SPRING FLOW CONTRIBUTION TO THE HEADWATERS OF THE GUADALUPE RIVER IN WESTERN KERR COUNTY, TEXAS

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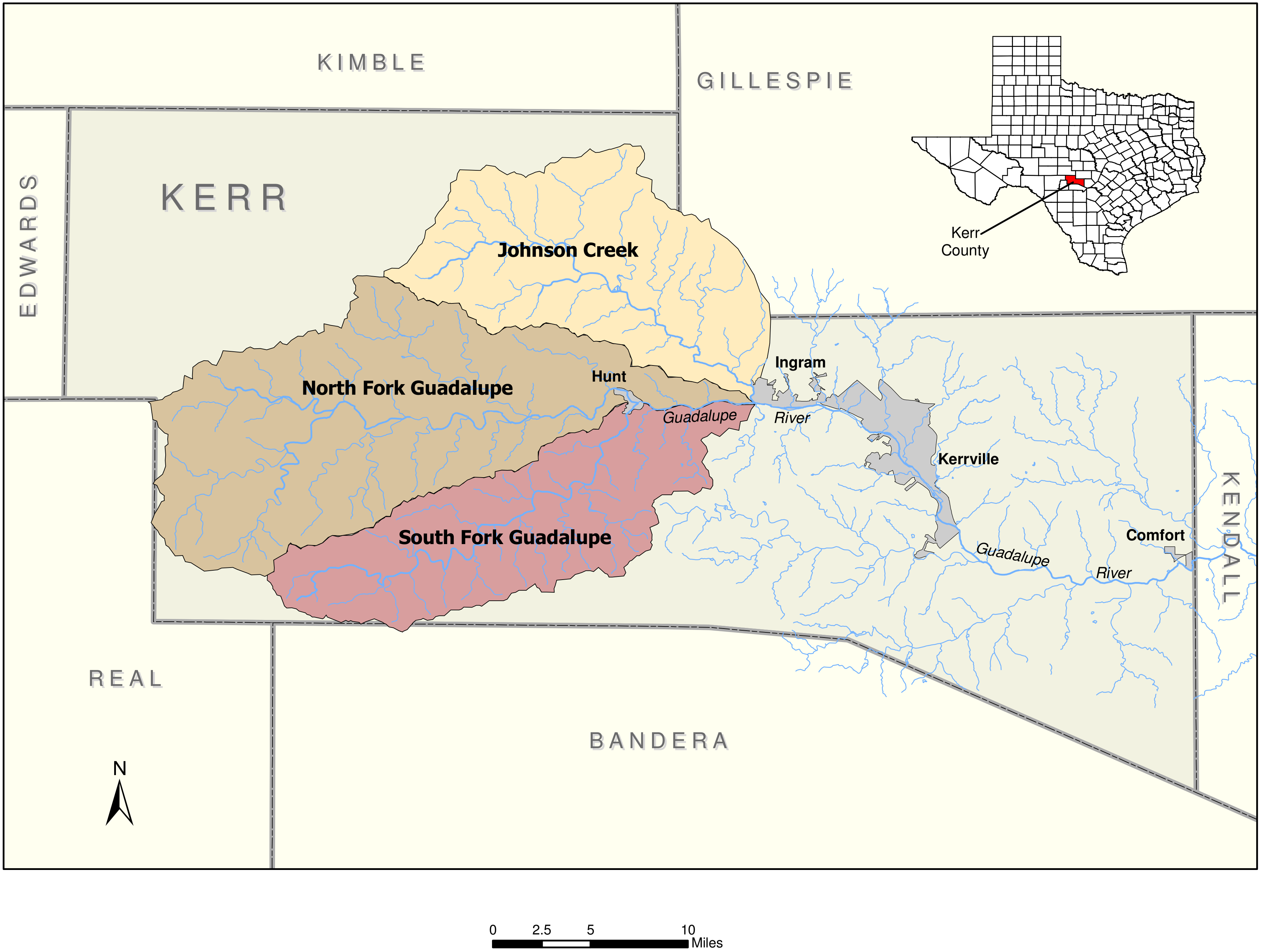
INTRODUCTION

Three drainage basins in western Kerr County merge to form the upper headwaters catchment area of the Guadalupe River (Figure 1). Other than surface runoff following significant precipitation events, water entering the three branches that feed the main stream of the Guadalupe originates as spring flow. Springs are the natural discharge points of aquifers that underlie the river drainage area. Projected population and water demand increases in Kerr County dictate a concern for the long-term preservation of these springs that contribute to the base flow of the Guadalupe. Also, the spring environments support a rich aquatic habitat that is a critical component of the local tourist and recreational economy. The purpose of this study is to demonstrate the groundwater / surface water relationship that exists between the springs, their host aquifer systems, and the Guadalupe River.

METHODOLOGY

Data used in this study was obtained from a number of sources and incorporated into a Geographic Information System (GIS). From this data, a base map was generated that depicts surface geographic data including roads, cities, watercourses, topography, and geology. Stream gage data from four gauging stations is available from the U.S. Geological Survey (USGS) and precipitation data for two sites is available from the National Weather Service (NWS). Geologic coverage is consistent with the Llano and San Antonio Geologic Atlas Sheets published by the University of Texas at Austin, Bureau of Economic Geology. Locations and accompanying data for 51 springs were obtained from four sources; (1) Texas Water Development Board Report 102, *Ground-Water Resources of Kerr County*, (2) a USGS spring database (Heitmuller and Reece, 2003), (3) locations shown on 7.5 minute USGS topographic maps, and (4) locations observed from field surveys conducted for this study.



