April 3, 2009

Transmittal to Basin and Bay Expert Science Teams (BBESTs)

Report # SAC-2009-02

Title: Geographic Scope of Instream Flow Recommendations.

The attached document constitutes another deliverable from the SB3 Science Advisory Committee (SAC) to assist the BBESTs in carrying out their responsibilities under SB3. This report addresses the geographic scope of environmental flow regime recommendations; that is, the number and spatial distribution of locations where specific flow recommendations will be developed in order to characterize an environmental flow regime for a particular basin.

The document presents various factors which should be considered by the BBEST in determining geographic scope. The importance of existing streamflow-gaging stations, primarily operated by the USGS, is identified. The report suggests using the USGS Core Network gages as a starting point, but strongly encourages the BBESTs to fully evaluate the adequacy of this network, and to increase or decrease the number of recommended streamflow-gaging stations as they deem appropriate to adequately define the environmental flow regime.

The SAC continues to offer this information as guidance and not prescription. The SAC is hopeful that the BBESTs will find this information useful in their deliberations, and we invite feedback as we all move forward with our respective responsibilities under SB3.

Robert J. Huston, Chairman, SB3 Science Advisory Committee

# GEOGRAPHIC SCOPE OF INSTREAM FLOW RECOMMENDATIONS

**Senate Bill 3 Science Advisory Committee for Environmental Flows**

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**Report # SAC-2009-02**

## TABLE OF CONTENTS

## FIGURES

## SECTION 1. INTRODUCTION

The purpose of this paper is to address the geographic scope of environmental flow regime recommendations for the Senate Bill 3 (SB 3) process. As defined by SB 3, an environmental flow regime means a schedule of flow quantities that reflect seasonal and yearly fluctuations that typically would vary geographically, by specific locations in a watershed, and that are shown to be adequate to support a sound ecological environment and to maintain the productivity, extent, and persistence of key aquatic habitats in and along the affected water bodies and receiving coastal bay system. The question of geographic scope for the SB 3 process is a matter of recommending the number and spatial distribution of locations where flow regime recommendations will be developed. This document does not address implementation of flow recommendations.

In contrast to the SB 3 process, environmental assessments of water rights applications are currently conducted on a case by case basis. Numerous sources are utilized to determine whether special conditions, including streamflow restrictions, are necessary to satisfy environmental concerns. If streamflow restrictions are recommended, an effort is made to tie the restrictions to a nearby active USGS gage. However, this is not always possible or practical.

For a diversion or project on an ungaged stream, an effort is made to locate an active gage with at least 20 years of flow data in the same watershed or an adjacent watershed. In addition to proximity, factors such as stream characteristics, ecological characteristics, hydrological characteristics (e.g. whether the gage and project location are influenced by wastewater discharges or reservoir releases), and drainage area size may be taken into consideration in selection of an appropriate gage. Once a gage has been selected and a historical period of record determined, streamflow restrictions for the gaged location are calculated based on median flow values for each month of the year. The resulting monthly restrictions are then prorated to the project location using a drainage area ratio. If streamflow restrictions are placed in the permit, the permittee is responsible for developing a method or installing a reference device to measure the appropriate flow value.

There are a number of issues that should be considered in determining the geographic scope of instream flow recommendations for the SB 3 process. For example, flow recommendation locations should consider, and be compatible with, the river segments identified by the Texas Instream Flow Program (TIFP) for Senate Bill 2 (SB 2) studies. In addition, biologic, hydrologic, and geomorphic information, water quality segments, basin management subdivisions and water availability could play a role in these location determinations. There are a broad range of aquatic ecosystems in Texas' rivers and the study methodology for instream flow recommendations may need to be customized for specific river systems (TCEQ et al., 2008). Thus for each river basin, the choices may be different.

The document includes general information that could be used to segment a river basin for purposes of determining the number of flow recommendation locations that might be needed to characterize an environmental flow regime in a particular basin. Available information includes the spatial scale units adopted by the TIFP and other general information, such as hydrology, geomorphology, biology and water quality that are available for all river basins and should be considered in location determinations.

The document also describes basin specific information that could be added to the general information, or used to enhance this information, using the Trinity River Basin as an example application. The summary outlines a general process for determining geographic scope.

## SECTION 2. GENERAL INFORMATION FOR DETERMINING GEOGRAPHIC SCOPE

This section begins with a brief discussion of the spatial scale units adopted by the TIFP, followed by general information that could be used to segment a river basin for the purpose of determining how many points are needed to adequately identify environmental flow needs consistent with SB 3. The data sets discussed in this section are readily available and could be used in any Texas river basin to facilitate the location selection process.

### 2.1 SPATIAL SCALE UNITS ADOPTED BY THE TEXAS INSTREAM FLOW PROGRAM

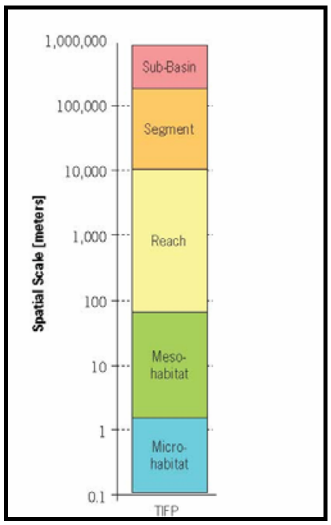


**Figure 1. TIFP spatial scale units (adapted from TCEQ et al., 2008, p. 29. Figure 3.1 Nomenclatures describing the spatial scales of riverine ecosystems).**

The TIFP adopted five specific definitions for the spatial scale of watershed components used in SB 2 studies (Figure 1.):

1. Sub-basin - *the full geographic extent of priority studies within major river basins in Texas, including the main channel, floodplain, tributaries, and contributing watershed area of all study segments.*
2. Segment - *subset of sub-basin study area. For priority studies, segments are equated to the corresponding river segments described in 30 Texas Administrative Code §307.1 through 307.10. The Agencies recognize that significant processes at this scale extend beyond the channel and include tributaries and contributing watershed area.*
3. Reach – *subdivision of a segment that exhibits relatively homogeneous channel and floodplain conditions…bounded by breaks such as the confluence of major tributaries and significant geomorphic features. The number of reaches within a segment depends on the degree of heterogeneity.*
4. Mesohabitats – *basic structural elements of a river or stream from an ecological perspective. For alluvial rivers, these elements include scour pools and submerged transverse bars…For smaller streams, mesohabitats are known by such names as pool, riffle, run and chute.*
5. Microhabitats – *zones of similar physical characteristics within a mesohabitat unit. Differentiated by aspects such as substrate type, water velocity, and water depth.*

These spatial scale units are intended to promote consistent nomenclature among the different disciplines for the multiple spatial scales of the SB 2 studies. The timeline for completion of studies for the priority river sub-basins is 2016.

Limited information is available for most of these scales for the priority basins.[1] At this time, the most readily accessible data is hydrologic data, which provides a "convenient, initial understanding of riverine systems (SAC, 2009, p. 6)." Hydrologic data is typically measured and reported at United States Geological Survey (USGS) gages. USGS gages represent discrete locations and do not necessarily coincide with the SB 2 study scales. In effect, gage locations provide point data at different scales and the user must determine the spatial extent over which the data can be used for hydrologic analysis. In addition to hydrologic data, any available data for any of these scales, biological, chemical, or geological, could be considered in determining and refining appropriate locations.

