Kinney County Groundwater Conservation District

Management Plan – 2003

I. District Mission

The mission of the Kinney County Groundwater Conservation District is to develop, promote and implement water conservation and management strategies to conserve, preserve, and protect the groundwater supplies of the District, to protect and enhance recharge, prevent waste and pollution, and to efficient use of groundwater within the District. The District seeks to protect the rights of owners of water rights within the District from impairment of their groundwater quality and quantity within the District, pursuant to the power and duties granted under Chapter 36, Subchapter "D" of the Texas Water Code.

II. Purpose of Management Plan

The 75th Texas Legislature in 1997 enacted Senate Bill 1 (SB 1)[1] to establish a comprehensive state-wide water planning process. In particular, SB 1 contained provisions which required groundwater conservation districts to formulate management plans to identify the water supply resources and water demands that will shape the decisions of each district. The management plans for the groundwater conservation districts would also include the management goals that each district would establish to manage and conserve the groundwater resources within their boundaries. In 2001, the Texas Legislature enacted Senate Bill 2 (SB 2)[2] to enhance the planning requirements of SB 1 and to further clarify the actions necessary to manage and conserve the groundwater resources of the state of Texas.

The Kinney County Groundwater Conservation District management plan satisfies the requirements of SB 1, SB 2, the statutory requirements of Chapter 36 of the Texas Water Code and the administrative requirements of the Texas Water Development Board's (TWDB) rules.

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[1] Act of June 2, 1997, 75th Leg. R.S., ch. 1010, 1997 Tex. Gen.Laws 3610.

[2] Act of May 27, 2001, 77th Leg., R.S., ch. 966, 2001 Tex. Gen. Laws 1991.

III. District Information

A. Creation

In 2001, the Texas Legislature authorized the creation of the District during the 77th Regular Session through House Bill 3243[3]. The voters of Kinney County confirmed the creation of the District on January 12, 2002 with 87 percent of the voters casting favorable ballots. As required by 31 TAC § 356.3, this management plan is being submitted within two years of the confirmation election.

B. Location and Extent

The District is located in Kinney County, Texas. The boundaries of the District are the same boundaries that are used by Kinney County. Kinney County is in southwestern Texas and is bounded on the north by Edwards County, on the east by Uvalde County, on the south by Maverick County, and on the west by Val Verde County and Mexico. Kinney County has an area of 1,391 square miles. Brackettville is the county seat and the largest town in the county.

C. Background

The Board of Directors ("Board") for the District consists of the following members:

1. One at-large director who resides in the District;

2. One at-large director who resides in the city of Brackettville;

3. One at-large director who resides in the Fort Clark Springs Municipal Utility District;

4. One director from each of the four county commissioner precincts who is elected by the voters of the respective precincts and who resides in a rural area of the precinct that they represent.

D. Authority / Regulatory Framework

In its preparation of its management plan, the District has followed all procedures and satisfied all requirements mandated by Chapter 36 of the Texas Water Code and Chapter 356 of the Texas Water Development Board's (TWDB) rules contained in Title 31 of the Texas Administrative Code. The District exercises the powers that it was granted and authorized to use by and through the special and general laws that govern it, including Chapter 1344, Acts of the 77th Texas Legislature, Regular Session, 2001, and Chapter 36 of the Texas Water Code.

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[3] Act of May 25, 2001, 77th Leg., R.S. ch. 1344, 2001 Tex. Gen. Laws 3329.

E. Groundwater Resources of Kinney County

According to the Region J (Plateau Water Planning Region) Regional Water Plan submitted in 2001 to the Texas Water Development Board, the groundwater resources of Kinney County are located within the following hydrogeologic formations:

1. Edwards-Trinity (Plateau) Aquifer

The Edwards-Trinity (Plateau) aquifer consists of saturated sediments of Lower Cretaceous age Trinity Group and overlying limestones and dolomites of the Edwards Group. The Glen Rose Limestone is the primary unit in the Trinity in the southern part of the plateau. Springs issuing from the aquifer form the headwaters for several eastward and southerly flowing rivers. The aquifer generally exists under water-table conditions. However, where the Trinity is fully saturated and a zone of low permeability occurs near the base of the overlying Edwards, artesian conditions may exist in the Trinity. Reported well yields commonly range from less than 50 gallons per minute (gpm) where saturated thickness is thin to more than 1,000gpm where large-capacity wells are completed in jointed and cavernous limestone.

Usable quality water (containing less than 3,000 mg/l dissolved solids) in the Edwards-Trinity (Plateau) aquifer occurs to depths of up to about 3,000 feet. The water is typically hard and may vary widely in concentrations of dissolved solids made up mostly of calcium and bicarbonate. The salinity of the ground water in the Trinity portion of the aquifer tends to increase toward the southwest. There is little pumpage from the aquifer over most of its extent, and water levels have generally fluctuated only with seasonal precipitation. In some instances, water levels have declined as a result of increased pumpage. Water quality from primarily the Edwards portion of the aquifer is acceptable for most municipal and industrial purposes, however, excess concentrations of certain constituents in many places exceed drinking-water standards for municipal supplies. In some instances, excess levels of constituents are naturally occurring.

2. Edwards (BFZ) Aquifer

In the Plateau region, the westernmost end of the Edwards (BFZ) aquifer occurs only in Kinney County. The aquifer, composed predominantly of limestone formed during the early Cretaceous Period, exists under water-table conditions in the outcrop and under artesian conditions where it is confined below the overlying Del Rio Clay. In Kinney County, the Edwards aquifer consists of the Devils River Limestone or the Salmon Peak, McKnight and West Nueces Limestones. Aquifer thickness is as much as 1,000 feet. Recharge to the aquifer occurs primarily by the downward percolation of surface water from streams draining off the Edwards Plateau to the north and west and by direct infiltration of precipitation on the outcrop. Water in the aquifer generally moves from the recharge zone toward natural discharge points such as Los Moras Springs near Brackettville. Water is also discharged artificially from pumping wells. The aquifer is significantly less permeable farther downdip where the concentration of dissolved solids exceeds 1,000 mg/l. Water levels have shown some minor

changes through time but have remained relatively constant. The chemical quality of water in the aquifer is typically fresh, although hard, with dissolved-solids concentrations averaging less than 500 mg/l. The downdip interface between fresh and slightly-saline water represents the extent of water containing less than 1,000 mg/l. Within a short distance of this downgradient "bad water line," the ground water becomes increasingly mineralized.

3. Other Groundwater Resources

The District is aware of the existence of local aquifers and other hydrogeological formations that exist within the boundaries of the District and are capable of producing groundwater such as the Austin Group and the Uvalde Gravel. The District believes additional study is needed to better understand these local aquifers and hydrogeologic formations. The management plan for the District will be amended and updated as additional hydrogeologic information becomes available to the District.

F. Drainage

The Texas Water Commission issued Bulletin 6216 entitled "Geology and Ground-Water Resources of Kinney County, Texas" in 1962 which contained the following information regarding the drainage of Kinney County:

> Kinney County lies in parts of two major drainage basins, those of the Rio Grande and the Nueces River. The major streams in the county that are in the Rio Grande drainage basin are Sycamore, Mud, Pinto, and Las Moras Creeks, and those in the Nueces drainage basin are Elm (east of Brackettville), Liveoak, and Turkey Creeks, and the West Nueces River.
>
> The Rio Grande, which borders the southwestern part of Kinney County, is a perennial stream that rises far to the northwest. Las Moras Creek is fed by artesian springs some distance below its head and is perennial from the spring to its mouth. The regimen of Mud and Pinto Creeks is similar to that of Las Moras Creek, but the springs that feed them cease to flow after extended periods of drought. The West Nueces River, which is fed by gravity springs from the Edwards and associated limestones, is perennial to the point where the water reenters the limestone. In most stretches of the stream below this point the flow is intermittent, but after storms there may be underflow through the thick deposits of gravel underlying the channel. The underflow feeds a few pools in the channel which remain for a considerable period after surface flow ceases. Liveoak Creek has a small perennial spring-fed flow and has cut its valley through the Edwards limestone and into the Glen Rose limestone or Comanche Peak limestone throughout most of its course in Kinney County. The flow of this creek disappears into the Edwards limestone a short distance east of the county line. Sycamore Creek (in western Kinney County) also flows in some reaches. Like the West Nueces River, however it generally consists of a series of disconnected

pools of water that are fed by underflow. All the other streams in the county are intermittent and contain water only after heavy rains.

Kinney County is well drained. The streams on the Edwards Plateau have developed an intricate pattern, and the plateau has been dissected into numerous high hills and narrow, deep valleys. The gradient of these valleys is relatively steep; for example, the West Nueces River has a gradient of almost 12 feet per mile. The streams on the Coastal Plain lie in shallow, broad valleys having moderate to slight gradients.

The limestone units that comprised the aforementioned "Comanche Peak limestone" formation are now included within the stratigraphic unit known as the West Nueces Formation. Some publications, including the work of Lozo and Smith published in 1964, have made this distinction.

IV. Technical District Information Required by Texas Administrative Code

A. Estimate of Total Usable Amount of Groundwater in District – 31 TAC § 356(a)(5)(A)

69,800 Acre Feet

Note: This estimate of the total usable amount of groundwater in the district has been set to equal the recharge figure set forth under Paragraph IV.C., below, as a policy decision by the Board of Directors to define such usable amount of groundwater as the amount of aquifer recharge for purposes of protecting the long term viability of the groundwater resources of Kinney County. The estimate reflects the most recent information available to the District. As additional technical and hydrogeological information is gathered by the District, the District will revise and update its management plan and the information contained therein to include the most up-to-date data available.

B. Amount of Groundwater Being Used within the District on an Annual Basis - 31 TAC §356.5(a)(5)(B)

15,836 Acre Feet

Note: The amount of groundwater being used within the District is based on the revised Region J (Plateau) – Regional Water Planning Group's ("RWPG") regional water plan. The amount reflects the most recent information available to the Region J RWPG and the District. As additional technical and hydrogeological information is gathered by the District, the District will revise and update its management plan and the information contained therein to include the most up-to-date data available. In calculating the amount of groundwater used, Region J-RWPG considered the various uses that currently exist within the District including agricultural irrigation, livestock, and municipal uses.

C. Annual Amount of Recharge to the Groundwater Resources within the District – 31 TAC § 356.5(a)(5)(C)

69,800 Acre Feet

Note: The annual amount of recharge was derived from the work of Dr. Robert Mace and Roberto Anaya. The research of Mace and Anaya was published in August 2003 by the Texas Water Development Board in a report, attached hereto as Appendix __, entitled "Estimate of Recharge to the Edwards (Balcones Fault Zone) and Edwards-Trinity (Plateau) aquifers in Kinney County, Texas" ("the Mace / Anaya report"). As additional technical and hydrogeological information is gathered by the District, the District will revise and update its management plan and the information contained therein to include the most up-to-date data available.

D. Options to Increase Natural or Artificial Recharge of Groundwater within the District - 31 TAC § 356.5(a)(5)(C)

Brush Management: The removal of mesquite, juniper and ceniza from areas of moderate to heavy brush canopy would yield additional groundwater supplies.
Groundwater Recharge Structures: Structures designed to impound surface water in canyons and streambeds cut into fractured rock may increase the volume of water available for recharge by slowing the amount of surface runoff during flood events.
Precipitation Enhancement: The artificial inducement of precipitation by injecting silver iodine crystals into potential rain-producing clouds from flares attached to planes. Increasing evidence suggests that this technology may generate additional rainfall under appropriate climate conditions.

E. Projected Water Supply within the District – 31 TAC § 356.5(a)(5)(D)

69,935 Acre Feet (Surface Water 135 Acre Feet/GW 69,800 Acre Feet)

Note: The projected water supply is based on the revised Region J (Plateau) – Regional Water Planning Group's ("RWPG") regional water plan, as well as on the Mace / Anaya report. The amount reflects the most recent information available to the Region J RWPG and the District. As additional technical and hydrogeological information is gathered by the District, the District will revise and update its management plan and the information contained therein to include the most up-to-date data available.

F. Projected Water Demand within the District – 31 TAC § 356.5(a)(5)(D)

15,228 Acre Feet

Note: The projected water demand is based on the revised Region J (Plateau) – Regional Water Planning Group's ("RWPG") regional water plan. The amount reflects the most

recent information available to the Region J RWPG and the District. As additional technical and hydrogeological information is gathered by the District, the District will revise and update its management plan and the information contained therein to include the most up-to-date data available. In calculating the water demand, Region J-RWPG considered both the current demand of various uses that exist within the District including agricultural irrigation, livestock, and municipal uses and the future demands of those uses.