UPPER GUADALUPE RIVER STUDY AREA

FIGURE 1

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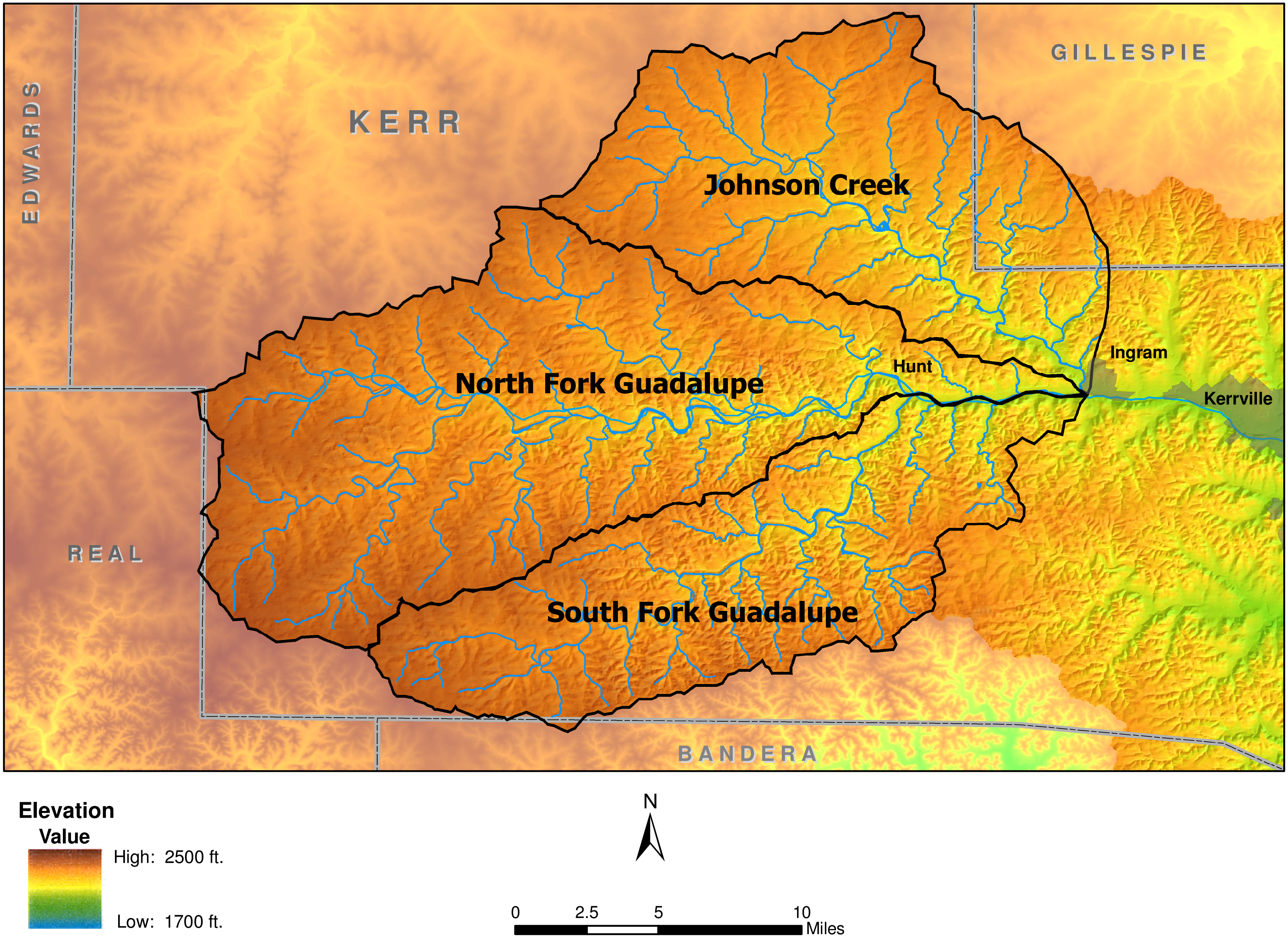
Fieldwork for this project involved visiting as many springs as possible to verify their location, appropriate name, general flow conditions, and geologic unit from which the spring water exits. Most springs are on private property and thus many were not accessible. Because of wetter than normal rainfall conditions preceding the field survey, there appeared to be significantly more springs and seeps than are currently recorded. Therefore, a second task was to measure the streamflow of each tributary at a point below all contributing springs, such that a combined spring flow within each tributary could be determined. Staff of the Upper Guadalupe River Authority, Texas Parks and Wildlife Hart of the Hills Fisheries Science Center, and the Headwaters Groundwater Conservation District proved assistance to the author in accomplishing the fieldwork and data compilation.

HEADWATERS OF THE GUADALUPE RIVER

The Guadalupe River originates entirely within western Kerr County as three branches of the river (Johnson Creek, North Fork, and South Fork) merge west of Kerrville to form the main river course (Figure 2). From there, the river flows eastward through eastern Kerr County and beyond on its ultimate destination with the Gulf of Mexico. Johnson Creek is the northernmost of the three river branches and enters the main stream at Ingram. The middle branch, or North Fork, merges with the South Fork at Hunt and, combined, flow eastward to Ingram where they are joined by Johnson Creek to form the main stem of the Guadalupe.

A line drawn from the upper northeast corner of Kerr County to the northeast corner of Real County roughly divides surface drainage, with precipitation runoff northwest of the divide flowing to the Colorado River drainage basin and flows to the southeast contained within the Guadalupe drainage basin. A southern topographic divide occurs approximately along the southern Kerr – northern Bandera county line and separates surface drainage between the Guadalupe to the north and the Medina of the San Antonio River Basin to the south.



DRAINAGE BASIN BRANCHES OF THE UPPER GUADALUPE RIVER

FIGURE 2

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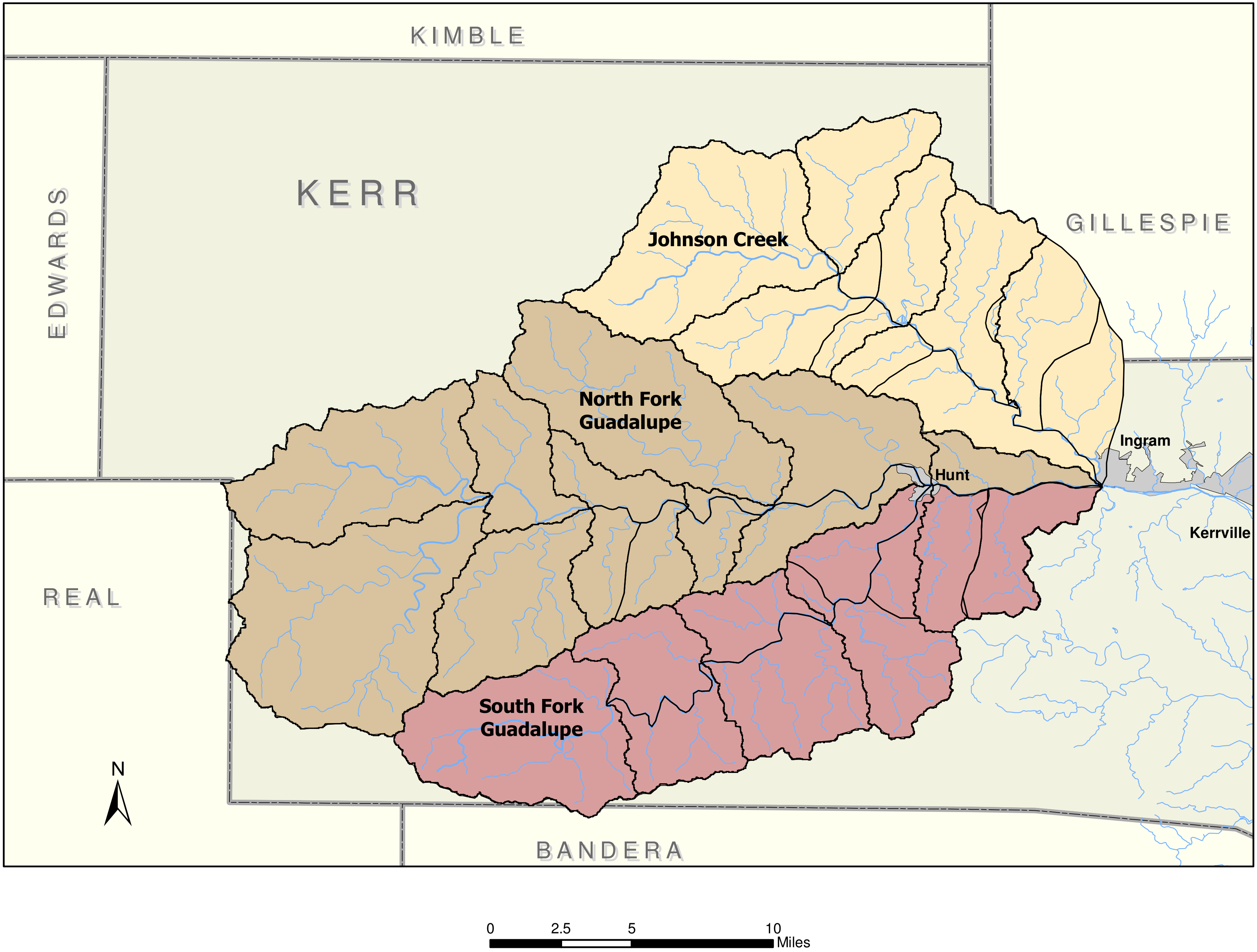
Likewise, each of the three Guadalupe branches can be subdivided into drainage basins (Figure 3). The importance of recognizing these separate drainage basins is that shallow groundwater underlying each of the basins also tends to move toward and exit the aquifer system through springs located within the same surface drainage basin.