## 2.2 NATIONAL HYDROGRAPHY DATA SET (NHD)

The National Hydrography Dataset (NHD) is a geospatial data set representing surface water body features.[2] The NHD is basically analogous to state watercourses (30 TAC §297.1 (59)). The NHD is available in several resolutions (high, medium and local), originally based on 1:100,000 scale data. The high resolution NHD uses 1:24,000 or 1:12,000 scale data to add detail to the original NHD. NHDPlus is a geospatial data set, developed by the U.S. EPA and partners, which includes features from the NHD, NED (National Elevation Data Set), the NLCD (National Land Cover Data Set) and the WBD (Water Boundary Data Set). NHDPlus includes flow lines, flow directions and other attributes useful in geospatial applications.[3] The NHD is also presented in a new database design known as NHDinGEO.[4] NHDinGEO supports web-based access and data queries.

The NHD has a number of features that could be useful in the SB 3 context. For example, in NHDPlus, attributes such as average precipitation, average temperature, velocity, cumulative drainage area, and categorical data[5] are linked to the line coverage for streams. Other attributes that could be used for SB 3 streamflow analyses are elevation-derived catchments, Strahler stream order identifiers, links to water quality databases and USGS gaging stations that enable streams to be queried in upstream to downstream order. The utility of this additional data depends on the level of analysis undertaken for a particular river basin.

One main disadvantage of the NHD, regardless of format, is the sheer volume of data, i.e. the number of line segments. For example, the NHD for the Trinity River Basin includes over 155,000 individual line features (Figure 2). The number of stream features could overwhelm the computational methodologies (for example, the HEFR Methodology) currently being discussed for use in the SB 3 process. Measured hydrologic data is often only available for USGS gage locations and determining varying methods to apply the

[1] A list of completed and ongoing studies can be found at http://www.twdb.state.tx.us/instreamflows/studies.html
[2] United States Geological Survey. National Hydrography Data Set. Available at http://nhd.usgs.gov/index.html.
[3] Horizon Systems Corporation. NHDPlus. Available at http://www.horizon-systems.com/nhdplus/
[4] United States Geological Survey. NHD Data Availability. Available at http://nhd.usgs.gov/data.html.
[5] For example perennial vs. intermittent streams are identified and artificial flow paths such as canals are included.

computations at ungaged locations would be extremely time-consuming. Methods could be developed to aggregate data and reduce the number of line segments, however, time constraints for the SB 3 process may preclude development and validation of these methods.

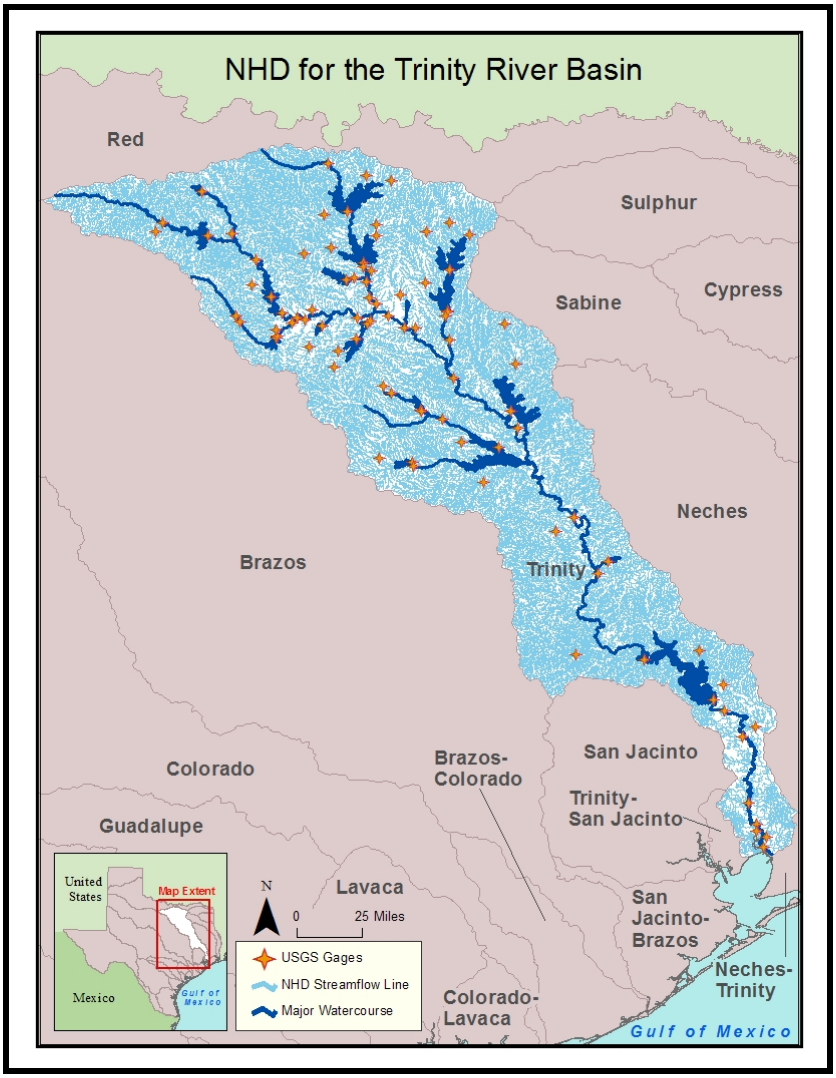


**Figure 2. NHD for the Trinity River Basin.**

## 2.3 TCEQ CLASSIFIED SEGMENTS

TCEQ applies water quality standards to designated water bodies in Texas (Figure 3). These water bodies are included in both river basins and coastal areas. The designated water bodies, referred to as segments, are based on regional hydrologic and geologic diversity (TCEQ, 2009). Although the classified segments, and data associated with them, are informative because of their use in water quality programs, relying solely on the classified segment network would not necessarily be useful. For example, classified segments include the impounded area of reservoirs. In addition, long classified segments may have many factors affecting their flow characteristics because of the segment length.

In this case, consideration should be given to breaking up long segments into smaller segments.

