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April 29, 2026

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Justin Baer
14725 342nd Avenue
Onaka, SD 57466

Re: In the Matter of Water Permit Application No. 8982-3, Century Swine RE, LLC

To Whom It May Concern:

Enclosed and intended as service upon you are the Pre-Hearing Submissions of Petitioners, Larry Heinz, Cindy Heinz, and Garett Heinz, in the above-referenced matter.

Sincerely,

CONNOR R. SHAULL
For the Firm

Enclosures

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STATE OF SOUTH DAKOTA
DEPARTMENT OF AGRICULTURE AND NATURAL RESOURCES
WATER MANAGEMENT BOARD

IN THE MATTER OF WATER PERMIT APPLICATION NO. 8982-3, CENTURY SWINE RE, LLC	**PETITIONERS' PRE-HEARING SUBMISSIONS (HEINZS)**

Petitioners, Larry Heinz, Cindy Heinz, and Garett Heinz (collectively, "Petitioners"), by and through their counsel of record, submit the following:

1. **Fact Witnesses**: Petitioners intend to call the following during the hearing in this matter:

   a. Garett Heinz
   b. Larry Heinz
   c. Cindy Heinz
   d. Amanda Abarca
   e. Any records custodian or other similar witness to lay foundation for exhibits
   f. Any other witness to impeach the testimony from or credibility of any witness
   g. Any witness for rebuttal purpose
   h. Any witness identified by any other party in the above-referenced matter.

2. **Exhibits**: Petitioners intend to introduce Exhibits 201 through 204, which are attached hereto and described in the list on the following page. Petitioners reserve the right to introduce any document or exhibit that is publicly available as part of the contested case file or any other document or exhibit identified by any other party.

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Exhibit No.	Description
201	Letter, filed April 12, 2012, in *In the Matter of Water Permit Application No. 7239-3, by Hanson County Dairy v. Robert Bender*, Case No. 30CIV11-000054
202	Order, filed May 10, 2012, in *In the Matter of Water Permit Application No. 7239-3, by Hanson County Dairy v. Robert Bender*, Case No. 30CIV11-000054
203	Edmunds County Map
204	Declaration of Thiele R. Dunaway

Dated at Sioux Falls, South Dakota, this 29th day of April, 2026.

DAVENPORT, EVANS, HURWITZ &
SMITH, L.L.P.

/s/ Connor R. Shaull

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CERTIFICATE OF SERVICE

The undersigned hereby certifies that on the 29th day of April 2026, a true and correct copy of the foregoing documents were served via First Class Mail upon the following:

Adam Mathiowetz, Chief Engineer
DANR - Water Management Board
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/s/ Connor R. Shaull
Connor R. Shaull

EXHIBIT 201

-First Judicial Circuit Court-

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Chief Court Services Officer
Charles R. Frieberg
Circuit Assistant
Joan Novak

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April 11, 2012

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Re: In the Matter of Water Permit Application No. 7239-3, by Hanson County Dairy, Appellee/Applicant v. Robert Bender and Stace Nelson, Appellants/Intervenors

Dear Counsel,

The court has under advisement in the above-entitled matter an appeal from the Water Management Board's (WMB) decision granting Hanson County Dairy (HCD) a water permit for use in a dairy facility to be constructed in Hanson County, South Dakota. Robert Bender and Stace Nelson (Intervenors) intervened in the permit application process and have filed this appeal. The court held oral arguments on March 23, 2012, at the Hanson County Courthouse, in Alexandria, South Dakota. Having considered the evidence, the parties' briefs, and the arguments of counsel, the court now issues its decision.

I. STANDARD OF REVIEW

"The standard of review of an agency's decision is governed by SDCL § 1-26-36 and ordinarily requires de novo review of questions of law and clearly erroneous review of findings of fact." *Horn v. Dakota Pork*, 2006 SD 5, ¶ 12, 709 N.W.2d 38, 41 (citing *Brown v. Douglas School Dist.*, 2002 SD 92, ¶ 9, 650 N.W.2d 264, 267). "Mixed questions of law are also fully reviewable." *Kuhle v. Lecy Chiropractic*, 2006 SD 16, ¶ 16, 711 N.W.2d 244, 247 (citing *Enger v. FMC*, 1997 SD 70, ¶ 10, 565 N.W.2d 79, 83).

II. BACKGROUND

On March 8, 2011, HCD applied for a commercial water permit. The application sought a permit to pump 500 gallons of water per minute (GPM), or 1.11 cubic feet per second (CFS) from three wells located in the James River basin, more specifically the Floyd East James Aquifer. The location of point of diversion is in Hanson County, South Dakota, SW ¼ Section 34, T104N, R58W. The project is described as "7,000 cow dairy."

On April 4, 2011, Hayes Haas, Natural Resources Engineer, submitted his Report on Water Permit Application No. 7239-3. His conclusions were as follows:

1. Water is available from the Floyd East James aquifer.
2. The aquifer is under confined conditions at this location. Drawdown will result from pumping. Interference is not expected to be a problem.
3. These wells must be constructed in accordance with SD Well Construction Standards.
4. Plans and specifications for this facility have not been received (as of 4/6/2011) and must be approved by the Department [of Environment and Natural Resources].

On April 7, 2011, Garland Eberle, Chief Engineer, recommended approval of HCD's water permit. He cited four reasons for this conclusion:

1. There is reasonable probability that there is unappropriated water available for the applicant's proposed use;
2. The proposed diversion can be developed without unlawful impairment of existing rights;
3. The proposed use is a beneficial use; and
4. It is in the public interest with the following qualifications:

   1. The wells approved under this Permit will be located near domestic wells and other wells which may obtain water from the same aquifer. The well owner under this Permit shall control his withdrawals so there is not a reduction of needed water supplies in adequate domestic wells or in adequate wells having prior water rights.
   2. The wells authorized by Permit No. 7239[1] shall be constructed by a licensed well driller and construction of the well and installation of the pump shall comply with Water Management Board Well Construction Rules, Chapter 74:02:04 with the well casing pressure grouted (bottom to top) pursuant to Section 74:02:04:28.
   3. Permit No. 7239-3 is subject to compliance with requirements of the Department's Water Pollution Control Permit issued pursuant to SDCL §34A-2-36 or 34A-2-112 for concentrated animal feeding operations.
   4. Permit No. 7239-3 is subject to compliance with all existing and applicable Water management Board Rules including but not limited to:

   a) Chapter 74:54:01 Ground Water Quality Standards;
   b) Chapter 74:54:02 Ground Water Discharge Permit;
   c) Chapter 74:51:01 Surface Water Quality Standards;
   d) Chapter 74:51:02 Uses Assigned to Lakes;
   e) Chapter 74:51:03 Uses Assigned to Streams; and

[1] This number is incorrect. All of the other references in this and other records used the correct permit number 7239-3. Appellants' argument that this error resulted in them not receiving adequate notice is without merit.

f) Chapter 74:52:01 through 74:52:11 Surface Water Discharge Provisions
5. Hanson County Dairy shall report to the Chief Engineer annually the amount of water withdrawn from the Missouri: Elk Point Aquifer.[2] See report on application for additional information.

Also on April 7, 2011, Eric Gronlund, Natural Resources Engineer, sent a letter to HCD CEO Michael Crinion. The letter indicated the water permit was "examined and found to comply with the South Dakota Water Laws and applicable rules." The letter also stated that a notice had been sent to the Alexandria Review.[3] Gronlund explained to Crinion that Crinion would need to contact the newspaper and authorize publication of the notice.

In a letter dated May 1, 2011, Robert Bender sent a letter to the WMB indicating he was intervening against HCD's application. He stated that he has two wells on his property. In a letter dated May 9, 2011, Chief Engineer Erbele sent a notice of hearing concerning Bender's petition opposing approval to Crinion and Bender. The notice indicated the specifics of the hearing on water permit No. 7239-3. The notice briefly described the applicant's planned use, when and where the WMB will hold a hearing, the Chief Engineer's recommendation details, a statement that the "hearing may be an adversarial hearing," and enclosed a copy of the report, recommendation, affidavit of publication and petition.

On May 9, 2011, Stace Nelson wrote Gronlund, "as a potential affected property owner opposed to the granting of the above cited permit." He stated that he has one well on his property. In a letter dated May 17, 2011, Bender asked for an extension to the proposed June 1, 2011 hearing date. On May 19, 2011, Erbele sent a letter to Nelson, indicating the hearing date was moved to July 13, 2011. The letter also advised Nelson that he was not timely in filing his opposition, and that the WMB would consider his untimely filing prior to the start of the hearing. In the second paragraph of the May 19, 2011 letter, Erbele states, "Attached is the notice to the applicant and Mr. Bender scheduling a June 1st hearing."

In a May 23, 2011 letter to Crinion, Nelson, and Bender, the WMB indicated the hearing was now scheduled for July 13, 2011. "NOTICE" is indicated in bold print at the top of the letter. At the July 13, 2011 hearing, several people were present, including: the seven WMB members, counsel for the WMB, Assistant Attorney General Best, Attorney Kerkvliet, along with Nelson and Bender. Witnesses who testified were: Eric Gronlund, Hayes Haas, Garland Erbele, Michael Crinion, Walt Bones, Robert Bender, and Stace Nelson. At the conclusion of the hearing, a board member made a motion to approve the permit application in accordance with the recommendations of the Chief Engineer, and the correction of the aquifer. Another board member seconded the motion. Some discussion followed. The motion to approve the permit was unanimously passed by the board. July 13, 2011 hearing transcript, P 175, L 18. On July 19, 2011, the WMB sent a letter to Eric Kerkvliet, Bender, and Nelson indicating that Kerkvliet was responsible for preparing Findings of Fact, Conclusions of Law, and the Final Decision.

On September 14, 2011, Bender and Nelson [Intervenors] made a motion to the Department of Environment and Natural Resources (DENR) and WMB for rehearing and reconsideration. Their reasons for such a motion were that the notices in the Alexandria

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[2] This name is incorrect. The correct aquifer is the Floyd East James aquifer. Mr. Erbele corrected this at the July 13, 2011 hearing. TR 58:2-6.

[3] The name of the newspaper is the "Alexandria Herald," not the "Alexandria Review."

Herald were untimely, did not comply with SDCL §46-2A-4, wrongfully referenced an erroneous recommendation by the Chief Engineer, were legally insufficient because they were not published in one official newspaper in each county where the water will be diverted or used or project works will be located, and testimony received by the WMB was improper and prejudicial pursuant to a conflict of interest or lack of foundation or assumed facts not in evidence. On this same day, HCD submitted its Proposed Findings of Fact and Conclusions of Law.

On September 21, 2011, the WMB sent a letter to all parties indicating that it would consider the motion for rehearing and reconsideration at its October 5, 2011 meeting. The DENR and Intervenors each made responses to the proposed Findings of Fact and Conclusions of Law. Rodney Freeman, Chairman of the WMB signed the final Findings of Fact, Conclusions of Law, and Final Decision on October 5, 2011. On the same day, the WMB issued its rulings on the various objections and responses to the proposed Findings of Fact and Conclusions of Law. Notice of the adopted Ruling and Final Decision was sent to all parties in a letter dated October 7, 2011. On October 14, 2011, Intervenors filed their Notice of Appeal, and Application for Stay of Water Management Board Decision and Notice of Hearing. This court denied the Application for Stay on December 2, 2011.

Intervenors filed a brief in this appeal on December 16, 2011. The issues identified within that brief for this court to review are as follows:

1. Whether the notices given to Appellants and/or published in the newspaper complied with state statutes;
2. Whether the requirements of SDCL 46-6-3.1 were met;
3. Whether it was a conflict of interest for the Secretary of Agriculture to testify in favor of the application at the hearing before the Water Management Board.

III. DECISION

1. Notices

Before deciding Appellants' first issue, the court must determine what standard to apply in deciding whether the appellees complied with the various statutory notices. Appellants argue that the appellees must strictly comply with the various notice provisions. Appellants cite *Hein v. Marts*, 295 N.W.2d 167 (S.D. 1980), for this assertion. *Hein* also involved a water permit. In October, 1976, Thomas Marts applied for a permit to build a dugout and pump water on his land. After notice was published in the local paper for two successive weeks, a hearing was held in Huron, South Dakota. Walter Hein appeared at the hearing, and objected to the issuance of the permit. Hein asserted that his water source, a spring-fed stream, would be depleted if Marts were granted the permit. A rehearing was held in Brookings, South Dakota on July 28, 1977. Marts was subsequently granted the permit. Hein was not sent notice of the final decision to grant the permit. Marts began constructing the dugout in accordance with the permit. After Hein observed this construction, he hired attorney Rick Johnson of Gregory, South Dakota to challenge the permit. Attorney Johnson contacted the Water Rights Commission, and was sent a letter indicating that Marts had been granted the permit. Attorney Johnson provided the Heins a copy of this letter. The Heins sued in July of 1978 for injunctive and prohibitive relief alleging the permit to be invalid for lack of notice of the final decision. Marts and the Department of Natural Resources Development [DNRD] (now known as the Department of Environment and Natural

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Resources) argued that the letter to attorney Johnson constituted notice of the final decision. SDCL § 1-26-25 required notice of any final decision or order to be made "either personally or by mail[.]" The Supreme Court of South Dakota disagreed with Marts and the DNRD that the letter to Attorney Johnson satisfied the statutory requirement for the method of notice. The court explained, "As a general rule, where a *method* of giving notice is prescribed by statute, there must be strict compliance with the prescribed method in form of notice." 295 N.W.2d at 170 (citing *Smith v. D.R.G., Inc.*, 29 Ill.App.3d 406, 331 N.E.2d 614 (1975)[4]; *Cowl v. Wentz*, 107 N.W.2d 697 (N.D. 1961); *In re Sioux City Stockyards Co.*, 222 Iowa 323, 268 N.W. 18 (1936)) (emphasis added). "Moreover these cases emphasize that there must be strict compliance with notice provisions where the notice affects property rights or where it is to form the basis for a suit." *Hein*, 295 N.W.2d at 170.

It is this court's position that *Hein* dealt with the issue of the proper statutory *method* of providing notice, such as personal service or service via mail. *Hein* did not address the issue of compliance with the contents of specific provisions of a notice statute, such as the Appellants assert in this case. Hein was not given notice, personally or via mail, of the final decision to grant Marts a permit. The Court's general rule, as stated above, involves strictly complying with the method of notice. In this case, Appellants' objections, pertaining to the various notices, deal mostly with the content of the notices. However, Appellants have an issue with the method of the notice provided to Appellant Nelson regarding the WMB hearing. This issue will be addressed on pages 8 and 9.

The DENR argues that the statutes "need not parrot the statutory language," and in the alternative that DENR substantially complied with the statutes. For this alternative argument, DENR cites *Gridley v. Engelhart*, 322 N.W.2d 3 (S.D. 1982). *Gridley* involved the state soliciting bids for insurance contracts. The notice required for the bid process was defined by statute. The appellant in *Gridley* argued that the state did not comply with the statutory language, which stated, "blank schedules and specifications in detail for bids may be obtained from the bureau of administration." 322 N.W.2d at 6. The appellant, and many other insurance agents, however, were able to obtain copies of the bid proposals and specifications. *Id.* The state Supreme Court also pointed to a statement in the notice that was in bold capital letters, ""THE DIRECTOR OF PURCHASING & PRINTING WILL OPEN IN HIS OFFICE AT PIERRE, SOUTH DAKOTA BIDS ON THE FOLLOWING . . . ." *Id.* The Court explained its holding on the notice issue as follows:

> This information, while not in strict compliance with the statutory language, would put prospective bidders on notice as to where they might obtain additional desired data. There is no showing in this record that anyone, including the appellant, was in any manner restricted or prevented from submitting a bid on these contracts. While there may have been a technical defect in the publication of notice, such deficiency, under the facts of this case, will not invalidate the execution of any subsequent contract. The intent of the legislature in requiring such notice was to give all interested persons an adequate opportunity to obtain the necessary information and allow them to submit a bid. The appellees, while strictly not in compliance with the statute, did carry out the intent of the legislature, and substantially complied with the statute. A technical defect in a notice of advertisement will not serve to invalidate a contract where there has been substantial compliance with such

[4] This citation is incorrect. The correct citation for the intermediate appellate court's ruling in *Smith v. D.R.G., Inc.* is 30 Ill.App.3d 162, 331 N.E.2d 614 (1975). Subsequently, the Illinois Supreme Court reversed that court's decision, and can be found at 63 Ill.2d 31, 344 N.E.2d 468 (1976).

> statute. *Cf. Blood v. Spring Creek Number 12, Common School Dist.*, 78 S.D. 580, 105 N.W.2d 545 (1960). *See also Bud Johnson Const. Co. v. Metro. Tran. Com'n*, 272 N.W.2d 31 (Minn.1978); *Nielsen v. City of Saint Paul*, 252 Minn. 12, 88 N.W.2d 853 (1958); *Royal v. City of Des Moines*, 195 Iowa 23, 191 N.W. 377 (1923); 64 Am.Jur.2d *Public Works and Contracts* §§ 17, 50 (1972); 10 McQuillin, *Municipal Corporations* § 29.65 (3d ed. 1981).

Gridley, 322 N.W.2d at 6.

In its brief, appellee HCD adopts the arguments of the DENR in regard to the notice issues. In the alternative, HCD argues that if there was deficient notice, any error is harmless error. HCD argues that each of the Appellants received actual notice of the permit application, and subsequent hearings. Moreover, HCD argues that if the notices were provided to the satisfaction of the Appellants, the result would not have been any different.

For purposes of analyzing whether the Appellees complied with the various statutory notice requirements, the court finds the *Gridley* case persuasive and relies on this decision in adopting a substantial compliance standard. Whether the appellees substantially complied with the various statutory requirements will be determined in more detail below.

Appellants have pointed out several instances where they believe the notices were deficient, and the court will determine whether the appellees substantially complied in each of those areas. The court is mindful that the language of certain statutory provisions leaves open for interpretation the precise wording that may be used in the actual notices. However, certain provisions of the various statutory notices, in the court's view, leave no room for interpretation. Appellees have not provided any legal authority to support their argument that the Chief Engineer is granted discretion when providing the various statutorily required notices. Failure to follow a specific provision verbatim, however, does not always result in voiding the entire notice. The court agrees that the *method* of providing notice must be strictly complied with, as articulated by *Hein v. Marts.*

The first notice issue involves the newspaper notice required by SDCL § 46-2A-4.[5] That statute relates to SDCL § 46-2A-23,[6] which involves notice to determine opposition to an application or recommendation of the chief engineer. SDCL § 46-2A-23 requires the publication notice to contain subsections (1), (2), (3), (5), (6), and (10) of SDCL § 46-2A-4.

Appellants assert that this notice should have been published in Hanson, Sanborn, Miner, Kingsbury, and Beadle counties. SDCL § 42-2A-4 requires that "the applicant shall publish notice of the application and recommendation at least once a week for two successive weeks in one official newspaper in each county where the water will be diverted or used or project works will be located." There are two official newspapers in Hanson County, the Alexandria Herald and the Emery Enterprise. The water will be diverted in Hanson County, used in Hanson County, and all of the project works will be located in Hanson County. The court finds that the notice required by SDCL §§ 46-2A-4 and 46-2A-23 was published in the proper newspaper for the proper period of time, and that the Findings of Fact on this issue are not clearly erroneous.

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[5] As a reference, SDCL § 46-2A-4 is copied at the end of the court's decision.

[6] As a reference, SDCL § 46-2A-23 is copied at the end of the court's decision.

Additionally, Appellants assert that subsections (10) and (6) were not complied with. The newspaper notice stated in pertinent part:

> In accordance with SDCL 46-2A-23, the Chief Engineer will act on this application, as recommended, unless a petition is filed opposing the application or the applicant files a petition contesting the Chief Engineer's recommendation. If a petition opposing the application or contesting the recommendation is filed, then a hearing will be scheduled and the Water Management Board will consider this application.

Appellants argue that "there was no clear indication to Appellants or the public at large that if no petitions were received from either Appellants or other persons similarly situated in, around or within the aquifer related to the proposed Hanson County Dairy location that 'no hearing may be held before the board.'" *Appellants Brief*, page 11. By reading the above-quoted portion of the newspaper notice, the court finds that the newspaper notice meets the requirement of SDCL § 46-2A-4(10). The notice begins by stating that the Chief Engineer will act on his recommendation unless a petition in opposition is filed. The notice indicates that if a petition opposing the application or contesting the recommendation is filed, then a hearing will be held. The court finds Appellants' argument regarding subsection (10) to be without merit.

As to subsection (6), Appellants argue that the notice is deficient because it does not indicate where copies of the Chief Engineer's recommendation can be obtained. Additionally, Appellants submit that the "notice deficiency should be deemed to have been compounded in its error" because the Chief Engineer's recommendation referred to the incorrect aquifer, the Missouri: Elk Point Aquifer instead of the Floyd East James Aquifer, and the incorrect permit number, no. 7239 instead of no. 7239-3. *Appellants Brief*, footnote 4. The Chief Engineer corrected these two errors at the July 13, 2011 hearing before the WMB. As to where copies of the Chief Engineer's recommendation can be obtained, the newspaper notice provided, "Contact Eric Gronlund at the above Water Rights Program address to request copies of information pertaining to this application." The Water Rights Program's phone number was also included in the notice. SDCL § 46-2A-4(6) requires, "A statement telling where copies of the recommendation, application, or other information may be obtained." While the statute is clear that the notice shall include a statement telling where copies of the recommendation, application, or other information may be obtained, and the DENR did not include the words "recommendation" and "application" within the notice, the court finds that the notice substantially complied with the intent of SDCL 46-2A-4(6). Moreover, the May 9, 2011 notice indicates that copies of the report, recommendation, affidavit of publication, and petition were enclosed.

The next notice issue involves notice of the contested hearing before the WMB, as required by SDCL § 1-26-17.[7] SDCL § 46-2A-23 states in part, "If a petition to contest the recommendation or to oppose the application is timely filed, the chief engineer shall provide notice of a board hearing pursuant to § 1-26-17." The contested hearing notice was sent to Michael Crinion of HCD and Robert Bender on May 9, 2011. Stace Nelson had not intervened as of this date. Appellants argue that SDCL §§ 1-26-17(6) and (7) were not complied with. Subsection (6) requires a statement that the hearing "is an adversary proceeding[.]" The notice letter indicated, "This hearing may be an adversarial proceeding. Any party of record and/or the applicant have the right to be represented by a lawyer and may present evidence or cross-examine witnesses according to SDCL 1-26." Appellants argue

[7] As a reference, SDCL § 1-26-17 is copied at the end of the court's decision.

that the WMB's use of the phrase "may be an adversarial proceeding" was "significantly misleading to them as lay persons," and the error was "magnified given the fact that this contested case hearing, unfortunately, escalated into an extremely adversarial proceeding on July 13, 2011." Appellees argue that the notice was sufficient because the WMB is not sure, at the time the notice was given, whether the hearing will be a hotly contested adversarial hearing, in layman's terms.