TRAVERSE OF STREAMBEDS OVER GEOLOGIC FORMATIONS

Surface flow in the three branches and their contributing tributaries begins at higher elevation on the Edwards Plateau. The Buda Limestone, which elsewhere overlies the Edwards, caps only the highest elevations on the far western edge of the Guadalupe drainage basin. The geologic rock units over which the branches of the Guadalupe traverse include, in descending order, the Segovia and Fort Terrett members of the Edwards Formation and the Upper Glen Rose Limestone of the Trinity Group (Figures 4 and 5). Limestone beds of the Segovia member crop out at the highest land surface elevation (2,300 feet above mean sea level) and form the divides that separate the individual basins. Precipitation runoff moves rapidly down gradient from the highlands, eroding small steam beds that will eventually coalesce into the major channels of the three Guadalupe branches. As the surface water gravity flows to the east, the riverbed continuously erodes deeper into the Edwards limestone creating along the way spectacular canyons and relatively narrow floodplains.

The main streambeds begin to make their westernmost appearance over the Fort Terrett at an approximate elevation of 2,100 feet. Within a downstream distance of approximately five miles the streambeds have incised steep canyons through the Fort Terrett and have exposed the underlying limestone beds of the Upper Glen Rose (1,900 feet). From this point onward, the floodplains widen relative to the upstream canyons as they spread out over Glen Rose limestone outcrop.



SUB-BASINS IN THE UPPER GUADALUPE RIVER STUDY AREA

FIGURE 3

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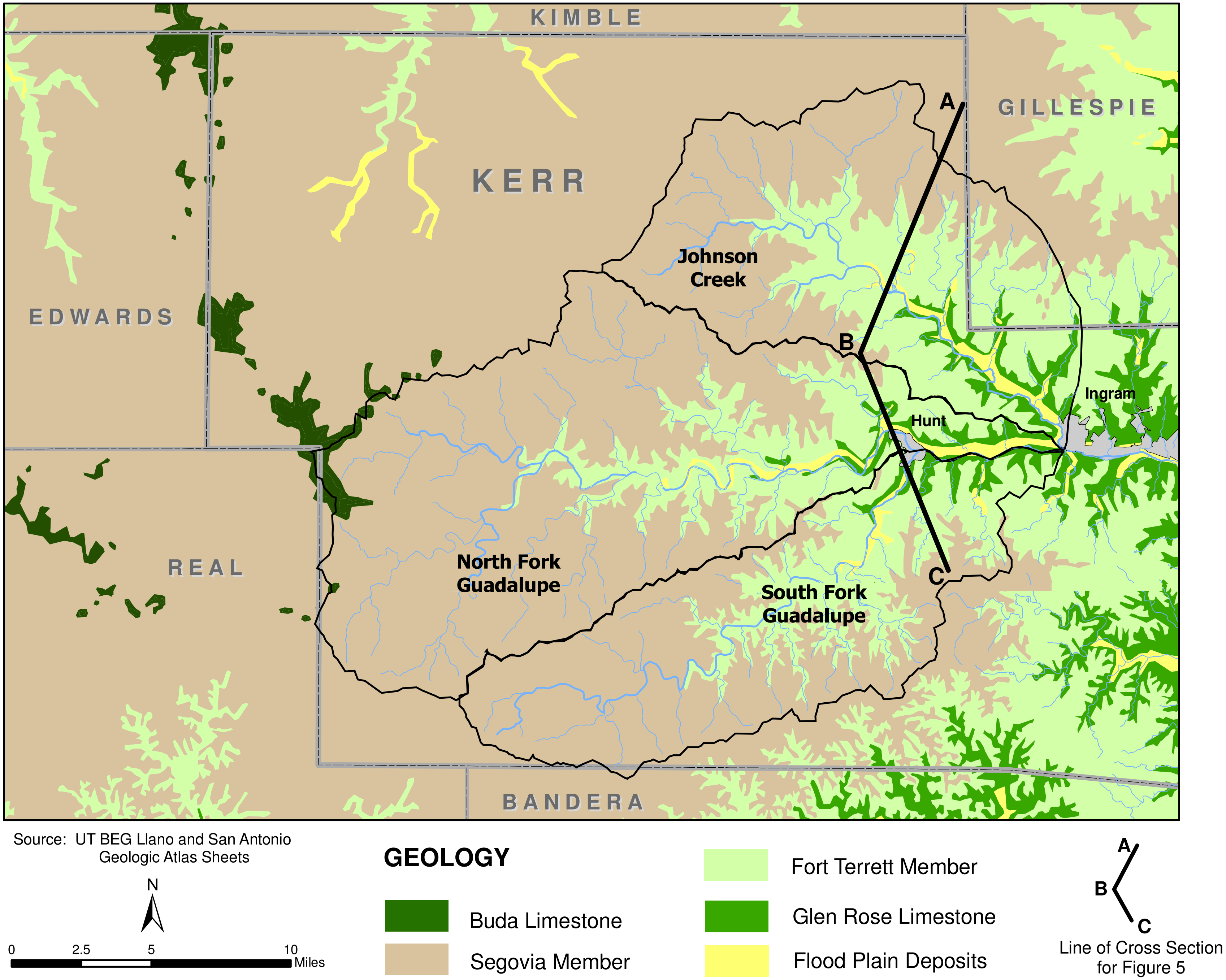
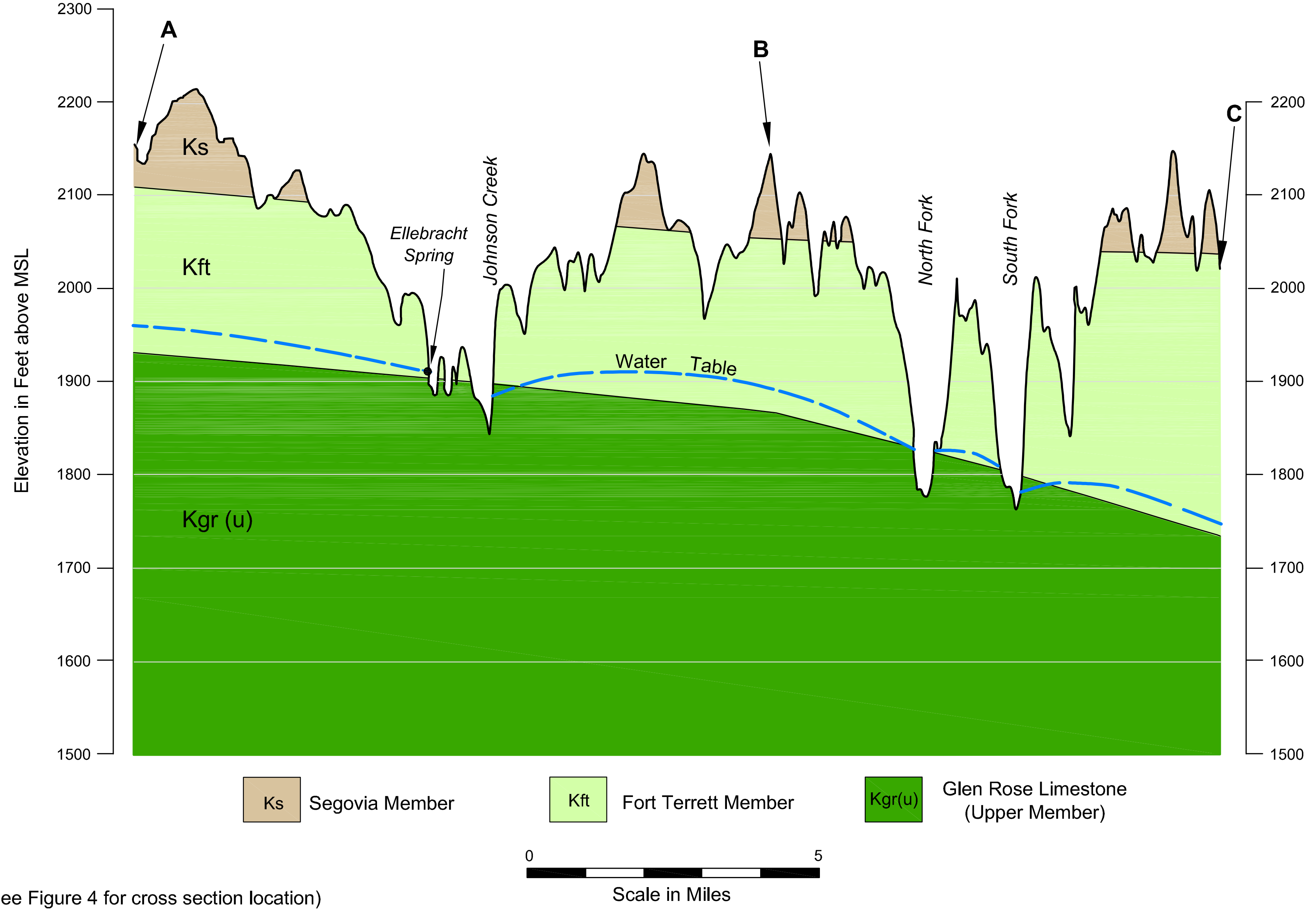