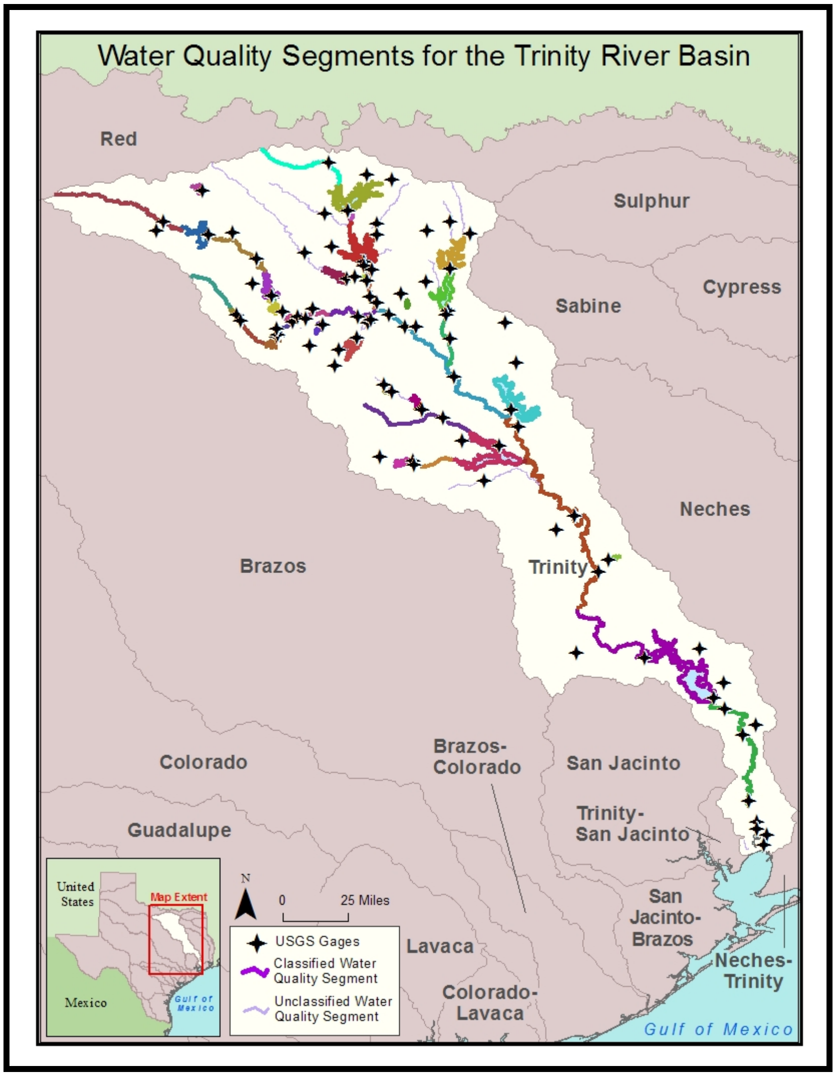


**Figure 3. TCEQ Water Quality Segments for the Trinity River Basin.**

## 2.4 GEOMORPHIC ZONATION

Geomorphic processes vary between and within river systems (TCEQ et al., 2008, p. 26). Large river basins can typically be separated into three geomorphic zones: the headwaters, transfer, and deposition zones, based on the dominant geomorphic processes in those zones (Figure 4). Basin characteristics such as channel slope, width, depth and discharge change from the upper to the lower sections of a river. For river systems with minimal site specific geomorphic data, this simple classification can be used to guide the location selection for instream flow recommendations. In some Texas basins (such as the middle and lower Trinity, lower Sabine, middle and lower Brazos and lower San Antonio), geomorphic classifications are provided as part of the SB 2 study process.[6] The geomorphic classifications may provide additional information to guide further

[6] A list of completed and ongoing studies can be found at http://www.twdb.state.tx.us/instreamflows/studies.html

segmentation of a particular river basin. However, using the detailed geomorphologic information to prioritize site selection for instream flow recommendations may have limited utility, because in those basins where geomorphic classification is completed, USGS gages will more than likely be used to represent the zones.

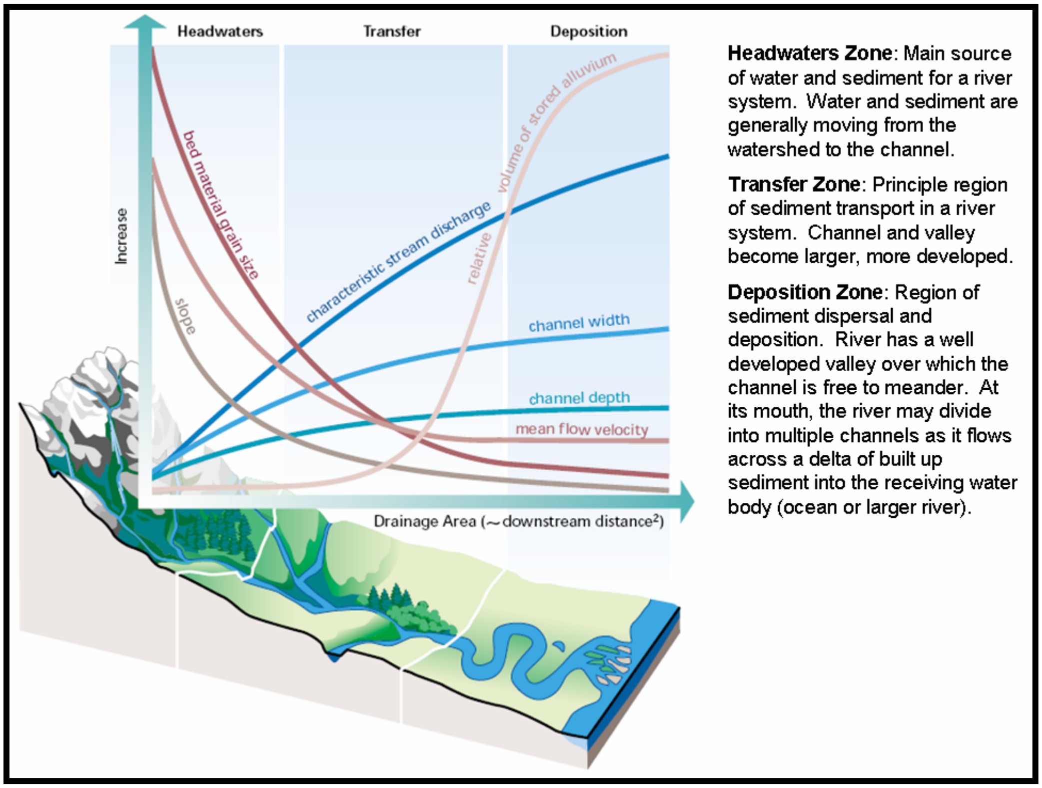


**Figure 4. General geomorphic zones (adapted from FISWRG 2001).**

## 2.5 ECOLOGIC ZONATION

An ecoregion is defined as:

> *A geographic area over which the macroclimate is sufficiently uniform to permit development of similar ecosystems on sites with similar geophysical properties. Ecoregions contain multiple landscapes with different spatial patterns of ecosystems.(TCEQ et al., 2008, p. 132)*

The spatial differences in landscape attributes such as geology, physiology, land use, climate, soils, and vegetation among defined ecoregions, may be useful for evaluating biological and ecological differences among watersheds in a river basin (Griffith et al. 2007). These distinctions may indicate either locations where there is a need for specific flow recommendations or provide an additional overlay to refine the calculation of flow components for individual instream flow recommendations. The ecoregions may be at the segment or sub-basin scale (Figure 5). GIS data and descriptions of the ecoregions are available for ecoregions in all river basins in Texas at various scales.[7]