The court disagrees with Appellees' assertion that this provision refers to an adversarial hearing in the sense of hostility, or disagreement. The DENR's argument that it re-phrases the statutory requirement set out in subsection (6) because it doesn't know if the meeting will become adversarial is incongruent with the meaning of the statute. The statute refers to "an adversary hearing," not an "adversarial hearing." The court interprets the statute's phrase to mean that the hearing will be one of opponents, with individuals advocating on both sides of the issue, witnesses, and the right to cross-examine those witnesses. Whether the meeting will become hostile or adversarial, is yet to be determined as of the time for noticing the hearing, and is not contemplated by the statute. The court finds, however, that the phrase used in the notice was not significantly misleading, as Appellants suggest. Appellants were notified, pursuant to SDCL § 1-26-17 that they were entitled to have an attorney represent them, and that their due process rights may be forfeited if not exercised at the hearing. The notice substantially complied with the intent of the statute.

Appellants also argue that SDCL § 1-26-17(7) was not complied with when the Chief Engineer made a discretionary determination that this hearing did not involve the termination of any property rights that may have allowed Appellants to utilize the Office of Hearing Examiners. The Chief Engineer made the following determination at the conclusion of his notice letter:

> NOTE: Since this matter does not involve a monetary controversy in excess of $2,500.00 or termination of a property right in accordance with SDCL 1-26-18.3, the Chief Engineer has determined this contested case need not be referred to the Office of Hearing Examiners. If any party disagrees with this determination, the Chief Engineer shall be notified by May 23, 2011.

Appellants argue that they were "arbitrarily and wrongly foreclosed of the prospect of seeking to elect to utilize the Office of Hearing Examiners since they were not fully and specifically apprised of such right as further required by the statutorily mandated provisions of SDCL § 1-26-17(7)." Appellants did not notify the Chief Engineer that they disagreed with this note. It is this court's position that the hearing did not involve a monetary controversy in excess of $2,500.00, nor did it involve termination of a property right. While Appellants may believe their water wells will be depleted, the court finds that the hearing that ultimately resulted in the granting of HCD's water permit did not involve the termination of a property right. The notice substantially complied with the intent of the statute.

As referenced on page 5, Appellant Nelson was not an Intervenor of record until the July 13, 2011 hearing. The board considered his petition and allowed him to intervene even though his petition was received after the deadline. On May 14, 2011 Nelson notified the DENR that he wished to intervene in the permit process. On May 19, 2011, he was notified by the DENR that it would consider his petition to intervene at the July 13, 2011 hearing. In the May 19, 2011 letter, the DENR states, "Attached is the notice to the applicant and Bender scheduling a June 1st hearing." This court can only assume that this notice was attached to Nelson's letter because the May 19, 2011 letter is Bates Stamped WMB22 but the record file from the WMB does not include the May 9, 2011 notice that was sent to Bender. *See* WMB

22 and 23. It is also unclear if the May 19, 2011 notice letter also included the enclosures indicated in the May 9, 2011 notice letter, such as the report, recommendation, affidavit of publication, and petition. DENR attorney Diane Best indicated at the March 23, 2012 oral arguments that the WMB simply did not include the May 9, 2011 letter because it was already contained within the record file a few pages prior to the May 19, 2011 letter. Again, the WMB falls short of precisely following the statutory requirements. The court finds that Appellant Nelson was adequately notified of the July 13, 2011 hearing, and provided the same timely notice of the hearing as Bender. As such, the various findings of fact that relate to Nelson's late intervention and untimely petition are not clearly erroneous. *See* Findings of Fact 11-14.

The court cautions the DENR from straying too far from modifying the statutory language required in the various notice statutes. The court agrees that the DENR is not required to parrot all of the statutory language. Yet, some provisions by their very language do not leave room for interpretation. The court is not going to reverse these proceedings on the notice issues Appellants have asserted, even though the DENR made several mistakes in the various notices. The court finds that the DENR substantially complied with the intent of the various statutorily required notices, and that the Findings of Fact on this issue are not clearly erroneous.

2. *SDCL § 46-6-3.1*[8]

The second issue that the appellants raise in this appeal relates to the first criterion of SDCL § 46-2A-9. A permit may be issued for appropriating water only if the following four criteria are met: "there is reasonable probability that there is unappropriated water available for the applicant's proposed use, that the proposed diversion can be developed without unlawful impairment of existing rights and that the proposed use is a beneficial use and in the public interest." SDCL § 46-2A-9. For the purposes of that requirement, the DENR must determine, pursuant to SDCL § 46-6-3.1, if it is probable that the quantity of water withdrawn annually from the groundwater source (that HCD will draw water from) will exceed the quantity of the average estimated annual recharge of water to the groundwater source. Two Findings of Fact address this issue: Finding of Fact 33, which states, "Average annual recharge to the Floyd East James aquifer has not been quantified for the aquifer," and Finding of Fact 37, which states, "The Chief Engineer reviewed the best information reasonably available to determine whether the proposed use would exceed the annual recharge rate of the Floyd East James aquifer, pursuant to SDCL § 46-6-3.1." Moreover, Conclusions of Law 16 through 22 pertain to this issue as well:

> 16. Consideration of water availability also includes consideration of the criteria in SDCL § 46-6-3.1 pertaining to recharge/withdrawal: whether "according to the best information reasonably available, it is probable that the quantity of water withdrawn annually from a groundwater source will exceed

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[8] SDCL 46-6-3.1 states,

> No application to appropriate groundwater may be approved if, according to the best information reasonably available, it is probable that the quantity of water withdrawn annually from a groundwater source will exceed the quantity of the average estimated annual recharge of water to the groundwater source. An application may be approved, however, for withdrawals of groundwater from any groundwater formation older than or stratigraphically lower than the greenhorn formation in excess of the average estimated annual recharge for use by water distribution systems.

the quantity of the average annual recharge of water to the groundwater source." *SDCL § 46-6-3.1.*

17. Although there is an exception to the recharge/withdrawal consideration in SDCL § 46-6-3.1, it applies only to applications filed by water distributions systems and is not applicable here.

18. The DENR and the Chief Engineer have considered the best information reasonably available, and it is not probable that the quantity of water withdrawn annually from the Floyd East James aquifer will exceed the quantity of the average annual recharge of water to said aquifer.

19. Annual recharge to the Floyd East James aquifer has not been and is not likely to be quantified in the near future. The Floyd East James aquifer is a confined aquifer. The criteria of SDCL § 46-6-3.1 can be fulfilled by analysis of the observation well data and irrigation pumping records.

20. Water levels for these two observation wells show good response to climatic conditions, i.e., rising water levels during wet years (recharge) and gradually declining water levels during dry years due to natural discharge and pumping. The water level record of these two observation wells indicate that the Floyd East James aquifer is capable of sustaining additional withdrawals.

21. In general, the hydrographs of the two observation wells show that, over the period of record, withdrawals have not exceeded recharge of the Floyd East James aquifer.

22. Given the foregoing Findings of Fact and Conclusions of Law, the Board concludes that there is sufficient water available for the proposed water use.

Appellants argue that since the average estimated annual recharge of water to the aquifer was never calculated, "WMB was lacking in sufficient factual evidence from which to make the required findings under the statutory criteria as required under SDCL § 46-6-3.1." *Appellants Brief*, page 17. Appellants cite *In the Matter of Permit No. 4300-3*, 295 N.W.2d 743 (S.D. 1980), which is the only Supreme Court of South Dakota case that has reviewed SDCL § 46-6-3.1. The recharge of the aquifer in that case was also unknown. *Id.* at 746. The Court explained, "SDCL 46-6-3.1 precludes the Board from allowing the quantity of water withdrawn annually from a ground water source to exceed the quantity of the 'average estimated annual recharge of water to the ground water.'" *Id.* The Court, however, determined that the exception contained in SDCL § 46-6-3.1 was applicable. The exception states, "An application may be approved, however, for withdrawals of groundwater from any groundwater formation older than or stratigraphically lower than the greenhorn formation in excess of the average estimated annual recharge for use by water distribution systems." SDCL § 46-6-3.1. All parties seem to agree that the exception contained in SDCL § 46-6-3.1 does not apply because HCD is not a water distribution system as defined by SDCL § 46-1-6(17).[9] The Court concluded its discussion of this issue by explaining, "We therefore concur with the trial court's conclusion that the Board need not have made a determination regarding the rate of annual recharge because SDCL 46-6-3.1 vests the Commission with authority to

[9] SDCL §46-1-6(17) states,

> "Water distribution system," a system of piping, valves, storage tanks, pumps, and appurtenances by which water is conveyed for domestic or municipal use by a common distribution system, including a municipality as defined in § 9-1-1, a nonprofit rural water supply company as defined in § 10-36A-1, a water user district as defined in § 46A-9-2, a sanitary district as defined in chapter 34A-5, or homes, including mobile homes as defined in § 32-3-1, and manufactured homes as defined in § 34-34A-1.1 supplied by a common distribution system[.]

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grant the permit notwithstanding that withdrawal may exceed the average estimated annual recharge."

This court's interpretation of the Court's decision in the above case is that the WMB must make a determination regarding the rate of annual recharge, unless the exception applies. Here, the exception does not apply; therefore the WMB must make that determination. Regarding this issue, the WMB based its decision on a four-page report from Hayes Hass, Natural Resources Engineer. In the report, Haas discusses the general characteristics of the aquifer, highlights observation well data (hydrographs), and reviews existing water permits/rights/water use. *Report on Water Permit Application No. 7239-3*, WMB 7-10. Haas explains that the Water Rights Program monitors two observation wells that are within two miles of the proposed HCD wells. He notes that the water levels show rising levels during wet years and declining levels during dry years. He states, "The water level record indicates that the aquifer is capable of sustaining additional withdrawals (Water Rights, 2011)." Regarding the hydrographs, which show various water levels from August 1979 to more recent levels, Haas indicates, "In general, the hydrographs show that over the period of record, withdrawals have not exceeded recharge." As to existing water permits/rights/use, Haas states, "Water levels do fluctuate as a result of area pumping but this does not affect the availability of water from the aquifer." Finally, Haas explains in a section entitled "Recharge":

> Recharge to the Floyd East James aquifer in Hanson County is from the underlying Sioux Quartzite which is recharged by precipitation on outcrops in central Hanson County and by leakage from the till (Hansen, 1983). Direct recharge to the Floyd East James in this area probably occurs in McCook County and flows west-northwest into this area (Hansen, 1983). Average annual recharge to the aquifer has not been quantified for the aquifer.

Id. at 10. At the July 13, 2011 hearing, the following colloquy took place between Nelson and Haas:

> Q. But as far as estimations from this petition as far as how accurately or as far as an estimated appraisal on the actual drawdown that will result from this pumping, you don't have any type of estimations in your reports on that, correct?
> A. Correct.
> Q. Do you have the capabilities to provide that information?
> A. Yes.
> Q. So would you qualify that information as being reasonably available, since it's at your disposal?
> A. Could you rephrase that?
> Q. The estimations you said that you have come up with as far as the drawdown from this type of well on the aquifer, you indicated you could provide that information. Would you qualify that as being reasonably available to you, then, since you can come up with those calculations?
> A. Yes.

WMB July 13, 2011 hearing, P 48, L11 – P 49, L 3. Appellees rely on Haas's report, and the WMB's Findings of Fact and Conclusions of Law in arguing that the requirements of SDCL § 46-6-3.1 were met.

When read in the affirmative, SDCL § 46-6-3.1 requires the determination to be made that it is probable that the average estimated annual withdrawal of water from the groundwater source will not exceed the average estimated annual recharge of water to the groundwater source. In an in-depth law review article published in 1995, longtime Professor John Davidson of the University of South Dakota School of Law explained how groundwater is managed under South Dakota law:

> Groundwater managers refer to two concepts for calculating the potential yield of an aquifer. The first concept is the mining yield, which occurs when "groundwater is withdrawn at a rate exceeding the recharge." The second concept is perennial yield, which is "the rate at which water can be withdrawn perennially under specified operating conditions" without leading to adverse conditions. The determination of perennial yield requires accurate predictions of future pumping costs and discount rates as well as detailed knowledge of the underground (and invisible) aquifer. The obvious complexity of calculating a safe perennial yield makes it a daunting task.
>
> South Dakota's approach is both bold and conservative; bold because it sets the State apart from its western cousins, and conservative because it places preservation of groundwater ahead of short-term exploitation.
>
> ***
>
> The statute does not allow the WMB to grant a permit which will result in mining of groundwater aquifers. Recognizing the scientific uncertainty in every case to which the no-mining statute applies, the standard is that when it is "probable" mining will occur, no permit may be issued. This standard mandates the WMB err on the side of the no-mining rule.

Davidson, *South Dakota Groundwater Protection Law*, 40 S.D.L.Rev. 1, 23-24 (1995) (citing David K. Todd, *Groundwater Hydrology* 7-13, 363-4 (2d ed. 1980); Jeff Masten, *Current Issues in South Dakota Water Rights Litigation*, in South Dakota Water Law 3 -11, 3 -13 (State Bar of S.D. Comm. on Continuing Legal Educ. eds., 1980)).[10]

First, the court finds a contradiction in the WMB's Findings of Fact and Conclusions of Law relating to this issue. Finding of Fact 33 and Conclusion of Law 19 pertain to a similar subject matter. Finding of Fact 33 states, "Average annual recharge to the Floyd East James aquifer has not been quantified for the aquifer." Conclusion of Law 19 states in part, "Annual recharge to the Floyd East James aquifer has not been and is not likely to be quantified in the near future." The court considers Finding of Fact 33 and Conclusion of Law 19 to be contradictory to Conclusion of Law 18, which states, "The DENR and the Chief Engineer have considered the best information reasonably available, and it is not probable that the quantity of water withdrawn annually from the Floyd East James aquifer will exceed the quantity of the average annual recharge of water to said aquifer." The court finds these two conclusions to be inconsistent with one another. It seems contradictory to assert that it is not probable that the water withdrawn annually will exceed the average annual recharge without ever calculating the annual recharge or the average annual recharge. Attorney Best indicated that a recharge study could be done, but that the statute does not require it. She

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[10] Davidson explains the potential pitfalls of inadequate recharges to an aquifer:

> Typically, groundwater is pumped at a greater rate during the summer and fall, especially in areas practicing agricultural irrigation. During such periods, aquifer levels fall below normal. Ideally, aquifers will naturally recharge during the annual hydrologic cycle and return to their normal level before the next pumping season. However, aquifers are often times exploited at rates which exceed recharge capacity. Such pumping has the potential to lead to adverse conditions including: "(1) progressive reduction of the water resource; (2) development of uneconomic pumping conditions; (3) degradation of groundwater quality; (4) interference with prior water rights; or (5) land subsidence caused by lower groundwater levels."

40 S.D.L.Rev. at 23 (citing Todd, *Groundwater Hydrology 7-13*, 363-4). HCD's application seeks a permit for year-round usage.

explained that such a study would cost thousands of dollars. Interestingly, Best indicated at the July 13, 2011 hearing that some water permit applications include recharge studies as part of the process. July 13, 2011 hearing transcript, P 13, L 24-25. While there may be some other way to satisfy the statute, it is the court's view that the above-referenced conclusions are inconsistent with one another. Moreover, the 720,000 gallons per day that HCD is proposing it will use did not seem to be considered in this determination. The court finds this inconsistency calls into question the validity of the WMB's determinations regarding the first criterion of SDCL §§ 46-2A-9 and 46-6-3.1.

The court finds it perplexing that the board chose to analyze observation well data, almost exclusively, to satisfy the requirement set out in SDCL § 46-6-3.1. Engineer Haas largely based his report on the two hydrographs from the observation wells. His statement in his report is that "over the period of record, withdrawals have not exceeded recharge." It appears that Haas determined this by comparing the water level at the far right side of the hydrograph (the date is not listed, but appears to be around 2010), to the water level at the far left side of the hydrograph (measured on August 12, 1979). On both hydrographs, for observation wells HS-79D and HS-79E, the point on the right is slightly higher than the point on the left.[11] The WMB included this observation in Conclusion of Law 21. What the hydrographs do not show, and what Haas's report does not contain is whether it is probable that the quantity of water withdrawn *annually* from a groundwater source will exceed the quantity of the average estimated *annual* recharge of water to the groundwater source, as required by SDCL § 46-6-3.1. The court holds that simply looking at two hydrographs that contain three decades' worth of observations, and comparing the beginning observation with the last observation does not approach the requirements of SDCL § 46-6-3.1.

The court finds that Haas's observations of the hydrographs are not what SDCL § 46-6-3.1 contemplates when it refers to the quantity of water withdrawn annually compared to the quantity of average estimated annual recharge. The statute requires the two average annual quantities to be compared. Moreover, the inadequacy of Haas's report is exacerbated by the fact that no annual recharge of the aquifer has been quantified nor is it likely to be quantified in the near future. WMB Conclusion of Law 19. The board's conclusion that SDCL § 46-6-3.1 "can be fulfilled by analysis of the observation well data and irrigation pumping records" flies in the face of the statute requiring a comparison between the estimated annual withdraw and average estimated annual recharge of water. The court is aware that historic data is part of the information that may be considered when comparing the withdraw/recharge estimations, but that is not the sole piece of information reasonably available to form the basis for the requirement of SDCL § 46-6-3.1. Haas testified that he did not consider the drawdown that will occur with HCD's pumping. WMB July 13, 2011 hearing, P 48, L 11-16. SDCL § 46-6-3.1, however, requires a comparison between the annual withdraw and the annual recharge. The court finds that the statute necessarily requires not only analyzing existing, and historic drawdown and recharge to the aquifer, but also how the applicant's drawdowns will affect the recharge to the aquifer.

The board's Conclusion of Law 20 fails to relate in any meaningful way to the requirements of SDCL § 46-6-3.1. This conclusion states that water levels from the observation wells indicate declining levels during dry years and recharges during wet years.

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[11] It seems apparent, specifically from the closer of the two wells to the HCD site (HS-79E), that the recharge did not always bring the water level back to where it was the year before. From around 1995 to the early 2000s, the water level steadily decreased, before increasing from 2006 to the end of the hydrograph. This is probably reflecting the various years of drought experienced throughout parts of South Dakota.

This may be a fair statement for any well, in any part of South Dakota. The WMB concludes that the groundwater source is "capable of sustaining additional withdrawals." The board's conclusion, based on Haas's report, does not appropriately take into account, nor even estimate, the effect that HCD's use of 720,000 gallons of water per day will have on the annual recharge of the aquifer.

Appellees restate Haas's conclusions and argue that the WMB utilized the best information reasonably available. Therefore, Appellees argue, the WMB's findings and conclusions are not clearly erroneous. Appellee HCD filed a post-hearing brief, which contained a number of calculations. HCD comes to the conclusion that HCD's use of water per year represents 3.32% of the average acre feet of water per year of irrigation appropriations. It asserts that this is not a substantial proposed increase in the appropriations already being made to the Floyd East James aquifer. It is the court's opinion that this calculation does not address the requirements of SDCL § 46-6-3.1.

The court holds that the board did not satisfy the requirements of SDCL § 46-6-3.1, and that the Findings of Fact and Conclusions of Law on this issue are clearly erroneous. On this basis, the court reverses the WMB's decision and remands the water permit application back to the WMB for proceedings consistent with this court's decision.

3. Secretary Bones Testimony

Lastly, Appellants argue that the testimony given by South Dakota Department of Agriculture Secretary Walt Bones was improper. The WMB did not make a credibility determination concerning Bones, but did make such a determination for others that testified. *See Findings of Fact* 35 and 36. According to Appellants, since no credibility determination was made, reliance on Bones's testimony was "unsupported" and should be stricken from the record. Moreover, Appellants argue that Bones's testimony presented a conflict of interest. Appellants cite *Hanig v. City of Winner*, 2005 SD 10, ¶ 15, 692 N.W.2d 202, 207 (citing *Speckels v. Baldwin*, 512 N.W.2d 171, 175), for this argument. Appellants acknowledge the distinctions between this case and those cited above, chief among them is that "the primary thrust of the arguments behind such significant conflict of interest authority is in the realm of disinterested decision-makers in administrative hearing matters[.]" *Appellants brief*, page 22. Nonetheless, Appellants want this court to hold those arguments similarly applicable in this case. Such a leap this court is not willing to make. *Hanig* involved a city councilwoman's indirect pecuniary interest in a matter before the council. *Speckels* also involved a city officer having a personal interest in a city matter. Both were held to involve conflicts of interest. That is simply not the case here. One of the components of granting a water permit is the public interest involved in the granting of the permit. Secretary Bones testified from his personal and professional experiences to the public interest that would be served by such a dairy operation. He provided a number of financial benefits such an operation may have on the community specifically and the state in general. *See Conclusions of Law* 46-48. Appellants fail to cite any authority for the argument that the WMB must make a determination as to a witness's credibility, and any failure to do so means such testimony should be stricken. The court holds that the arguments set forth by Appellants in issue three are without merit. The WMB did not commit error when it considered Bones's testimony.

For all the reasons set forth above pertaining to Issue 2, this matter is remanded back to the WMB for proceedings consistent with this decision. Therefore, HCD's request for costs is denied. The parties may prepare Findings of Fact and Conclusions of Law, and Mr.

Tornow shall prepare Findings of Fact and Conclusions of Law, and an order consistent with this court's decision.