Source: UT BEG Llano and San Antonio Geologic Atlas Sheets

SURFACE GEOLOGY OF WESTERN KERR COUNTY

FIGURE 4



(See Figure 4 for cross section location)

CROSS SECTION

FIGURE 5

A variable thickness of gravel often accumulates in the streambeds where flow velocities are at their weakest. During low-flow conditions, a significant amount of flow is likely occurring through the gravel sections even though water is not visible at the surface. Pools of water may be visible in sections of the streambed where bedrock is exposed, but may reenter a gravel section within a short distance (Figure 6).

Individual Edwards Formation beds are highly fractured and permeable thus allowing precipitation to rapidly infiltrate downward to the groundwater table. The underlying Glen Rose limestone contains more clay, is less subject to fracturing, and therefore acts as a semi-impermeable barrier to further downward groundwater migration. Unable to migrate easily downward into the Glen Rose, much of the groundwater in the Edwards aquifer preferentially moves laterally until it escapes its underground confinement and flows back to the land surface through springs and seeps.

EDWARDS AQUIFER WATER LEVEL

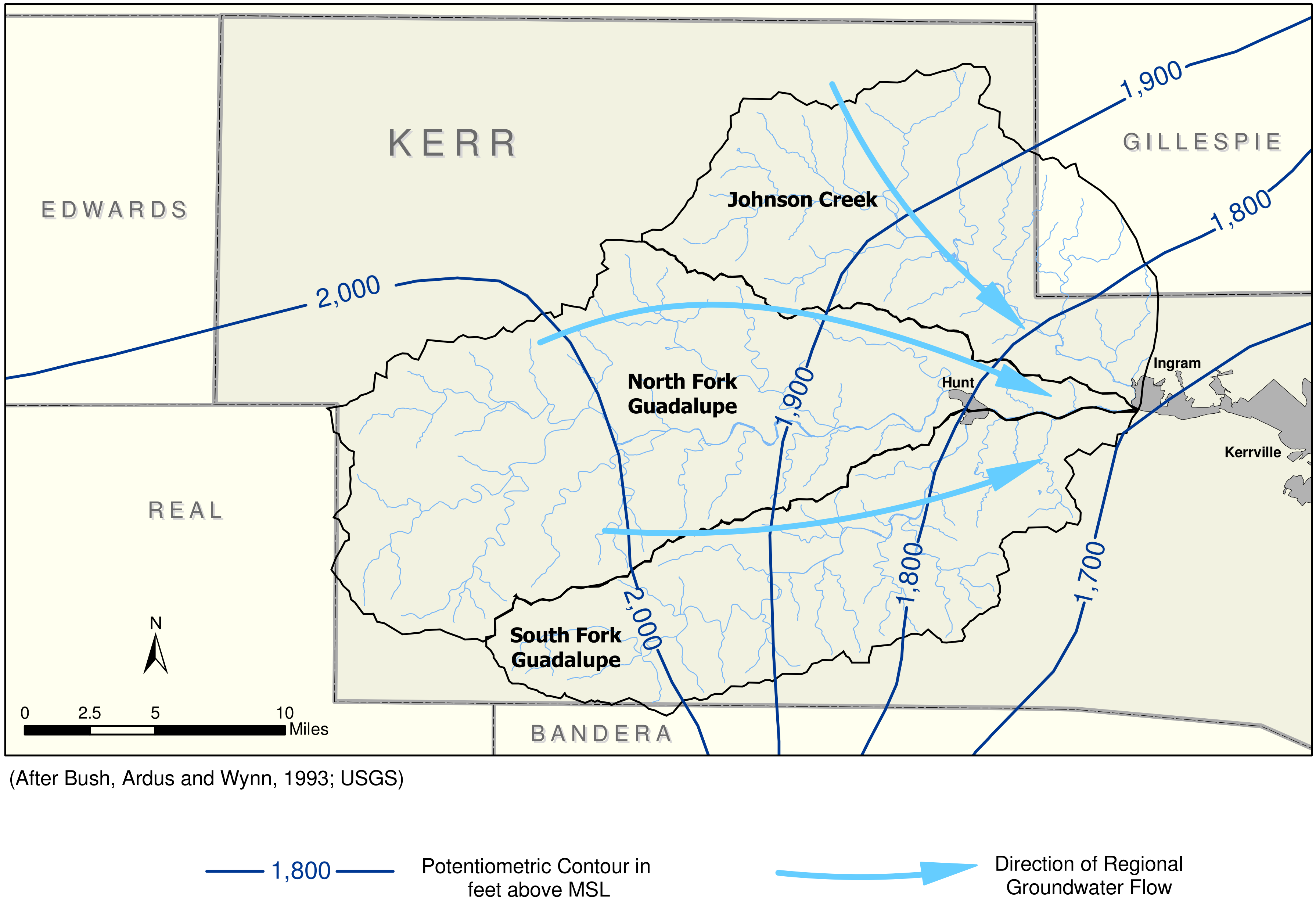
All springs contributing to the three river branches appear to issue from various horizons within the Edwards Formation. Therefore, water levels within the Edwards Formation part of the aquifer system are an integral factor in determining where springs are possible and how sustainable there flow might be. Water-level data is lacking in this area due to its remoteness and limited wells that provide access to the aquifer. For the purpose of this study, an historical potentiometric (water level) map generated by Bush and others (1993) (Figure 7) was used to establish flow direction and saturated thickness. Staff of the Headwaters Groundwater Conservation District measured water levels in a few accessible wells that verified the general accuracy of the map.

The water level elevation in the Edwards is at its highest (2,000+ feet) in southwestern Kerr and northern Real counties. In this area, the saturated thickness of the Edwards ranges from 100 to 150 feet. From there, the water-level elevation declines to between 1,800 and 1,900 feet within the general area where most of the springs occur. This equates to a west-to-east hydraulic gradient of approximately 15 feet per mile. The water-level elevation in the vicinity of most of

Stream flow visible where bedrock is exposed in primarily a gravel covered segment of Dry Branch, a tributary of Johnson Creek.