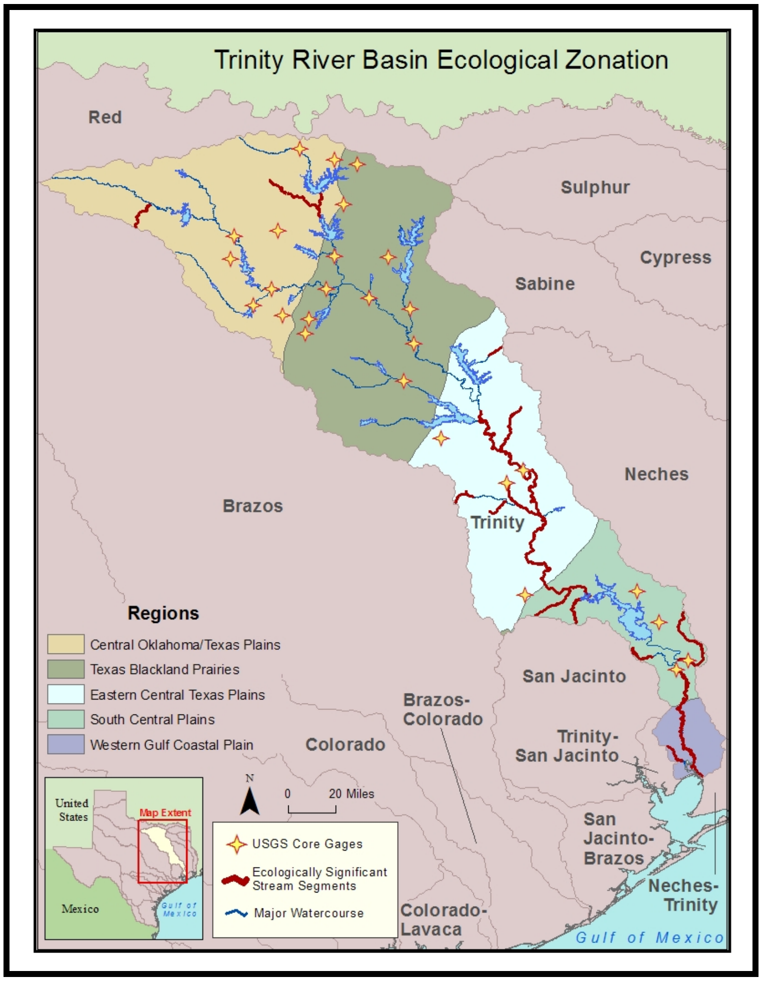


**Figure 5. Trinity River Basin Ecoregions and Ecologically Significant Stream Segments.**

In addition, the Texas Parks and Wildlife Department (TPWD) identifies ecologically significant stream segments for Texas river basins.[8] The segment designations take into account biological and hydrological function, riparian conservation areas, water quality, aquatic life and aesthetic value, threatened and endangered species, and unique communities. Ecologically significant stream segments for the Trinity River Basin are included in Figure 5.

For some SB 2 priority basins, additional information may be available to help guide the choice of locations. For example, documentation of species declines in the lower Brazos, lower Sabine and lower San Antonio Rivers (Bonner and Runyan, 2007) may indicate

[7] See http://www.tceq.state.tx.us/implementation/water/tmdl/atlas.html, http://www.epa.gov/wed/pages/ecoregions/tx_eco.htm and http://www.tpwd.state.tx.us/landwater/land/maps/gis/data_downloads/

[8] A list of ecologically significant stream segments for Texas River Basins can be found at http://www.tpwd.state.tx.us/landwater/water/environconcerns/water_quality/sigsegs/ This list is not exhaustive and additional segments may need to be considered.

that these areas require consideration of species-specific information with respect to selection of point locations for instream flow recommendations.

## 2.6 HYDROLOGIC ZONATION

The USGS maintains a network of 478 streamflow gaging stations in Texas.[9] Other entities also maintain streamflow gaging stations, for example the United States International Boundary and Water Commission (USIBWC) for the Rio Grande.[10] These gages are funded by federal, state and local governmental agencies (Slade et al., 2001). The USGS and the Texas Water Development Board (TWDB) evaluated existing gaging stations on the basis of four criteria: regionalization, major flows, outflow from the State, and streamflow conditions assessment. The USGS proposed a Core Network of gages that contribute to at least one of these four criteria (Figure 6).[11] Although these four criteria are certainly factors which contribute to understanding the hydrology of a river system, the Core Network was not specifically developed for purposes of computing environmental flows or to represent an environmental flow regime. Rather, gages that are not included in the Core Network for Texas provide redundant data or are maintained to meet objectives besides those outlined above (Slade et al., 2001, p. 7). These gages could, however be useful in developing flow recommendations by providing data to fill in gaps or to ensure adequate coverage for a particular river system.

Regionalization gages are selected because they provide flow data for regions with similar hydrological characteristics, i.e. these gages characterize a range of attributes within a hydrologically similar area (Slade et al., 2001, p.7). Regionalization stations provide data that can be used in the development of regional regression equations. Regional regression equations can be used to estimate flow characteristics at specific ungaged locations (Slade et al., 2001, p. 7). Major flow gages are selected so as to define spatial and temporal changes in streamflow along major streams (Slade et al., 2001, p.8). These gages are used to monitor and define streamflow rates and volumes in major streams across the state. Gages that provide data for the objective of streamflow conditions assessment measure flows in large natural watersheds and are geographically diverse (Slade et al., 2001, p. 9). Thus, the USGS Core Network can provide a framework to refine site selection for purposes of identifying measurement points for flows that are adequate to support a sound ecological environment.

[9] http://waterdata.usgs.gov/tx/nwis/current/?type=flow

[10] http://www.ibwc.state.gov/Water_Data/rtdata.htm The BBEST members may also be aware of additional sources of streamflow gaging data in their basins. For example the Lower Colorado River Authority maintains 50 gages that are not part of the USGS network. (http://hydromet.lcra.org/repframe.html). Note that the BBESTs may consider whether any additional gaging information is publicly available on an instantaneous or near real time basis.

[11] The USGS Core Network does not include gages that measure springflow. A list of the Core Network Gages and their attributes, including drainage area, period of record, hydrologic region and objective for each gage's data can be found in Slade and others, Table 5. Core Network of Streamflow Gaging Stations in Texas, p. 32-40.