V. Management of Groundwater Supplies – 31 TAC § 356.5(a)(6)

The District will manage the production of groundwater from the Edwards-Trinity and the Edwards aquifers within the District in a sustainable manner. The Texas Legislature has specifically provided in Section 36.0015 of the Texas Water Code that groundwater conservation districts ("districts"), such as the Kinney County Groundwater Conservation District (the "District"), are the state's preferred method of groundwater management through rules developed and implemented in accordance with Chapter 36 of the Texas Water Code. Chapter 36 gives directives to districts and the statutory authority to carry out such directives, so that districts are provided with the proper tools to protect and conserve the groundwater resources within their boundaries. Among the regulatory tools granted to districts, the Legislature empowered districts to protect existing users of groundwater, which are those individuals or entities currently invested in and using groundwater or the groundwater resources within the district for a beneficial purpose, and historic users, which are those individuals or entities who used groundwater beneficially in the past. Most, but not all, of the existing and historic use of groundwater in Kinney County has been applied to agricultural irrigation and domestic and livestock purposes. The District strives to protect such uses to the extent practicable under the goals and objectives of this Management Plan and without discriminating against any other use of such groundwater for any other lawful and beneficial purpose.

The groundwater resources of the District include a number of springs, which support habitat and provide flows to surface water bodies within and outside of the District. In order to manage the groundwater resources of the District in a manner that will not deplete such resources for future generations, the District through its rules and this Management Plan will attempt to manage total groundwater withdrawals in the District at a level that will not cause depletion of the aquifer in the future. In order to balance the need to allow as much groundwater to be produced from the district as possible for beneficial use with the need to prevent the overproduction and mining of the groundwater resources of Kinney County in an effort to protect the springs and long-term productivity of those groundwater resources, the District shall continue to collect data and information on the total amount of groundwater that can be produced in the District from its various geological formations while achieving those objectives. Necessarily, only a finite amount of groundwater can be produced from these finite resources each year if these objectives are to be realized.

In response to these management objectives and these regulatory provisions enacted by the Legislature, the District has created a tiered process that categorizes groundwater use and allocates such use through the rules of the District. The tiered process prioritizes

groundwater use for protection of existing users, protection of historic users who are not existing users, and other users who may be allocated remaining groundwater available after the needs of existing users and historic users have been addressed. As part of the District's prioritization of uses through its permitting process, the District has established, through its rules, time periods to define "existing users" and "historic users" for purposes of its regulatory program and management objectives.

Pursuant to legislative authority, such as Section 36.113(e) of the Texas Water Code, the District will protect existing use by imposing more restrictive permit conditions on new permit applications and increased use by historic users. In protecting existing users, the District will establish limitations that apply to all subsequent new permit applications and increased use by historic users, regardless of type or location of use, which bear a reasonable relationship to this Management Plan; and are reasonably necessary to protect existing use. In accordance with Section 36.116(b), Water Code, the District will also preserve historic use when developing and implementing rules limiting groundwater production to the maximum extent practicable consistent with this Management Plan.

The District shall attempt to develop information regarding the conditions in or use of aquifers within its boundaries which can be utilized as the District further implements its permitting process through its rules. Once the District has gathered better information on the location and conditions of the aquifers within its boundaries, the District intends to develop and implement groundwater spacing and production regulations that are specific to the geographic area, aquifer, subdivision of an aquifer, or geologic strata from which groundwater is to be produced from a given well, while still attempting to meet its goals of protection of existing users, historic users, springs, and long-term viability of the aquifers. These concepts are set forth in the District's rules as the "proportionate reduction" and "management zone" processes. The District shall select a method of regulation that is appropriate based on the hydrogeological conditions of the aquifer or aquifers in the District when regulating the production of groundwater pursuant to Section 36.116(a)(2), Water Code, and may limit the amount of water produced based on contiguous surface acreage.

VI. Methodology to Track District Progress in Achieving Management Goals – 31 TAC § 356.5(a)(6)

The general manager of the District will prepare and submit an annual report ("Annual Report") to the Board of the District. The Annual Report will include an update on the District's performance in regards to achieving management goals and objectives. The general manager of the District will present the Annual Report within ninety (90) days following the completion of the District's fiscal year, beginning with the fiscal year that starts October 1, 2003. The Board will maintain a copy of the Annual Report on file, for public inspection at the District's offices upon adoption.

VII. Actions, Procedures, Performance, and Avoidance for District Implementation of Management Plan – 31 TAC § 356.5 (a)(4)

The District will implement the goals and provisions of this management plan and will utilize the objectives of this management plan as a guideline in its decision-making. The

District will ensure that its planning efforts, operations, and activities will be consistent with the provisions of this plan.

The District will adopt rules in accordance with Chapter 36 of the Texas Water Code, and all rules will be followed and enforced. The District may amend the District rules as necessary to comply with changes to Chapter 36 of the Texas Water Code and to insure the best management of the groundwater within the District. The development and enforcement of the rules of the District will be based on the best scientific and technical evidence available to the District.

The District will encourage cooperation and coordination in the implementation of this plan. All operations and activities of the District will be performed in a manner that best encourages cooperation with the appropriate state, regional or local water entity. Pursuant to District Rule 2.04, the Board meetings of the District will be noticed and conducted in accordance with the Texas Open Meetings Law. The District has also established in District Rule 4.06 that all official documents, reports, records and minutes of the District will be available for public inspection and copying in accordance with the Texas Public Information Act.

VIII. Management Goals

A. Providing the Most Efficient Use of Groundwater – 31 TAC § 356.5(a)(1)(A)

A. 1. **Objective** – Each year, the District will require all new exempt or permitted wells that will be operated within the boundaries of the District to be registered or permitted in accordance with the District Rules.

A. 1. **Performance Standard** – The number of exempt and permitted wells registered and permitted by the District during each year will be incorporated into the Annual Report submitted to the Board of the District.

A. 2. **Objective** – Each year, the District will regulate the production of groundwater by maintaining a system of permitting of the use and production of groundwater within the boundaries of the District in accordance with the District Rules.

A. 2. **Performance Standard** – The District will accept and process applications each year for the permitted use of groundwater in the District in accordance with the permitting process established by District Rules. The number and type of applications made for the permitted use of groundwater in the District and the number and type of permits issued by the District, will be included in the Annual Report given to the Board of Directors of the District.

B. Controlling and Preventing Waste of Groundwater – 31 TAC § 356.5(a)(1)(B)

B. 1. **Objective** – Each year, the District will make an evaluation of the District Rules to determine whether any amendments are recommended to decrease the amount of waste of groundwater within the District.

B. 1. **Performance Standard** – The District will include a discussion of the annual evaluation of the District Rules and the determination of whether any amendments to the rules are recommended to prevent the waste of groundwater in the Annual Report of the District provided to the Board of Directors of the District.

B. 2. **Objective** – The District will annually apply a water use fee structure to the permitted use of groundwater in the District to encourage the elimination and reduction of waste of groundwater.

B. 2. **Performance Standard** – Each year, with the exception of wells exempt from permitting, the District will apply a water use fee to permitted use of groundwater in the District pursuant to District Rules. The amount of fees generated by the water use fee structure and the amount of water used for each type of permitted use of groundwater will be included in a section of the Annual Report given to the Board of Directors of the District.

C. Conjunctive Surface Water Management Issues – 31 TAC § 356.5(a)(1)(D)

C. 1. **Objective** – Each year, the District will participate in the regional planning process by attending at least 25 percent of the Region J (Plateau Region) – Regional Water Planning Group meetings to encourage the development of surface water supplies to meet the needs of water user groups in the District.

C. 1. **Performance Standard** – The attendance of representatives of District at each Region J (Plateau Region) – Regional Water Planning Group meeting will be noted in the Annual Report presented to the Board of Directors of the District.

D. Drought Conditions

D. 1. **Objective** – Quarterly, the District will download the updated Palmer Drought Severity Index (PDSI) map and identify for periodic updates to the Drought Preparedness Council Situation Report (Situation Report) posted on the Texas Water Information Network website www.txwin.net.

D. 1. **Performance Standard** – Biannually, the District will make an assessment of the status of drought in the District and prepare a biannual report to the Board of Directors. The downloaded PDSI maps and Situation Reports will be included with copies of the biannual reports in the Annual Report to the Board of the District.

E. Conservation

E. 1. **Objective** – The District will annually submit an article regarding water conservation for publication to at least one newspaper of general circulation in Kinney County.

E. 1. **Performance Standard** – A copy of the article submitted by the District for publication to a newspaper of general circulation in Kinney County regarding water conservation will be included in the Annual Report to the Board of Directors.

E. 2. **Objective** - The District will develop or implement a pre-existing educational program for use in the schools located in Kinney County to educate students on the importance of water conservation by January 1, 2005.

E. 2. **Performance Standard** – An explanation of the educational program developed or implemented by the District for use in Kinney County schools will be included in the Annual Report to the Board of Directors for the year 2005.

E. 3. **Objective** – Each year, the District will include an informational flier on water conservation within at least one mail out to groundwater use permit holders distributed in the normal course of business of the District, or otherwise make such an informational flier on water conservation available for distribution to permit holders at the District office.

E. 3. **Performance Standard** – The District's Annual Report will include a copy of the informational flier, if any, distributed to groundwater use permit holders regarding water conservation and the number of fliers distributed.

IX. Management Goals Non-Applicable to District

A. **Controlling and Preventing Subsidence – 31 TAC § 356.5(a)(1)(C)** – The District is not advised at this time of any issues with subsidence that exist within the boundaries of the District.

B. Natural Resource Issues – 31 TAC § 356.5(a)(1)(E) - The District is not advised at this time of any natural resource issues that exist within the boundaries of the District.

X. Action Required for Plan Certification – 31 TAC § 356.6

A. Planning Period – 31 TAC § 356.5(a)

The Board of Directors of the District adopted by resolution on December 4, 2003, the management plan for the District. The management plan will remain effective until December 4, 2013, unless the District adopts a revised management plan that is certified by the Texas Water Development Board or another appropriate entity. The revised management plan will take effect as of the date of certification. In accordance with the provisions of Chapter 36 of the Texas Water Code, the District's management plan shall be reviewed annually and readopted with or without revisions at least every five years.

B. Certified Copy of District's Resolution Adopting Management Plan – 31 TAC § 356.6(a)(2)

A certified copy of the District's resolution adopting the plan is located in Appendix A – District Resolution.

C. Evidence of Management Plan Adoption After Notice and Hearing – 31 TAC § 356.6(a)(3)

Evidence, such as public notices, that the management plan was adopted following applicable public meetings and hearings is located in Appendix B - Notice of Meetings.

D. Coordination with Surface Water Management Entities – 31 TAC § 356.6(a)(4)

Evidence that District coordinated with surface water management entities in regards to the District's management plan in Appendix C.

References

1. Bennett, R. R. and Sayre, A. N., December 1962. Texas Water Commission Bulletin 6216, "Geology and Ground-Water Resources of Kinney County, Texas," published by Texas Water Commission in December 1962 in cooperation with United States Geological Survey.

2. Lozo, F.E., Jr; Smith, C.I. 1964. Revision of Comanche Cretaceous Stratigraphic Nomenclature, South Edwards Plateau, Southwest Texas. Transactions of the Gulf Coast Association of Geological Societies 14, 285-307.

3. Mace, Robert E., Ph.D. and Anaya, Roberto, P.G. Estimate of recharge to the Edwards (Balcones Fault Zone) and Edwards-Trinity (Plateau) aquifers in Kinney County, Texas, Texas Water Development Board August 2003.

4. Regional Water Management Plan of Region J (Plateau Region) – Regional Water Planning Group.

5. Rules of the Kinney County Groundwater Conservation District, as amended.

6. Water for Texas-2002 – Texas Water Development Board (January 2002).

APPENDIX A

RESOLUTION
OF THE BOARD OF DIRECTORS OF THE KINNEY COUNTY GROUNDWATER CONSERVATION DISTRICT
DECEMBER 4, 2003

A RESOLUTION ADOPTING MANAGEMENT PLAN

WHEREAS, the Kinney County Groundwater Conservation District (the "District") is a political subdivision of the State of Texas organized and existing under and by virtue of Article XVI, Chapter 59, of the Texas Constitution;

WHEREAS, under the direction of the Board of Directors, and in accordance with Section 36.1071, Texas Water Code, and Chapter 356, Title 31, Texas Administrative Code, the District developed a Management Plan;

WHEREAS, the District requested the technical assistance of the Texas Water Development Board and worked with TWDB's staff throughout 2003 on ascertaining the technical information and estimates that are required by the TWDB, the Texas Administrative Code, and Chapter 36, Texas Water Code, to be included in the Management Plan;

WHEREAS, the District held public hearings to receive public and written comments on the Management Plan for the District on November 6, 2003, November 20, 2003, and December 4, 2003, at the District Courtroom, Kinney County Courthouse, located in Brackettville, Texas; and

WHEREAS, the Board of Directors finds that the Management Plan meets all of the requirements of Chapter 36, Texas Water Code, and Chapter 356, Title 31, Texas Administrative Code.

NOW THEREFORE BE IT RESOLVED THAT:

The Management Plan is hereby adopted as the management plan for the District; and

The Board and General Manager are further authorized to take any and all action necessary to file the adopted Management Plan with the Texas Water Development Board, and to coordinate with the Texas Water Development Board as may be required in furtherance of certification pursuant to the provisions of Section 36.1072 of the Texas Water Code.

AND IT IS SO ORDERED.