GRAVEL SEGMENTS

FIGURE 6



(After Bush, Ardus and Wynn, 1993; USGS)

FIGURE 7

EDWARDS - TRINITY WATER LEVEL ELEVATION AND REGIONAL GROUNDWATER FLOW DIRECTION

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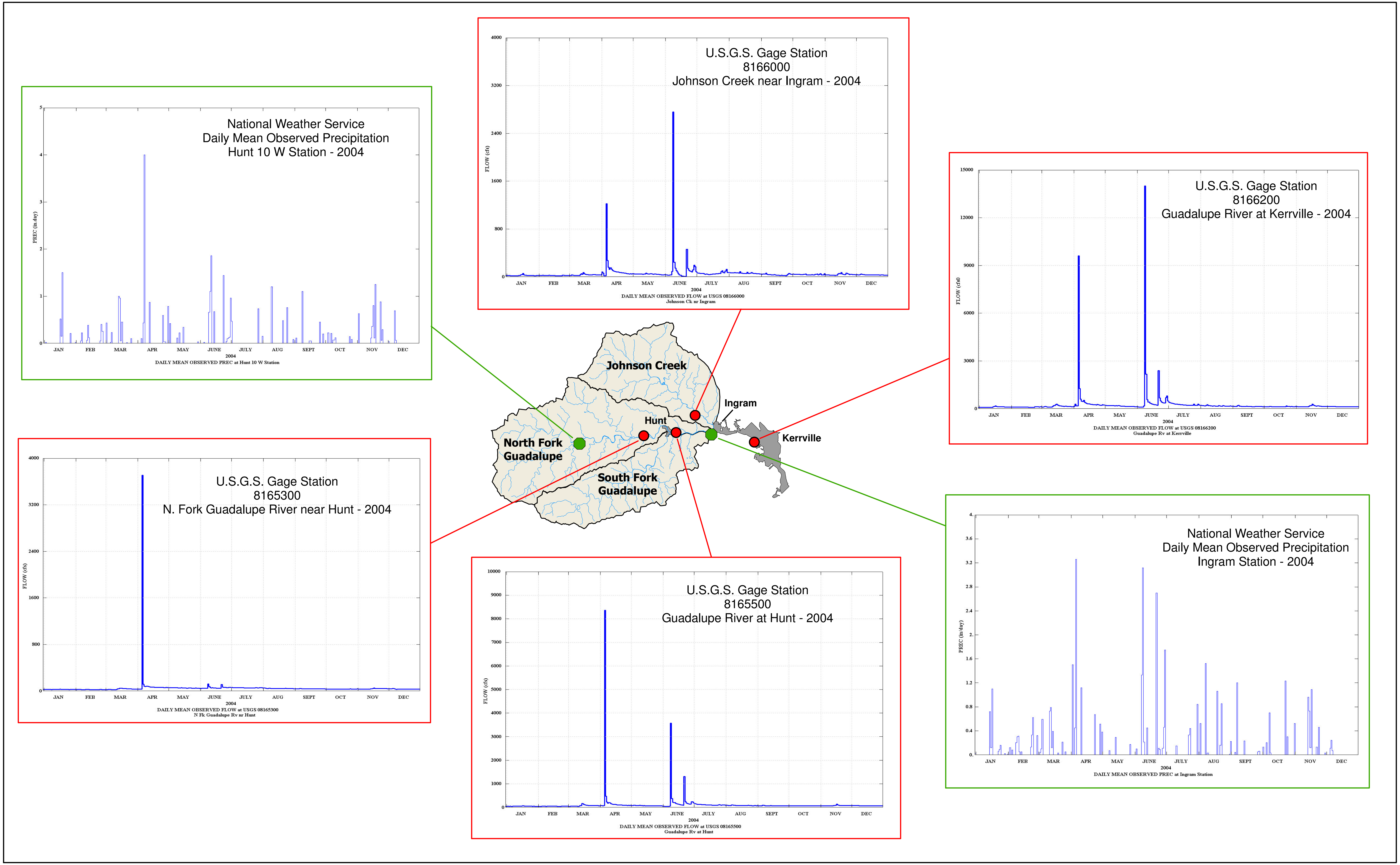
the springs is approximately 1,900 feet, which is generally the elevation of the contact between the Edwards and the underlying Glen Rose (Figure 5). This suggests that the springs rapidly dewater the aquifer at their locations and thus the saturated thickness approaches zero. Significantly more water level measurements from additional well sites are needed to establish more detailed water-level elevation, saturated thickness, and flow direction maps.

STREAM FLOW GAGE MEASUREMENTS

The topography and shallow soils of western Kerr County are conducive to rapid runoff following significant precipitation events resulting in short-term elevated river flows. The cessation of runoff eventually returns the river to a base flow condition. These events can be observed in the continuous-flow hydrographs generated from data obtained from the four USGS gaging stations and two NWS precipitation stations (Figure 8). Source water contributing to base flow is primarily generated from the many springs that feed the tributaries to the river. The volumetric contribution of these springs is discussed in the following sections.

SPRINGS

The principal consideration in this study is the physical location of springs, their relationship to specific geologic formations, and their contribution to the base flow of the Guadalupe River. Figure 9 shows the location of 51 currently recognized springs in western Kerr County including those shown on USGS 7.5 minute topographic maps and those listed in USGS and TWDB databases. Table 1 lists these springs and the associated tributary basins in which they occur. It became quite apparent after visiting a number of reported spring sites that in most cases the location contains numerous springs rather than a single outlet. It is also apparent that, especially during wetter periods, there are many more springs in existence than may have been previously reported.



YEAR-2004 USGS RIVER GAGE AND NWS PRECIPITATION DATA

FIGURE 8

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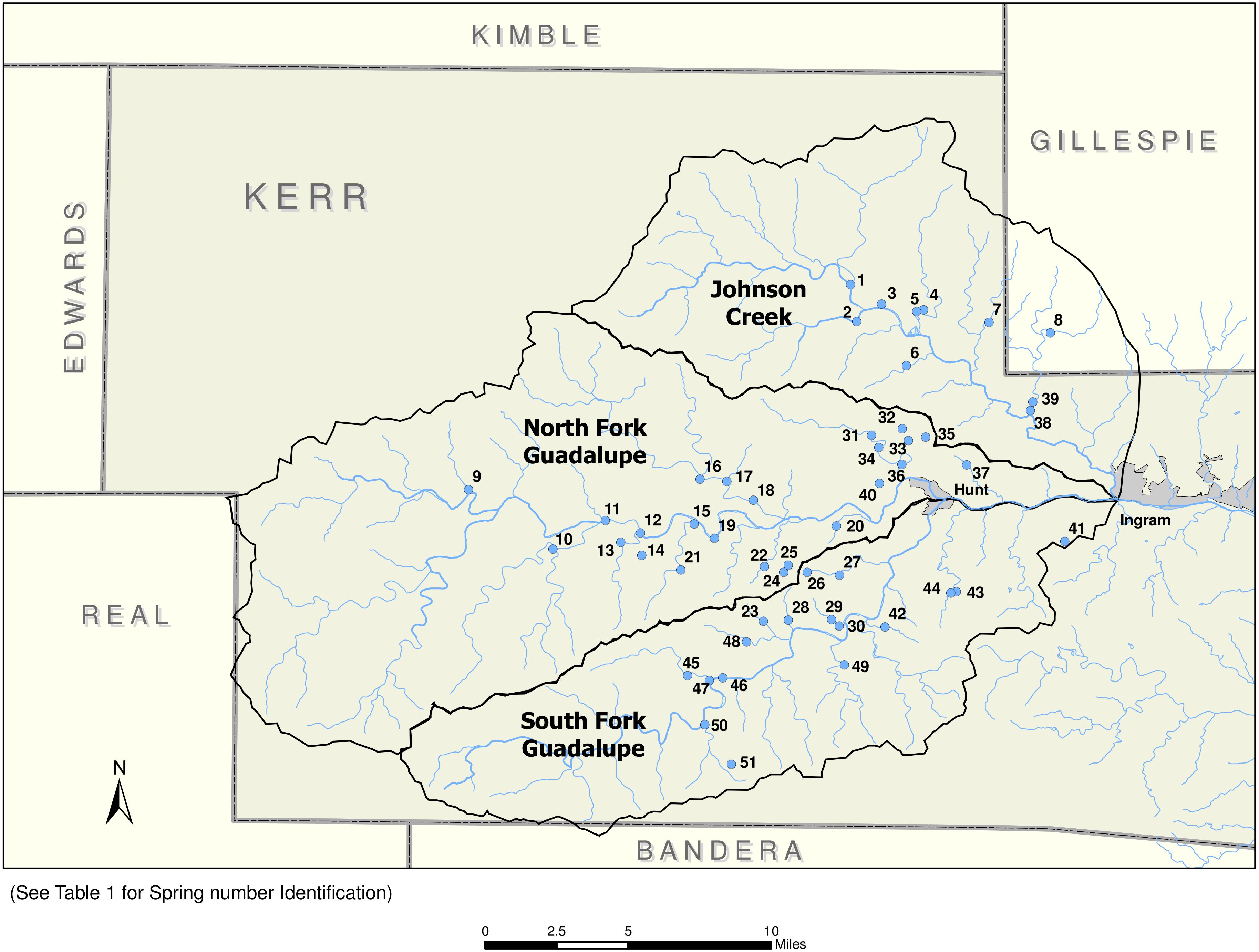