Sincerely,

Hon. Sean M. O'Brien
Circuit Court Judge

SDCL 46-2A-4 states,

> Except in the case of an application for a well driller license or a well pump installer license, if a recommendation is to approve or defer an application or if an applicant has filed a petition to oppose a recommendation to deny an application, the applicant shall publish notice of the application and recommendation at least once a week for two successive weeks in one official newspaper in each county where the water will be diverted or used or project works will be located. The official newspaper shall be selected by the chief engineer and shall be a newspaper designated as an official newspaper pursuant to § 7-18-3. The second publication shall be at least twenty days before the first day of the Water Management Board meeting at which the matter is noticed to be heard. No application for a permit, license, or amendment may be considered and approved by the board until proof of all required publications has been filed with the chief engineer. The notice, which shall be provided by the chief engineer to the applicable newspapers, shall include the following, as applicable:
>
> (1) The name and address of the applicant;
>
> (2) A brief description of the project, including, where applicable, the proposed place or places of use of the water or facilities, including the point of diversion, the amount of water to be used and the purpose for which the water or facility is to be used;
>
> (3) A brief statement describing the recommendation and the reasons for the recommendation;
>
> (4) A statement that any interested person who intends to participate in the hearing shall file a petition to oppose or support the application and that the petition shall be filed with the chief engineer and applicant at least ten days before the published date for hearing;
>
> (5) A statement that a petition to oppose or support an application may be informal, but shall be in writing and shall contain the following:
>
> (a) A statement describing the petitioner's interest in the application;
>
> (b) The reasons for the petitioner's opposition to or support for the application; and
>
> (c) The signature and mailing address of the petitioner or the petitioner's legal counsel;
>
> (6) A statement telling where copies of the recommendation, application, or other information may be obtained;
>
> (7) The time when and the place where the application will be considered by the board;
>
> (8) A statement that the recommendation of the chief engineer is not final or binding upon the board and is subject to the approval of the board after it reaches a conclusion based on facts at the public hearing;
>
> (9) A statement that the time of hearing will be automatically extended for at least twenty days upon written request of the applicant or any person who has filed a petition to oppose or support the application and a statement that any such request by the applicant or person filing a petition shall be made at least ten days before the published date for hearing; and

(10) A statement that if the applicant does not contest the recommendation of the chief engineer and no petition to oppose the application is received, the chief engineer shall act on the application pursuant to the chief engineer's recommendation and no hearing may be held before the board, unless the chief engineer makes a finding that an application, even if uncontested, presents important issues of public policy or public interest that should be heard by the board.

SDCL 46-2A-23 states,

Following the issuance of a recommendation to approve an application pursuant to § 46-2A-2, the chief engineer may publish, at the expense of the applicant, a notice to determine whether any person opposes the application or recommendation of the chief engineer. The notice shall be published as provided for in § 46-2A-4, and the notice shall contain the information provided for in subdivisions 46-2A-4(1), (2), (3), (5), (6), and (10). The notice is not required to refer to a board meeting or hearing date. In addition, the notice shall include a statement that if the applicant intends to contest the recommendation, the applicant shall file a petition with the chief engineer, and any interested person who intends to oppose or support the application or recommendation shall file a petition with the chief engineer and the applicant. Any petition shall be filed within ten days of the second published notice.

If no petition to contest the recommendation or to oppose an application is timely filed, the chief engineer, following receipt of proof of publication, shall act on the application consistent with the chief engineer's recommendation as provided by rules promulgated by the Water Management Board pursuant to chapter 1-26 delegating authority to the chief engineer to issue uncontested permits pursuant to §§ 46-1-16 and 46-2-3.1, without hearing by the board.

If a petition to contest the recommendation or to oppose the application is timely filed, the chief engineer shall provide notice of a board hearing pursuant to § 1-26-17. The notice shall also include a statement that the recommendation of the chief engineer is not final or binding upon the board and is subject to the decision of the board based on evidence and record of the public hearing. A statement shall also be included in the notice that the applicant or any interested person who has filed a petition to oppose or support an application, may file a written notice with the chief engineer requesting postponement of the original hearing date. The written notice requesting postponement shall be filed within twenty days of the date of the notice scheduling the board hearing, but not less than ten days before the date the application is scheduled for hearing. Upon timely receipt of a written notice, the chief engineer shall cancel the original hearing and reschedule the hearing not less than twenty days after the original hearing date. Notice of hearing shall be provided by personal service or by first class mail to the applicant and parties of record.

SDCL 1-26-17 states,

The notice shall include:

(1) A statement of the time, place, and nature of the hearing;

(2) A statement of the legal authority and jurisdiction under which the hearing is to be held;

(3) A reference to the particular sections of the statutes and rules involved;
(4) A short and plain statement of the matters asserted. If the agency or other party is unable to state the matters in detail at the time the notice is served, the initial notice may be limited to a statement of the issues involved. Thereafter upon application a more definite and detailed statement shall be furnished;
(5) A statement of any action authorized by law, which may affect the parties, as a result of any decision made at the hearing, whether it be the revocation of a license, the assessment of a fine or other effect;
(6) A statement that the hearing is an adversary proceeding and that a party has the right at the hearing, to be present, to be represented by a lawyer, and that these and other due process rights will be forfeited if they are not exercised at the hearing;
(7) Except in contested cases before the Public Utilities Commission, a statement that if the amount in controversy exceeds two thousand five hundred dollars or if a property right may be terminated, any party to the contested case may require the agency to use the Office of Hearing Examiners by giving notice of the request to the agency no later than ten days after service of a notice of hearing issued pursuant to § 1-26-17;
(8) A statement that the decision based on the hearing may be appealed to the circuit court and the State Supreme Court as provided by law.

EXHIBIT 202

STATE OF SOUTH DAKOTA) IN CIRCUIT COURT
:SS
COUNTY OF HANSON) FIRST JUDICIAL CIRCUIT

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* *

IN THE MATTER OF WATER PERMIT APPLICATION NO. 7239-3, by HANSON COUNTY DAIRY,
Appellee,

vs.

ROBERT BENDER and STACE NELSON,
Appellants.

CIV. NO. 11-54

FILED
MAY 10 2012
Ramona Schroeder
Hanson County Clerk of Courts
First Judicial Circuit Court of SD

ORDER OF REVERSAL AND REMAND FOR REHEARING

* *

This Court having issued its Findings of Fact and Conclusions of Law, therefore, it is:

ORDERED that the water permit granted to HCD by and through the WMB's final decision and order as served on the parties on October 7, 2011, is hereby reversed and HCD's water permit application is remanded back for further proceedings consistent with the Court's decision herein; and, it is further

ORDERED that neither of Appellees are entitled to a recovery of costs pursuant to SDCL §1-26-36 and/or SDCL §15-17-37.

Dated this 9th day of May, 2012.

BY THE COURT:

[signature]
Honorable Sean O'Brien
Circuit Court Judge, First Judicial Circuit

ATTEST:
Ramona Schroeder, Clerk
By Ramona Schroeder

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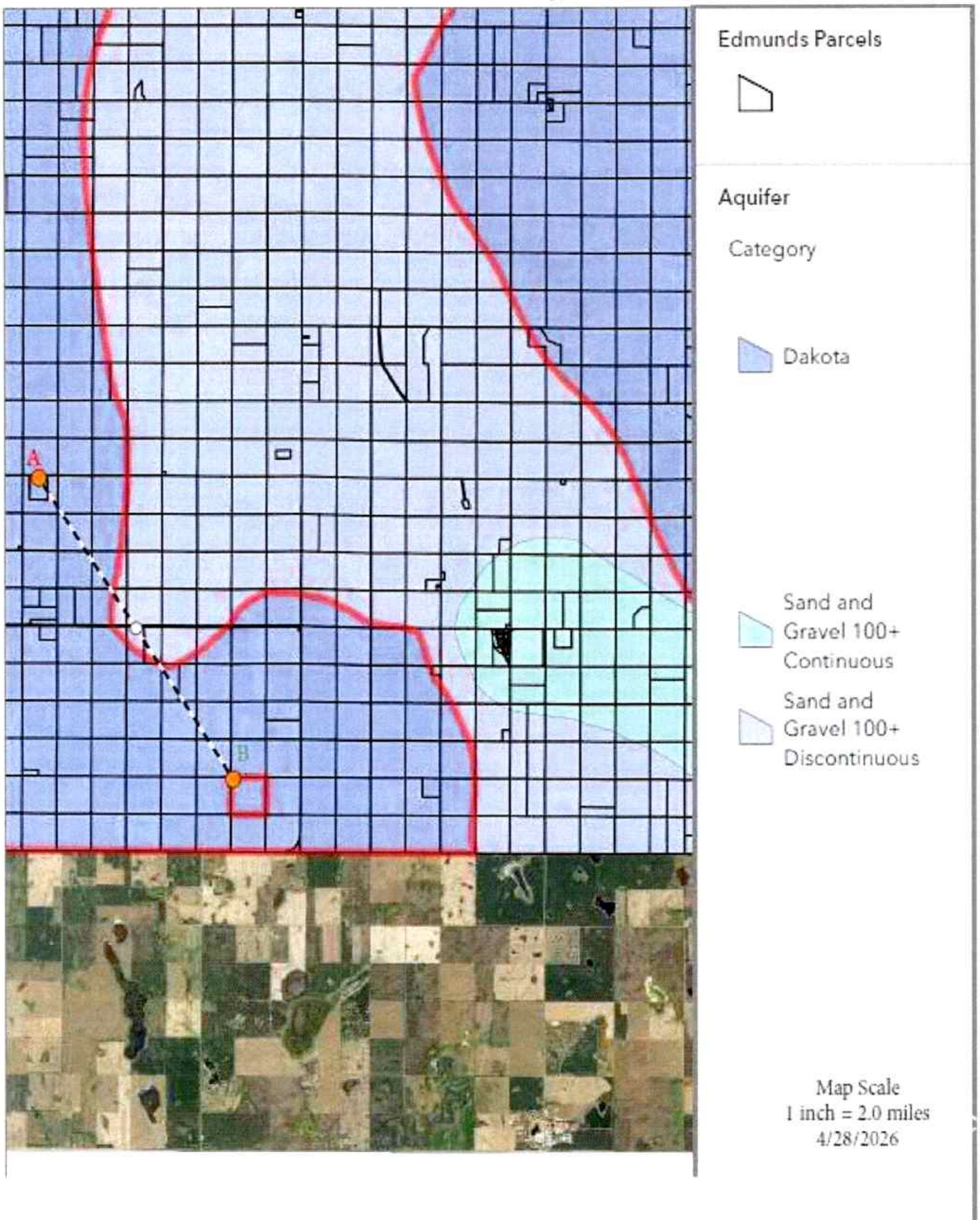
EXHIBIT
203

Edmunds County, SD



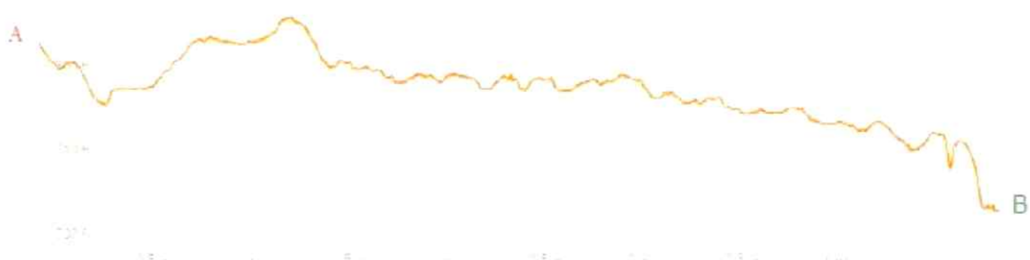


EXHIBIT
204

DECLARATION OF THIELE R. DUNAWAY IN SUPPORT OF PETITIONERS GARETT HEINZ, CINDY HEINZ AND LARRY HEINZ REGARDING WATER PERMIT APPLICATION 8982-3

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I, Thiele R. Dunaway, declare and state:

1. I make this declaration pursuant to SDCL 18-7-4.1, and I submit it in support of Petitioners Garett Heinz, Cindy Heinz and Larry Heinz ("Petitioners") in the matter pending before the Water Management Board ("Board") of the State of South Dakota Department of Agriculture and Natural Resources ("DANR") concerning Century Swine RE, LLC's Water Permit Application No. 8982-3 ("Permit Application"). I am not able to attend the hearing on the Permit Application on May 6, 2026, in person as I am currently living in California and preparing for my move back to my farm in Edmunds County, South Dakota in June. I am available to attend the hearing remotely through Zoom or a similar electronic appearance, but I am unaware of any such option at this time.

2. I have personal knowledge of the matters set forth herein and if called as a witness could and would competently testify thereto.

3. I own real property located in Section 24, Township 122 North, Range 72 West in Edmunds County, South Dakota ("Property"). Based on my review of a plat map and the information contained in the Permit Application, my Property is within a very few miles of the well proposed in the Permit Application to be located in Section 9, Township 121 North, Range 71 West in Edmunds County.

4. My Property has been in my family since the early 1900's. My mother was born there in 1920, was one of the younger of nine children, and during her youth she lived there with her parents and siblings who all worked on the farm, raising crops and livestock. After my grandparents died in the 1950's, two of my mother's brothers remained on the Property and continued farming the land, including raising crops and grazing cattle there. Since they moved onto that Property, my family has always relied on their well for all of their domestic water needs, and it has never been used for irrigation purposes. In the early years, they used a

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windmill and a hand-pump to draw water from the well. In later years, my uncle installed an electric pump.

5. When I was growing up, I spent all of my summers on the Property or on my mother's sister's property located directly west of, and adjacent to, the Property. When my remaining uncle decided to retire from farming, I bought the Property from him. I rented the land to my cousin (my mother's oldest brother's son) who lived on a nearby farm, and he continued to raise crops and graze livestock on the Property, using water from the well for the livestock. I continued to use the well for household purposes. When that cousin retired, another cousin of mine began farming the Property and continues to do so currently.

6. In 2001, the existing well on the Property, which had been in use my entire lifetime up to that point, began having trouble producing sufficient water for my household use. Consequently, I had a new well drilled that year by Huron Drilling, Inc. That well was drilled to a depth of 420 feet, and a well driller's report was filed with the Department of Environment and Natural Resources shortly after the well was completed. Since that new well has been in operation, I have always had sufficient water from that well to meet all of my reasonable domestic uses, including both household uses and watering livestock. Based on the well driller's report and other drilling information, it is my understanding that as constructed, my well is an adequate well within the meaning of ARSD 74:02:04:20(6).

7. My Property does not have a connection to rural water such as WEB Water, and, as a recent retiree on a fixed income, I have no intention of ever getting such a connection as it would be cost prohibitive. I rely solely on my existing well for all of my domestic water needs. When I move back to the Property in June 2026, I will be bringing my three horses and two dogs, so having a reliable, uninterrupted water source is imperative for the health and welfare of me and my animals.

8. Having reviewed the Permit Application and the Report to the Chief Engineer On Water Permit Application No. 8982-3, Century Swine RE, LLC, dated November 18, 2025 ("Engineer's Report" or "Report"), I am very concerned that applicant Century Swine RE,

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LLC's ("Applicant") proposed well and drawdown will have an adverse and unlawful impact on my senior water rights and will result in depriving me of the water I need for my domestic uses. This is particularly true given that the proposed well is so close to mine, and it is drilled to the exact same depth as mine—420 feet. SDCL 46-6-3.1 provides that "No application to appropriate groundwater may be approved if . . . it is probable that the quantity of water withdrawn annually from a groundwater source will exceed the quantity of the average estimated annual recharge of water to the groundwater source." However, neither the Application nor the Report provide any evidence to support a conclusion that the Applicant's proposed well will not exceed the estimated annual recharge of water. Rather, the Engineer's Report states:

> Given the **lack of information on recharge** for deeper and more eastern parts of the Pierre Shale aquifer in South Dakota, and the **lack of well monitoring data in Edmunds County** completed into the Pierre Shale, **determining the recharge estimate is difficult without extensive further study**.

(Report, p. 5 [emphasis added].) However, despite the admission that critical data with respect to recharge is not available, and the fact that a determination based on actual evidence cannot be made as to whether the quantity of water proposed by the Applicant to be withdrawn annually from the aquifer will not exceed the estimated average annual recharge of the aquifer—as required under South Dakota law—the Report recommends approval of the Application.

9. A U.S. Geological Survey report on the Water Resources of Mellette and Todd Counties, South Dakota (1998) [Water Resources Investigations Report 98-4146] ("USGS Report") states that the Pierre Shale aquifer is a bedrock aquifer, and that yields from it are from 1 to 8 gallons per minute. (*See* USGS Report, p. 38.) A true and correct copy of that USGS Report is attached hereto as Exhibit A and is incorporated herein by this reference.) The USGS Report further states that "Recharge to the Pierre Shale aquifer primarily is by infiltration of precipitation on the outcrops of the Pierre Shale. . . . The greatest recharge to the aquifer occurs during the spring after snowmelt and during storms events. Infiltration rates generally are less

than the lowest rate (0.06 inches/hour) measured by the U.S. Soil Conservation Services (1974, 1975)." (USGS Report, p. 42.) Given this information about the limited recharge rate of the Pierre Shale aquifer, it is all the more important that adequate data on recharge be obtained, reviewed and considered in connection with this water Permit Application, and certainly before any permit is approved.

10. SDCL 46-2A-9 provides that "[a] permit to appropriate water may only be issued if there is a reasonable probability that unappropriated water is available for the applicant's proposed use . . . ." However, the Report *admits* that "[t]here are domestic wells completed into the Pierre Shale aquifer that do not require a water permit/right, so the "withdrawal amount from those wells **is unknown**." (Report, p. 5 [emphasis added].) The Report has absolutely no evidentiary basis to conclude that "there is a reasonable probability unappropriated water is available" when the Report itself states that withdrawal from the Pierre Shale aquifer is "unknown." The Report tries to ignore this lack of evidence by speculating that "[d]ue to their relatively low diversion rates, withdrawals from domestic wells are generally not considered to be a significant portion of the hydrologic budget." (Report, p. 5.) However, the Report is relying on "generalities" or speculation as to what may/may not be happening in water drawdowns in this area. The Report goes on to speculate that "[a]t those distances, it is **likely** that sufficient water is available locally to supply this application and the existing domestic wells." (Report, p. 6.) Yet the Report states that the nearest domestic well on file is 2.2 miles away. The Report then ignores any potential impact the Applicant's proposed well may have on nearby domestic wells and instead states that "[b]cause these domestic wells have operated for many years without reported issues and given the relatively limited volume requested by this application, localized pumping from the Pierre Shale is not expected to substantially affect aquifer conditions or water availability." (Report, p. 6.) However, this is purely speculative as to what future impact Applicant's well will have. The Applicant wants to pump 10 million gallons at a rate of 25 gallons per minute. The Report lacks critical baseline data and

information and has no evidentiary basis for the Report's conclusion that Applicant's proposed well would not substantially and adversely impact existing domestic wells.

11. The Report admits that there is no observation well in the Pierre Share aquifer. (Report, p. 6.) In other words, the DANR has **no actual idea of the water demands of domestic wells in the vicinity of the Applicant's well**. Rather than deal with this issue as it may impact domestic wells closest to the Applicant's well, the Report instead discusses the four permitted wells that are 54 miles, 86 miles, and 198 miles from Applicant's well. (Report, pp. 6-7.) The Report relies on the "low transmissivity" of the Pierre Shale aquifer purportedly to show no purported impact on the four permitted wells. However, the Report essentially disregards the impact on domestic wells within 2.2, 5, 10, and 20, etc. miles of Applicant's well, one of which is my well. With "low transmissivity," there may be no impact on wells a hundred miles away, but what about those in close proximity? The Report should certainly address the impacts of the Applicant's well on nearby local domestic wells, but it does not. It mentions the closest domestic wells *on file* (2.2 miles, 5.3 miles, 6.3 miles), and states, without support, that "it is likely that sufficient water is available locally." (Report, p. 6.) Despite admitting that it does not know how many domestic wells may be operating near the Applicant's site and drawing water from the Pierre Shale aquifer (*i.e.*, existing wells that may not be "on file"), the Report "concludes" that the "estimated average annual withdrawal rate from the Pierre Shale aquifer is approximately 272 acre-feet per year" and that "there is a reasonable probability unappropriated water is available from the Pierre Shale aquifer." (Report, p. 6.) Despite the lack of evidence to support it, the Report concludes that "[b]ased on the small amount of water appropriated out of the Pierre Shale aquifer and the low diversion requested in the application, there is a reasonable probability unappropriated water is available from the Pierre Shale aquifer." (Report, p. 9.)

12. SDCL 46-2A-9 also provides that "[a] permit to appropriate water may only be issued if . . . the proposed diversion can be developed without unlawful impairment of existing domestic water uses and water rights . . . ." However, as noted above, the Report admits that there is **no** observation well in the Pierre Share aquifer. (Report, p. 6.) Without having baseline

data, the DANR has no actual idea of the water demands of domestic wells in the vicinity of the Applicant's well, or how the Applicant's requested drawdown will affect those domestic users.

13. The Report "recommend[s] that an observation well be installed to monitor drawdown for potential unlawful impairment." (Report, p. 8.) But even that is only a recommendation, and not a condition, requirement or qualification of approving the Permit Application. Absent making one or more observation wells a condition of approval, there is absolutely no protection afforded to existing domestic well users. If the Permit Application is approved and the Applicant begins its pumping, when I go out to my hydrant to water my horses and no water comes out, the damage to me and my Property has been done.

14. The Applicant has not met its burden of showing that its proposed water Permit Application would not exceed the annual recharge rate of the Pierre Shale aquifer. Nor has the Applicant met its burden of establishing that there is a reasonable probability that unappropriated water is available for Applicant's use and that the proposed diversion can be made without unlawful impairment of existing domestic water uses and water rights.

15. I ask the Board to protect the water rights of all of the domestic users in the area by taking the following action:

(a) Deny this Permit Application, because the statutory requirements have not been met by the Applicant, as there is no evidence to support findings that Applicant's proposed well drawdowns would not exceed the annual recharge rate of the Pierre Shale aquifer, that there is a reasonable probability that unappropriated water is available for Applicant's use, and that the proposed diversion can be made without unlawful impairment of existing domestic water uses and water rights; or

(b) If the Board is inclined to approve the Permit Application, that the Board defer approval of the Application and order that one or more observation wells be drilled in the vicinity of Applicant's well, and that those observation wells be operational for not less than two years before the Board reconsiders the Application, based on data accumulated from the observation wells; or

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(c) If the Board chooses not to defer approval and approves this Permit Application now, that in addition to ordering the qualifications recommended by the Engineer's Report, the Board also order that one or more observation wells be completed in the area to allow monitoring of water levels to aid in determining the effects pumping has on area domestic wells and to monitor drawdowns and recharge for potential unlawful impairment of existing water rights.