Upon motion duly made by Director Don Hood, and seconded by Director Christopher Ring, and upon discussion, the Board voted 6 in favor and 0 opposed, 0 abstained, and 1 absent, and the motion thereby PASSED on this 4th day of December, 2003.

KINNEY COUNTY GROUNDWATER CONSERVATION DISTRICT

By: Cecil Smith
Cecil Smith, President

ATTEST:

Darlene Shahan, Secretary/Treasurer

APPENDIX B

NOTICE OF HEARING AND MEETING OF THE GOVERNING BOARD OF THE KINNEY COUNTY GROUNDWATER CONSERVATION DISTRICT

Notice is hereby given that the Board of Directors for the Kinney County Groundwater Conservation District will hold a Hearing and a Regular Meeting on Thursday, December 4, 2003, commencing at 4:00 p.m., Thursday, December 4, 2003, in the District Courtroom of the Kinney County Courthouse located in Brackettville, Texas. At any time during the hearing or meeting and in compliance with the Texas Open Meetings Act, Chapter 551, Government Code, Vernon's Texas Codes, Annotated, the Board of Directors may meet in executive session on any of the agenda items below for consultation concerning attorney-client matters (§551.071); deliberation regarding real property (551.072); deliberation regarding prospective gift (§551.073); personnel matters (§551.074); investments (§551.075); and deliberation regarding security devices (§551.076). Any subject discussed in executive session may be subject to action during an open meeting.

HEARING ON MANAGEMENT PLAN

1. Call to Order to reconvene continued hearing on District's proposed management plan.
2. Public hearing and possible action to adopt and authorize for filing District's proposed management plan.
3. Adjourn.

MEETING AGENDA

Meeting to commence immediately following adjournment of the reconvened Public Hearing on the District's proposed Management Plan.

Review, consider/discuss, approve/disapprove, and/or adopt:

1. Call to Order.
2. Public Comment.
3. Approve Minutes.
4. Review and possible action regarding procedures for the processing and determination of Historic Use and Existing Use Claims.
5. Review and possible action to approve the sale of Trust Property 15463, Lot 74, Unit 15, F.C.S. by the Kinney County Appraisal District.
6. Review Open Records Request from Jackson, Sjoberg, McCarthy & Wilson, L.L.P. concerning any communications with RGEC.
7. Executive Session for consultation with District's attorney on a matter in which the duty of the attorney to the governmental body under the Texas Disciplinary Rules of Professional Conduct of the State Bar of Texas clearly conflicts with this chapter.
8. Discussion and possible action concerning matters reviewed during Executive Session.
9. Review and approval of financial report.
10. General Manager report.
11. New business items for future consideration.
12. Public Comment.
13. Adjourn.

I, the undersigned authority, do hereby certify that the above NOTICE OF HEARING AND MEETING of the Board of Directors of the Kinney County Groundwater Conservation District is a true and correct copy of said Notice. I have posted a true and correct copy of said Notice on the bulletin board in the Kinney County Courthouse, located in Brackettville, Texas, and said Notice was posted on December 1, 2003, and remained posted continuously for at least 72 hours immediately preceding the day of said meeting; a true and correct copy of said Notice was furnished to the Kinney County Clerk, in which the above named political subdivision is located.

Dated December 1, 2003.

Kinney County Groundwater Conservation District

By: _____
Donald D. Ralston, General Manager

I, the undersigned authority, do hereby certify that the above NOTICE OF HEARING AND MEETING of the Board of Directors of the Kinney County Groundwater Conservation District is a true and correct copy of said Notice received by me on December 1, 2003, and that I posted the true and correct copy of said Notice on the bulletin board in the Kinney County Courthouse on December 1, 2003, and said Notice remained so posted continuously for at least 72 hours immediately preceding the day of said Meeting.

Dated December 1, 2003

Dora Alicia Sandoval
County Clerk, Kinney County, Texas

By: _____

NOTICE OF HEARINGS OF THE KINNEY COUNTY GROUNDWATER CONSERVATION DISTRICT

Notice is hereby given that the Board of Directors for the Kinney County Groundwater Conservation District will hold a Hearing on the Management Plan, on Thursday, November 6, 2003, at 4:00 p.m., in the District Courtroom of the Kinney County Courthouse located in Brackettville, Texas.

At any time during the meeting and in compliance with the Texas Open Meetings Act, Chapter 551, Government Code, Vernon's Texas Codes, Annotated, the Kinney County Groundwater Conservation District Board may meet in executive session on any of the above agenda items for consultation concerning attorney-client matters (Sec. 551.071); deliberation regarding real property (Sec. 551.072); deliberation regarding prospective gift (Sec. 551.073); personnel matters (Sec. 551.074); investments (Sec. 551.075): and deliberation regarding security devices (Sec. 551.076). Any subject discussed in executive session may be subject to action during an open meeting.

HEARING ON MANAGEMENT PLAN

1. Call to Order.
2. Public Forum
3. Public Hearing and possible action on adoption of proposed Kinney County Groundwater Conservation District Management Plan.
4. Public Forum
5. Adjourn.

I, the undersigned authority, do hereby certify that the above NOTICE OF HEARINGS of the Board of Directors of the Kinney County Groundwater Conservation District, is a true and correct copy of said Notice. I have posted a true and correct copy of said Notice on the bulletin board in the Kinney County Courthouse, located in Brackettville, Texas, and said Notice was posted on October 17, 2003, and remained posted continuously for at least Seventy Two (72) hours immediately preceding the day of said meeting; a true and correct copy of said Notice was furnished to the Kinney County Clerk, in which the above named political subdivision is located.

Dated: October 17, 2003.

Kinney County Groundwater Conservation District

By: _____

Donald D. Ralston, General Manager

I, the undersigned County Clerk, do hereby certify that the Notice of Hearing of the Kinney County Groundwater Conservation District is a true and correct copy of said Notice received by me on October 17, 2003, and that I posted the true and correct copy of said Notice on the bulletin board in the Kinney County Courthouse, on October 17, 2003, and said Notice remained so posted continuously for at least Seventy Two (72) hours immediately preceding the day of said Meeting.

Dated October 17, 2003.

County Clerk, Kinney County, Texas

Dina Elia Lindsell

Jessica M. Pina, Deputy

#ALBA1081245251657A/B, situated in Kinney County, Texas, as shown by a deed of record in volume A-121, page 642 of the deed records of Kinney County, Texas; No. 3285, Kinney County Appraisal District vs. Gilbert G. Meyer, Jr. and Ruby Meyer, Lots 14 and 15, block 53 of the Brackett addition to the City of Brackettville, situated in Kinney County, Texas, as shown by a deed of record in Volume 115, page 384 of the deed records of Kinney County, Texas; No. 3286, Kinney County Appraisal District vs Roger Perez, III. Tract 1: part of lot 4 and all of lot 5, block 40 to the Town of Brackettville and a 14 foot by 70 foot Country Squire mobile home label #TX20535558, serial #11724701106, situated in Kinney County, Texas, as shown by a deed of record in volume A-125, page 192 of the deed records of Kinney County, Texas; or upon the written request of said defendants or their attorney, a sufficient portion thereof to satisfy said judgment, interest, penalties and costs; subject, however, to the right of redemption, the defendants or any person having an interest therein, to redeem the said property, or their interest therein, within the time proscribed, from the recordation of the deed, in the manner provided by law, and subject to any other and further rights to which the defendants or anyone interested therein may be entitled, under the provisions of law. Said sale to be made by me to satisfy the judgment rendered in the above styled and numbered cause, together with interest, penalties, and costs of suit, and the proceeds of said sale to be applied to the satisfaction thereof, and the remainder, if any, to be applied as the law directs. Dated this the 3rd day of October, 2003, at Brackettville, Texas. Leland K. Burgess, Sheriff, Kinney County, Texas.

at 5:45 p.m., November 10, 2003
Location: Hunt Library

The purpose of this meeting is to discuss Brackett ISD's rating on the state's financial accountability system.

NOTICE OF HEARING OF THE KINNEY COUNTY GROUNDWATER CONSERVATION DISTRICT

Notice is hereby given that the Board of Directors for the Kinney County Groundwater Conservation District will hold Hearings on the Management Plan on Thursday, November 6, 2003, at 4:00 p.m., in the District Courtroom of the Kinney County Courthouse located in Brackettville, Texas.

HEARING ON MANAGEMENT PLAN

1. Call to Order
2. Public Forum
3. Public Hearing and possible action on adoption of proposed Kinney County Groundwater Conservation District Management Plan.
4. Public Forum.
5. Adjourn

I, the undersigned authority, do hereby certify that the above NOTICE OF HEARING of the Board of Directors of the Kinney County Groundwater Conservation District, is a true and correct copy of said Notice. I have published a true and correct copy of said Notice at least 5 days immediately preceding the day of said hearings and will post said Notice on the bulletin board in the Kinney County courthouse, located in Brackettville, Texas, continuously for at least Seventy Two (72) hours immediately preceding the day of said hearings; a true and correct copy of said Notice was furnished to the Kinney County Clerk, in which the above named political subdivision is located.

Dated October 17, 2003

Kinney County Groundwater Conservation District By: Donald D. Ralston, General Manager

APPENDIX C

KINNEY COUNTY GROUNDWATER CONSERVATION DISTRICT

Post Office Box 369
Brackettville, Texas

Phone: 830/563-9699
Facsimile: 830/563-9606
Email: kcgcd@rionet.org

December 16, 2003

Region J Water Planning Group
Attn: Jonathan Letz
700 Main Street
Kerrville, TX 78028

Dear Mr. Letz,

On December 9, 2003, I forwarded you by certified mail a copy of the recently adopted Management Plan of the Kinney County Groundwater Conservation District (District) along with correspondence asking you to review the plan and to provide any comments you may have on it to the District. However, the correspondence did not specifically request that the Region J Regional Water Planning Group review the District's Management Plan and specify any areas of conflict you may identify between it and Region J's approved regional water plan. While the District reviewed the Region J regional water plan in developing its own Management Plan and certainly does not believe that any conflicts exist between the two, I hereby request that the Region J Regional Water Planning Group review the District's Management Plan and specify any areas of conflict, if any, between it and Region J's approved regional water plan, as required by Section 356.6, Title 31, Texas Administrative Code, in addition to any other comments the group may have. Please do not hesitate to contact me if you have any questions on this matter or related issues.

Sincerely,

Donald D. Ralston
General Manager

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Sent To: Region J Water Planning Group
Street, Apt. No.; or PO Box No.: 700 Main Street
City, State, ZIP+4: Kerrville TX 78028

PS Form 3800, June 2002 — See Reverse for Instructions

SENDER: *COMPLETE THIS SECTION*

- Complete items 1, 2, and 3. Also complete item 4 if Restricted Delivery is desired.
- Print your name and address on the reverse so that we can return the card to you.
- Attach this card to the back of the mailpiece, or on the front if space permits.

1. Article Addressed to:

Region J Water Planning Group
Attn: Jonathan Letz
700 Main Street
Kerrville TX 78028

COMPLETE THIS SECTION ON DELIVERY

A. Signature
X [signature] ☐ Agent ☐ Addressee

B. Received by (Printed Name): THEA SOVIK
C. Date of Delivery: 12-22-03

D. Is delivery address different from item 1? ☐ Yes
If YES, enter delivery address below: ☐ No

3. Service Type
☒ Certified Mail ☐ Express Mail
☐ Registered ☐ Return Receipt for Merchandise
☐ Insured Mail ☐ C.O.D.

4. Restricted Delivery? *(Extra Fee)* ☐ Yes

2. Article Number
(Transfer from service label) 7002 2030 0005 9054 6973

PS Form 3811, August 2001 — Domestic Return Receipt — 102595-02-M-1540

KINNEY COUNTY GROUNDWATER CONSERVATION DISTRICT

Post Office Box 369
Brackettville, Texas 78832
Phone: 830/563-9699
Facsimile: 830/563-9606
Email: kcgcd@rionet.org

December 9, 2003

Region J Water Planning Group
Attn: Jonathan Letz
700 Main Street
Kerrville, TX 78028

Dear Mr. Letz,

On November 25, 2003 we sent you a copy of the Kinney County Groundwater Conservation Districts' draft Management Plan. The District adopted the management plan with some revisions on December 4, 2003 and I am forwarding a copy for your consideration. Please review the plan and let us know if you have any comments.

Sincerely,

Donald D. Ralston
General Manager

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Total Postage & Fees	$ 5.11

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Sent To: Region J Water Planning Group

Street, Apt. No.; or PO Box No.: 700 Main St.

City, State, ZIP+4: Kerrville TX 78028

PS Form 3800, June 2002 — See Reverse for Instructions

7003 3110 0002 6133 2745

SENDER: COMPLETE THIS SECTION

- Complete items 1, 2, and 3. Also complete item 4 if Restricted Delivery is desired.
- Print your name and address on the reverse so that we can return the card to you.
- Attach this card to the back of the mailpiece, or on the front if space permits.