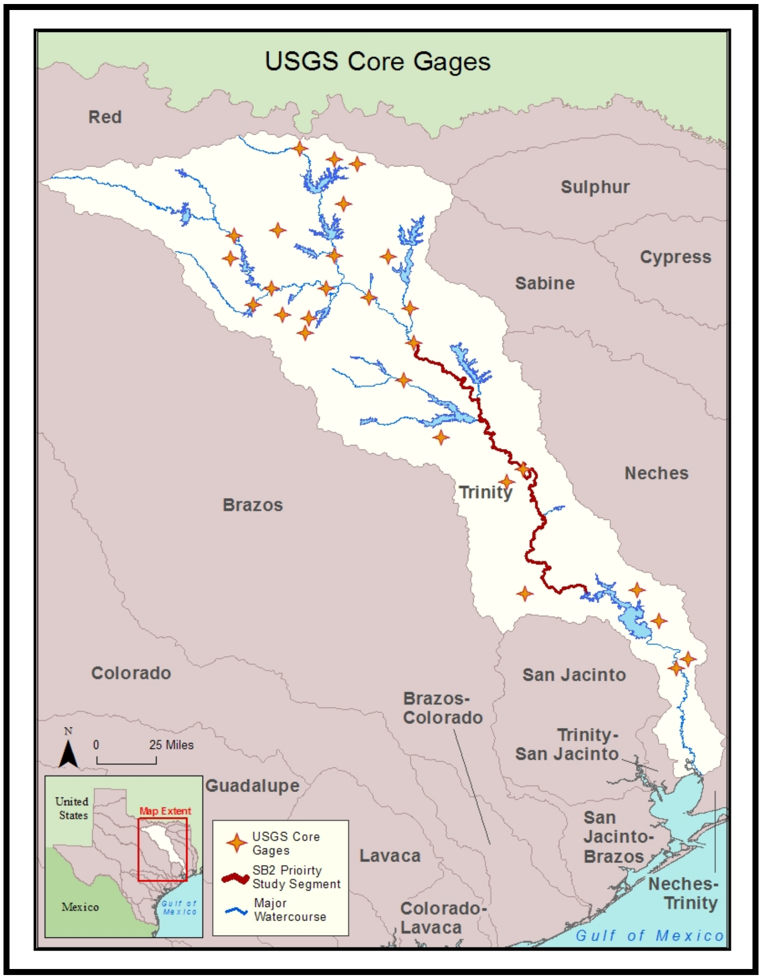


**Figure 6. USGS Core Network Gages in the Trinity River Basin.**

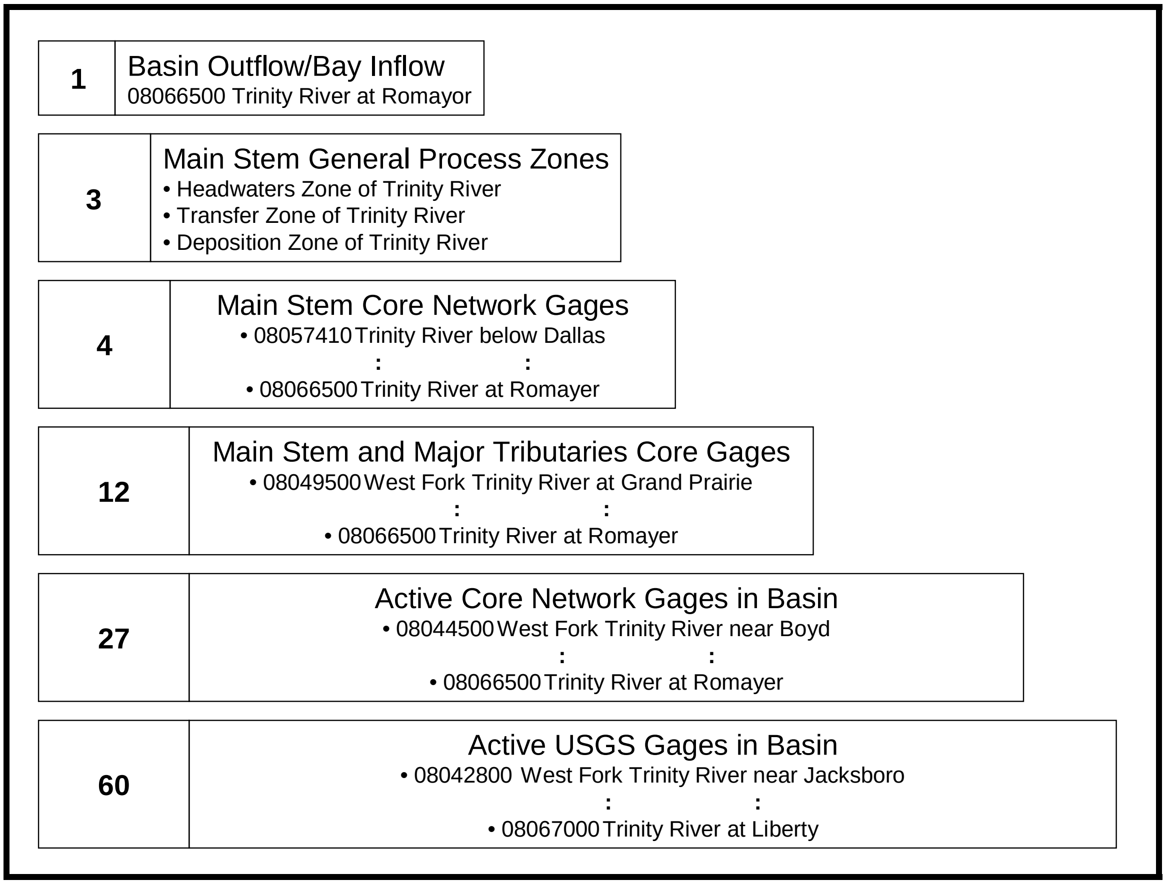


**Figure 7. Hierarchy of Gage and Point Locations in the Trinity River Basin.**

All USGS gages in a river basin can be arranged in a hierarchical structure with increasing numbers of gages at higher levels (Figure 7). For example, the number of gaging stations that might be needed to classify basin outflow is a single point at the coast. In contracts, all USGS gages in a river basin can be used to capture total flow in the basin.

## SECTION 3. DETERMINING GEOGRAPHIC SCOPE AND EXAMPLE APPLICATION

The following example uses readily available data sources, including both general data sets discussed in Section 2 and additional basin specific information, as described below, to identify an adequate number of locations on a basin wide scale to characterize an environmental flow regime. The geographic scope of instream flow reference points for SB 3 in each river basin may be different because of the broad range of aquatic ecosystems in Texas' rivers. The following is an example of how a river basin could be segmented to determine an adequate number of locations for quantifying an environmental flow regime consistent with SB 3. This example is not intended to be an attempt to dictate to the Trinity and San Jacinto Rivers and Galveston Bay BBEST which points might be selected in those basins, but merely to illustrate a process that could be used in a river basin to quickly and efficiently determine locations where environmental flow regimes could be determined.

### 3.1 TRINITY RIVER BASIN DESCRIPTIVE INFORMATION

The Trinity River Authority (TRA) identifies four major types of streams in the basin. These are described by TRA as follows:

1. Effluent-dominated streams. In these streams, during dry periods, treated wastewater constitutes the majority of the flow. The major stream section in this class is the main stem of the Trinity from below the Dallas-Fort Worth Metroplex to Lake Livingston.
2. Reservoir release-dominated streams. In these streams, reservoir releases support baseflows. The TRA identifies five reaches where reservoir releases dominate the flow regime. (Figure 8)
3. Intermittent streams. These streams may stay dry for long periods.
4. Perennial streams. These streams, typically found in the eastern portion of the watershed from Cedar Creek Reservoir to Liberty, have baseflows supported by groundwater.

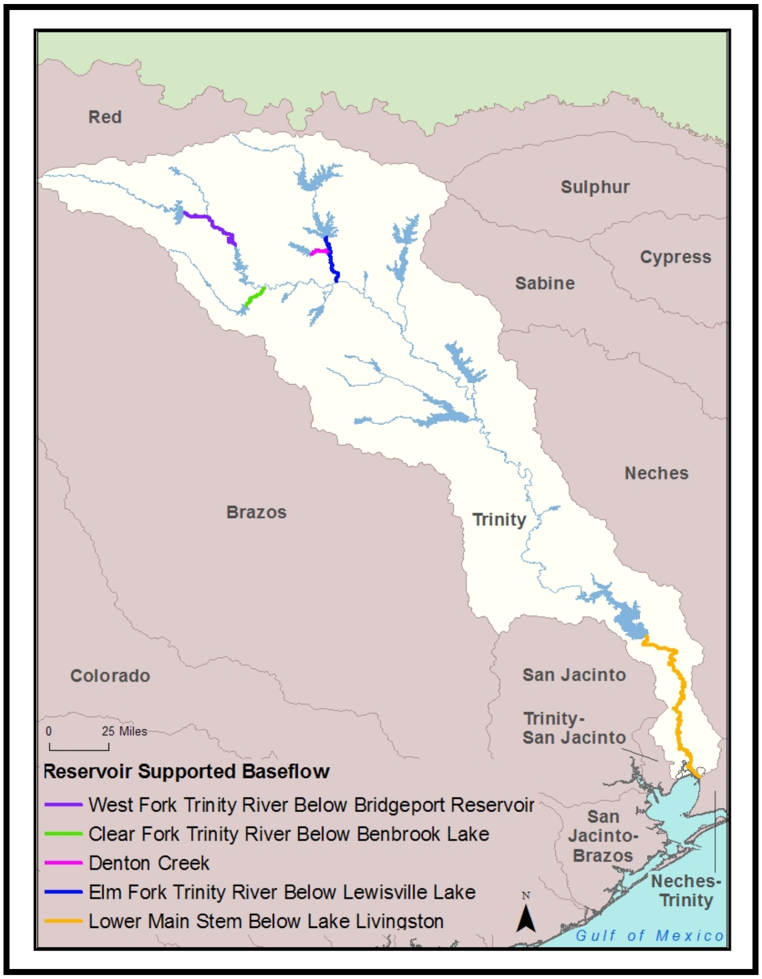


**Figure 8. Reservoir supported baseflow in the Trinity (adapted from TRA, 2007, p. 21).**

The TRA divides the basin into ten major sub-watersheds for water quality monitoring and management (Figure 9).