I declare under penalty of perjury under the laws of the State of South Dakota that the foregoing is true and correct. Signed on this 28th day of April, 2026, at El Cerrito, California.

Thiele R. Dunaway

7254 Cutting Boulevard
El Cerrito, California 94530

USGS

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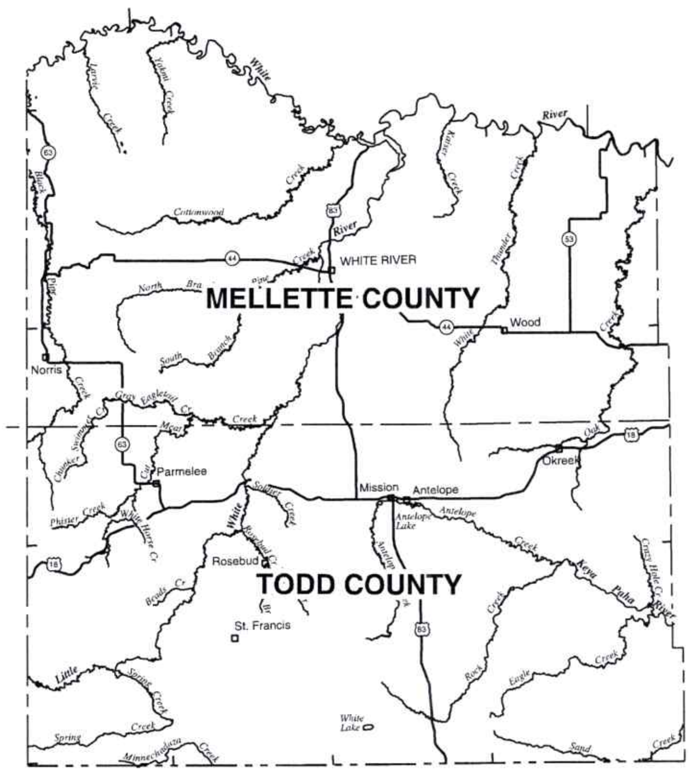
Prepared in cooperation with the Rosebud Sioux Tribe, Mellette County, West River Water Development District, and the South Dakota Geological Survey

Water Resources of Mellette and Todd Counties, South Dakota

Water-Resources Investigations Report 98-4146



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Water Resources of Mellette and Todd Counties, South Dakota

By Janet M. Carter

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Prepared in cooperation with the Rosebud Sioux Tribe, Mellette County,
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U.S. Department of the Interior

Bruce Babbitt, Secretary

U.S. Geological Survey

Thomas J. Casadevall, Acting Director

Rapid City, South Dakota: 1998

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Rapid City, SD 57702

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U.S. Geological Survey
Branch of Information Services
Box 25286
Denver, CO 80225-0286

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Sea level: In this report, "sea level" refers to the National Geodetic Vertical Datum of 1929 (NGVD of 1929)—a geodetic datum derived from a general adjustment of the first-order level nets of both the United States and Canada, formerly called Sea Level Datum of 1929.

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Water Resources of Mellette and Todd Counties, South Dakota

By Janet M. Carter

ABSTRACT

Mellette and Todd Counties are located in south-central South Dakota and have a combined area of 2,694 square miles. The White River and its tributaries, which include the Little White River, drain Mellette County and about one-half of Todd County. Tributaries to the Niobrara River, which include the Keya Paha River, drain the other one-half of Todd County. The average discharge of the Little White River is about 56 cubic feet per second as the river enters Todd County and is about 131 cubic feet per second as it discharges to the White River in northern Mellette County. The average discharge of the Keya Paha River just outside Todd County is about 39 cubic feet per second. The average annual runoff for Mellette and Todd Counties ranges from 0.94 to 2.36 inches based on records from nine streamflow-gaging stations in and near the counties. The average annual runoff is 1.62 inches, which compares with the average annual precipitation of about 19 inches.

In Todd County, shallow wells completed in the alluvial, Ogallala, Arikaree, and White River aquifers generally can supply water that has low concentrations of dissolved solids, is fresh, and is soft to moderately hard. Ground water from shallow aquifers is limited in Mellette County; therefore, deep wells, often greater than 1,000 feet, are sometimes installed. The Pierre Shale often is used to supply rural domestic and stock wells in Mellette County even though well yields are low and the water has high dissolved solids, is moderately saline, and is very hard.

Alluvial aquifers are present in both counties and store an estimated 1.6 million acre-feet of water. The water quality of the alluvial aquifers is dependent on the underlying deposits, and generally the water has low concentrations of dissolved solids, is fresh, and is soft to moderately hard where underlain by the Ogallala and Arikaree Formations; has moderate concentrations of dissolved solids, is slightly saline, and is hard where underlain by the White River Group; and has high concentrations of dissolved solids, is saline, and is very hard where underlain by the Pierre Shale. Also, yields often are lower where the alluvial aquifers are underlain by the Pierre Shale.

The Ogallala aquifer is present in only Todd County, and the Arikaree aquifer is present throughout most of Todd County and southwestern and south-central Mellette County. The Ogallala aquifer contains an estimated 17 million acre-feet of water in storage, and the Arikaree aquifer contains an estimated 50 million acre-feet of water in storage. Both aquifers generally are suitable for irrigation, and yields from these aquifers are sometimes greater than 1,000 gallons per minute. Nitrate concentrations in 13 out of 92 water samples collected from the Ogallala aquifer exceeded the Primary Drinking Water Maximum Contaminant Level (MCL) of 10 milligrams per liter. In 11 out of 46 samples collected from the Arikaree aquifer, arsenic concentrations exceeded the MCL of 50 micrograms per liter.

The White River aquifer, where present, is usually the shallowest source of ground water in Mellette County. The White River aquifer also is used in northern Todd County where the Ogallala and Arikaree aquifers are not present. The White River aquifer contains an estimated 50 million acre-feet of water in storage. Reported yields from the aquifer range from 1 to 30 gallons per minute, which generally is insufficient to support irrigation in most areas. However, yields are sufficient for livestock-watering and rural-domestic purposes.

In both counties, the Pierre Shale is the shallowest bedrock aquifer and is exposed at the land surface throughout most of Mellette County. This aquifer is used primarily in Mellette County. Although the aquifer contains an estimated maximum of 1.5 million acre-feet of water in storage, it is not a viable source of ground water because the aquifer is relatively impermeable, yields are low, and water usually can be obtained from shallower sources, especially in Todd County. Reported yields from the Pierre Shale aquifer range from 1 to 8 gallons per minute.

Because few test holes and wells penetrate below the Pierre Shale, little is known about the extent of the deeper bedrock aquifers. All wells completed in the Dakota Sandstone, Inyan Kara, and Minnelusa and Madison aquifers in the counties are used for stock-watering purposes. High concentrations of dissolved solids and hard water are characteristic of the water quality in the bedrock aquifers. Depths to the top of the deeper bedrock aquifers range from 1,270 feet to greater than 2,000 feet below land surface.

INTRODUCTION

In 1992, the U.S. Geological Survey (USGS) in cooperation with the Rosebud Sioux Tribe, Mellette County, West River Water Development District, and the South Dakota Geological Survey, began a 5-year investigation to describe and quantify the water resources of Mellette and Todd Counties. This investigation was needed because of the limited information available on the surface- and ground-water resources in Mellette and Todd Counties. This information is needed by local, county, State, and Tribal officials to develop sound water-management plans.

Mellette and Todd Counties, which comprise the study area, are located in south-central South Dakota (fig. 1). Mellette County has an area of 1,306 square miles, and Todd County has an area of 1,388 square miles. According to the U.S. Census Bureau, the 1995 population was 2,002 in Mellette County and 9,105 in Todd County. The climate is subhumid, and the average annual precipitation is about 19 inches in both counties. Most of the land area is used for range or native hay production, and the main source of income in both counties is cattle ranching. Less than 15 percent of the land is used for crops, which include wheat, sorghum, oats, corn, and alfalfa.

The White River forms the northern boundary of Mellette County. Most of the area of the two counties is rolling, and numerous deep valleys drain into the White River to the north or into the Niobrara River to the south in Nebraska. The headwaters to the Keya Paha River are located in Todd County. All of Mellette County and the northern part of Todd County are in the Great Plains physiographic province. The southern part of Todd County is in the Sand Hills physiographic province (fig. 1).

The original boundaries of the Rosebud Indian Reservation included all or nearly all of Mellette, Todd, Gregory, and Tripp Counties, and a small portion of Lyman County. In the early 1900's, the Rosebud Reservation was opened for homesteading. As a result, scattered tracts of non-Indian owned land are present in both Mellette and Todd Counties. In 1975, the Rosebud Indian Reservation boundary was revised to include only Todd County (fig. 2).

Purpose and Scope

The results of a 5-year water-resources study of Mellette and Todd Counties are presented in this report. Specifically, this report includes descriptions of the quantity, quality, and availability of surface and ground water, the extent of the major shallow and bedrock aquifers, and surface- and ground-water uses in the two counties.

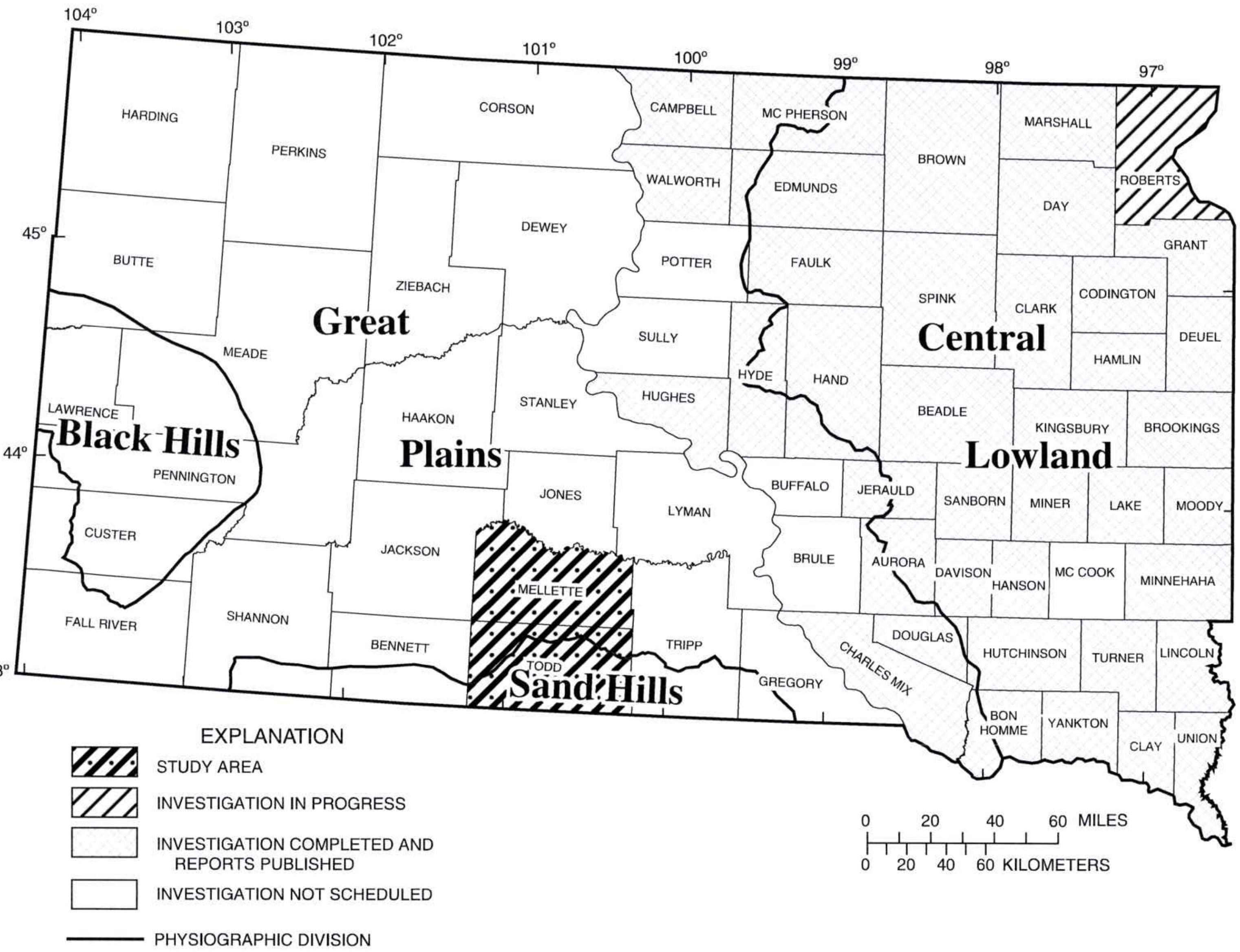

Figure 1. Index map of South Dakota showing location of Mellette and Todd Counties, status of county investigations, and locations of main physiographic divisions (physiographic divisions modified from Flint, 1955; Fenneman, 1946).

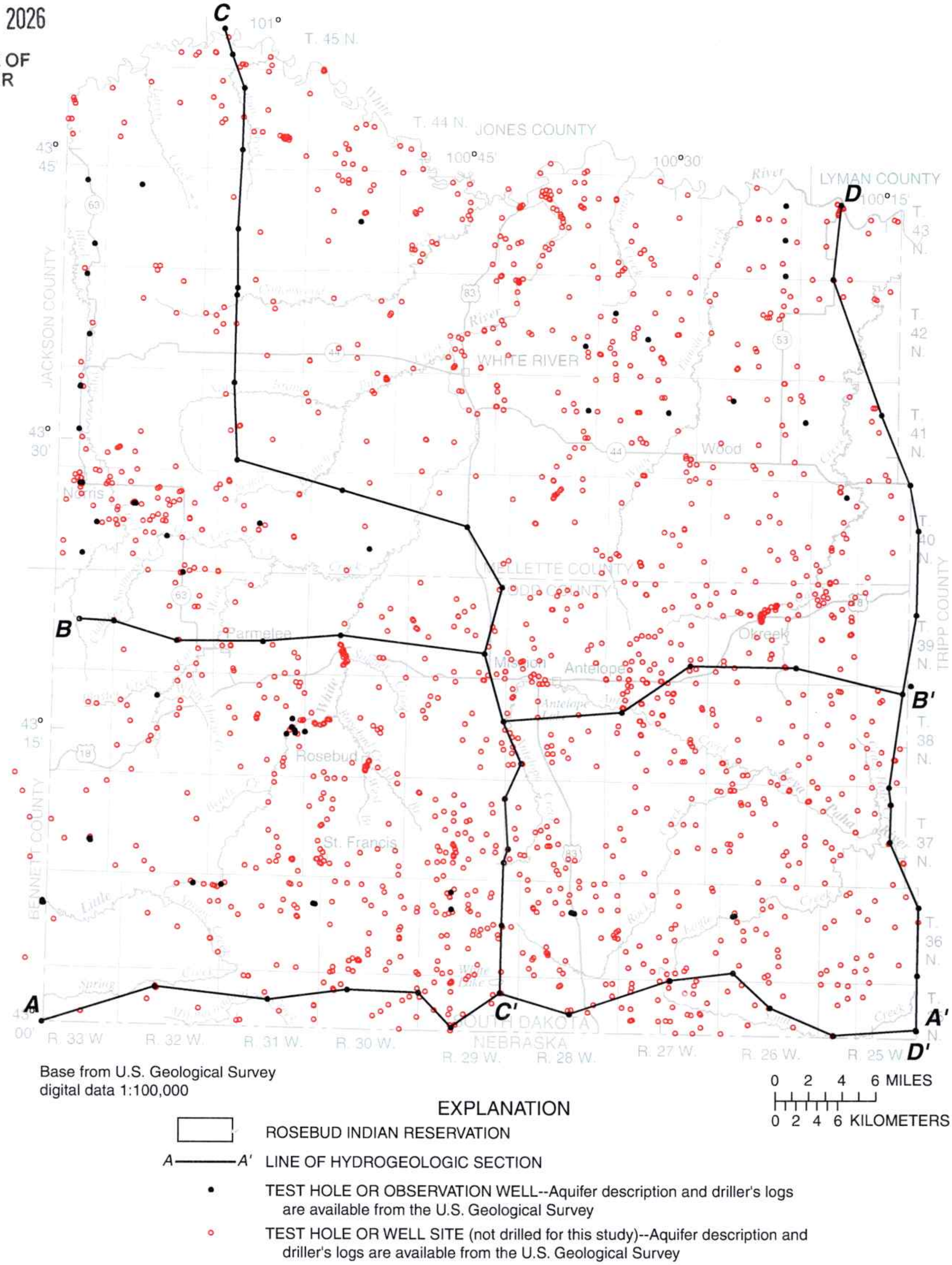

Figure 2. Locations of selected wells, test holes, and lines of hydrogeologic section in Mellette and Todd Counties.

Methods of Investigation

Methods of investigation included analyses of streamflow records, a well inventory, analyses of preexisting drillers' logs, test drilling and observation-well installation, measurement of static water levels, compilation of chemical analyses of surface- and ground-water samples, and analyses of water uses. Seventy-eight test holes were drilled; of these, 56 observation wells were installed for the study. Although the drilling was concentrated in Mellette and Todd Counties, a few of the test holes and wells were drilled in Bennett County just outside the western boundary of Todd County, in Jones County just outside the northern boundary of Mellette County, and in Tripp County just outside the eastern boundary of Todd County. The locations of test holes and observation wells drilled specifically for this study and the locations of four lines of hydrogeologic section are shown in figure 2. The locations of additional test holes and private or public wells used to help determine the structure contours of the formations and the extent, thickness, yield, potentiometric surface, and water quality of the aquifers also are shown in figure 2.

Many ground-water samples were collected and analyzed for this study. In 1990, 100 private domestic wells were sampled prior to the development of the water-resources investigation study. Between 1994 and 1996, samples were collected from 47 of the 56 observation wells installed for the study; between 1990 and 1994, an additional 12 wells, which included private and observation wells, were sampled for a nitrate study conducted by the USGS in Todd County. The sampling methods, quality-assurance procedures, and water-quality analyses for these studies are presented by Carter (1997). Between 1991 and 1995, samples were collected from 21 wells, which included community, private, and observation wells, for an arsenic study conducted by the USGS in Todd County. The sampling methods, quality-assurance procedures, and water-quality analyses for the arsenic study are presented by Carter and others (1998).

All data collection sites are numbered according to the Federal land survey system of western South Dakota (fig. 3). The local number consists of the township number followed by "N," range number followed by "W," and section number, followed by a maximum of four uppercase letters that indicate, respectively, the 160-, 40-, 10-, and 2.5-acre tract in which the well is located. These letters are assigned in a counterclockwise direction beginning with "A" in the northeast quarter. A serial number following the last letter is used to distinguish between wells in the same 2.5-acre tract. Thus, well 38N28W36ABCB is in the NW$^{1}/4$ of the SW$^{1}/4$ of the NW$^{1}/4$ of the NE$^{1}/4$ of section 36 in township 38 north and range 28 west.

Generalized Geology

As a result of different depositional environments in the past in western South Dakota, the geology in the study area consists mostly of marine, fluvial, and unconsolidated deposits ranging in age from the Precambrian to the present (table 1). In this report, descriptions of the geology is limited to deposits in Mellette and Todd Counties. Granitic rocks of Precambrian age dating to about 1,460 million years before present are located in a narrow strip across the southern edge of the study area (Richard Hammond, South Dakota Geological Survey, written commun., 1998); however, the rocks are not exposed at the surface. A geologic map showing the surficial deposits for Mellette and Todd Counties is shown in figure 4. Surficial deposits range from sedimentary rocks of Cretaceous age to unconsolidated deposits of Quaternary age.

Sedimentary rock sequences of Paleozoic and Mesozoic age were deposited by alternating transgressive and regressive seas. In the two counties, these rocks are composed mainly of limestone, dolomite, siltstone, sandstone, and shale. Rocks of Cambrian, Silurian, Devonian, Triassic, and Jurassic age are missing in the study area. The Red River and Winnipeg Formations, the Madison Limestone, and Minnelusa Formation are examples of transgressive seas. The study area was covered by seas from the Mississippian through the early Permian periods. From the late Permian period through the beginning of the Cretaceous period, deposits primarily were continental. Continental deposits are formed on land rather than in the sea and may include sediments of lake, swamp, wind, stream, or volcanic origin. Deposition and erosion of continental deposits prevailed throughout this time until another marine transgression occurred during the early Cretaceous period. Deposits during the Cretaceous period primarily were shale (Darton, 1905). Tertiary rocks generally consist of poorly consolidated claystones, siltstones, sandstones, and shale deposited in fluvial (stream/river) and lacustrine (lake) environments. Unconsolidated deposits of Quaternary age include terrace gravels, graded fluvial sand and gravels (alluvium), and eolian (windblown) sand. Glaciation during the Quaternary period did not affect the study area (Flint, 1955).