1. Article Addressed to:

Region J Water Planning Group
Attn: Jonathan Letz
700 Main Street
Kerrville, TX 78028

COMPLETE THIS SECTION ON DELIVERY

A. Signature: X Thea Soul ☐ Agent ☐ Addressee

B. Received by (Printed Name): Thea Soul

C. Date of Delivery: 12/10/03

D. Is delivery address different from item 1? ☐ Yes
If YES, enter delivery address below: ☐ No

3. Service Type
☒ Certified Mail ☐ Express Mail
☐ Registered ☐ Return Receipt for Merchandise
☐ Insured Mail ☐ C.O.D.

4. Restricted Delivery? *(Extra Fee)* ☐ Yes

2. Article Number *(Transfer from service label)* 7003 3110 0002 6133 2745

PS Form 3811, August 2001 — Domestic Return Receipt — 102595-02-M-1540

KINNEY COUNTY GROUNDWATER CONSERVATION DISTRICT

Post Office Box 369
Brackettville, Texas 78832
Phone: 830/563-9699
Facsimile: 830/563-9606
Email: kcgcd@rionet.org

December 9, 2003

Nueces River Authority
Attn: Con Mims III
Executive Director
P.O. Box 349
Uvalde, TX 78802-0349

Dear Mr. Mims,

On November 25, 2003 we sent you a copy of the Kinney County Groundwater Conservation Districts' draft Management Plan. We want to thank you for your comments on the plan. We were able to institute most of your suggested changes. The District adopted the management plan on December 4, 2003 and I am forwarding a copy for your consideration. Please review the plan and let us know if you have any additional comments.

Sincerely,

Donald D. Ralston
General Manager

KINNEY COUNTY GROUNDWATER CONSERVATION DISTRICT

Post Office Box 369
Brackettville, Texas 78832
Phone: 830/563-9699
Facsimile: 830/563-9606
Email: kcgcd@rionet.org

December 9, 2003

International Boundary & Water Commission
HCR #3, Box 37
Del Rio, TX 78840

Dear Sirs,

The Kinney County Groundwater Conservation District adopted its management plan on December 4, 2003. I am forwarding a copy of the plan to you for your consideration. Please review the plan and let us know if you have any comments.

Sincerely,

Donald D. Ralston
General Manager

Estimate of recharge to the Edwards (Balcones Fault Zone) and Edwards-Trinity (Plateau) aquifers in Kinney County, Texas

Robert E. Mace, Ph.D., and Roberto Anaya, P.G.
Texas Water Development Board
P.O. Box 13231
Austin, TX 78711-3231
(512) 463-7847

August 2003

Executive summary

Special Counsel to the Kinney County Groundwater Conservation District requested that the Texas Water Development Board estimate the amount of recharge to the Edwards (Balcones Fault Zone) and Edwards-Trinity (Plateau) aquifers in Kinney County. To do this, we reviewed and evaluated existing estimates of recharge and estimated recharge based on a method developed by Bennett and Sayre (1962). Bennett and Sayre (1962) estimated the amount of recharge in Kinney County using streamflow-gage information from the West Nueces and Nueces Rivers from 1939 to 1950. Using a modified Bennett and Sayre (1962) approach, a longer period of record (1939 to 1950 and 1956 to 2001), and more accurate estimates of recharge areas, we estimate that the mean annual recharge to the Edwards (Balcones Fault Zone) and Edwards-Trinity (Plateau) aquifers in Kinney County is about 69,800 acre-ft per year.

Introduction

On February 13, 2003, the Texas Water Development Board (TWDB) received a written request from Brian Sledge, Special Counsel to the Kinney County Groundwater Conservation District, to compile technical information and estimates for the preparation of its management plan. This included a request to assess the annual amount of recharge to the groundwater resources within the district. The district is assessing the amount of water that can be produced and permitted while protecting springflows. An accurate estimate of recharge is important to this assessment.

The Texas Water Commission published a report in 1962 conducted by the U.S. Geological Survey on the hydrogeology of Kinney County (Bennett and Sayre, 1962). This report includes an estimate of recharge. However, the validity of the recharge estimate in this report has been called into question because of the limited amount of data used to make the estimate. The purpose of this document is to present the methodology and results of our assessment of mean annual recharge to the aquifers in Kinney County. We did this by (1) reviewing previous estimates of recharge and (2) estimating recharge in the county using available data. We also provide recommendations for possible future studies.

Study Area

The study area is located in Kinney County, Texas. Kinney County is located in southwestern Texas about 130 miles west of San Antonio and adjacent to the Mexican border (Figure 1). The county is one of the most sparsely populated in the state with a current population of about 3,400 of which approximately two-thirds is concentrated in the county seat of Brackettville (US Census Bureau, 2000). The region is subtropical steppe transitional with the Chihuahua Desert (Long, 2002) and has a hot semiarid climate where the mean annual pan evaporation of about 68 inches exceeds the mean annual precipitation of about 24 inches. Overgrazing during the past 100 years has deteriorated previous grassland savanna and soil covers into the present rock, shrub, cactus, and oak-mesquite-juniper brushland dominated landscape (Mecke, 1996). This alteration of the landscape has changed many perennial springs and creeks into ephemeral or intermittent ones. Agricultural landuse is still dominated by rangeland primarily for sheep, goat, and, to a much lesser extent, cattle livestock (Kinney County Extension Office, 2001). Irrigated and non-irrigated farmland for hay, grain sorghum, cotton, oats, and wheat is minimal (Kinney County Extension Office, 2001; Long, 2002). The boundaries of the Kinney County Groundwater Conservation District coincide with the boundaries of the county.

The study area includes rock outcrops of the Edwards (Balcones Fault Zone [BFZ]) and Edwards-Trinity (Plateau) aquifers located within the Nueces and West Nueces River basins as well as within Kinney County (Figure 2). Both aquifers collectively occupy the northern half of Kinney County where the western Balcones Fault Zone escarpment terminates the southern margin of the Edwards Plateau. In the Nueces and West Nueces River basins as well as within Kinney County, the Edwards (BFZ) aquifer consists of rocks of the Edwards Group that include the West Nueces, McKnight, and Salmon Peak formations (Figure 3). In Kinney County, the Edwards-Trinity (Plateau) aquifer consists of rocks of the Edwards Group that include the West Nueces, McKnight, Salmon Peak, and the Devils River formations (Figure 3). In the Nueces and West Nueces River basins, the Edwards-Trinity (Plateau) aquifer consists of rocks of the Edwards Group that include the West Nueces, McKnight, Salmon Peak, Devils River, Fort Terrett, and Segovia formations (Figure 3). In addition to Edwards Group rocks, the Edwards-Trinity (Plateau) aquifer also consists of rocks of the underlying Trinity Group occurring mostly in the subsurface except where exposed by erosion in the lower valleys and canyons of the Nueces River basin (Figure 3). Edwards Group rocks outcrop at elevations ranging from about 1,100 feet to about 2,000 feet above mean sea level within Kinney County and from about 950 feet to about 2,400 feet above mean sea level within the Nueces and West Nueces River basins.

Terminology

'Recharge' is generally defined as the amount of water that reaches the water table from the unsaturated zone above (for example, see Freeze and Cherry, 1979; Domenico and Schwartz, 1990; Jackson, 1997; Wilson and Moore,1998; Fitts, 2002). TWDB rules concerning groundwater management plan certification define recharge as "The addition

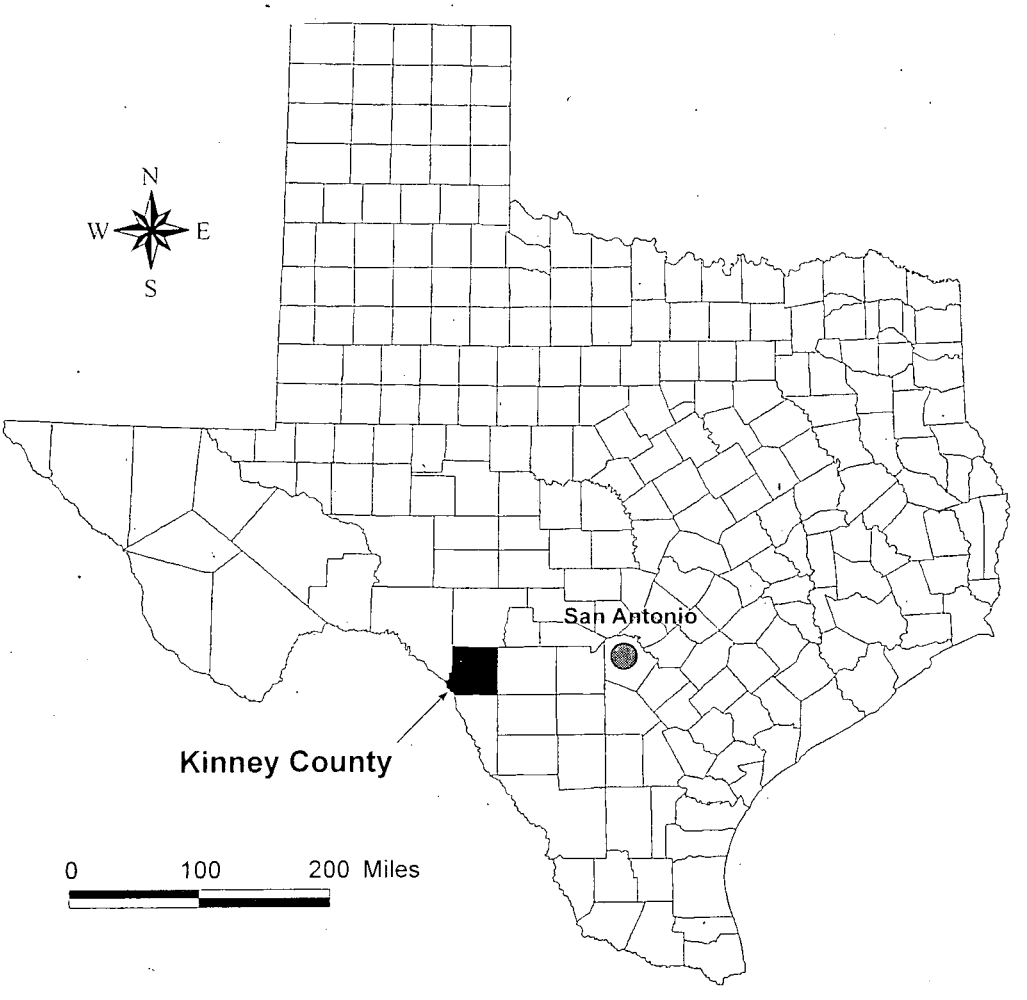

Figure 1. Location of Kinney County in Texas

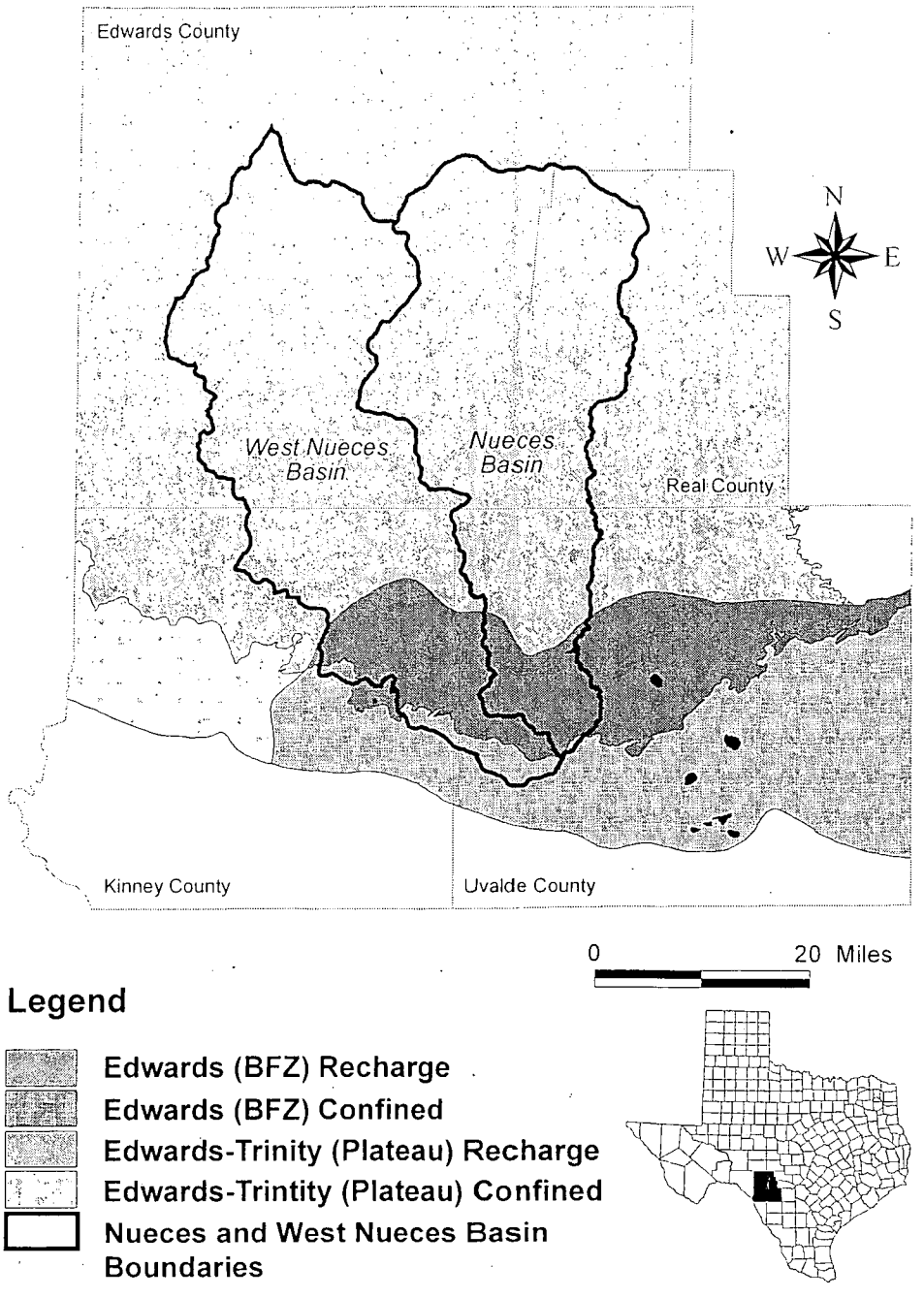

Figure 2. Edwards (BFZ) and Edwards-Trinity (Plateau) aquifers in study area.