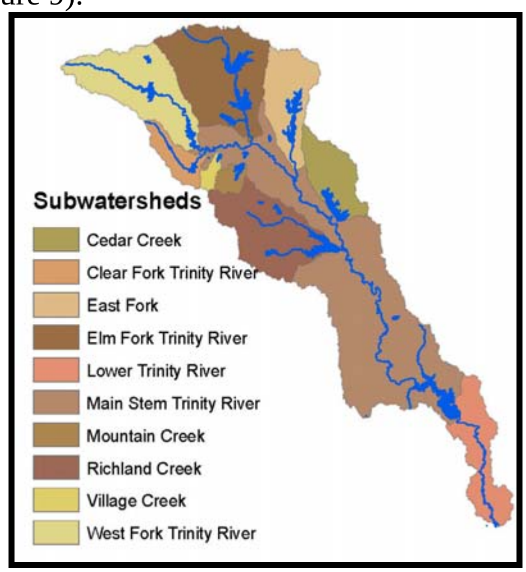


**Figure 9. Subwatersheds in the Trinity River (from TRA, 2007, p. 22).**

## 3.2 TRINITY RIVER BASIN GENERAL WATER AVAILABILITY

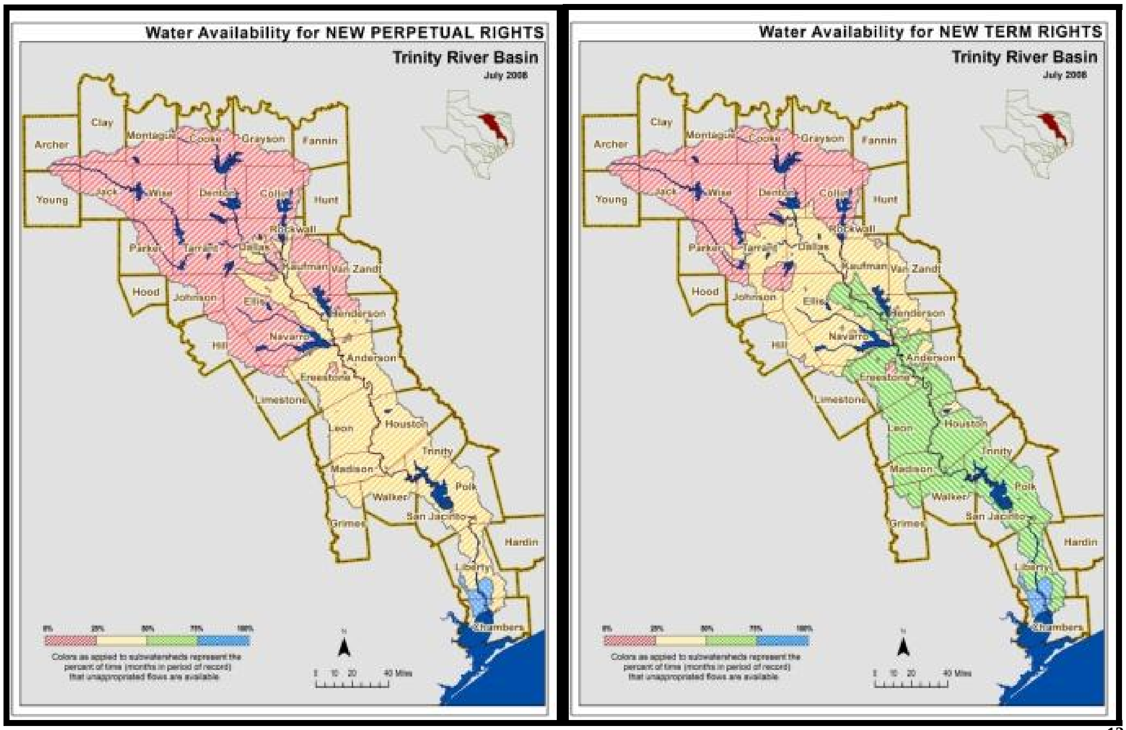


**Figure 10. Water availability in the Trinity River Basin for new perpetual and term water rights.**[12]

The TCEQ determines water availability for new appropriations using the TCEQ Water Availability Model (WAM). The Trinity WAM has a period of record from 1940-1996. This period is representative of hydrologic variability in the basin because it includes the drought of record, smaller droughts and both major and minor flood events. The hydrologic basis of the WAM is a data set of naturalized flows, representing an approximation of the flows in the river without human impacts such as reservoir storage, diversions and return flows. The WAM incorporates prior appropriation accounting. This means that senior rights divert or store their full authorized amounts before junior water rights can be exercised (Alexander Martin and Chenoweth, 2009). Instream flow requirements are treated like any other water right. For example, in water rights permitting, an instream flow requirement with a priority date of 2008 would constrain the diversion or storage of any upstream water right with a priority date junior to 2008. Water availability is extremely limited in the upper Trinity basin (Figure 10). Some water may be available in the middle and lower basin.

SB 3 does not limit the development of environmental flow regimes to areas where water is available for appropriation. SB 3 environmental flow standard development is independent of water availability. The goal is to develop flow targets wherever appropriate. There may be other ways to meet flow targets other than flow requirements in permits for new appropriations, for example, voluntary market transactions or dedicated return flows. The Science Advisory Committee (SAC) is only suggesting that

[12] These maps are available at http://www.tceq.state.tx.us/permitting/water_supply/water_rights/wam.html

water availability could be considered as a factor, along with other factors, in deciding how to segment a basin.