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Table 1. Generalized stratigraphic column showing geologic units and some of their characteristics

Era	System	Formation or deposit	Thickness (feet)[1]	Description and origin[2]	Remarks[2]
Cenozoic	Quaternary	Alluvium	0-35	Brown, varies between clay, silts, fine to coarse sand, and gravel. Generally sandy along the Little White River and other streams that flow over deposits of Tertiary age. Generally clayey with some thin sand beds along intermittent streams that flow over the Pierre Shale. Fluvial.	Locally, deposits are moderately permeable along the Little White River and relatively impermeable along streams that flow over the Pierre Shale. Yields generally are adequate to supply domestic and stock wells except along streams that flow over the Pierre Shale. Water is fresh, low in concentrations of dissolved solids, and soft to moderately hard except in deposits underlain by the Pierre Shale.
		Windblown sand deposits	0-150	Brown, unconsolidated, very fine to medium grained, uniform, quartz sand; characterized by dune topography and blowouts. Eolian.	Generally very permeable and water bearing; yields are adequate to supply stock and domestic wells except where deposits are small.
		Terrace deposits	0-105	Brown, silty clay, sand, and gravel. Commonly, the silty and sandy layers are partly cemented, and the gravel and sand beds commonly are interbedded with laminated silty clay. Fluvial.	Generally water bearing in the basal portion of the deposits. Yields are usually adequate to supply stock and domestic wells. Water is fresh, low in concentrations of dissolved solids, and soft to moderately hard except in areas where the water-bearing deposits are underlain by the Pierre Shale.
	Tertiary	Ogallala Formation	0-240	Tan to olive, fine- to medium-grained sandstone with some silty clay. Upper unit of Ogallala Formation also is known as the Ash Hollow Formation and the lower unit as the Valentine Formation. Fluvial.	Permeable and generally water-bearing; yields are adequate to supply stock and domestic wells and can supply irrigation wells in some areas. Water is fresh, low in concentrations of dissolved solids, and soft to moderately hard.
		Arikaree Formation	0-620	Pinkish tan to red; consists of poorly consolidated, tuffaceous sandstone, siltstone, shale, and silty clay. The Rosebud Formation sometimes is differentiated as a unit within the Arikaree Formation. Basal unit is composed mostly of silts and sands. Fluvial.	The upper part of the formation generally is impermeable, but can yield small amounts of water from fractures, joints, and silty layers. The basal part is moderately permeable and can supply water for domestic and stock wells. Water is fresh, low in concentrations of dissolved solids, and soft to moderately hard.
		White River Group (undifferentiated)	0-470	Yellow to brown, poorly consolidated siltstone and claystone with some beds of fine-grained sand. Units of the White River Group sometimes are differentiated into the Brule and Chadron Formations. Fluvial.	Permeability varies from impermeable to moderately permeable, depending on the clay content. Yields are usually adequate to supply water to stock and domestic wells. Water is slightly saline, moderate in concentrations of dissolved solids, and hard depending on the proximity of the aquifer to the Pierre Shale.
Mesozoic	Cretaceous	Pierre Shale	600-1,395[3]	Bluish-black shale with some layers of bentonite. Marine.	Most of the formation is relatively impermeable. Can yield small amounts of water if fractures or sandy zones are present. Typically not considered an aquifer. Water is saline, high in concentrations of dissolved solids, and very hard.
		Niobrara Formation	125-175[4]	Tan to gray, highly calcareous shale. Commonly described by drillers as "chalk." Marine.	Water-bearing traits are largely unknown. May yield sufficient water for some purposes.

Mesozoic	Cretaceous	Carlile Shale	300-400[4]	Light grayish blue to black, noncalcareous shale. Marine.	Nearly impermeable. Water-bearing traits are largely unknown.
		Greenhorn Formation	100-120[4]	Tan, bluish, white, or gray calcareous shale. Marine.	Water-bearing traits are largely unknown.
		Graneros Shale	130-200[4]	Dark-gray non-calcareous shale. Marine.	Nearly impermeable. Water-bearing traits are largely unknown.
		Dakota Formation (Dakota Sandstone)	270-340[4]	Interbedded tan to white sandstone and dark-colored shale. Sandstone is composed of loose to well-cemented, very fine to coarse quartz sand; cement most commonly is calcium carbonate. Marine.	Permeable sandstone beds yield moderate quantities of water under artesian pressure for stock and domestic wells. The water is highly mineralized and cannot be used for irrigation purposes.
		Skull Creek Shale	95-150[4]	Dark bluish-gray shale. Marine.	Relatively impermeable. Water-bearing traits are largely unknown.
		Inyan Kara Group undifferentiated	100-275[4]	White to light-gray or tan sandstone and siltstone; contains beds of gray to black and reddish to buff shale. The Inyan Kara Group sometimes is divided into the Fall River and Lakota Formations. Continental to marginal marine.	Permeable sandstone beds yield moderate quantities of water under artesian pressure for stock and domestic wells. The water is highly mineralized and cannot be used for irrigation purposes.
Paleozoic	Permian and Pennsylvanian	Minnelusa Formation	300-530[4]	Consists of interbedded sandstone, siltstone, dolomite, limestone, anhydrite, and shale. Marine.	Permeable zones can yield adequate water for stock and domestic wells under artesian pressure. Water is lower in dissolved solids than the Dakota Sandstone and Inyan Kara aquifers. Can be used for irrigation on crops that are tolerant of salt with proper salinity management.
	Mississippian	Madison Formation	90-240[4]	Light gray to buff, varies from pure limestone to pure dolomite with various combinations of the two. Marine.	Permeable zones can yield adequate water for stock and domestic wells under artesian pressure. Water is lower in dissolved solids than the Dakota Sandstone and Inyan Kara aquifers. Can be used for irrigation on crops that are tolerant of salt with proper salinity management.
	Ordovician	Red River and Winnipeg Formations (undifferentiated)	0-170[4]	The Red River Formation mostly consists of dolomite, and the Winnipeg Formation mostly consists of sandstones[5]. Marine.	
Precambrian				Granite.	

[1]Based on interpretation and projection of data from electric logs and drillers' logs.
[2]Based on interpretation of data collected during study and from drillers' logs.
[3]From Ellis and others (1972).
[4]From Ellis and others (1971).
[5]From Agnew and Tychsen (1965).

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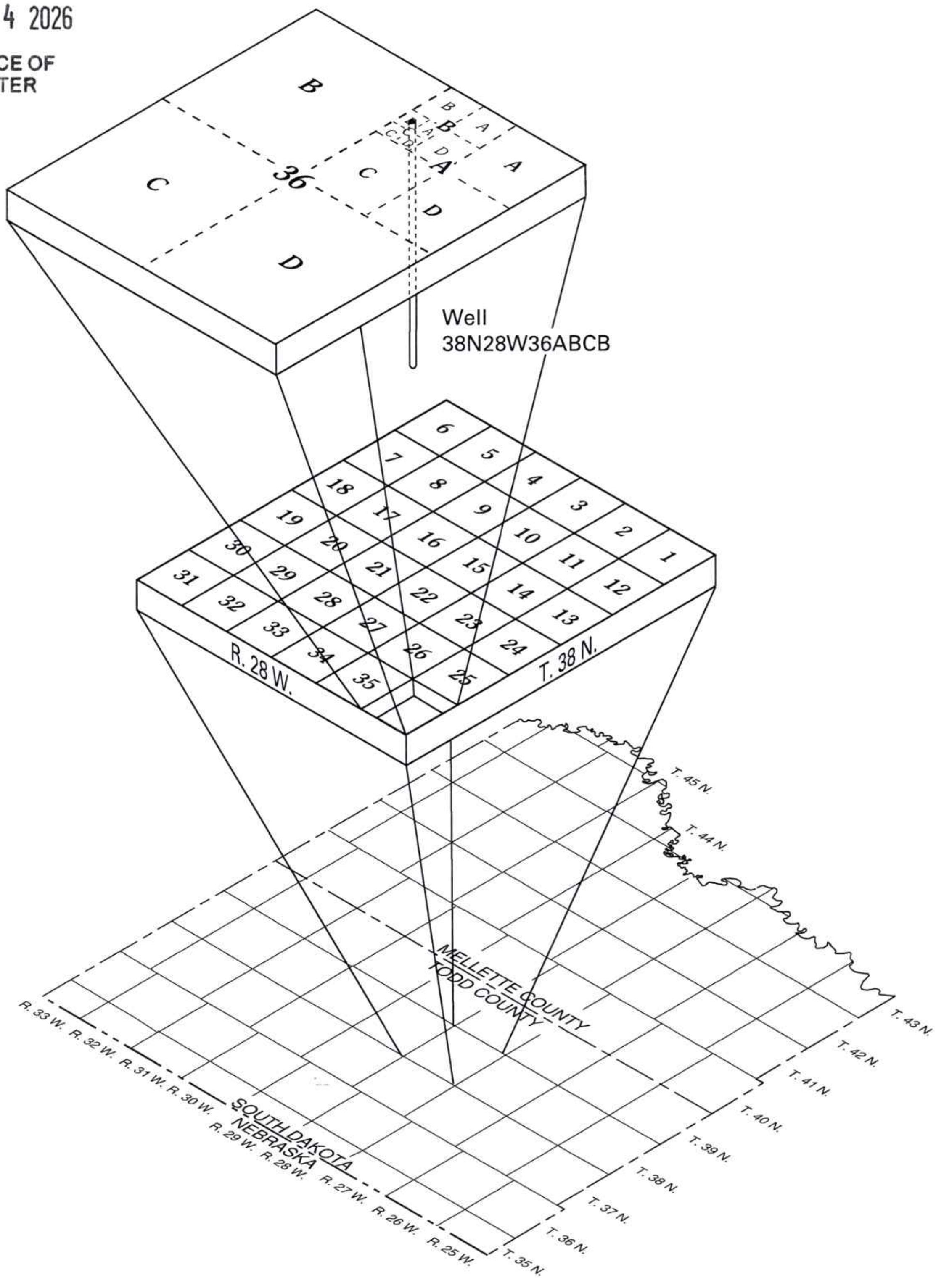


Figure 3. Well-numbering system. The well number consists of the township number, followed by "N," the range number followed by "W," and the section number followed by a maximum of four uppercase letters that indicate, respectively, the 160-, 40-, 10-, and 2 1/2-acre tract in which the well is located. These letters are assigned in a counterclockwise direction beginning with "A" in the northeast quarter. A serial number following the last letter is used to distinguish between wells in the same 2 1/2-acre tract.

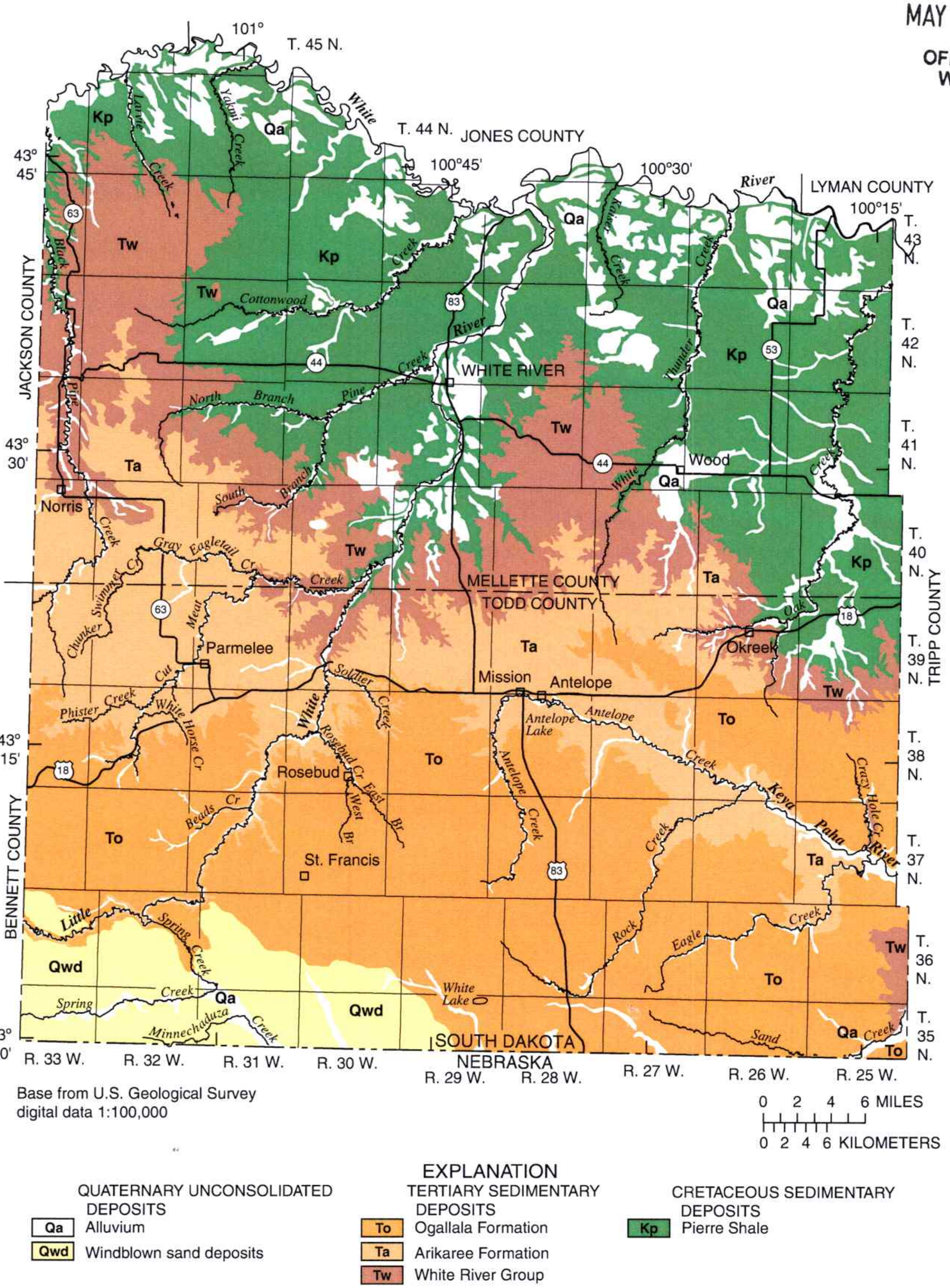


Figure 4. Generalized geologic map showing surficial geology of study area (modified from Ellis and others, 1971).

Known water-bearing bedrock formations in the study area include the Madison Limestone of Mississippian age, the Minnelusa Formation of Pennsylvanian and Permian age, and the Inyan Kara Group, Dakota Sandstone, and Pierre Shale of Cretaceous age (table 1). The youngest bedrock formation, the Pierre Shale, is exposed at land surface throughout most of Mellette County. The bedrock surface is the boundary between the bedrock formations and the overlying poorly consolidated Tertiary formations and surficial deposits. The Tertiary deposits in the study area are exposed at land surface (fig. 4), except where covered by unconsolidated deposits or where missing. The Tertiary deposits in the study area, from oldest to youngest, are the White River Group of Eocene and Oligocene age, the Arikaree Formation of Miocene age, and the Ogallala Formation of Pliocene age. A generalized map showing the unconsolidated deposits and outcrops of the Tertiary formations and Pierre Shale is shown in figure 4. Structure contour maps, which show the altitude of the tops of the formations, were constructed based on driller's logs and data collected during this study for the Pierre Shale (fig. 5), the White River Group (fig. 6), and the Arikaree Formation (fig. 7). Unconsolidated deposits of Quaternary age within the study area consist of alluvial, terrace, and windblown sand deposits.

Acknowledgments

Many people have assisted with the development and implementation of the study. In particular, Syed Huq, Charles Mack, and John Whiting of the Office of Water Resources of the Rosebud Sioux Tribe and Sena Lauritsen of the Mellette/Todd Water Resources Coordination Project provided valuable assistance with the collection of water-quality samples and other hydrologic data. The South Dakota Geological Survey drilled the test holes and installed the observation wells for the study. Dick Hammond and Patricia Hammond of the South Dakota Geological Survey provided valuable insight and technical guidance for the study. Appreciation is expressed to the Mellette County officials and the West River Water Development District personnel for their cooperation during this study. The cooperation of residents of Mellette and Todd Counties for providing information concerning their private wells is appreciated.

WATER RESOURCES

Precipitation

The average precipitation at Wood in Mellette County and at a precipitation station located 14 miles south of Mission in Todd County from 1961-90 was 18.96 inches and 19.32 inches, respectively (U.S. Department of Commerce, 1994). The total annual volume of water from precipitation in Mellette and Todd Counties is about 2,751,000 acre-feet. About 8 percent of the average annual precipitation becomes streamflow (230,000 acre-feet); however, this quantity varies from year to year and month to month because of climatic conditions.

Surface Water

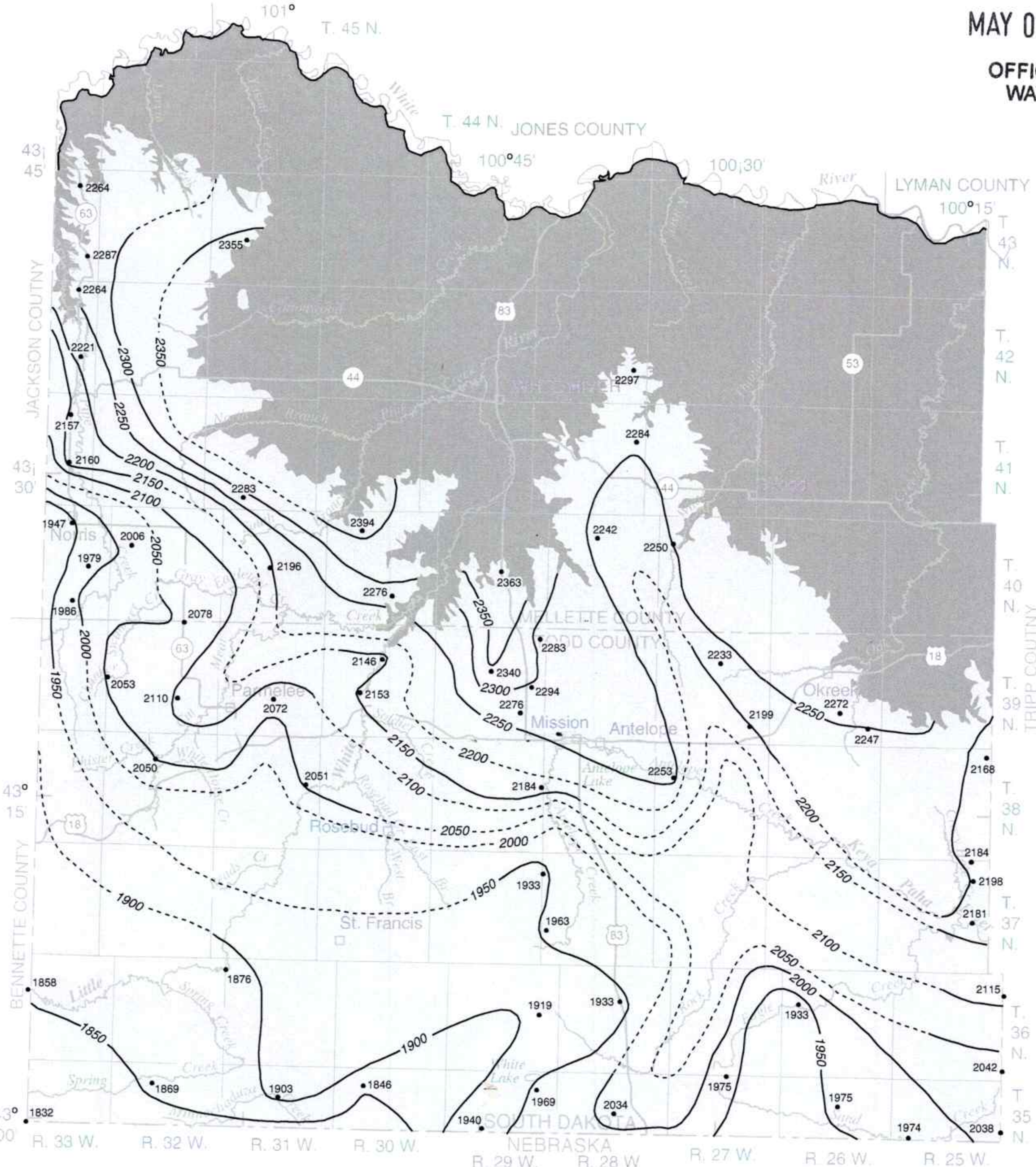
The surface-water resources in Mellette and Todd Counties include rivers, streams, and lakes. The major rivers are the White River, Little White River, and Keya Paha River. Some of the smaller streams include Blackpipe Creek, Antelope Creek, and Rosebud Creek. Two of the largest lakes in the study area are Antelope Lake (an artificial lake) and White Lake, which are located in Todd County.

Drainage Basins

The major drainage basins within the study area are the White River Basin and the Niobrara River Basin (fig. 8). The White River and Niobrara River, in Nebraska, flow easterly into the Missouri River. All of Mellette County and about 51 percent of Todd County is drained by the White River and its tributaries (1,306 square miles in Mellette County and about 710 square miles in Todd County). About 49 percent of Todd County is drained by tributaries of the Niobrara River (about 680 square miles), which include the Keya Paha River.

Streams

Four streamflow-gaging stations are located within the study area (fig. 8) and five gaging stations are located in adjacent counties. A summary of streamflow-gaging records for sites in and near Mellette and Todd Counties is presented in table 2.



Base from U.S. Geological Survey
digital data 1:100,000

0 2 4 6 MILES

0 2 4 6 KILOMETERS

EXPLANATION

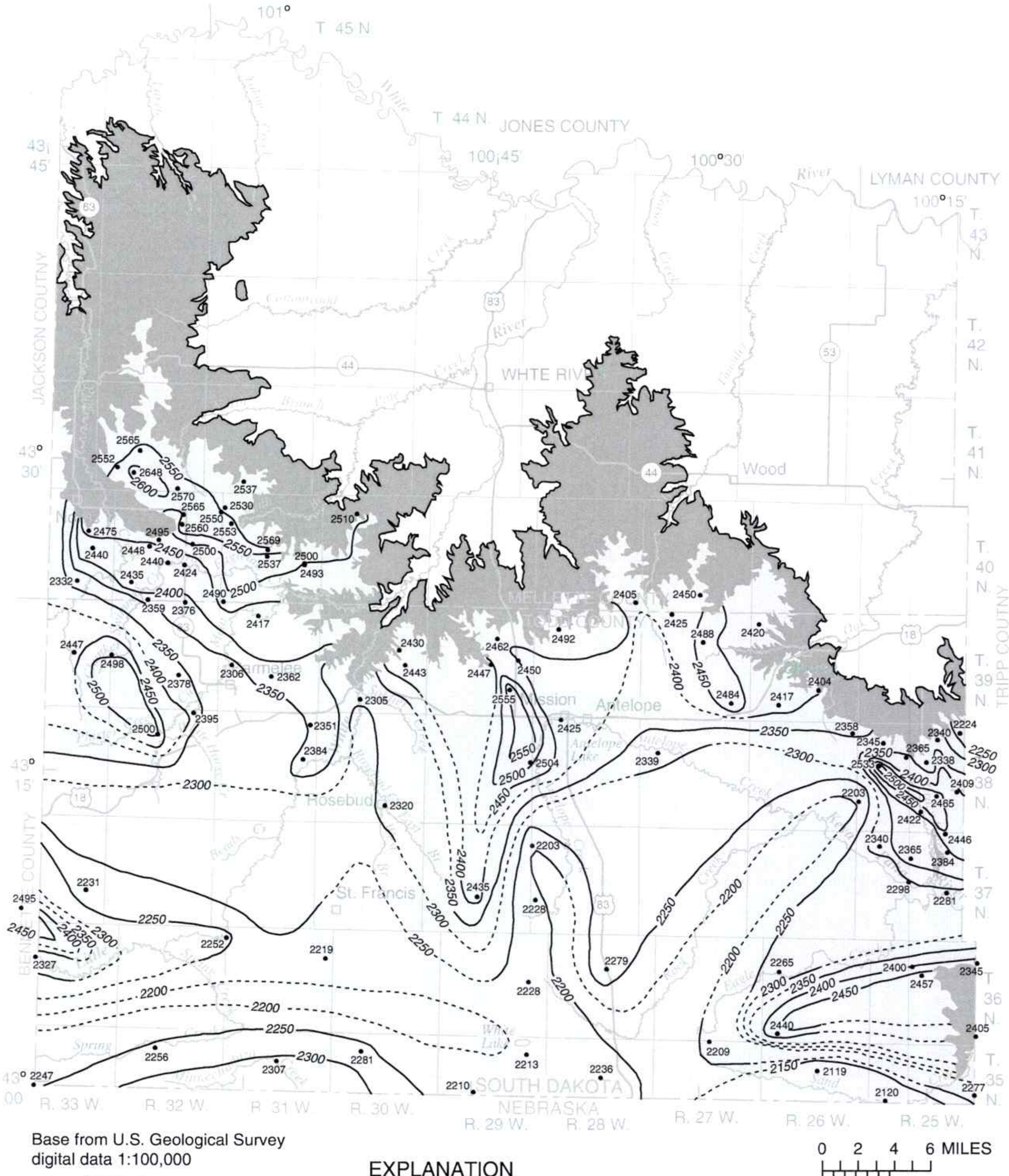
APPROXIMATE AREA UNDERLAIN BY THE PIERRE SHALE (modified from Ellis and others, 1971)

APPROXIMATE AREA OF PIERRE SHALE EXPOSED AT LAND SURFACE (modified from Ellis and others, 1971)

—2300- - - STRUCTURE CONTOUR--Shows altitude of top of the Pierre Shale. Dashed where inferred. Contour interval 50 feet. Datum is sea level.