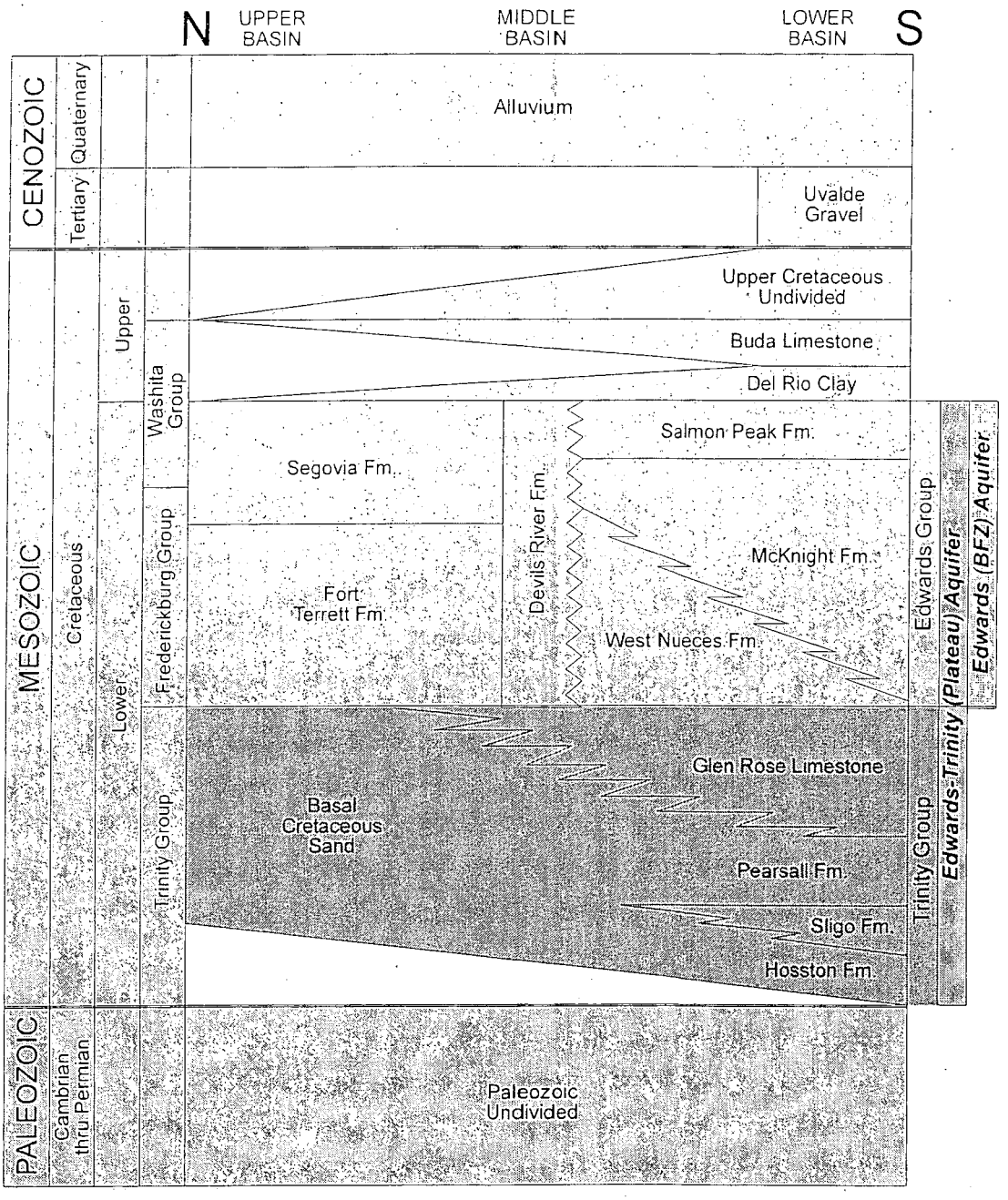

Figure 3. Correlation chart showing chronostratigraphic, lithostratigraphic, and hydrologic units of the Edwards-Trinity and Edwards Aquifer systems within the Nueces and West Nueces River basins (After Barker and Ardis, 1996). The Edwards (BFZ) consists only of the West Nueces, McKnight, and Salmon Peak formations within the study area.

of water from precipitation or runoff by seepage or infiltration to an aquifer from the land surface, streams, or lakes directly into a formation or indirectly by way of leakage from another formation." Recharge generally does not consider underflow (flow into the county from outside of the county within the same formation). Furthermore, 'direct recharge' is defined as seepage or infiltration along specific discrete features such as streams while 'diffuse recharge' is defined as relatively slow and uniform infiltration over large areas.

We interpreted 'groundwater resources,' the term used in the letter from Mr. Sledge, to include the aquifers recognized by TWDB in Kinney County. These aquifers are the Edwards (BFZ) aquifer and the Edwards-Trinity (Plateau) aquifer (Figure 4). The Edwards-Trinity (Plateau) aquifer in Kinney County primarily expresses itself at land surface with rocks of the Edwards Group. It is these rocks of the Edwards Group that accept recharge in Kinney County. Therefore, we refer to recharge to the Edwards (BFZ) and Edwards-Trinity (Plateau) aquifers as recharge to the Edwards aquifers in this document when referred to collectively.

We report recharge in two ways in this report: as a total volume per year (that is, acre-feet per year) and as a rate (that is, inches per year). If the area of the recharge zone is known, it is possible to convert between these two conventions.

Previous estimates of recharge

Previous estimates of recharge to the Edwards aquifers in Kinney County fall into three categories: (1) published estimates of recharge specifically for Kinney County, (2) published estimates of recharge for a greater area that includes Kinney County, and (3) unpublished estimates, generally consultant reports, of recharge for Kinney County.

Published estimates of recharge for Kinney County

Bennett and Sayre (1962) used streamflow information (as measured between September 28, 1939 and September 30, 1950) for the Nueces and West Nueces Rivers to estimate the amount of recharge to the Edwards aquifers in Kinney County (an explanation of their approach is described later). This resulted in an estimate of recharge of "...roughly..." 70,000 acre-feet/year to the Edwards aquifers in Kinney County, or an equivalent of 1.4 inches per year.

Published estimates of recharge for an area that includes Kinney County

Muller and Price (1979) estimated recharge to the Edwards-Trinity (Plateau) aquifer in the Nueces and West Nueces River basins at 107,500 acre-ft per year. The Nueces and West Nueces River basins include parts of Edwards, Kinney, Real, and Uvalde counties (Figure 5). We calculated this to be a recharge rate of about 1.4 inches per year (using the area of 1,464 square miles estimated by Bennett and Sayre (1962) for Nueces and West Nueces River basins above their upstream gages). Muller and Price (1979) do not explain how they calculated their recharge number, but it is likely that they used Bennett and Sayre's (1962) estimate.

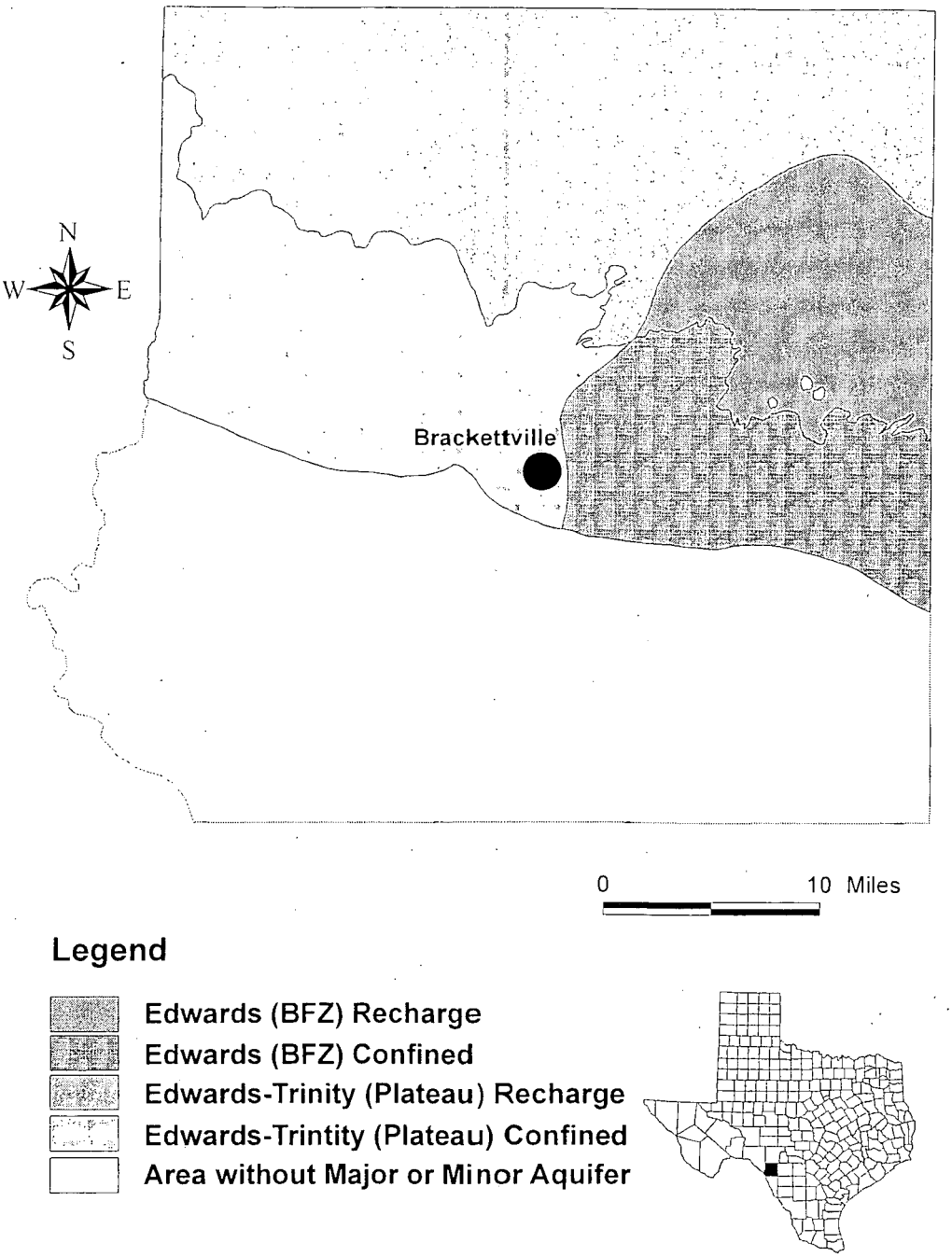

Figure 4. Aquifers in Kinney County recognized by TWDB.

