IRR19521007 | | | |
| | 60804279005 | 6,666 | IRR19140626 | 08-4279 | CHAMBERS-LIBERTY COS ND | TRINITY RIVER |
| | 60804279006 | 800 | MIN19361107 | 08-4279 | CHAMBERS-LIBERTY COS ND | TRINITY RIVER |
| | 60804279007 | 2,147 | MUN19711111 | 08-4279 | CHAMBERS-LIBERTY COS ND | TRINITY RIVER |
| | 60804279008 | 30,000 | IND19711111 | 08-4279 | CHAMBERS-LIBERTY COS ND | TRINITY RIVER |

* Source: TCEQ Water Availability Model (WAM), updated 2009

## Trinity River Authority of Texas

## Appendix 6

## Trinity River and Galveston Bay Environmental Flow Standards

| West Fork Trinity River near Grand Prairie | | | |
|---|---|---|---|
| **Season** | **Subsistence** | **Base** | **Pulse** |
| Winter | 19 cfs | 45 cfs | Trigger: 300 cfs<br>Volume: 3,500 af<br>Duration: 4 days |
| Spring | 25 cfs | 45 cfs | Trigger: 1,200 cfs<br>Volume: 8,000 af<br>Duration: 8 days |
| Summer | 23 cfs | 35 cfs | Trigger: 300 cfs<br>Volume: 1,800 af<br>Duration: 3 days |
| Fall | 21 cfs | 35 cfs | Trigger: 300 cfs<br>Volume: 1,800 af<br>Duration: 3 days |

| Trinity River at Dallas | | | |
|---|---|---|---|
| **Season** | **Subsist-ence** | **Base** | **Pulse** |
| Winter | 26 cfs | 50 cfs | Trigger: 700 cfs<br>Volume: 3,500 af<br>Duration: 3 days |
| Spring | 37 cfs | 70 cfs | Trigger: 4,000 cfs<br>Volume: 40,000 af<br>Duration: 9 days |
| Summer | 22 cfs | 40 cfs | Trigger: 1,000 cfs<br>Volume: 8,500 af<br>Duration: 5 days |
| Fall | 15 cfs | 50 cfs | Trigger: 1,000 cfs<br>Volume: 8,500 af<br>Duration: 5 days |

| Trinity River Near Oakwood | | | |
|---|---|---|---|
| **Season** | **Subsistence** | **Base** | **Pulse** |
| Winter | 120 cfs | 340 cfs | Trigger: 3,000 cfs<br>Volume: 18,000 af<br>Duration: 5 days |
| Spring | 160 cfs | 450 cfs | Trigger: 7,000 cfs<br>Volume: 130,000 af<br>Duration: 11 days |
| Summer | 75 cfs | 250 cfs | Trigger: 2,500 cfs<br>Volume: 23,000 af<br>Duration: 5 days |
| Fall | 100 cfs | 260 cfs | Trigger: 2,500 cfs<br>Volume: 23,000 af<br>Duration: 5 days |

| Trinity River at Romayor | | | |
|---|---|---|---|
| **Season** | **Subsistence** | **Base** | **Pulse** |
| Winter | 495 cfs | 875 cfs | Trigger: 8,000 cfs<br>Volume: 80,000 af<br>Duration: 7 days |
| Spring | 700 cfs | 1,150 cfs | Trigger: 10,000 cfs<br>Volume: 150,000 af<br>Duration: 9 days |
| Sum-mer | 200 cfs | 575 cfs | Trigger: 4,000 cfs<br>Volume: 60,000 af<br>Duration: 5 days |
| Fall | 230 cfs | 625 cfs | Trigger: 4,000 cfs<br>Volume: 60,000 af<br>Duration: 5 days |

**Bay and Estuary Freshwater Inflow Standards for the Galveston Bay System**

| Basin | Annual Inflow Quantity (af) | Annual Target Frequency | Winter Inflow Quantity (af) | Winter Target Frequency | Spring Inflow Quantity (af) | Spring Target Frequency | Summer Inflow Quantity (af) | Summer Target Frequency | Fall Inflow Quantity (af) | Fall Target Frequency |
|---|---|---|---|---|---|---|---|---|---|---|
| Trinity | 2,816,532 | 50% | 500,000 | 40% | 1,300,000 | 40% | 245,000 | 40% | N/A | N/A |
| | 2,245,644 | 60% | 250,000 | 50% | 750,000 | 50% | 180,000 | 50% | N/A | N/A |
| | 1,357,133 | 75% | 160,000 | 60% | 500,000 | 60% | 75,000 | 60% | N/A | N/A |
| San Jacinto | 1,460,424 | 50% | 450,000 | 40% | 500,000 | 40% | 220,000 | 40% | 200,000 | 40% |
| | 1,164,408 | 60% | 278,000 | 50% | 290,000 | 50% | 100,000 | 50% | 150,000 | 50% |
| | 703,699 | 75% | 123,000 | 60% | 155,000 | 60% | 75,000 | 60% | 90,000 | 60% |

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## Photography

All photography provided by the Trinity River Authority.