• 1940 WELL OR TEST HOLE THAT PENETRATED PIERRE SHALE--Number is altitude of the top of the Pierre Shale, in feet above sea level

Figure 5. Structure contour map for the top of the Pierre Shale.



EXPLANATION

APPROXIMATE AREA UNDERLAIN BY THE WHITE RIVER GROUP (modified from Ellis and others, 1971)

APPROXIMATE AREA OF WHITE RIVER GROUP EXPOSED AT LAND SURFACE (modified from Ellis and others, 1971)

—2500- - - STRUCTURE CONTOUR--Shows altitude of top of the White River Group. Dashed where inferred. Contour interval 50 feet. Datum is sea level.

• 2265 WELL OR TEST HOLE THAT PENETRATED WHITE RIVER GROUP--Number is altitude of the top of the White River Group, in feet above sea level

Figure 6. Structure contour map for the top of the White River Group.

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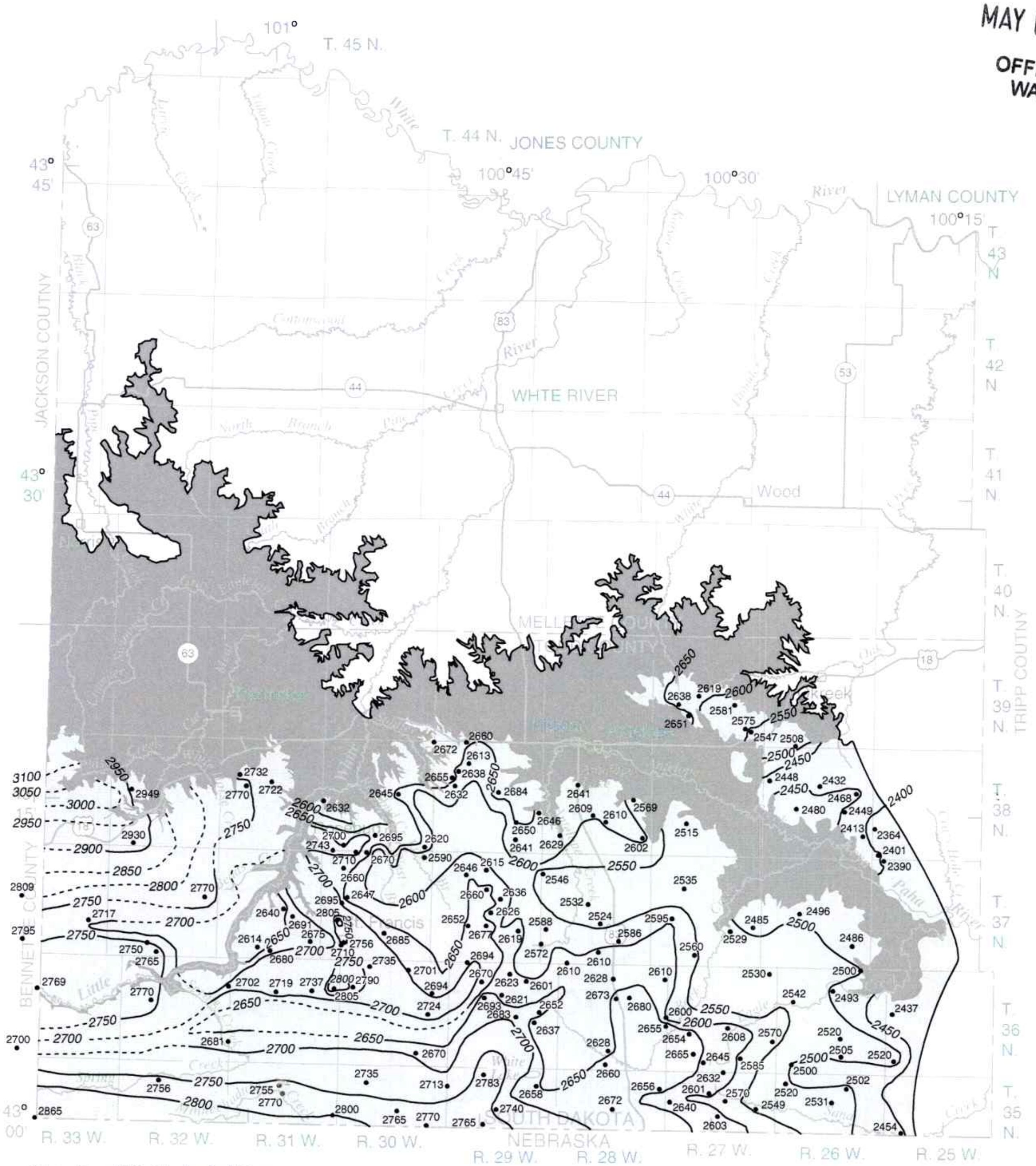

EXPLANATION

APPROXIMATE AREA UNDERLAIN BY THE ARIKAREE FORMATION (modified from Ellis and others, 1971)

APPROXIMATE AREA OF ARIKAREE FORMATION EXPOSED AT LAND SURFACE (modified from Ellis and others, 1971)

—2700- - - STRUCTURE CONTOUR--Shows altitude of top of the Arikaree Formation. Dashed where inferred. Contour interval 50 feet. Datum is sea level.

• 2770 WELL OR TEST HOLE THAT PENETRATED ARIKAREE FORMATION--Number is altitude of the top of the Arikaree Formation, in feet above sea level

Figure 7. Structure contour map for the top of the Arikaree Formation.

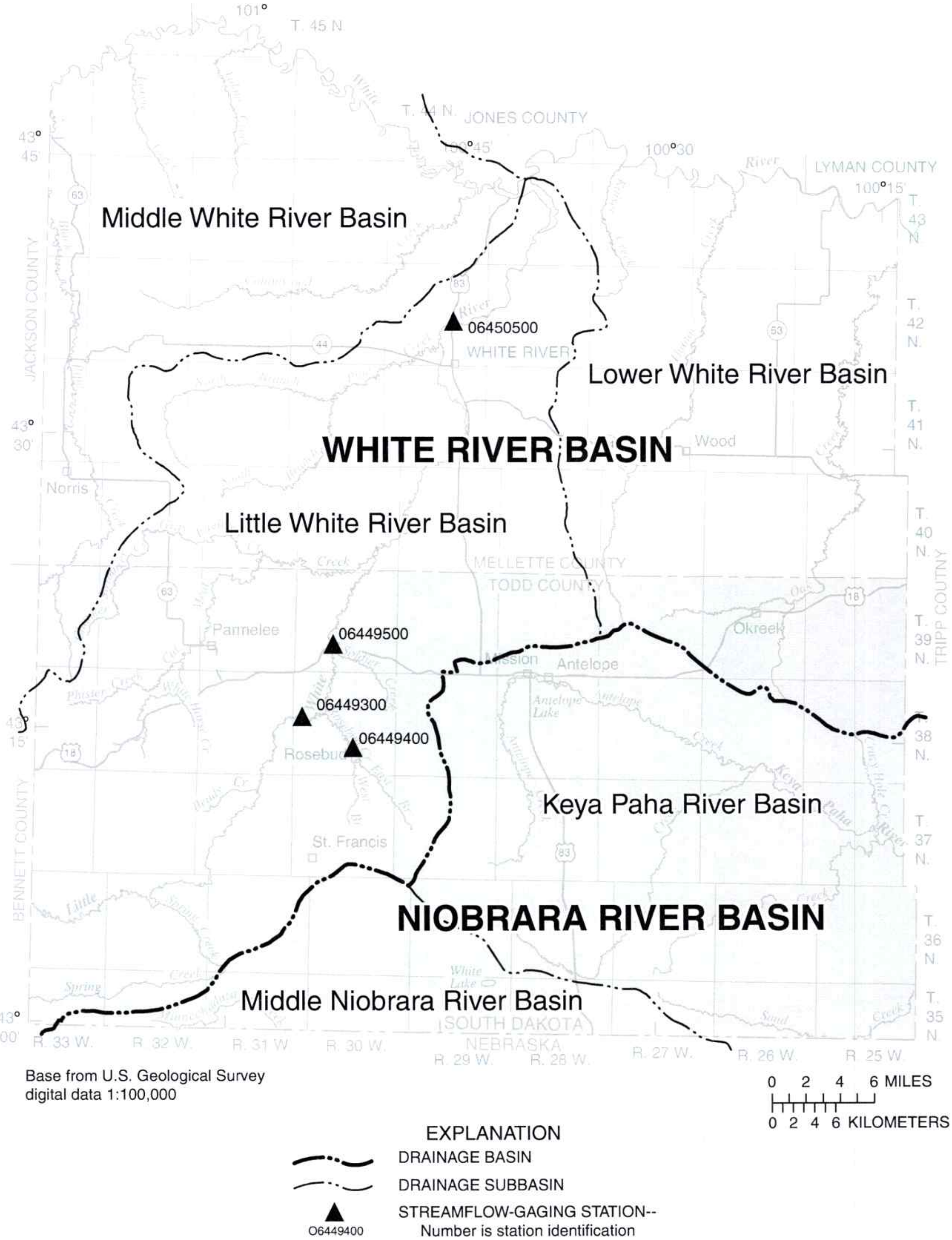

Figure 8. Locations of drainage basins and U.S. Geological Survey streamflow-gaging stations in Mellette and Todd Counties.

Table 2. Summary of data for streamflow-gaging stations in and near Mellette and Todd Counties

Station number	Station name	Drainage area (square miles)	Noncontributing drainage area (square miles)	Period of record used (water year)	Streamflow (cubic feet per second)					
					Extreme flow		Annual flow			
					Maximum instantaneous	Minimum daily	Average	25th percentile	Median 50th percentile	75th percentile
[1]06447230	Blackpipe Creek near Belvidere	250	0	1993-95	3,500	0.00	31.8	15.0	19.9	60.5
[1]06447500	Little White River near Martin	310	80	1939, 1963-95	1,190	0.60	20.1	15.6	18.8	22.5
[1]06449100	Little White River near Vetal	590	175	1960-95	3,540	9.0	55.7	45.8	56.3	65.0
06449300	Little White River above Rosebud	890	260	1982-95	2,190	20	110	94	111	124
06449400	Rosebud Creek at Rosebud	50.8	0	1975-95	670	.00	7.54	6.98	7.44	8.10
06449500	Little White River near Rosebud	1,020	260	1944-95	4,640	10	113	99	116	125
06450500	Little White River below White River	1,570	260	1950-95	13,700	7.0	131	100	128	149
[1]06464100	Keya Paha River near Keyapaha	466	0	1982-95	852	2.4	39.1	25.0	40.0	49.4
[1]06464500	Keya Paha River at Wewela	1,070	0	1939-95	5,430	.00	73.4	47.5	59.0	99.0

[1]Outside study area.

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The average flow of the Little White River is about 56 cubic feet per second as the river enters Todd County near Vetal (station 06449100). The average flow of the Little White River is about 131 cubic feet per second as it discharges to the White River in northern Mellette County based on the average discharge of the most downstream gaging station (station 06450500). The Keya Paha River near Keyapaha (station 06464100) has an average flow of about 39 cubic feet per second.

The average annual runoff for the nine gaging stations ranges from 0.94 to 2.36 inches and averages 1.62 inches. The average annual runoff for the Little White River for the period of record is 1.18 inches (63 acre-feet per square mile) near Martin, 1.82 inches (97 acre-feet per square mile) near Vetal, 2.36 inches (126 acre-feet per square mile) above Rosebud, 2.03 inches (108 acre-feet per square mile) near Rosebud, and 1.37 inches (73 acre-feet per square mile) below White River. For Rosebud Creek, which is a tributary to the Little White River, the average annual runoff at Rosebud for the period of record is 2.03 inches (108 acre-feet per square mile). The average annual runoff for the period of record for the Keya Paha River near Keyapaha is 1.14 inches (61 acre-feet per square mile) and for the Keya Paha River at Wewela is 0.94 inches (50 acre-feet per square mile). The average annual runoff for Blackpipe Creek near Belvidere is 1.73 inches (92 acre-feet per square mile).

Streamflow is directly affected by precipitation and evapotranspiration. Streams generally receive more than one-half of their flow from discharge from the aquifers, especially during the winter months, when the stage in the streams often is lower than the hydraulic heads in the aquifers. Numerous ephemeral springs occur along the Little White River.

Flow Duration

Daily-duration hydrographs for the indicated percentage of time daily mean streamflow is exceeded for the Little White River below White River (station 06450500) in Mellette County is shown in figure 9. The duration hydrographs show the maximum and minimum daily flows and the 20-, 50-, and 80-percent exceedance values for the period 1957-95. Streamflow for the indicated hydrographs can be expected to be equaled or exceeded 20, 50, and 80 percent of the time, respectively, on any individual day. For example, on April 1, a flow equal to or exceeding 113 cubic feet per second can be expected 80 percent of the time, a discharge equal to or exceeding 186 cubic feet per second can be expected 50 percent of the time, and a flow equal to or exceeding 249 cubic feet per second can be expected 20 percent of the time. Flows are highest during late winter and spring when runoff of snowmelt and rainfall are greatest. Streamflow gradually decreases during late spring and summer due to increasing evapotranspiration and decreasing precipitation. Flows are lowest from fall to mid-winter. There are no days when the flow was less than 10 cubic feet per second for the 39-year period shown.

Because there are no gaging stations within the study area on the Keya Paha River, daily-duration hydrographs for the indicated percentage of time daily mean streamflow is exceeded is shown in figure 10 for the Keya Paha River at Wewela (station 06464500) in southwest Tripp County. The period of record used to construct the duration hydrographs is 1957-95. Flows of the Keya Paha River are highest during late winter and spring and lowest from fall to mid-winter. Although a flow equal to or exceeding 10 cubic feet per second can be expected 80 percent of the time on any individual day, there are several days during some years when there was no flow at the Keya Paha River at Wewela station.

Flood Information

Flooding from snowmelt and rainfall during the spring is common along the White River and parts of the Little White River because of numerous ice jams. Flood-stage data are not available in Mellette and Todd Counties, but data are available for two gaging stations located on the White River outside the study area. At the gaging station located near Kadoka in Jackson County, flood stage of the White River is 13 feet (Tresté Huse, National Weather Service, Rapid City, S. Dak., written commun., 1997). Flood stage of the White River near Oacoma in Lyman County is 15 feet (Tresté Huse, National Weather Service, Rapid City, S. Dak., written commun., 1997). Maps of flood prone areas along the White River in Mellette County, at a scale of about 2.64 inches to the mile, can be obtained from the USGS District office in Rapid City, South Dakota.

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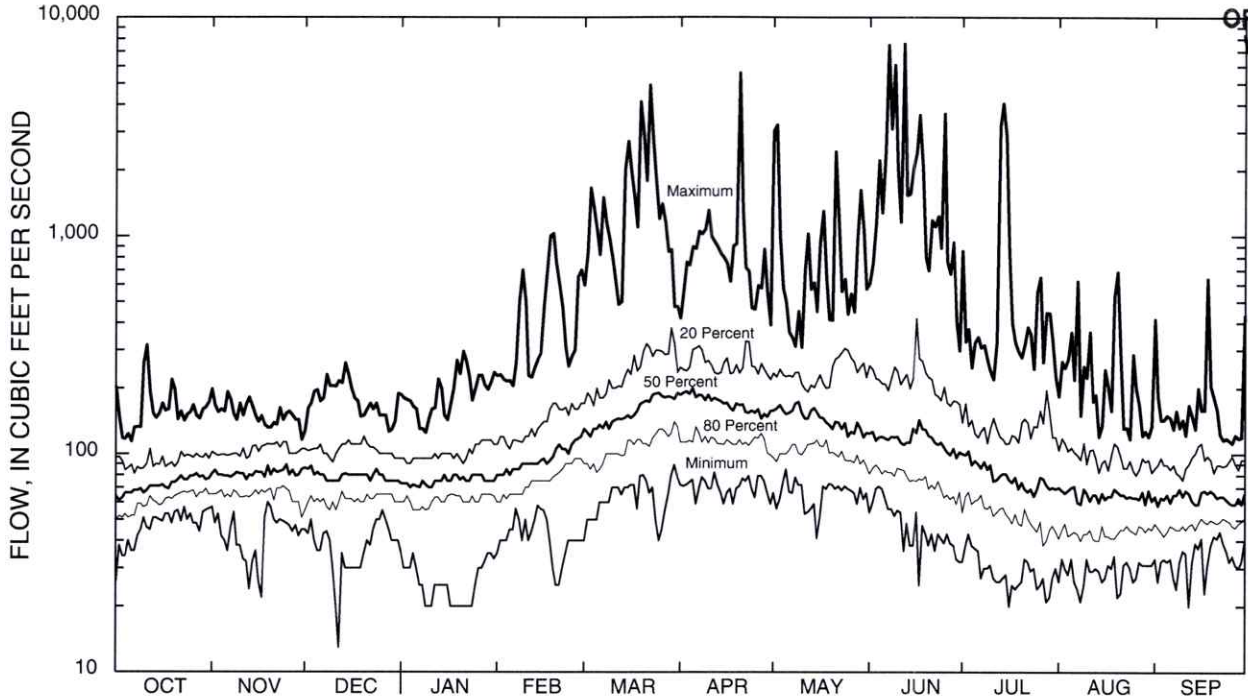


Figure 9. Daily-duration hydrographs for indicated percentage of time flow of the Little White River below White River (station 06450500) in Mellette County was equal to or greater than that shown, water years 1957-95.

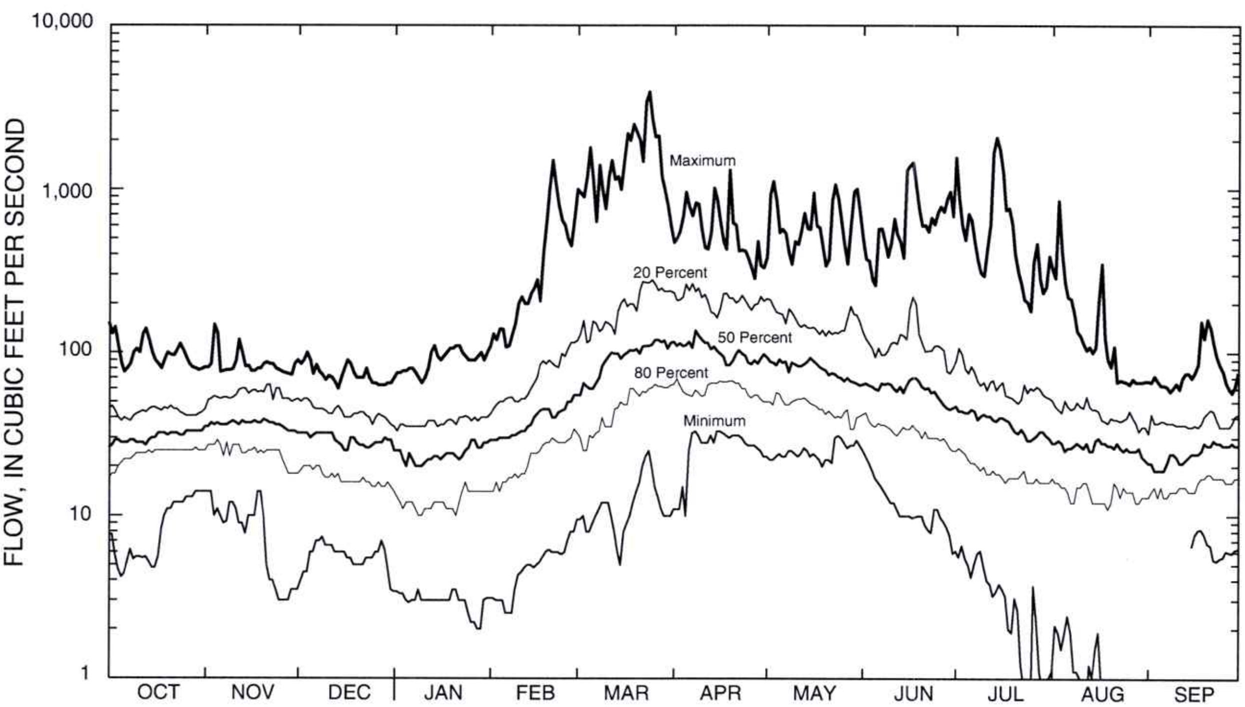


Figure 10. Daily-duration hydrographs for indicated percentage of time flow of the Keya Paha River at Wewela (station 06464500) in Tripp County was equal to or greater than that shown, water years 1957-95.