### 3.3 INCORPORATING THE SB 2 PRIORITY STUDY SEGMENT

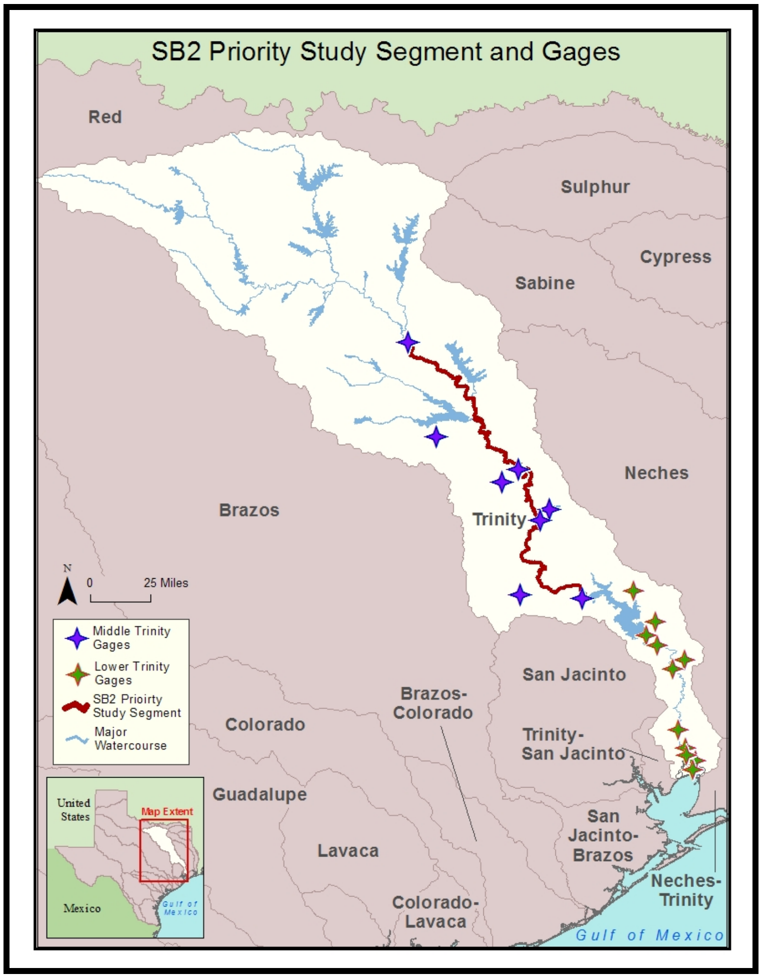


**Figure 11. SB 2 study segment for the Trinity River Basin and all associated USGS Gages.**

It is important to ensure that any ongoing studies for SB 2 are considered in the SB 3 process to determine an adequate number of environmental flow reference locations. SB 2 study results can inform the adaptive management process envisioned for SB 3. When completed, the SB 2 studies can be used to refine the SB 3 recommendations in the future. For example, the boundaries of the SB 2 study segment in the Trinity River Basin includes the main stem of the Trinity River from USGS gage 08062500, Trinity River near Rosser (located just downstream of the confluence with East Fork) to the headwaters of Lake Livingston (Figure 11). The sub-basin associated with the Trinity River priority segment includes the contributing watershed area for this portion of the river. This SB 2 study segment should be represented during determination of the number of point locations for a particular river basin.

Recommendations to protect freshwater inflows to bays and estuaries could be represented by a point at the mouth of the Trinity River, and the WAM includes a control point at this location for purposes of water availability analyses. It is possible that instream flow requirements would not be sufficiently protective of flows needed to maintain the ecological health of bays and estuaries, and vice versa. If the recommendations for instream and freshwater inflows are sufficiently different, an additional point between Lake Livingston and Galveston Bay might be needed.

### 3.4 SEGMENTING A REACH USING BASIN SPECIFIC DATA SOURCES

Both general and basin specific data sources can be used to segment reaches of interest. As mandated by SB 2, studies are in progress to identify the biologic, geomorphic, and hydrologic processes in priority river systems. The SB2 studies will develop additional information on the interrelationship among these processes and their influence on attributes such as connectivity and water quality. The example provided below shows how the Trinity River, from downstream of Dallas to the coast, may be segmented to determine an adequate number of flow determination locations.

It is important to compare the spatial scales of biologic and geomorphic data, and hydrologic measurement points represented by all USGS gages and the smaller subset of gages comprising the USGS Core Network gages in this reach. In the Trinity River Basin, for example, there is not an exact correlation among classifications of this reach based on biology, hydrology or geomorphology (Figure 12).

All USGS gages could be used to segment the reach. However, as discussed in Section 2.6, the USGS Core Network gages were specifically identified based on regionalization, streamflow assessments and major flows. As such, these Core Network gages should adequately characterize processes within a segment and site specific data can be used to refine computations for instream flow recommendations at these points. Based on both generally available data and basin specific data, the USGS Core Network gages might provide adequate coverage for computation and application of environmental flow analysis methods. However, other gages not included in the Core Network may provide valuable information and should be considered when necessary to characterize important reaches or segments for which Core network gage data are not available.

In this case, the USGS Core Network Gages:

- provide flow determination locations within the reach designated for the SB 2 studies;
- account for TCEQ classified segments except for the reach located within the pool of Lake Livingston which, based on the method used to determine flow recommendations could be considered separately;
- account for ecoregions with the exception of the Western Gulf Coastal Plain, located in the lower basin, which could be taken into account based on the decision process for reconciling instream flow and bay and estuary inflow requirements for the basin; and
- are consistent with the water quality management divisions shown in Figure 9.

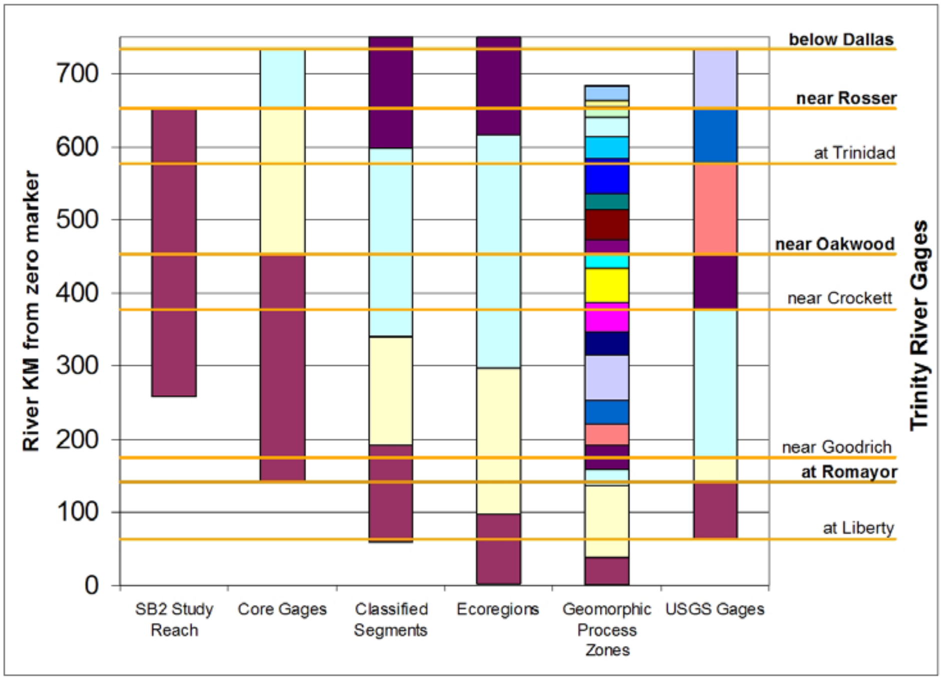


**Figure 12. Comparison of spatial scales for hydrologic, biologic, and geomorphic data.**[13]

The distribution and location of geomorphic process zones provide detailed information about some of the processes occurring within a segment (Figure 13). However, flows at USGS gages would likely be used to represent streamflows in those geomorphic areas. The geomorphic data set could be used as an overlay to refine hydrology-based computation of an environmental flow regime at gage locations.

[13] Points, such as USGS gages, are represented differently from segments. For USGS Gages, the beginning and end of the columns represent one gage. For water quality segments, geomorphic process zones, or ecoregions, one color represents the entire spatial segment. The bolded gage names are the USGS Core Network Gages.