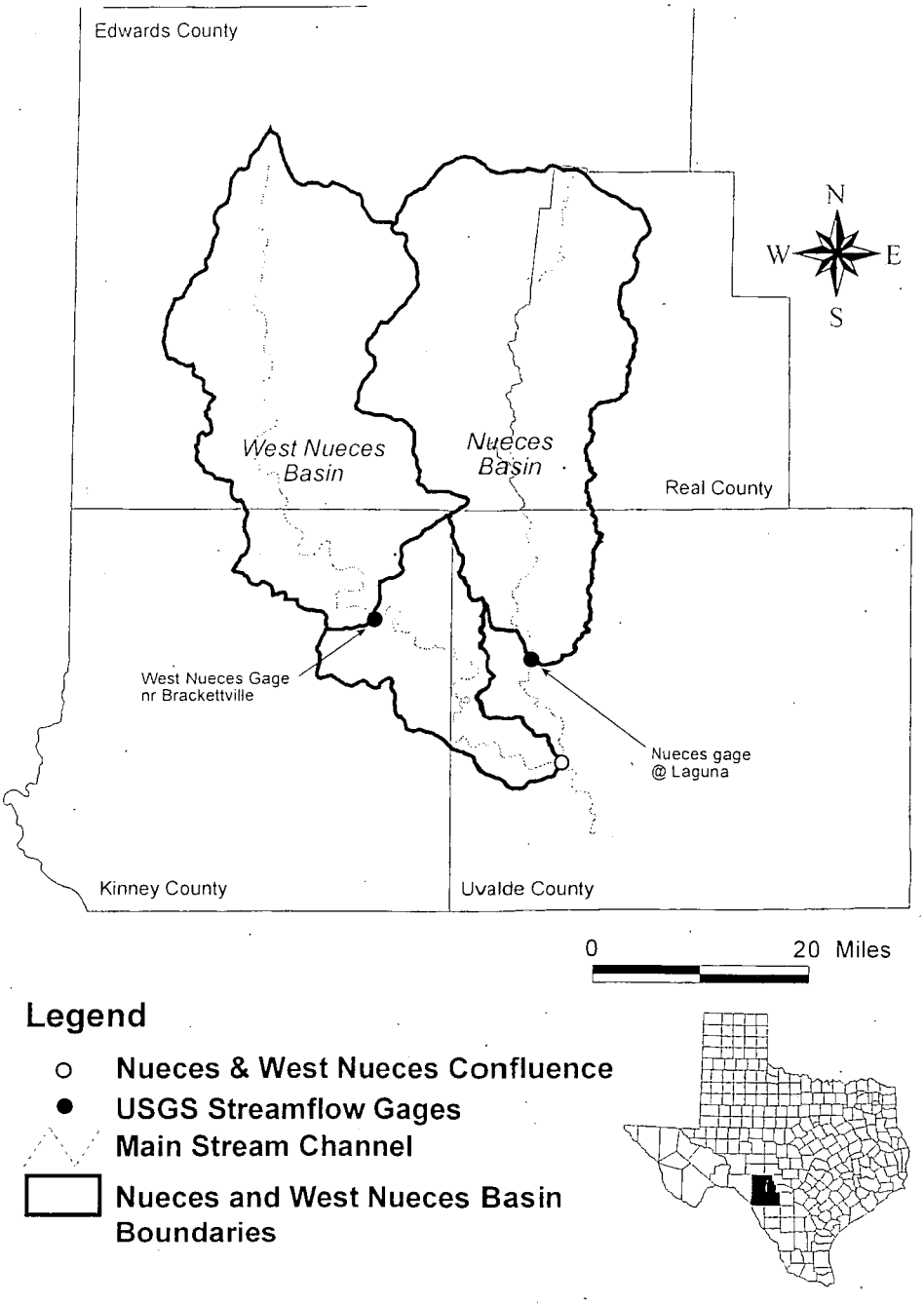

Figure 5. Nueces and West Nueces River basins.

Kuniansky and Holligan (1994) developed a numerical groundwater flow model of the Edwards (BFZ) and Edwards-Trinity (Plateau) aquifers and assigned recharge rates between 0.25 and 2.0 inches per year for the recharge zone in Kinney County with higher values generally in the eastern part of the county. They assigned recharge values according to baseflow estimates and variations in precipitation and then adjusted these values to calibrate the model. Kuniansky and Holligan (1994, using information from Kuniansky, 1989) did not calculate and therefore did not use baseflow estimates for the basins in Kinney County[1]. Recharge rates assigned in Kinney County appear to be based on calibration of the model, variations in precipitation, and relative consistency with the baseflow estimates of the Nueces River basin. Kuniasky and Holligan (1994) did not report recharge volumes on a county basis. We were not able to calculate recharge volume based on the information in the report.

The eastern part of Kinney County includes part of the recharge zone for the Edwards (BFZ) aquifer. Several authors have estimated recharge for the Edwards (BFZ) aquifer (for example, Petitt and George, 1956; Garza, 1962; Puente, 1978; Muller and Price 1979; Wanakule and Anaya, 1993; Choffel and Vaugh, 1993). However, those recharge estimates combine the recharge from both the Nueces and West Nueces River basins and exclude recharge in the western portion of Kinney County outside of those basins.

Unpublished estimates of recharge for Kinney County

Robert S. Kier Consulting (1998) produced a report on a preliminary assessment of groundwater availability for central Kinney County. They reported Bennett and Sayre's (1962) estimate of recharge and observed that Bennett and Sayre's (1962) discharge numbers suggest an average annual recharge of 90,000 to 95,000 acre-feet per year for Kinney County. Although not stated in the report, this definition of recharge used by Robert S. Kier Consulting (1998) includes underflow in addition to recharge due to infiltration.

In a letter sent to the Kinney County Groundwater Conservation District, Khorzad (2002) summarized work to assess the availability of groundwater in the county that included an estimate of recharge. He offered two estimates of average annual recharge to the Edwards aquifers in the county: 139,365 acre-feet per year and 140,498 acre-feet per year. The first value is derived from applying a modified Bennett and Sayre (1962) method over the longer period of record and adding an additional five percent of the recharge in the West Nueces River basin in Kinney County to account for cross-formational flow from the Glen Rose Limestone of the Trinity Group to the Edwards (BFZ) aquifer. The second value is derived by assigning two thirds of the recharge calculated from applying the modified Bennett and Sayre (1962) method over the longer period of record to the recharge area in the West Nueces River basin in Kinney County and then adding an additional five percent of the recharge in the West Nueces River basin in Kinney County

[1] This was appropriate. Using baseflow analysis to estimate recharge requires that water that recharges the aquifer within the basin be discharged as baseflow within that basin. This does not occur in the basins in Kinney County.

to account for cross-formational flow from the Glen Rose Limestone of the Trinity Group to the Edwards (BFZ) aquifer.

The Bennett and Sayre (1962) method

Bennett and Sayre (1962) noted that recharge to the Edwards aquifers in Kinney County "...cannot be computed directly...". This is because the Edwards aquifers in Kinney County are karstic, are recharged over a large area, and are not entirely discharged locally. However, Bennett and Sayre (1962) recognized that they could estimate recharge to the Edwards aquifers in Kinney County by taking advantage of similarities and an important difference between the adjacent catchment areas of the upper reaches of the West Nueces and Nueces River basins.

The similarities between the two basins are that they have similar catchment areas above their upstream gages, similar climates, similar vegetation, and similar geology in the recharge areas on the plateau. The important difference between the two basins is the geology exposed in the river valleys (Figure 6). The Nueces River and its major tributaries have cut through the Edwards Group rocks and into the Upper Glen Rose Formation of the Trinity Group. The Upper Glen Rose Formation has a lower permeability than does the overlying Edwards Group rocks. This dissimilarity in permeability enables most of the water that recharges the Edwards Group on the plateau to discharge into the Nueces River basin from springs near the contact between the Edwards Group and the Upper Glen Rose Formation. In contrast, the West Nueces River has not cut all the way through the Edwards Group rocks except in a few locations.

As Bennett and Sayre (1962) note, streamflow measured at the gage near Brackettville on the West Nueces River is only a fraction of the streamflow measured at the Laguna gage on the Nueces River despite their basin similarities and proximity to each other (Figure 7). This difference is due to the different geology exposed in the river valleys.

Bennett and Sayre (1962) estimated recharge in the West Nueces River basin by calculating the difference between the amount of water available for recharge and the amount of runoff that flowed out of the West Nueces basin. They estimated the amount of water available for recharge in the West Nueces basin by using streamflow measured by the Nueces River gage at Laguna. The gage at Laguna captures the surface runoff in the Nueces River basin and baseflow that is primarily derived from water that recharged the Edwards Group rocks on the plateau. Bennett and Sayre (1962) observed that the West Nueces River needed a minimum flow of 2,040 cubic feet per second at the gage near Brackettville for flow to reach the confluence with the Nueces River. Therefore, runoff out of the West Nueces River basin above the confluence is equal to the streamflow measured at the gage near Brackettville minus 2,040 cubic feet per second when flow at the gage is greater than 2,040 cubic feet per second.

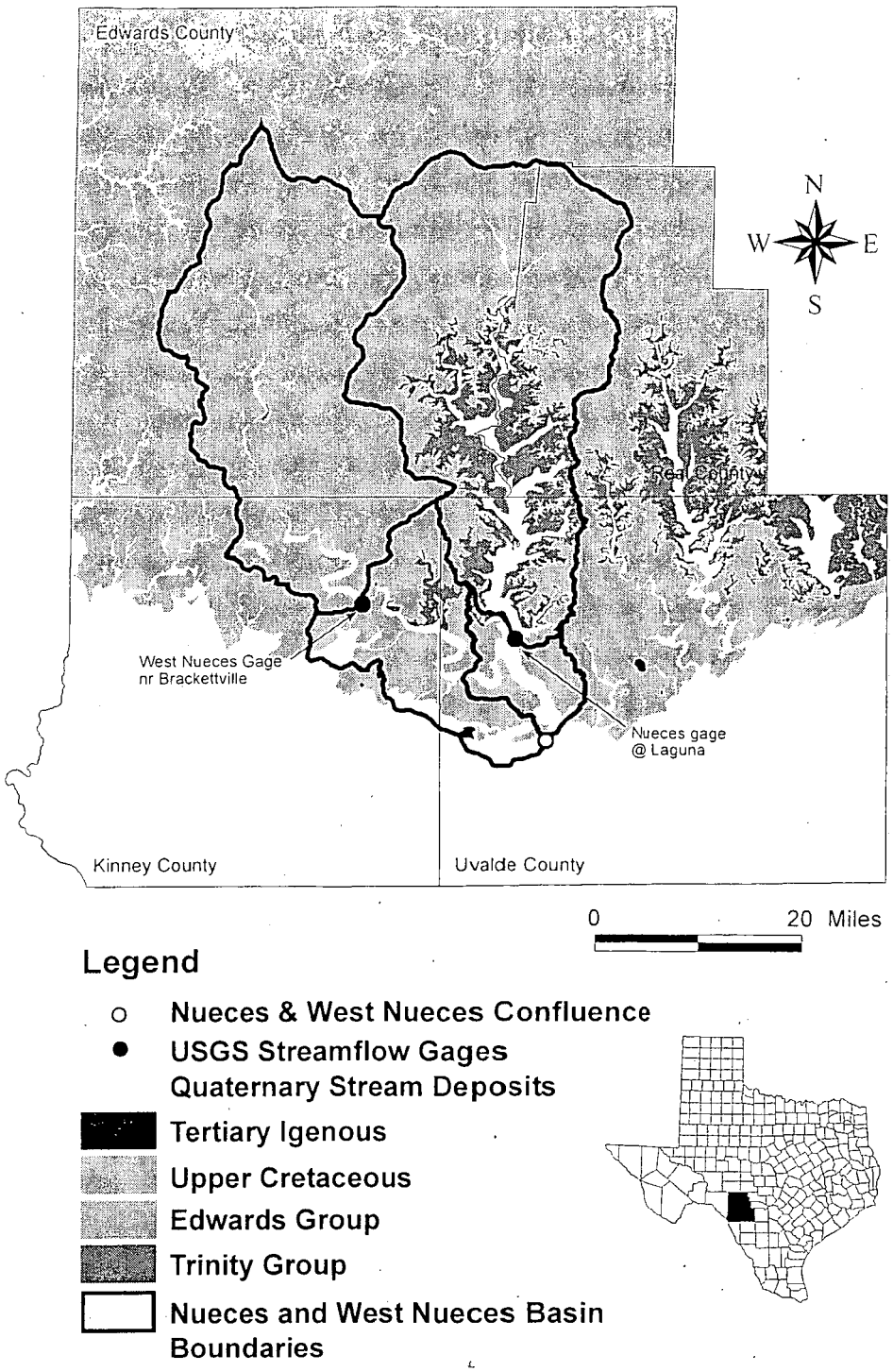

Figure 6. Geologic units of the Nueces and West Nueces River basins.