(See Table 1 for Spring number Identification)

SPRINGS IN THE UPPER GUADALUPE RIVER STUDY AREA

FIGURE 9

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TABLE 1. SPRINGS OF WESTERN KERR COUNTY

ID. No.	State Well No.	Spring Name	Tributary	Latitude	Longitude	Elev.	Topo Location	Remarks
CONTRARY CREEK QUADRANGLE								
1	56536--		Johnson Creek	30.1795	-99.3793	1898	Yes	Rough Hollow and Johnson Creek
2	56539--	Contrary	Contrary Creek	30.1608	-99.3761	1900	Yes	
MOUNTAIN HOME QUADRANGLE								
3	5654402	Welch	Welch Creek	30.1697	-99.3636	1900	No	
4	5654403	Ellebracht	Fessenden Branch	30.1667	-99.3423	1898	Yes	Supplies water for TP&W Hart of the Hills Fisheries Science Center.
5	56547--	Zock	Fessenden Branch	30.1658	-99.3459	1900	No	Complex of at least 4 main springs along west bank of lake.
6	5654701	Byas	Byas Branch	30.1385	-99.3511	1900	Yes	Complex of at least 4 main springs.
7	5654802		Dry Branch	30.1604	-99.3094	1900	No	
8	56549--		Fall Branch	30.1551	-99.2784	1910	Yes	Located in Gillespie County.
BONEYARD DRAW QUADRANGLE								
9	5660501		Unnamed	30.0759	-99.5724	2060	No	
10	5660601		Flat Rock Creek	30.0457	-99.5296	2020	No	
11	56606--	Headwaters	North Fork Guadalupe	30.0602	-99.5032	1940	Yes	Large flow from several main springs issuing from both sides of the river.

ID. No.	State Well No.	Spring Name	Tributary	Latitude	Longitude	Elev.	Topo Location	Remarks
BEE CAVES CREEK QUADRANGLE								
12	5661402		North Fork Guadalupe	30.0538	-99.4856	1920	Yes	Callum Ranch. Two springs shown on topo.
13	56614--	Joy	Unnamed	30.0491	-99.4955	1998	Yes	
14	56614--	Cherry	Unnamed	30.0426	-99.4848	1998	Yes	
15	56614--	Lower Bee Caves	Bee Caves Creek	30.0584	-99.4583	1900	Yes	
16	56615--	Bear Creek 1	Bear Creek	30.0811	-99.4553	1960	Yes	Reported to be large springs.
17	56615--	Bear Creek 2	Bear Creek	30.0800	-99.4418	1900	Yes	Reported to be large springs.
18	56615--	BSA	Bear Creek	30.0705	-99.4285	1895	No	Multiple seeps and springs on north bank below low-water dam.
19	5661504		North Fork Guadalupe	30.0512	-99.4481	1880	Yes	
20	56616--		Unnamed	30.0574	-99.3865	1860	Yes	Two springs shown on topo.
21	5661702	Bee Caves	Bee Caves Creek	30.0352	-99.4651	1987	Yes	
22	56618--		Unnamed	30.0368	-99.4228	1950	Yes	
23	56618--	White Oak	White Oak Creek	30.0092	-99.4233	1970	Yes	
24	56619--	Muskhog	Unnamed	30.0340	-99.4132	1970	Yes	Two springs shown on topo.
25	56619--		Unnamed	30.0375	-99.4110	1980	Yes	Two springs shown on topo.
26	56619--		Lange Ravine	30.0340	-99.4013	2050	Yes	
27	56619--		Lange Ravine	30.0325	-99.3849	1950	Yes	

ID. No.	State Well No.	Spring Name	Tributary	Latitude	Longitude	Elev.	Topo Location	Remarks
28	56619--		Cherry Creek	30.0098	-99.4110	1910	Yes	
29	56619--		Panther Creek	30.0101	-99.3890	1900	Yes	Springs located in two spring boxes on south side of creek.
30	56619--		Panther Creek	30.0068	-99.3852	1880	Yes	
HUNT QUADRANGLE								
31	5662101		Honey Creek	30.1033	-99.3687	1895	Yes	Conrad Meadows Ranch.
32	5662102		Honey Creek East	30.1066	-99.3532	1935	Yes	
33	5662103		Honey Creek East	30.1006	-99.3501	1880	Yes	
34	5662104		Honey Creek	30.0971	-99.3651	1860	No	
35	5662105	Whetstone	Honey Creek East	30.1024	-99.3413	1990	Yes	
36	5662106	Duncan	Honey Creek	30.0885	-99.3534	1780	No	Misslocated in TWDB database.
37	56622--		Unnamed	30.0883	-99.3207	1875	Yes	
38	56623--	Colleen	Fall Branch	30.1157	-99.2884	1770	No	Spring is submerged under lake near west end of dam.
39	56623--		Fall Branch	30.1201	-99.2872	1780	No	At least 2 springs on west bank. Star Ranch
40	56624--		Unnamed	30.0789	-99.3646	1855	Yes	
41	5662603	Indian	Unnamed	30.0496	-99.2711	1880	No	
42	56627--	Mystic	Edmunson Creek	30.0064	-99.3620	1900	Yes	
43	5662802		Tegener Creek	30.0242	-99.3259	1920	Yes	East of two springs.

ID. No.	State Well No.	Spring Name	Tributary	Latitude	Longitude	Elev.	Topo Location	Remarks
44	5662803		Tegener Creek	30.0235	-99.3288	1935	Yes	West of two springs.
DIAMOND S RANCH QUADRANGLE								
45	69051--		Sycamore Draw	29.9817	-99.4617	2000	Yes	
46	6905201		South Fork Guadalupe	29.9806	-99.4438	1955	No	Lynxhaven Ranch.
47	6905202		Sycamore Draw	29.9792	-99.4506	1975	No	Lynxhaven Ranch.
48	69052--		Indian Creek	29.9987	-99.4318	1980	Yes	
49	69053--		Buffalo Creek	29.9871	-99.3825	1900	Yes	
50	69055--		Mullen Creek	29.9569	-99.4529	2015	Yes	Diamond S Ranch.
51	69055--	Green	Mullen Creek	29.9369	-99.4396	2155	Yes	

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Springs in western Kerr County occur where the saturated portion of the underlying aquifer is exposed at the land surface. This generally occurs where a streambed has eroded deep into the surrounding landscape. In western Kerr County, water in the form of precipitation enters the Edwards Formation at higher elevation and migrates downward through fractures to the saturated zone or aquifer. When this groundwater reaches a less permeable zone, such as the Glen Rose, the groundwater moves laterally until it emerges at the land surface in the form of spring flow (Figure 5). The excellent water quality (low TDS) of the spring water testifies to the relatively short time period in which the groundwater has been in transition from percolating rainfall to its exit as spring flow.