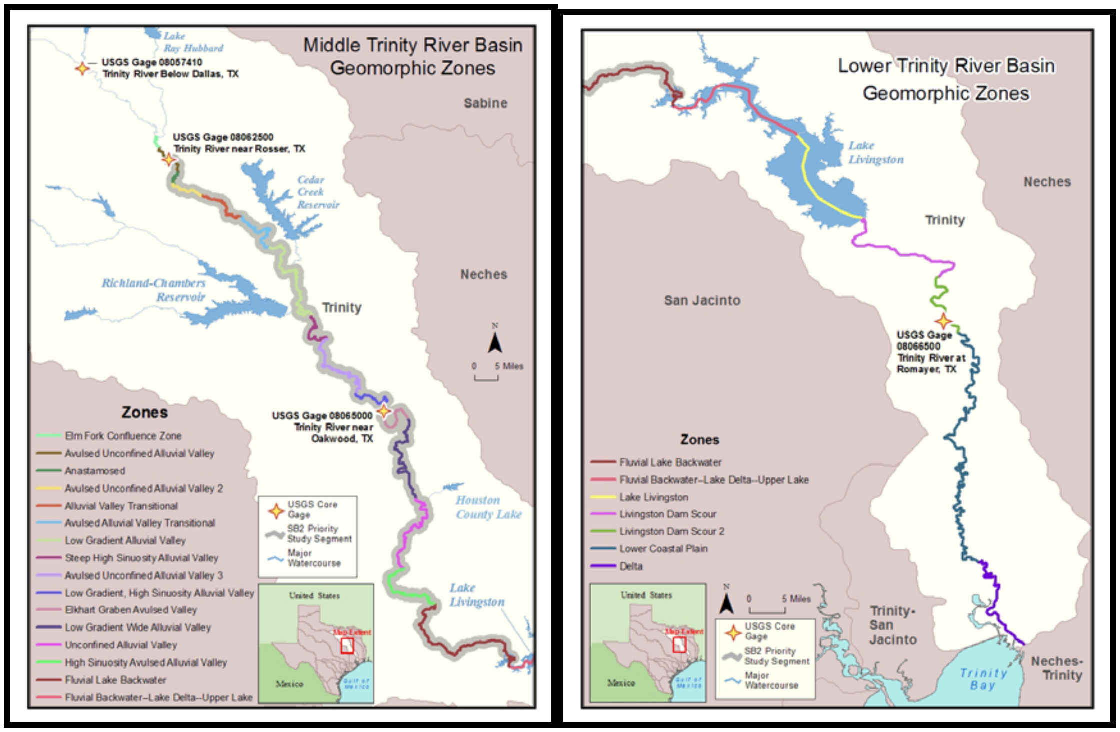


**Figure 13. Geomorphic process zones in the Trinity River Basin and USGS Core Network Gages.**

The SB 2 study segment for the Trinity River Basin includes three TCEQ classified segments, a portion of Segment 805, all of Segment 804 and a portion of Segment 803 which includes the pool of Lake Livingston. The 10 sub-watersheds delineated by TRA (Figure 9) generally represent the contributing watersheds of major reservoirs. The Main Stem Trinity River sub-watershed roughly coincides with the SB 2 study segment. It should be noted that for any future large water development projects, such as reservoirs, a site specific study may be required as part of the permitting process. If conducted, these site specific studies could possibly build on the SB 3 efforts.

USGS gages for the SB 2 study segment and tributaries are located below the upstream end of the reach (Figure 11). There are at least two major tributaries in the contributing watershed for the SB 2 reach, so it may be appropriate to include an additional point(s) farther downstream in this reach. The USGS Core Network includes a gage on the main stem of the Trinity River downstream of Richland Creek and Cedar Creek. There is an ecologically significant stream segment on Upper Keechi Creek that exhibits a high degree of biodiversity. There is a Core Network gage on Upper Keechi Creek and this location should be considered for inclusion as a flow determination location.

## SECTION 4. SUMMARY

In the current document, potential sources for general (Figure 3 through 7) and basin specific (Figures 8 through 13) information are provided. These sources can be used to identify segments of a particular river basin for purposes of determining the geographic scope of instream flow recommendations. As stated previously, these locational decisions may be different for each basin. Following is a list of questions that should be asked and issues to be considered to refine the number of flow recommendation points that would be needed for a particular river basin. This list assumes that the starting point is the USGS Core Network:

### 4.1 HYDROLOGY

- Do the USGS Core Network Gages have a sufficient period of record for the type of flow recommendation analysis contemplated for the basin? Gages that do not have a sufficient period of record may need to be excluded from the hydrologic analysis. The adequacy of the period of record depends on the type of hydrologic analysis.
- Are there redundant gages in the Core Network? One representative gage could be adequate to characterize the environmental flow regime for multiple sub-watersheds. The Core Network may include redundant gages, particularly on major tributaries (Figure 6).
- Can the most downstream gage in the Core Network be used to represent both instream flows and freshwater inflows to the bays and estuaries? This may be highly dependant on the method used to determine freshwater inflows for a particular river basin and an additional point may be needed to represent the basin outlet.
- Are segments that include habitats or features that perform hydrologic functions such as flood attenuation, flow stabilization and groundwater recharge and discharge accounted for? In particular, segments that include spring resources with unique or critical habitats should be considered, whether or not these locations are gaged. In addition, because gage locations provide point data, the user of gaged data must determine the spatial extent over which they are comfortable extending the data or analysis. This may guide the decision on whether additional points are necessary to represent important hydrologic functions.
- If particular reaches of interest do not have Core Network gages, additional gages may need to be added for flow regime analysis.

### 4.2 BIOLOGY

- Is there a USGS Core Network gage for all ecoregions and/or biologically important streams in a basin? If not, additional gages may need to be added.
- Are ecologically significant stream segments accounted for? Note that the list provided by the TPWD (Section 2.5) is not exclusive and additional stream segment specific factors may need to be considered:
  - Biological function such as segments with significant habitat value, including both quality and quantity considering the degree of biodiversity,

age and uniqueness of habitats including terrestrial, wetland, aquatic or estuarine areas.
- Riparian conservation areas such as wildlife management areas, preserves, mitigation areas.
- Threatened and endangered species, including sites along river segments that are significant because of the presence of unique, exemplary, or unusually extensive natural communities.

## 4.3 WATER QUALITY

- Are TCEQ Water Quality Segments accounted for? Water quality considerations may be important in specific locations. Therefore, TCEQ Water Quality Segments and any additional water quality issues such as the 303(d) list may be considered.[14]
- Are there basin-specific water quality concerns? Stream segments with exceptional aquatic life uses dependant on or associated with high water quality should be considered in determining an adequate number of points in a basin. These considerations could also factor into decisions as to whether or not selected reaches should be segmented further.

## 4.4 GEOMORPHOLOGY

- At a minimum, are the dominant geomorphic process zones represented? If additional basin specific information is available, this information could be used to further segment reaches of interest.
- Are unique or problematic fluvial geomorphic features or process zones (e.g., avulsions, distributaries, erosion-dominant reaches, or rapids) accounted for in the basin? Fluvial geomorphic features and processes support the physical structure of instream and overbank habitats.

## 4.5 OTHER FACTORS

- Additional basin specific factors, determined by the BBEST groups could be used to further refine the flow determination locations created from the considerations outlined above.

[14] The 303(d) lists can be found at http://www.tceq.state.tx.us/compliance/monitoring/water/quality/data/wqm/305_303.html

## SECTION 5. CONCLUSION

Determining an adequate number of points for environmental flow recommendations requires consideration of both general and site specific criteria as outlined in Section 4. Selection of an adequate number of locations for purposes of characterizing an environmental flow regime to support a sound ecological environment requires considerations of factors such as hydrology, biology, geomorphology, and water quality. In addition, the decision on how many points are adequate is basin specific in nature. Therefore, additional factors, as outlined for example in Section 3.1 may need to be included in the decision making process.

The considerations presented in Section 4 effectively represent decision points during a process of selection or elimination of streamflow-gaging stations and stream-channel reaches in a river basin. It is likely that particular reaches, tributaries, or distributaries could be subject to considerable debate prior to a decision. The BBEST groups should consider a careful documentation effort for both selected and non-selected gages and reaches, which might include a list of characteristics or reasons for their inclusion or exclusion. Documentation of the decisions made during this process may facilitate adaptive management strategies.

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