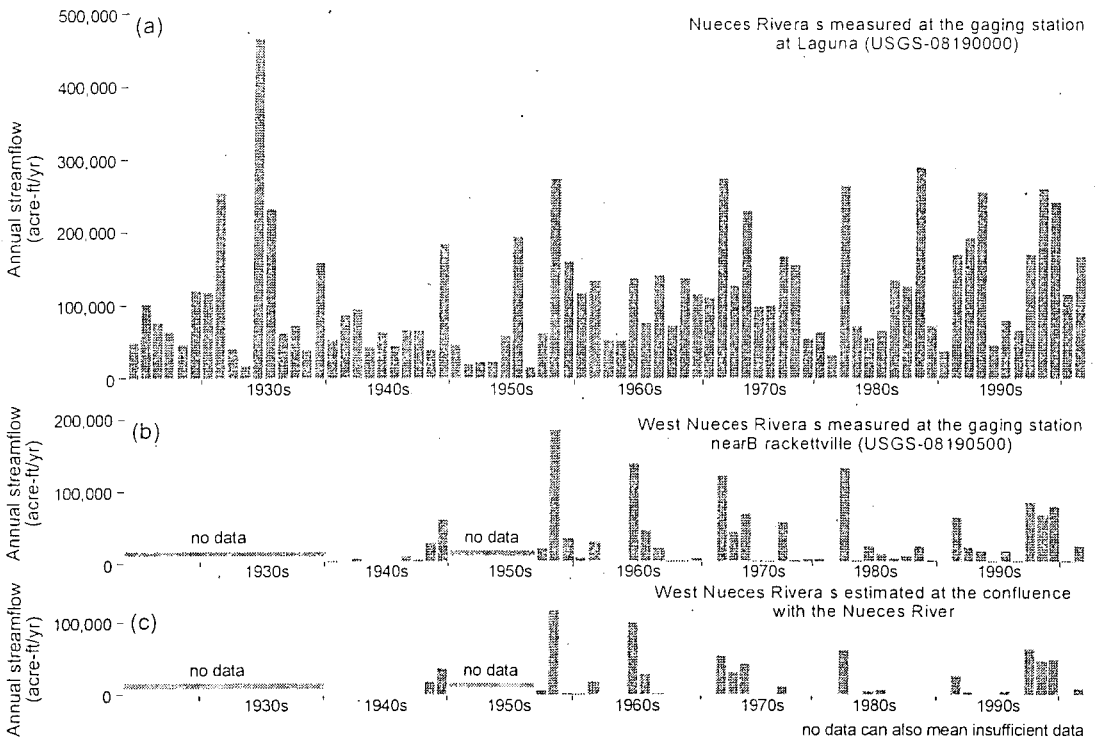

Figure 7. Annual streamflow as measured on (a) the Nueces River at Laguna and (b) West Nueces River near Brackettville and as (c) estimated at the West Nueces River at the confluence with the Nueces River (source data from USGS).

Based on the above observations, Bennett and Sayre (1962) estimated recharge in the West Nueces River basin using the following equation:

$$R_{wn} \approx Ro_n - Ro_{wn}$$

where:

R_{wn} = recharge per unit area in the West Nueces basin above the confluence,

Ro_n = runoff per unit area for the Nueces basin above the upstream gage at Laguna, and

Ro_{wn} = runoff per unit area for the West Nueces River basin above the confluence.

Bennett and Sayre's (1962) equation represents a simple water budget such that the difference between water available for recharge into a basin and water as runoff out of a basin is equal to the water that recharges the Edwards aquifers in the basin.

Methodology

After reviewing the available information and different methods of estimating recharge, we decided that the Bennett and Sayre (1962) method was the best available method for estimating recharge. However, additional streamflow information has been collected since Bennett and Sayre's (1962) original calculations. Our intent was to apply the Bennett and Sayre (1962) method with the longer period of streamflow record to improve upon the original recharge estimate for Kinney County, similar to what Khorzad (2002) did.

When we applied the Bennett and Sayre (1962) method, we wanted to be sure that we were applying it correctly. Therefore, we tried to reproduce the recharge estimates they published in their report. It was during this effort that we discovered two errors that Bennett and Sayre (1962) made when they applied their method. One error was using the wrong streamflow, and the other error was using an incorrect area for the West Nueces River basin in Kinney County. Note that although the recharge numbers originally reported in Bennett and Sayre (1962) are wrong, they are wrong because of how Bennett and Sayre (1962) applied their method, not because of a flaw in their method.

The errors that Bennett and Sayre (1962) made in their calculations result in large changes in estimates of recharge. Therefore, in the sub-sections below, we present what their estimates of recharge should have been if they had used the proper numbers. We do this so that the reader can understand and put into context our final estimates of recharge based on the longer period of record.

For our final estimate of recharge, we improved upon the Bennett and Sayre (1962) recharge estimate in three ways: (1) we used a longer period of record, (2) we more accurately quantified recharge area in the county and West Nueces basin, and (3) we more appropriately distributed recharge to the Edwards (BFZ) and Edwards-Trinity (Plateau) aquifers in Kinney County.

The following sections include (1) application of the Bennett and Sayre (1962) method to the original data set, (2) description of work to quantify county recharge and basin area, (3) application of the Bennett and Sayre (1962) method to the longer data set using more accurately quantified areas, (4) discussion and application of a modified Bennett and Sayre (1962) method that more appropriately distributes recharge to the Edwards (BFZ) and Edwards-Trinity (Plateau) aquifers in Kinney County, and (5) discussion of assumptions used in our modified Bennett and Sayre (1962) method. A summary of each of the recharge estimates is shown in Table 1.

Application of the Bennett and Sayre (1962) method to the original data set

To be sure that we were using the Bennett and Sayre (1962) method correctly, we applied it to streamflow data downloaded from the U.S. Geological Survey Web page for the same time period used by Bennett and Sayre (1962) in their study. This resulted in a recharge of about 86,000 acre-ft per year for the West Nueces River basin, greater than the 70,000 acre-ft per year reported by Bennett and Sayre (1962). After careful review, we found a disagreement between the annual flow reported for the Nueces River at Laguna by Bennett and Sayre (1962, table 2, p. 76, 21,600 acre-ft) and the value reported in the information downloaded from the U.S. Geological Survey Web site (165,600 acre-ft). The number reported in the online file agrees with the value reported in Geological Survey Water Supply Paper - 1148 for the 1949 water year (USGS, 1951). Therefore, it appears that Bennett and Sayre (1962) used the wrong streamflow value for the Nueces River for water year 1949.

Consequently, using the correct streamflow with Bennett and Sayre's (1962) estimates of recharge areas in Kinney County results in a recharge value of 86,000 acre-feet per year for the Edwards aquifers in Kinney County.

Description of work to quantify county recharge area and basin area

In their assessment of recharge, Bennett and Sayre (1962) qualitatively estimated the recharge area in Kinney County. They stated that "...the portion of the West Nueces River basin in Kinney County is about half the total area of the basin..." and that the recharge area for the rest of the county is about equal to the portion of the West Nueces River basin in Kinney County. We used ArcGIS, a geographic information system (GIS), to store and process spatial data within Kinney County and the Nueces and West Nueces River basins. We analyzed the spatial data using a statewide Albers equal area projection adopted by TWDB specifically for groundwater availability modeling studies. The GIS analysis included the application of spatial statistics and the intersection of various spatial themes to calculate specific areas used in our approach for estimating recharge to Kinney County.

Our GIS calculation for the drainage area of the West Nueces basin above its confluence with the Nueces River is 907 square miles, a bit less than Bennett and Sayre's (1962) estimate of 930 square miles (Table 2). In our recharge calculations, we decided to use our GIS calculated area and those published by the USGS for drainage areas above the upper most gages (Table 2). We calculated the portion of the West Nueces River basin in

Table 1. Summary of the original, adjusted, and final recharge estimates.

Description	Period of record	Average annual recharge in Kinney County (acre-feet per year)
(1) Value originally reported in Bennett and Sayre (1962)	October 1, 1939 to September 30, 1950	~70,000
(2) What the original value would have been if the correct 1949 water year streamflow had been used	October 1, 1939 to September 30, 1950	~86,000
(3) What the original value would have been if the correct 1949 water year streamflow and accurate drainage and recharge areas had been used	October 1, 1939 to September 30, 1950	46,600
(4) Value using corrected 1949 water year streamflow, accurate drainage and recharge areas, and longer period of streamflow record	October 1, 1939 to September 30, 1950 and April 1, 1956 to September 30, 2001	72,400
(5) As in (4) but accounting for different recharge processes	October 1, 1939 to September 30, 1950 and April 1, 1956 to September 30, 2001	69,800

Table 2. Drainage and recharge areas for the Nueces and West Nueces River basins and Kinney County.

TWDB		
Drainage area of West Nueces River above gage near Brackettville	688	mi^2
Drainage area of West Nueces River above confluence with Nueces River	**907**	mi^2
Drainage area of Nueces River above gage near Laguna	744	mi^2
Area of recharge zone in Kinney County inside West Nueces River basin	**275**	mi^2
Area of recharge zone in Kinney County outside West Nueces River basin	**216**	mi^2
USGS		
Drainage area of West Nueces River above gage near Brackettville	**694**	mi^2
Drainage area of Nueces River above gage near Laguna	**737**	mi^2
Bennett and Sayre (1962)		
Drainage area of West Nueces River above gage near Brackettville	700	mi^2
Drainage area of West Nueces River above confluence with Nueces River	930	mi^2
Drainage area of Nueces River above gage near Laguna	764	mi^2
Area of recharge zone in Kinney County inside West Nueces River basin	~350	mi^2
Area of recharge zone in Kinney County outside West Nueces River basin	~350	mi^2

Bold = values used in the final analysis presented in this document

Kinney County to be 275 square miles, only 30 percent of the total area of the 907 square mile basin (Table 2). This is considerably different than the 50 percent ("...about half...") mentioned by Bennett and Sayre (1962). We speculate that when they made this estimate, they compared the area of the West Nueces basin in Kinney County to the area of the West Nueces basin outside of Kinney County instead of to the area of the entire West Nueces basin (Figure 5). Bennett and Sayre (1962) estimated the recharge area for the rest of the county as being equal to that portion of the West Nueces basin in Kinney County. We calculated the rest of the county to be 216 square miles or about 79 percent of that portion of the West Nueces basin in Kinney County (Table 2).

Revising Bennett and Sayre's (1962) recharge estimate to consider the correct streamflow for water year 1949 and the correct drainage and recharge areas result in a recharge estimate of about 46,600 acre-ft per year for the Edwards aquifers in Kinney County. This is the value that Bennett and Sayre (1962) should have published in their report.

Application of the Bennett and Sayre (1962) method to the longer data set using more accurately quantified areas

In their assessment of recharge, Bennett and Sayre (1962) used streamflow measurements from October 1, 1939 to September 30, 1950. In our assessment, we used streamflow measurements from September 28, 1939 to September 30, 1950 and from April 1, 1956 to September 30, 2001 (streamflow was not measured in the West Nueces River between October 1, 1950 and March 31, 1956). This 56.5-year record allowed for a longer period to estimate an 'average' recharge value. In comparison, Bennett and Sayre (1962) used a period of record of 11 years during a time when rainfall was relatively low.

Using the longer period of record and the correct drainage and recharge areas resulted in a recharge of about 133,800 acre-ft per year for the West Nueces basin. This equates to a recharge of about 72,400 acre-ft per year for the Edwards aquifers in Kinney County.

Discussion and application of a modified Bennett and Sayre (1962) method that more appropriately distributes recharge to the Edwards (BFZ) and Edwards-Trinity (Plateau) aquifers in Kinney County

Recharge occurs differently for the Edwards (BFZ) aquifer than for the Edwards-Trinity (Plateau) aquifer. In the Edwards (BFZ) aquifer, much of the recharge occurs by rivers losing streamflow directly into the aquifer. This type of recharge is facilitated by faulting and fracturing associated with the Balcones Fault Zone. In the Edwards-Trinity (Plateau) aquifer, much of the recharge occurs more diffusely over a larger area instead of along a specific discrete feature such as faults and fractures in a riverbed. This diffuse type of recharge also occurs in the Edwards (BFZ) aquifer but at a lesser magnitude than the direct type of recharge. Kinney County likely includes both of these types of recharge: direct recharge where the West Nueces River crosses the Edwards (BFZ) aquifer and diffuse recharge everywhere else.

The Bennett and Sayre (1962) method does not distinguish between direct recharge from losing streamflow and diffuse recharge. Instead, their method averages both of these

types of recharge over the entire West Nueces basin. On one hand, this averaging potentially results in an underestimate of recharge to the Edwards (BFZ) aquifer in the West Nueces River basin in Kinney County. On the other hand, this averaging potentially results in an overestimate of recharge to the Edwards-Trinity (Plateau) aquifer in Kinney County.

We modified the Bennett and Sayre (1962) method to consider these differences in recharge mechanisms in Kinney County. The approach we followed (with volumes rounded to the nearest 100 acre-ft) was:

1. Estimate mean annual total recharge in the West Nueces basin above the confluence with the Nueces River using the Bennett and Sayre (1962) method using the longer period of record and correctly quantified areas (133,800 acre-ft per year).

2. Estimate the direct recharge to the Edwards (BFZ) aquifer from the West Nueces River by calculating the streamflow loss between the gage near Brackettville and the confluence with the Nueces River (all daily streamflows less than 2,040 cubic feet per second with those greater than or equal to 2040 cubic feet per second set to a maximum of 2040 cubic feet per second yields 12,200 acre-ft per year).

3. Estimate the amount of diffuse recharge by subtracting the estimate of direct recharge from the estimate of total recharge (133,800 acre-ft per year minus 12,200 acre-ft per year equals 121,600 acre-ft per year).

4. Calculate the diffuse recharge per square mile for the West Nueces basin (121,600 acre-ft per year divided by 907 square miles equals 134 acre-ft per year per square mile).

5. Estimate the diffuse recharge to the Edwards aquifers in Kinney County by multiplying the diffuse recharge per square mile by the total recharge area in the county (134 acre-ft per year per square mile multiplied by 491 square miles equals 65,800 acre-ft per year).