Lakes

Few natural lakes exist within the study area. Although many manmade lakes exist in the study area, most generally occupy less than 10 acres and are used for stock-watering purposes. White Lake, located in south-central Todd County near the South Dakota-Nebraska border (fig. 8), is the largest natural lake in the study area with a surface area of about 160 acres and an average elevation of 2,783 feet above sea level. Antelope Lake, an artificial lake located near Antelope in north-central Todd County (fig. 8), has a surface area of about 95 acres and an average elevation of 2,521 feet above sea level. Other lakes within the study area have a surface area of less than 50 acres.

Water Quality

Water-quality data are available in the USGS NWIS water-quality database for several stream sites located in Mellette and Todd Counties. Because little water-quality data are available for the lakes in the study area, this section discusses only the water-quality data from streams.

A summary of chemical analyses is shown in table 3 for the Little White River at the gaging stations above Rosebud (station 06449300) and below White River (station 06450500). The dominant chemical species in water are calcium and bicarbonate at the site above Rosebud and calcium, bicarbonate, and sulfate at the site below White River (fig. 11).

Specific conductance, a measure of total dissolved solids (TDS), data also are available for two streams that have gaging stations within 10 miles of the study area. The mean specific conductance was 760 µS/cm (microsiemens per centimeter at 25° Celsius) for 31 samples collected between 1992-95 on Blackpipe Creek near Belvidere (station 06447230), and 447 µS/cm for 144 samples collected between 1981-95 on the Keya Paha River near Keyapaha (station 06464100).

Most water-quality constituents and properties in streams vary with the volume of streamflow. For example, specific conductance shows a typical seasonal pattern due to variations in streamflow at Little White River above Rosebud (station 06449300) for the period of October 1981 through August 1995 (fig. 12). Conductance values are lowest in February and March, during the high flows of spring snowmelt, which causes dilution of TDS. The highest conductance values occur in November-January and are the result of low-flow and ice conditions. Conductance at this site ranged from 219 µS/cm on March 9, 1994, when the daily mean discharge was 684 cubic feet per second to 580 µS/cm on November 18, 1991, when the daily mean discharge was 111 cubic feet per second. Specific conductance at the site Little White River below White River (06450500) (not included in fig. 12) ranged from 210 µS/cm when the mean daily discharge was 2,000 cubic feet per second to 1,350 µS/cm when the mean daily discharge was 116 cubic feet per second. This cyclic pattern occurs at other sites along the Little White River and is similar to patterns shown by other water-quality constituents.

In addition to seasonal variability, specific conductance values varied between the sites located on the Little White River in Mellette and Todd Counties. Generally, specific conductance increases from upstream to downstream. For example, specific conductance increases from station 06449300 above Rosebud to station 06450500 below White River (fig. 13); the mean conductance was 312 µS/cm above Rosebud, 346 µS/cm at Rosebud Creek, 327 µS/cm near Rosebud, and 386 µS/cm below White River. The increase in conductance probably is at least partly attributed to the underlying geology. Three upstream sites overlie either the Arikaree or Ogallala Formations, which generally supply lower TDS; the downstream site overlies the Pierre Shale, which generally supplies higher TDS.

Ground Water

The shallow aquifers in the study area are the alluvial, Ogallala, Arikaree, and White River aquifers. The bedrock aquifers are the Pierre Shale, Dakota Sandstone, Inyan Kara, and Minnelusa and Madison aquifers.

In Todd County, ground water generally can be obtained from shallow wells (less than 300 feet) completed either in alluvial deposits or in deposits of Tertiary age (Ogallala Formation, Arikaree Formation, or White River Group). Ground water is more difficult to obtain in Mellette County because the Pierre Shale is exposed throughout much of the county (fig. 4), which means that the younger Tertiary deposits have been eroded and are not present in these areas. Water is difficult to obtain from the Pierre Shale, plus concentrations of dissolved solids are high and water is hard, thus deep wells (greater than 1,000 feet) are sometimes drilled in Mellette County to obtain ground water.

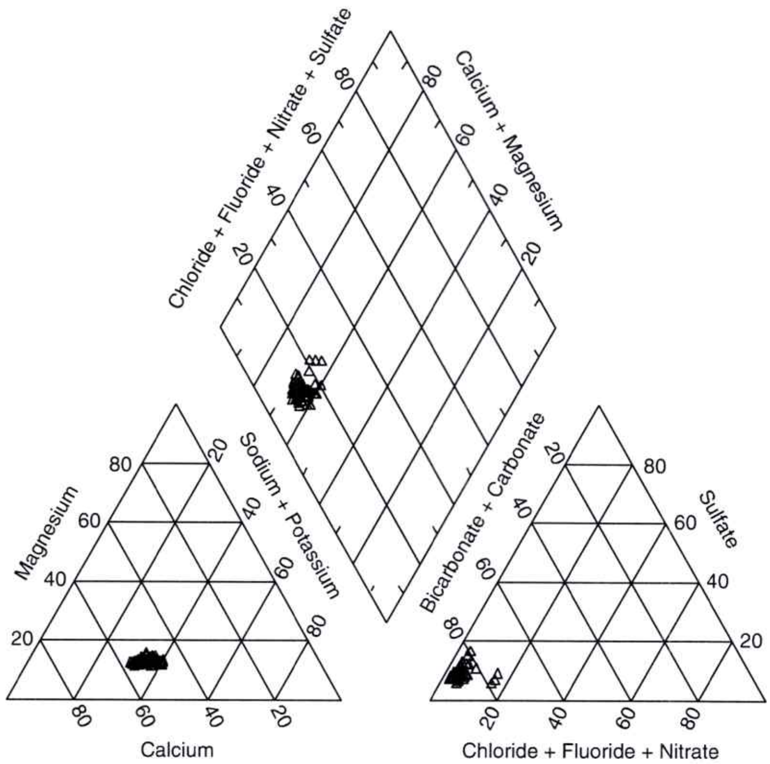
Table 3. Summary of chemical analyses for the Little White River at gaging stations above Rosebud and below White River, 1950-95

[Results based on data stored in USGS NWIS water-quality database. Results in milligrams per liter except as indicated. One milligram per liter (mg/L) is approximately equal to one part per million. One microgram per liter (µg/L) is equal to one part per billion; µS/cm, microsiemens per centimeter at 25° Celsius; --, not analyzed or not determined; <, less than indicated detection limit; ND, specifically analyzed for but not detected, and detection limit unknown]

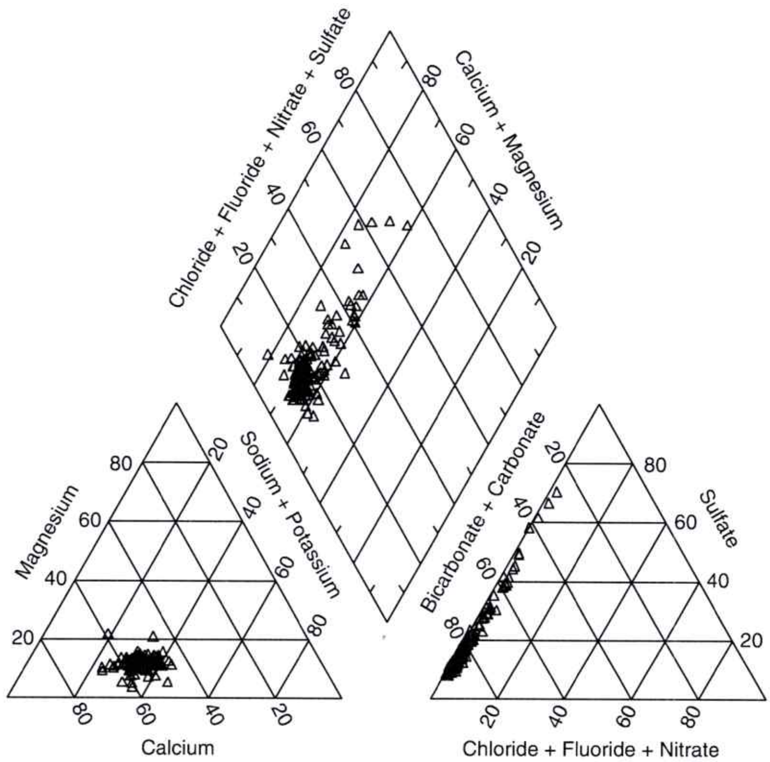
Property or dissolved constituent	06449300 Little White River above Rosebud (1981-95)				
	Number of samples	Mean	Median	Minimum	Maximum
Specific conductance (µS/cm)	157	312	305	219	580
pH (standard units)	111	8.0	8.1	7.1	9.4
Hardness, as $CaCO_3$	60	113	114	66	134
Solids, residue at 180° C	61	234	232	151	292
Solids, sum of constituents	57	202	192	114	269
Calcium	60	36	37	21	43
Magnesium	62	6	6	3	8
Sodium	62	22	21	10	31
Potassium	62	10	9	6	14
Bicarbonate	1	167	167	167	167
Alkalinity	105	149	147	65	195
Sulfate	61	16	15	6	30
Chloride	62	4	3.2	0.8	17.0
Fluoride	27	0.5	0.5	0.3	0.7
Silica	23	49	49	38	56
Nitrogen, nitrate	22	0.6	0.5	0.1	1.6
Nitrite plus nitrate	61	0.6	0.5	<0.1	1.6
Phosphorus, orthophosphate	59	0.18	0.18	0.02	0.47
Aluminum (µg/L)	33	138	90	20	1,500
Arsenic (µg/L)	60	8	8	5	13
Barium (µg/L)	51	89	100	<2	180
Boron (µg/L)	57	45	40	30	80
Cadmium (µg/L)	60	<10	<10	<10	<10
Chromium (µg/L)	19	<1	<1	<1	1
Cobalt (µg/L)	16	<3	<3	<3	<3
Copper (µg/L)	62	4	3	<1	29
Iron (µg/L)	62	90	35	5	1,100
Lead (µg/L)	59	1	<1	<1	20
Lithium (µg/L)	33	21	19	<4	50
Manganese (µg/L)	62	7	5	1	48
Mercury (µg/L)	59	<0.1	<0.1	<0.1	3.8
Molybdenum (µg/L)	1	2	2	2	2
Nickel (µg/L)	18	1	<1	<1	5
Selenium (µg/L)	109	<1	<1	<1	1
Silver (µg/L)	19	<1	<1	<1	<1
Strontium (µg/L)	33	202	210	<0.5	250
Vanadium (µg/L)	1	9	9	9	9
Zinc (µg/L)	95	14	8	<3	150

Table 3. Summary of chemical analyses for the Little White River, 1950-95—Continued

Property or dissolved constituent	06450500 Little White River below White River (1950-95)				
	Number of samples	Mean	Median	Minimum	Maximum
Specific conductance (µS/cm)	321	386	360	210	1350
pH (standard units)	147	7.7	7.8	7.0	8.9
Hardness, as $CaCO_3$	147	143	129	102	435
Solids, residue at 180° C	132	305	283	220	948
Solids, sum of constituents	92	283	258	174	915
Calcium	143	47	42	34	141
Magnesium	143	6	6	2	26
Sodium	147	30	27	18	109
Potassium	94	10	9	6	15
Bicarbonate	145	197	194	144	262
Alkalinity	0	--	--	--	--
Sulfate	144	46	28	14	445
Chloride	144	2	2	ND	9
Fluoride	75	0.5	0.4	0.2	1.1
Silica	79	51	53	5	84
Nitrogen, nitrate	0	--	--	--	--
Nitrite plus nitrate	0	--	--	--	--
Phosphorus, orthophosphate	0	--	--	--	--
Aluminum (µg/L)	0	--	--	--	--
Arsenic (µg/L)	47	ND	ND	ND	ND
Barium (µg/L)	0	--	--	--	--
Boron µg/L)	94	93	80	30	290
Cadmium (µg/L)	47	ND	ND	ND	ND
Chromium (µg/L)	0	--	--	--	--
Cobalt (µg/L)	47	ND	ND	ND	ND
Copper (µg/L)	0	--	--	--	--
Iron, total (µg/L)	17	34	20	ND	190
Lead (µg/L)	47	ND	ND	ND	ND
Lithium (µg/L)	0	--	--	--	--
Manganese, total (µg/L)	1	110	110	110	110
Mercury (µg/L)	0	--	--	--	--
Molybdenum (µg/L)	0	--	--	--	--
Nickel (µg/L)	0	--	--	--	--
Selenium (µg/L)	47	ND	ND	ND	80
Silver (µg/L)	0	--	--	--	--
Strontium (µg/L)	0	--	--	--	--
Vanadium (µg/L)	0	--	--	--	--
Zinc (µg/L)	0	--	--	--	--



LITTLE WHITE RIVER ABOVE ROSEBUD (station 06449300)



LITTLE WHITE RIVER BELOW WHITE RIVER (station 06450500)

Figure 11. Trilinear diagrams (Piper, 1944) showing proportional concentrations of major ions for the Little White River.

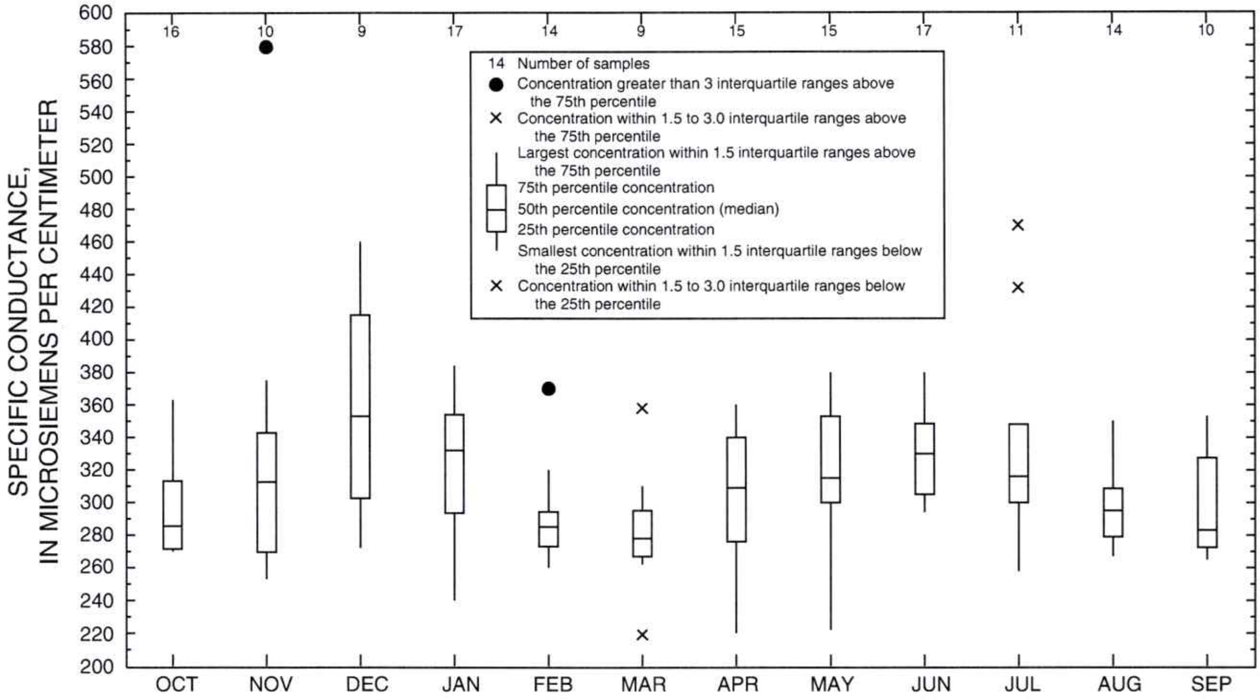


Figure 12. Monthly variations in specific conductance for the Little White River above Rosebud (station 06449300), 1981-95.

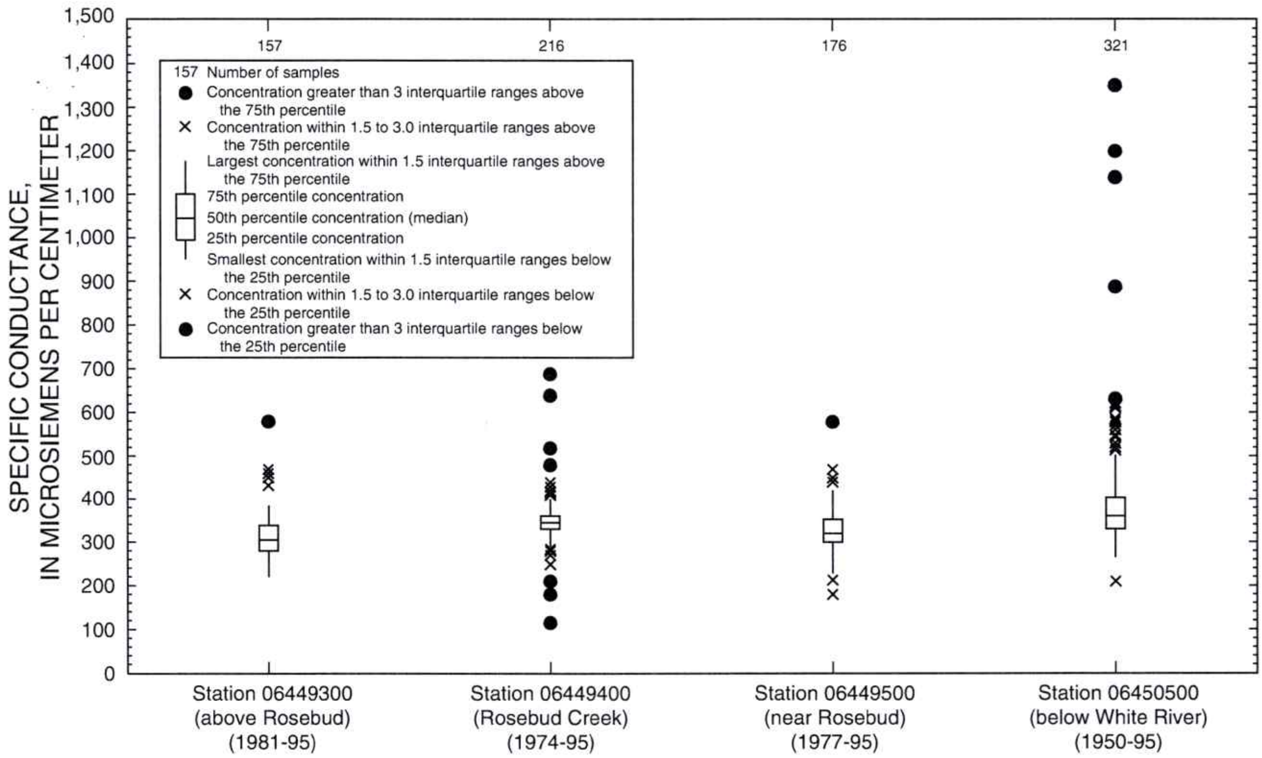


Figure 13. Variations in specific conductance at selected sites located on the Little White River, 1950-95.

The boundaries of five aquifers were delineated for this study: the alluvial, Ogallala, Arikaree, White River, and Pierre Shale aquifers. Because little information is available regarding the deeper aquifers in the study area (including the Dakota Sandstone, Inyan Kara, and Minnelusa and Madison aquifers), only their hydraulic properties will be discussed. For purposes of this report, alluvial aquifers include saturated portions of terrace and windblown deposits. The Minnelusa and Madison aquifers will be discussed together because the deepest wells in the study area are completed in both aquifers. A summary of the aquifers in the study area is presented in table 4.

Shallow Aquifers

The shallow aquifers in the study area consist primarily of unconsolidated sand and gravel or poorly consolidated sandstones and siltstones. Alluvial aquifers are found in both Mellette and Todd Counties; however, the water has high dissolved solids, is moderately saline, and is very hard in Mellette County where alluvial deposits are underlain by the Pierre Shale. The Ogallala aquifer is present in only Todd County. The Arikaree aquifer is present throughout most of Todd County and in only small areas of Mellette County. The White River aquifer is present in both counties, but the aquifer primarily is used only in Mellette County because shallower water usually can be obtained in Todd County.

Because the aquifer material within each of the formations can vary greatly even within a section of land, it was not possible to delineate specific water-bearing deposits within each formation. All formations were assumed to be fully saturated. Therefore, in the following discussions, the term "aquifer" refers to the entire formation where saturated and not to any particular interval within that formation. The following paragraph describes some of the other aquifer and formation names used in other reports to describe the shallow geologic units in the study area.

The High Plains aquifer system is a regional aquifer that consists mainly of deposits of Quaternary and Tertiary age that are hydraulically connected (Dugan and others, 1994). The High Plains aquifer system extends from southern South Dakota to Texas.

Table 4. Summary of the characteristics of major aquifers in Mellette and Todd Counties

[--, data insufficient for estimate]

Aquifer name	Estimated areal extent (square miles)	Maximum thickness (feet)	Average thickness[1] (feet)	Range in depth below land surface to top of aquifer (feet)	Range of water level (feet below or above (+) land surface	Estimated amount of water in storage[2] (million acre-feet)	Range in reported well yields (gallons per minute)	Suitable for irrigation[3]
Alluvial	440	104	29	0 - 94	0 - 94	1.6	1 - 125	Yes[4]
Ogallala	950	239	137	0 - 164	3 - 164	17	1 - 1,250	Yes
Arikaree	1,360	618	290	0 - 406	+18 - 170	50	1 - 1,005	Yes
White River	1,720	469	229	0 - 789	+6 - 261	50	1 - 30	Yes[4]
Pierre Shale	2,694	1,294	900	0 - 1,204	2 - 200	[5]1.5	1 - 8	No
Dakota Sandstone	2,694	336	[6]236	1,270 - 2,348	+102 - 450	[7]81	10 - 100	No
Inyan Kara	--	275	[6]136	[8]1,915 - 2,450	+289 - 300	--	9 - 160	No
Minnelusa and Madison	--	882	[6]608	[8]2,105 - 2,448	+79 - 44	--	25 - 40	Yes[9]

[1]Arithmetic mean from test-hole data; all formations assumed to be fully saturated.

[2]Storage estimated by multiplying average thickness times areal extent times a porosity of 0.20 for all aquifers except Pierre Shale; a porosity of 0.001 was used in storage calculation for Pierre Shale.

[3]Based on irrigation-water classification diagram (fig. 31).

[4]Though water quality generally is suitable for irrigation, in most places yields will be insufficient to support irrigation.

[5]Maximum value because saturated thickness probably is much less than average thickness.

[6]Average thickness greater than indicated because not all test holes fully penetrated the aquifer.

[7]Minimum value because average thickness greater than indicated.

[8]Minimum values because no information available on depths in Todd County.