As is to be expected, the majority of springs are encountered where the river branches have exposed the contact between the Glen Rose and the overlying Edwards. Flows generally emerge from rock crevices at or near the base of the Edwards Formation. Figure 10 shows an Edwards-Glen Rose contact location in the Johnson Creek basin that is now above the water table, but historically had witnessed significant flow as seen by the preserved cavernous rock layer. This geologic contact is shown in Figures 4 and 5 where the lighter green color representing the Fort Terrett is juxtaposed against the medium green color representing the Glen Rose.

Fewer springs occur and tributary flows are less or non-existent in the higher elevations of the far western reaches of the three main drainage basins. In this area, the aquifer water table is over 100 feet below the land surface. The few springs that do occur at the higher elevations in the far western extent of the North Fork basin, issue from higher in the Edwards section near the top of the Fort Terrett member.

PERMEABLE CONTACT BETWEEN THE EDWARDS LIMESTONE AND THE UNDERLYING GLEN ROSE LIMESTONE

FIGURE 10

The volumetric rate of flow from each spring is primarily a factor of its physical connection (or conduit) with the contributing aquifer, the size of the contributing area up gradient of the spring, and the water level in the aquifer as affected by recent recharge (precipitation) events. The previous four months prior to visiting the springs were wetter than normal, thus spring flows were at their maximum and some springs were flowing that only occasionally flow. Flow rates of individual spring complexes vary from mere seeps to over 16 cubic feet per second (cfs). The largest springs observed were Ellebracht Spring on the Fessenden Branch of Johnson Creek and the Headwaters Springs on the North Fork (Figure 11).

TRIBUTARY FLOWS

Because of the lack of access to all springs and the wetter than normal conditions, it was determined not to measure flows in individual springs but rather to measure the accumulated flow of all springs in each tributary (Table 2). Figure 12 shows the location of each of these measuring sites. In this manner, it is possible to compare the relative contribution of each tributary grouped spring system to the overall flow in each river branch.

The tributary with the greatest measured flow in the Johnson Creek basin was Fessenden Branch, which is supplied from Ellebracht Spring and the Zock Springs complex. A portion of the flow from Ellebracht Spring is channeled through an aqueduct to the Texas Parks and Wildlife Hart of the Hills Fisheries Research Center.

The greatest flow contribution to the North Fork is derived from the Headwaters Springs complex located near the headquarters of the Kerr State Wildlife Management Area. These moderately large springs are situated on the banks of both sides of the river and are, therefore, not assigned to specific tributaries. A combined flow of the North Fork downstream from the Headwaters Springs was measured at 31.38 cfs.

A. Ellebracht Spring facing downstream

B. Headwaters Springs (numerous outlets)

ELLEBRACHT SPRING AND HEADWATERS SPRINGS

FIGURE 11

TABLE 2. TRIBUTARY FLOW MEASUREMENTS

JOHNSON CREEK

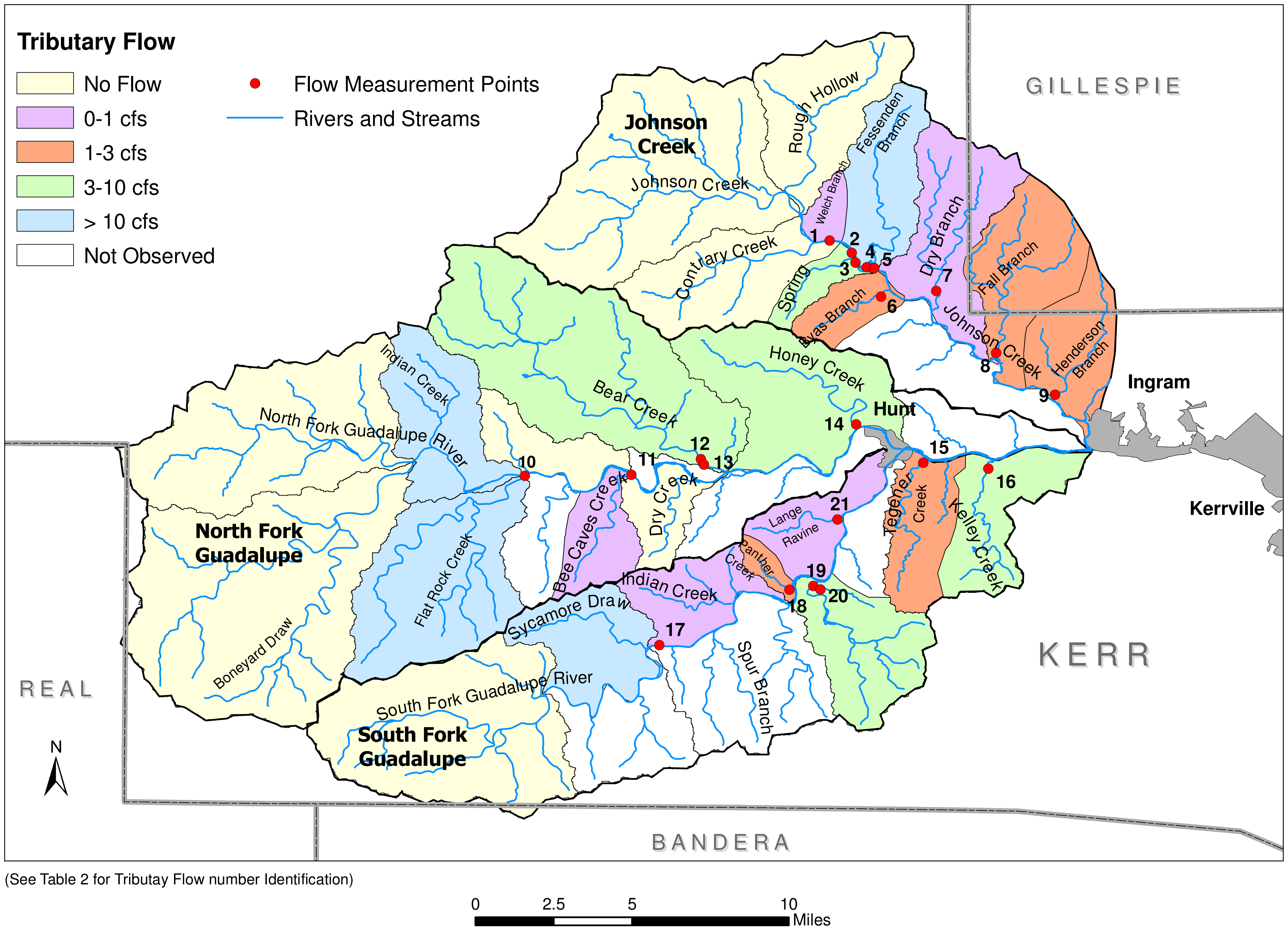
Map ID No.	Tributary	Flow (cfs)	Date
1	Welch Branch	2.71	12/14/2004
	Spring Creek		
2	North Shelton crossing	3.04	12/14/2004
3	South Shelton crossing	0.53	12/14/2004
	Fessenden Branch		
4	TP&W aquaduct	7.1	12/14/2004
5	Main stream	9.46	12/14/2004
6	Byas Branch	2.5 (est.)	12/14/2004
7	Dry Branch	0.78	12/14/2004
8	Fall Branch	1.03	12/14/2004
9	Henderson Branch	3.5	12/14/2004

NORTH FORK AND MAIN BRANCH

Map ID No.	Tributary	Flow (cfs)	Date
10	Headquarters Springs	20.0+ (est.)	12/21/2004
11	Bee Cave Creek	0.54	12/21/2004
	Bear Creek		
12	Bear Creek upper	3.29	12/21/2004
13	BSA spring on Bear Creek	0.52	12/21/2004
14	Honey Creek	4.86	12/14/2004
15	Tegener Creek	1.32	12/14/2004
16	Kelley Creek	3.07	12/14/2004

SOUTH FORK

Map ID No.	Tributary	Flow (cfs)	Date
17	Sycamore Draw / Lynxhaven Springs	10+ (est.)	12/21/2004
18	Panther Creek	1.25	12/21/2004
19	Cypress Creek at Camp Mystic	4.33	12/21/2004
20	Edmunds Creek at Camp Mystic	0.18	12/21/2004
21	Lange Ravine	0.56	12/21/2004