6. Estimate direct recharge into Kinney County by calculating the length of the West Nueces River in Kinney County below the gage near Brackettville, dividing by the length of the West Nueces River between the gage near Brackettville and the confluence in Uvalde County, and multiplying by the direct recharge ([13.7 miles divided by 41.6 miles] multiplied by 12,200 acre-ft per year equals 4,000 acre-ft per year).

7. Calculate the total recharge to the Edwards aquifer in Kinney County by summing the estimate of diffuse recharge to the Edwards aquifer in Kinney County with the estimate of direct recharge into Kinney County (65,800 acre-ft per year plus 4,000 acre-ft per year equals 69,800 acre-ft per year)

Therefore, our estimate of recharge to the Edwards aquifers in Kinney County is 69,800 acre-ft per year. Modification of the Bennett and Sayre (1962) method to account for differences in direct and diffuse recharge only yielded about a 3 percent correction to the

recharge estimate for Kinney County. However, we felt that this exercise was justified in that we were able to eliminate an otherwise additional assumption to the method.

Discussion of assumptions used in the Bennett and Sayre (1962) method

Bennett and Sayre (1962) state that an estimate based on their methodology may be in error due to several assumptions that may not be wholly true. The assumptions they list are:

- the surface-water divides and groundwater divides coincide,
- the rainfall in the Nueces and West Nueces River basins is the same,
- average evapotranspiration rates are the same in both basins, and
- withdrawals by man are negligible.

In addition, we identified several other assumptions associated with the methodology:

- direct recharge from streamflow losses of the West Nueces River into the Edwards (BFZ) aquifer is uniform along the entire stream reach,
- there are no surface-water diversions from the Nueces River above the streamflow gage at Laguna, and
- cross-formational flow of water from the underlying rocks of the Trinity Group into the Edwards aquifers is negligible.

We discuss each assumption in more detail below and the effects that each of the assumptions may have on an estimate of recharge in Kinney County.

Surface-water divides and groundwater divides coincide

This assumption is important relative to surface-water and groundwater flow in the basin above the gage on the Nueces River at Laguna. The Bennett and Sayre (1962) method assumes that the flow measured at the gage represents direct runoff and groundwater baseflow resulting from water that recharged the Edwards rocks on the plateau and then discharged back into the basin. Based on a water-level map developed by Bush and others (1993, sheet 3), it appears that this is a reasonable assumption. The map shows that groundwater divides approximate the location of surface-water divides for the Nueces basin above the gage near Laguna. If the surface-water divides delineate a greater area than the groundwater divides, recharge to Kinney County may be over estimated. If the surface-water divides delineate a smaller area than the groundwater divides, the recharge to Kinney County may be under estimated.

Rainfall in the Nueces and West Nueces River basins is the same

Rainfall affects how much runoff there is and the total amount of water that may be available for recharge. To test this assumption, we compared 1961 to 1990 mean annual precipitation data developed from the Parameter-elevation Regressions on Independent Slopes Model (PRISM) analytical model (Daly and Taylor, 1998) between the two basins. Since our objective was to analyze the relative precipitation difference between recharge areas of interest, we felt that the spatially interpolated PRISM data set would provide more accurate spatial characteristics of precipitation than would the longer period

of record National Weather Service (NWS) gage site data. For comparison, 1961 to 1990 mean annual precipitation for the NWS gage station at Brackettville is 22.24 inches per year. The PRISM interpolated 1961 to 1990 mean annual precipitation for the same location is 21.78 inches per year. We downloaded the 4-kilometer resolution PRISM data from http://www.ocs.orst.edu/prism/prism_products.html and resampled it into a 1-mile resolution equal area coordinate system using GIS. The ArcGIS Spatial Analyst extension was then used to calculate zonal statistics for each recharge area of interest (Table 3).

In general, precipitation is spatially variable and decreases toward the west with the highest precipitation occurring in the east-central portion of the Nueces River basin. We found that the West Nueces River basin above the streamflow gage near Brackettville has about 93 percent of the mean annual precipitation of the Nueces River basin above the gage at Laguna. The West Nueces drainage area between its confluence with the Nueces River and the gage near Brackettville has about 92 percent of the mean annual precipitation of the Nueces River basin above the gage at Laguna. This assumption also applies to precipitation in the western part of Kinney County, which is about 86 percent of the rainfall in the Nueces River basin. Correcting for the spatial variability of rainfall would require more extensive analysis and modeling of runoff response to spatially distributed precipitation data. Divergence from this assumption generally results in an overestimate of recharge in Kinney County.

Average evapotranspiration rates are the same in both basins

Evapotranspiration affects how much precipitation percolates into the ground and runs off into stream. We were not able to locate measured values of evapotranspiration or evaporation at detailed enough resolution to quantify differences between the two basins. However, similar to precipitation, we would not expect there to be large differences between the two basins, especially where there are Edwards rocks. However, we would expect evapotranspiration to be greater to the west. Consequently, a divergence from this assumption in this case will likely result in an overestimate of recharge for Kinney County.

Evapotranspiration also affects baseflow to the Nueces River. Water that recharges the Edwards rocks on the plateau in the Nueces basin discharges to tributaries where they cut through the Edwards rocks into lower permeability Trinity rocks beneath. When this water approaches the land surface and discharges, some of it has a potential to be evapotranspirated. It is not possible to estimate how much of this water may be evapotranspirated since it is likely to vary in space and time. The perennial nature of baseflow in the Nueces River suggests that divergence from this assumption in this case results in an underestimate of recharge for Kinney County.

Groundwater withdrawals by man are negligible

An important assumption for our approach to estimating recharge for Kinney County is that anthropomorphic groundwater withdrawals are negligible for the Nueces River basin above the streamflow gage at Laguna. Groundwater withdrawals from the Edwards rocks in the Nueces River basin would decrease discharge from the Edwards rocks to the

Table 3 – Precipitation statistics for specific recharge areas.

Zone	Zones of Interest	Area (mi^2)	Min (in/yr)	Max (in/yr)	Mean (in/yr)	% Mean Zone 1
1	Nueces River basin above upper gage @ Laguna	744	24.04	28.00	26.33	100
2	West Nueces River basin above upper gage near Brackettville	688	23.27	27.03	24.56	93
3	West Nueces River basin between confluence and upper gage near Brackettville	140	22.59	27.03	24.22	92
4	West Nueces River basin above confluence	907	22.59	27.03	24.48	93
5	Edwards outcrop in Kinney County inside of West Nueces River basin	275	22.59	27.03	24.10	92
6	Edwards outcrop in western Kinney County outside of basins	216	21.08	23.81	22.57	86

Nueces River tributaries where they cut through the Edwards rocks into lower permeability rocks beneath thus lowering flow at the Laguna gage. To assess the effect of this assumption, we compiled water-use information collected and estimated between 1980 and 2000 by the Texas Water Development Board Water Uses Section for the Edwards-Trinity (Plateau) aquifer for Uvalde, Real, and Edwards counties and within the Nueces River basin. We estimated that about one third of the 1,400 acre-feet of mean annual groundwater discharge to actually occur within the Nueces River basin above the streamflow gage at Laguna. Therefore, it appears to be a reasonable assumption that groundwater withdrawals by man are negligible at less than 1 percent of the 119,500 acre-feet mean annual streamflow at the Laguna gage. Divergence from this assumption would result in an underestimate of recharge in Kinney County.

Leakage from the West Nueces River into the Edwards (BFZ) aquifer is uniform

Leakage from the West Nueces River into the Edwards (BFZ) aquifer is affected by the availability of water to flow along the river reach and the ability of that water to leak into the aquifer, both of which are assumed to be uniform along the riverbed in our and Bennett and Sayre's (1962) method. The availability of water is actually greater in the upper part of the reach than in the lower part. This is because the upper reach has the first chance to access water flowing from the basin upstream of the gage near Brackettville. Flows less than 2,040 cubic per second do not reach the confluence and likely stop further upstream. Divergence from this assumption based on the availability of water results in an underestimate of recharge in Kinney County.

The ability for water to leak into the Edwards (BFZ) aquifer is also likely not uniform along the West Nueces River. This ability is greatly affected by faulting and underlying geology. The faulting and underlying geology suggest that there may be a greater ability for water to leak into the Edwards (BFZ) aquifer in Uvalde County than in Kinney County. Most of the primary faults that likely cross the West Nueces River appear to occur in Uvalde County. Furthermore, the lower permeability rocks of the Trinity crop out along the West Nueces River in Kinney County. Consequently, the ability for water to leak into the Edwards (BFZ) aquifer from the West Nueces increases downstream. Divergence from this assumption based on the ability of water toleak into the aquifer likely results in an overestimate of recharge in Kinney County.

There are no surface-water diversions from the Nueces River above the gage near Laguna

Our approach for estimating recharge for the West Nueces River basin assumes that there are no surface-water diversions from the Nueces River above the gage near Laguna. We investigated the water rights and permitted diversions for the Nueces River above the gage at Laguna and found that a maximum of about 6,200 acre-feet per year may potentially and legally be removed from the streamflow for 2003. Except for 1,000 acre-feet per year permitted for use by the town of Camp Wood, the use of these diversions is for irrigation. Although the 6,200 acre-feet may not necessarily be used in its entirety in any given year, it amounts to 5 percent of the 119,500 acre-feet of mean annual streamflow as measured at the gage near Laguna. Consequently, this assumption may

underestimate recharge in Kinney County by as much as six percent if the full permitted amounts are used and there is no return flow to the river.

Leakage of water from the underlying rocks of the Trinity Group into the Edwards aquifers is negligible

Rocks of the Trinity Group underlay the Edwards aquifers in Kinney County and most part of the Edwards-Trinity (Plateau) aquifer. There is potential for groundwater to flow between the Edwards aquifer and the Trinity aquifer. Khorzad (2002) discussed the possibility of water flowing from the Trinity aquifer up into the Edwards aquifer and reported a range of 5 to 53 percent (as discussed in Mace and others [2000, p. 57 and 86], the higher number from Kuniansky and Holligan [1994] is likely much too high). He used the lower value of the range (five percent) to estimate the possible component of flow into the Edwards aquifers.

The references named by Khorzad (2002) that estimate the amount of flow from the Trinity aquifer into the Edwards aquifer are for the Trinity aquifer in the Hill Country where the Trinity aquifer is exposed at land surface and can be easily recharged. The Trinity part of the Edwards-Trinity (Plateau) aquifer is not exposed on the plateau and therefore receives less recharge than its companion sediments in the Hill Country. To our knowledge, no one has estimated what this cross-formational flow may be. Divergence from this assumption results in an underestimate of recharge in Kinney County.

Discussion

We believe that the recharge value that we calculated for Kinney County is the best available estimate given the available information. The recharge value reported by Bennett and Sayre (1962) is in error because they used an incorrect streamflow and incorrect areas. Because Bennett and Sayre (1962) is in error, any of the estimates based on Bennett and Sayre (1962) (that is, Muller and Price, 1979; Robert S. Kier Consulting, 1998; and Khorzad, 2002) are also in error. The recharge values of Kuniansky and Holligan (1994) are not the best available because a single value cannot be computed from their report and the values are from a very large regional model that may have considerable uncertainty.

Recommendations for future work

We believe that there are several studies that could be done to further constrain estimates of recharge in Kinney County. These studies include:

- a detailed gain-loss study on the West Nueces River,
- installation of an additional stream gage,
- an aquifer-wide water budget, and
- surface-water modeling.

Each of these studies is briefly discussed below.

A detailed gain-loss study on the West Nueces River

Because of the uncertainties in where streamflow in the West Nueces River recharges the Edwards (BFZ) aquifer between the gage near Brackettville and the confluence, it would be very useful to do a detailed gain-loss study. It would be difficult to do this because the river generally only flows during flood events. Most gain-loss studies are done during baseflow periods. If it is possible to monitor how far downstream any given flow measured at the gage near Brackettville propagates, it would be possible to estimate infiltration capacity along the river reach. This information would allow a more accurate assessment of direct recharge to the Edwards (BFZ) aquifer in Kinney County.

Installation of an additional stream gage

An additional stream gage for the West Nueces River at the Kinney County line with 8 to 10 years of daily monitoring would help to further refine direct recharge estimates for Kinney County. This stream gage would help quantify the direct recharge from the West Nueces River to the Edwards (BFZ) aquifer.

An aquifer-wide water budget

An aquifer-wide water budget would be useful for defining the recharge to the aquifer as a whole. If all of the outflows from the aquifer are known, then the inflow (recharge) is equal to the outflow plus any change in storage. This project would require the monitoring of mean daily flow at all of the springs in Kinney and Val Verde County that discharge from the Edwards aquifers and good estimates of pumping and water levels from the aquifer.

Surface-water modeling

A deterministic continuous-based runoff model such as the U.S. Geological Survey HSPF model (Bicknell, and others, 1997) could be used to assess the streamflow components of baseflow and storm runoff for both the Nueces and West Nueces River basins. Although there are many assumptions with this type of modeling, it is another method that could be used to estimate recharge to the aquifers.

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