(See Table 2 for Tributay Flow number Identification)

TRIBUTARY FLOW MEASUREMENT POINTS AND RELATIVE FLOW COMPARISON

FIGURE 12

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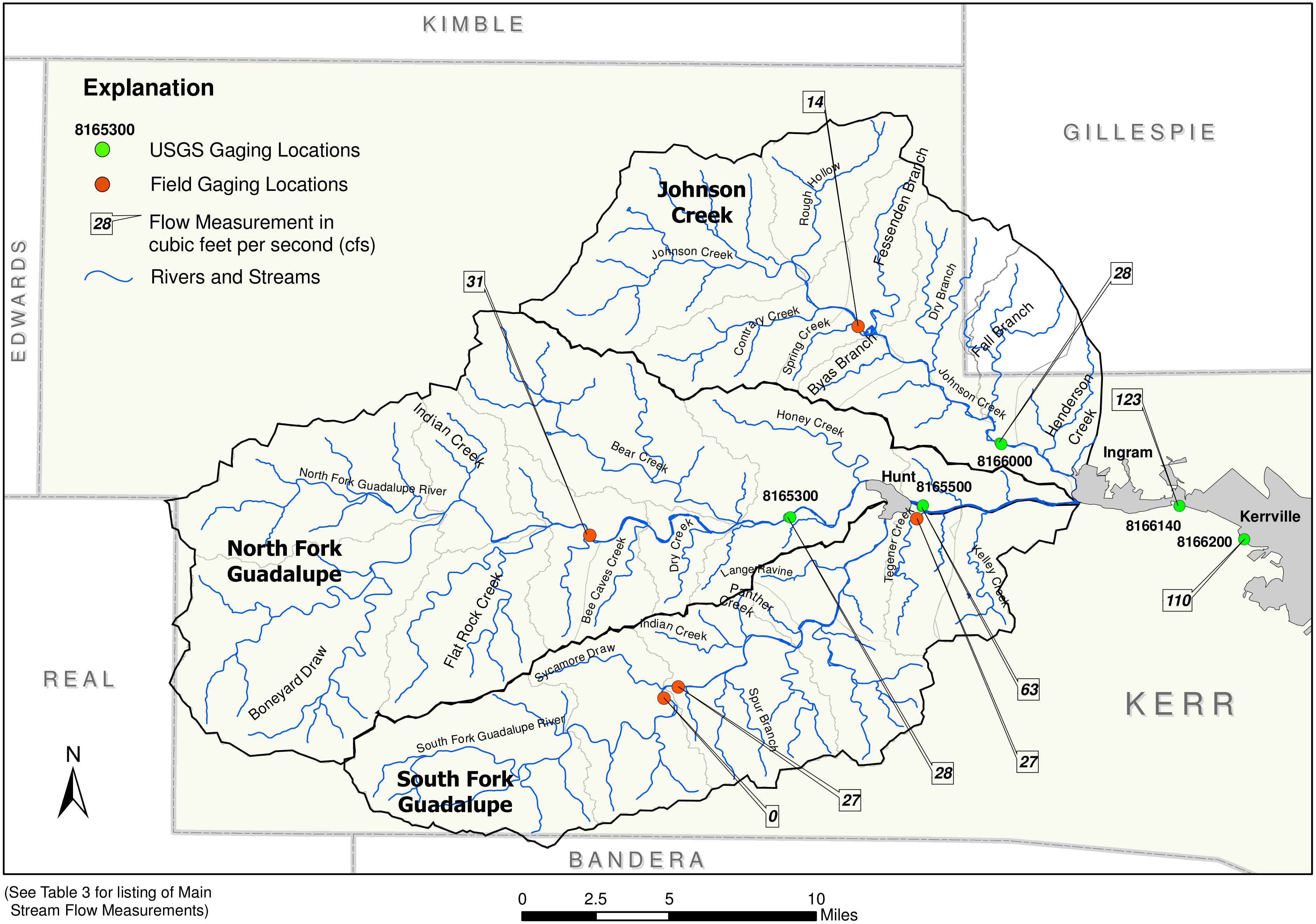
A flow of 27.4 cfs was measured on the South Fork at the Lynxhaven crossing. A half-mile upstream, no flow was observed in the streambed, however the streambed at this location contained a thick accumulation of gravel. Therefore, the quantity of flow measured at the Lynxhaven crossing is likely a combination of underflow in the upstream gravels and springs located on Sycamore Creek and the Lynxhaven property river frontage.

With contributions of tributary flow along the course of each branch, it would seem reasonable that stream gages would record increasing flows in the downstream direction (Table 3) and Figure 13. However, this is only apparent on Johnson Creek. River flow on the North Fork was greater near the Headwaters Springs than downstream near the confluence with Bear Creek. Likewise, on the South Fork, river flow at the Lynxhaven crossing is almost identical to flow at the terminus of the branch near Hunt, thus negating any tributary inflow between the two points. Underflow in streambed gravels along certain reaches of the rivers may contain the unaccounted flow volume.

A similar tributary contribution (base-flow) survey was performed by the USGS in 1965 (Kunze and Smith, 1966). Based on this study which was performed following drier conditions, the authors estimated that approximately 90 percent of the Guadalupe River base flow through its entire reach in Kerr County is contributed from springs issuing from the Edwards Formation and only 10 percent from Glen Rose springs. Under wetter conditions, the Edwards contribution is likely higher.



(See Table 3 for listing of Main Stream Flow Measurements)

FLOW MEASUREMENTS ON MAIN BRANCHES OF THE UPPER GUADALUPE RIVER

FIGURE 13

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TABLE 3.   MAIN STREAM FLOW MEASUREMENTS

JOHNSON CREEK

Measurement Site	Flow (cfs)	Date
USGS 8166000 Johnson Creek above Ingram	28	12/14-21/2004
Johnson Creek at Shelton Dam	13.8	12/14/2004

NORTH FORK AND MAIN BRANCH

Measurement Site	Flow (cfs)	Date
USGS 8165300 North Fork above Hunt	28	12/14-21/2004
USGS 8165500 Main Branch below Hunt	63	12/14-21/2004
River crossing at Rocky Bottom Road	31.38	12/21/2004

SOUTH FORK

Measurement Site	Flow (cfs)	Date
River crossing at Lynxhaven	27.4	12/21/2004
River crossing 0.5 miles above Lynxhaven crossing	0	12/21/2004
River crossing under Hwy 39 bridge	27.01	12/14/2004

GUADALUPE RIVER BELOW BRANCHES

Measurement Site	Flow (cfs)	Date
USGS 8166140 Main Stream at Bear Creek above Kerrville	123	12/14-21/2004
USGS 8166200 Main Stream at Kerrville	110	12/14-21/2004

CONCLUSIONS

Base flow in the three branches of the upper Guadalupe River is derived from the many springs that occur within the branch tributaries. These springs represent outflow from the underlying groundwater system, and thus provide the direct link that connects groundwater to surface water. Aquifer management is thus a critical step in the overall protection of both the groundwater and surface water resources in western Kerr County.

Tributary flow measurements provide insight into the overall contribution of springs without having to measure flow in each individual spring. Figure 12 illustrates those tributary sub-basins that contribute the most to flow in the three upper Guadalupe branches. However, it should not be assumed that protection of springs by restricting groundwater development only in these preferred sub-basins would insure continued base flow in the river. The groundwater system that feeds the springs is not restricted to the individual sub-basins, but rather is a much larger system from which each spring-fed tributary receives a portion. While it may be important to restrict groundwater withdrawals in the near vicinity of springs in order to maintain their flow, it is also important to guard against overdevelopment of the entire contributing aquifer system.

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