[9]Though generally suitable for irrigation, in some places the water in the aquifer is not suitable.

The principal aquifer in this system is the Ogallala; the Arikaree and Brule aquifers also are included in this system. The Brule Formation is the upper unit of the White River Group and the Chadron Formation is the lower unit. In some studies, it has been possible to distinguish between the two units of the White River Group; however, because the lithologic units could not be distinguished in most of the study area, the White River Group was not subdivided in this report. Additionally, references are sometimes made to the Rosebud Formation, which is part of the Arikaree Formation, and to the Ash Hollow and Valentine Formations, which are part of the Ogallala Formation.

In the following sections, monthly precipitation data were compiled from annual summaries (U.S. Department of Commerce, 1957-94) to determine the cumulative departure from normal precipitation. The National Weather Service station at Valentine, Nebraska, located 10 miles south of the South Dakota-Nebraska border on highway 83, was used because it had a more complete record than the stations at Wood and Mission.

Alluvial Aquifers

The major alluvial deposits are located along the Keya Paha, Little White, and White Rivers and associated tributaries, and are considered aquifers where saturated. Generally, the alluvial aquifers that overlie the Pierre Shale are essentially impermeable because of the high percentage of clay and supply only a small amount of water. Also, some alluvial aquifers along the White River are not in hydraulic connection with the river (Ellis and others, 1971), and therefore do not yield an adequate supply of water.

The composition of the alluvial deposits varies from clayey silt to gravel. Deposits that overlie Tertiary deposits are composed mainly of sand and gravel in comparison to deposits that overlie the Pierre Shale, which generally contain a greater percentage of clay. Alluvial aquifers underlie about 440 square miles of the study area and contain an estimated 1.6 million acre-feet of water in storage. The saturated thickness of the alluvial deposits along streams generally ranges from about 10 to 40 feet (fig. 14) and averages 29 feet. The thicknesses of two terrace deposits in Mellette County exceeded 100 feet, although only about 10 feet of these deposits were saturated. The general direction of ground-water flow in the alluvial aquifers is toward the streams and rivers and downstream (fig. 15). Water in alluvial aquifers along the Little White River, Blackpipe, Oak, and White Thunder Creeks generally flows north; water in aquifers along the Keya Paha and White Rivers generally flows east.

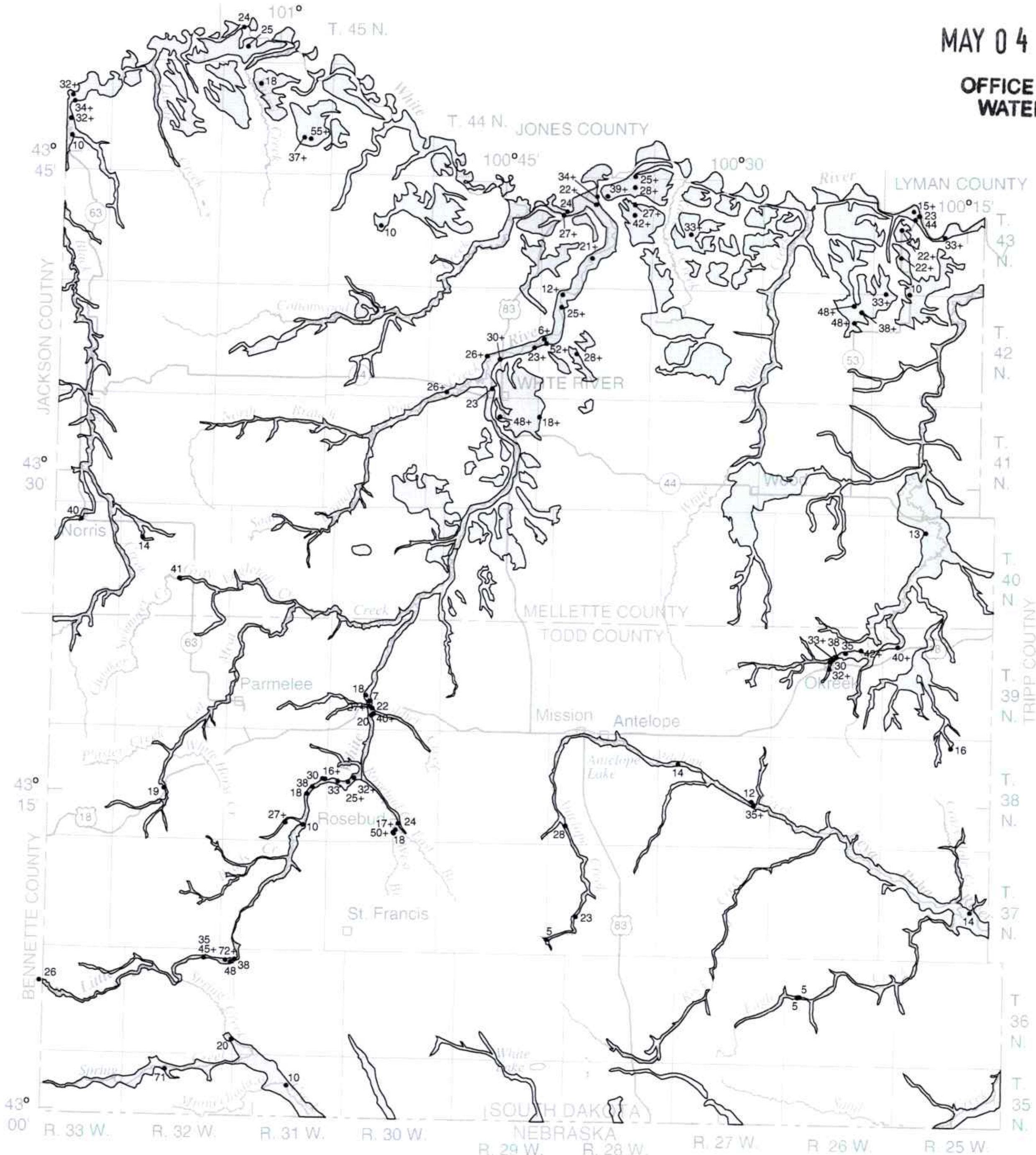
Records of long-term water-level fluctuations in well 43N28W8CCDC in Mellette County and well 38N28W32BBBB in Todd County (fig. 16) correlate well with long-term precipitation data, although the correlation is more evident in the Mellette County well. The water-level decline from 1974-76 was caused by below-normal precipitation. The increase in water levels from 1991-95 was caused by above-normal precipitation.

Recharge to the alluvial aquifers is by infiltration of precipitation, stream loss when the stream stage is higher than the hydraulic head in the aquifer, and discharge from springs originating in Tertiary aquifers. Generally, the greatest recharge occurs in the spring after snowmelt. Infiltration rates generally range between 1 and 6 inches/hour in the alluvial deposits (U.S. Soil Conservation Service, 1974, 1975), so precipitation is a major source of recharge to these deposits. Discharge from the aquifer is by withdrawals of water from domestic and stock wells and by evapotranspiration from the aquifer. The cyclic pattern of recharge and discharge is evident in the water-level fluctuations of well 38N28W32BBBB (fig. 16). Every year, the water level is highest in the spring due to snowmelt and high streamflows, and is lowest during the summer and fall months when potential evapotranspiration is the greatest and precipitation decreases.

The only available information concerning the hydraulic properties of the alluvial aquifers in the study area was specific capacity data stored in the USGS NWIS ground-water database for eight wells completed in alluvial deposits. The specific capacity of a well is the rate of discharge of water from a well divided by the drawdown of the water level within the well (Lohman and others, 1972). The specific capacity of the 8 alluvial wells ranged from 6 to 900 square feet per day with an average of 400 square feet per day.

Ogallala Aquifer

The Ogallala aquifer is present throughout most of Todd County, but not in Mellette County. A hydrogeologic section (A-A') across the southern boundary of Todd County (fig. 17) shows the Ogallala aquifer and the underlying Arikaree and White River aquifers. The Ogallala Formation is overlain by unconsolidated deposits consisting of alluvium and windblown sand deposits in the southwestern part of Todd County.



Base from U.S. Geological Survey
digital data 1:100,000

0 2 4 6 MILES
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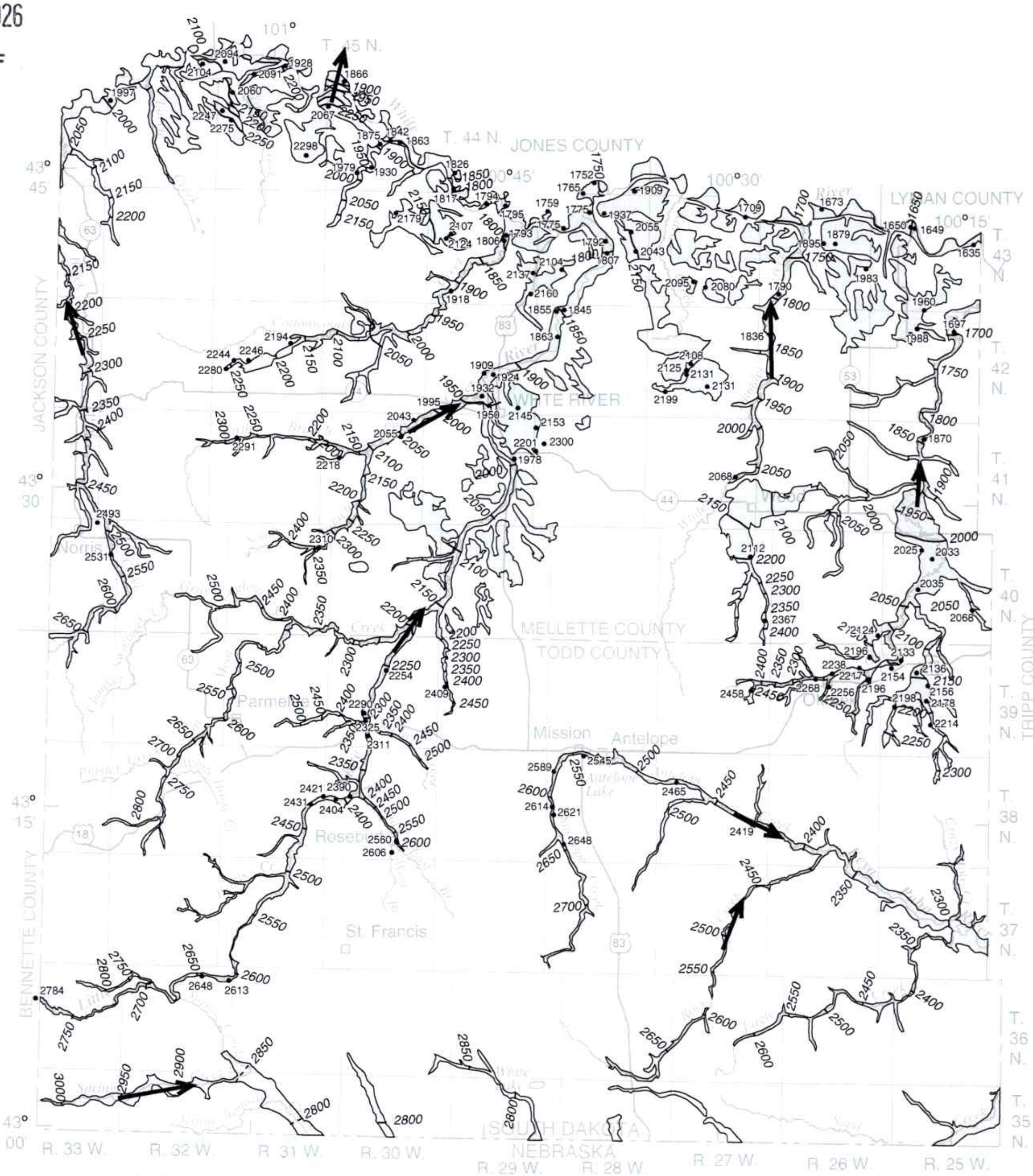
EXPLANATION

APPROXIMATE AREA UNDERLAIN BY ALLUVIAL AQUIFERS (modified from Ellis and others, 1971)

• 32+ WELL OR TEST HOLE--Numbers are saturated thickness, in feet, of aquifer. A plus (+) indicates a thickness greater than shown.

Figure 14. Extent and thickness of alluvial aquifers.



Base from U.S. Geological Survey
digital data 1:100,000

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0 2 4 6 KILOMETERS

EXPLANATION

APPROXIMATE AREA OF ALLUVIAL AQUIFERS (modified from Ellis and others, 1971)

—2500- - · POTENTIOMETRIC CONTOUR--Shows altitude at which water would have stood in tightly cased, nonpumping wells in 1996. Dashed where inferred. Contour interval 50 feet. Datum is sea level.

• 2431 WELL--Number is altitude of water level, in feet above sea level

⟶ GENERAL DIRECTION OF GROUND-WATER FLOW

Figure 15. Potentiometric surface of alluvial aquifers.

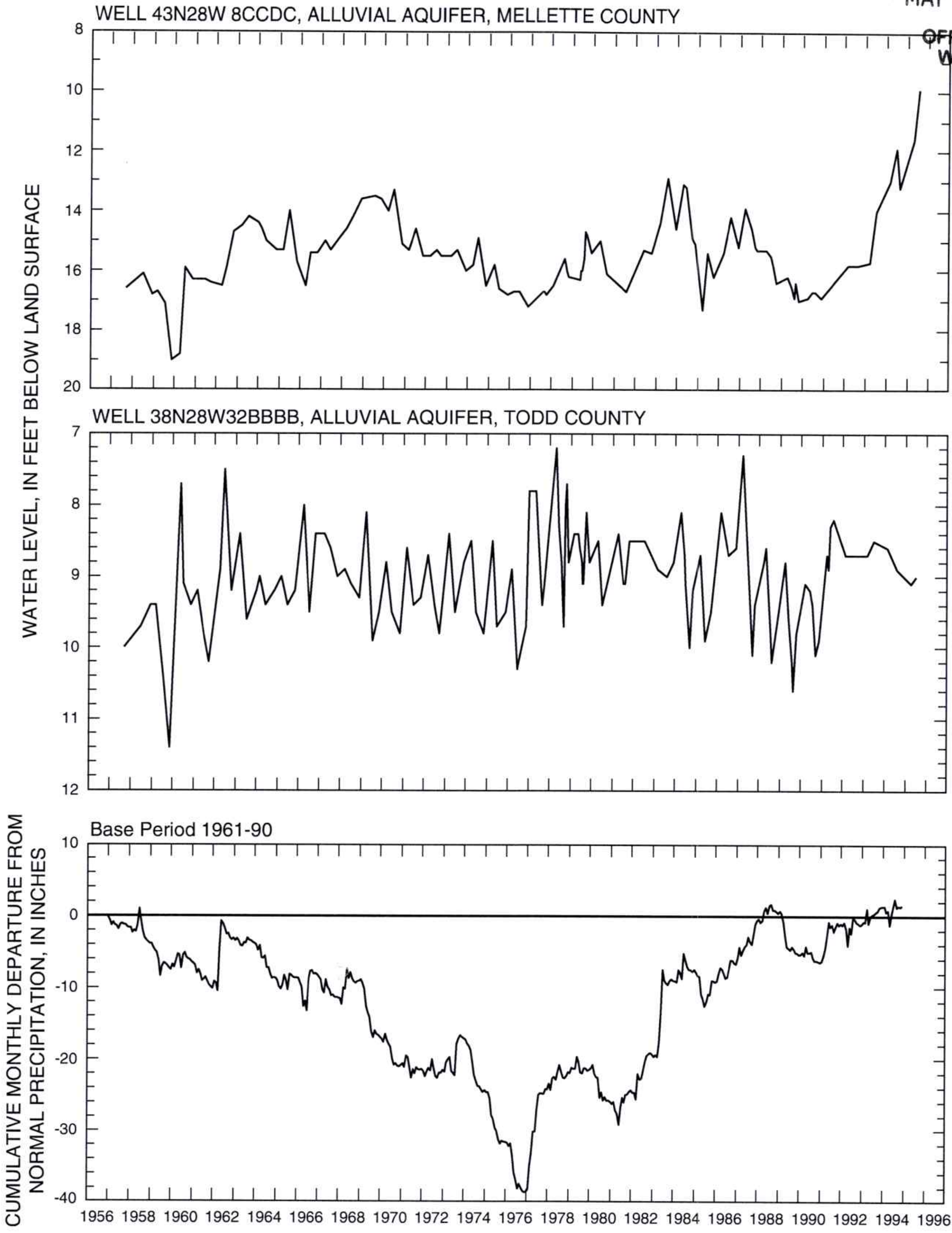


Figure 16. Water-level fluctuations in alluvial aquifers and cumulative monthly departure from normal precipitation at Valentine, Nebraska.

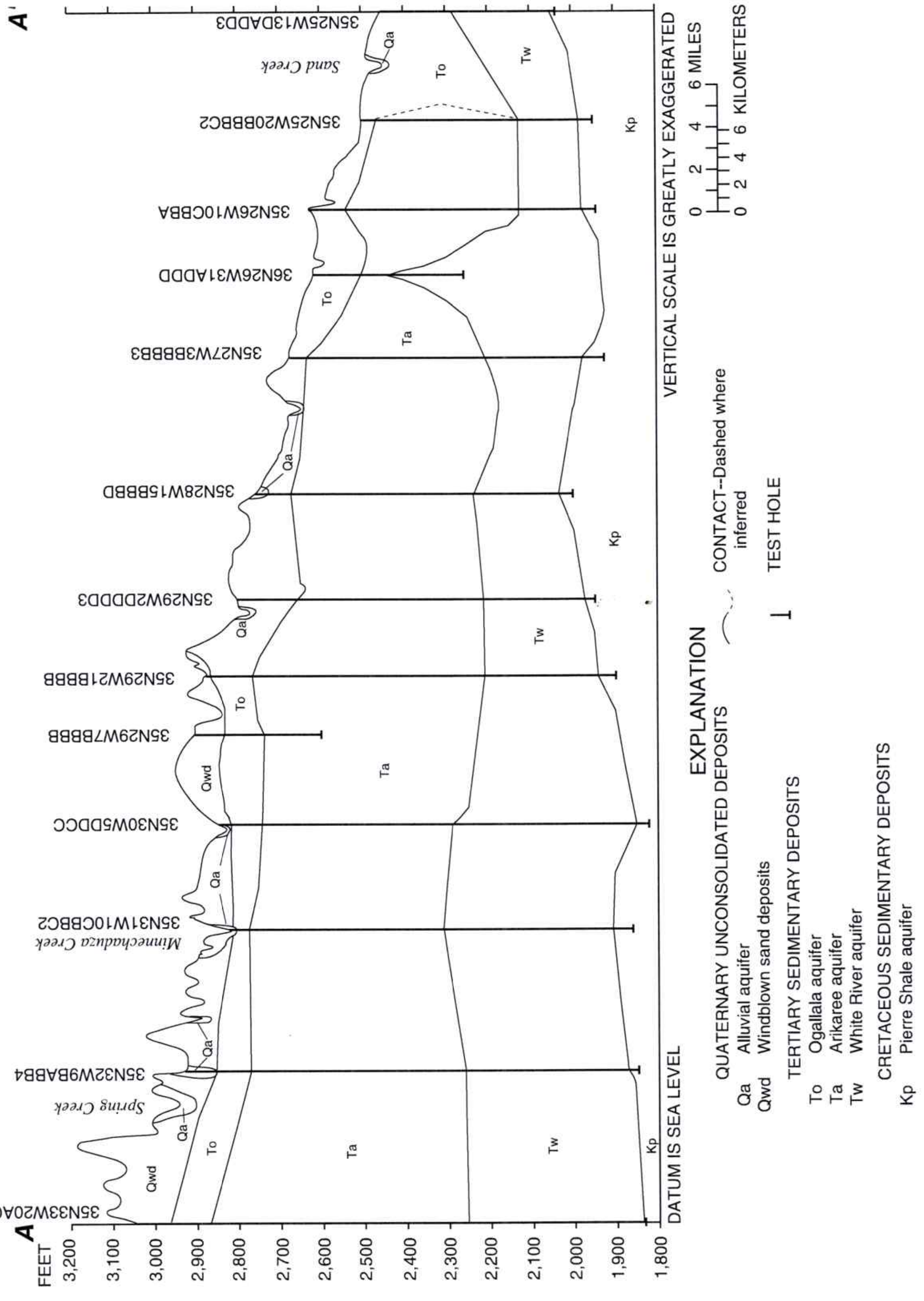


Figure 17. Hydrogeologic section A-A′ showing aquifers of Quaternary, Tertiary, and Cretaceous age in Todd County. (The location of section A-A′ is shown in fig. 2).

The Ogallala Formation consists primarily of poorly consolidated, fine- to medium-grained sandstone with some interbedded clay and silt. The saturated sandstones and silt of the Ogallala Formation make up the Ogallala aquifer. The depth to the top of the aquifer ranges from 0 to 164 feet below land surface, and the average thickness is 137 feet (table 4). The aquifer underlies about 950 square miles in Todd County and contains about 17 million acre-feet of water in storage. Generally, the aquifer is thickest in the central portion of Todd County, where use of the aquifer for irrigation is highest. The potentiometric surface of the Ogallala aquifer is shown in figure 18. Most of the aquifer is under water-table conditions, except in the southwest part of Todd County where the aquifer is confined by well-cemented or concretion beds in the upper part of the Ogallala Formation. The depth to water in wells generally is less than 10 feet below land surface where the aquifer is confined. Under water-table conditions, the depth to water ranges from 3 to greater than 150 feet below land surface. The aquifer has the highest yield potential of the aquifers in the study area; the maximum reported well yield is 1,250 gallons per minute (table 4).

Records of long-term water-level fluctuations in well 36N30W13BBBB and well 37N28W21CCCC (fig. 19) correlate well with long-term precipitation data prior to 1990. The water-level decline in 1981 was caused by below-normal precipitation. The increase in water levels from 1982 to 1984 was caused by above-normal precipitation. However, the water-level decline in both wells since 1990 does not correspond with below-normal precipitation; rather, the decline probably was caused by increased withdrawals of water for irrigation. In general, regional studies of the Ogallala aquifer indicate that water levels have not substantially declined in South Dakota due to irrigational development (Dugan and others, 1994). Predictions for further development of the Ogallala aquifer in South Dakota indicate that the water-level declines through 2020 generally will be less than 10 feet in most areas of Todd County (Luckey and others, 1988).

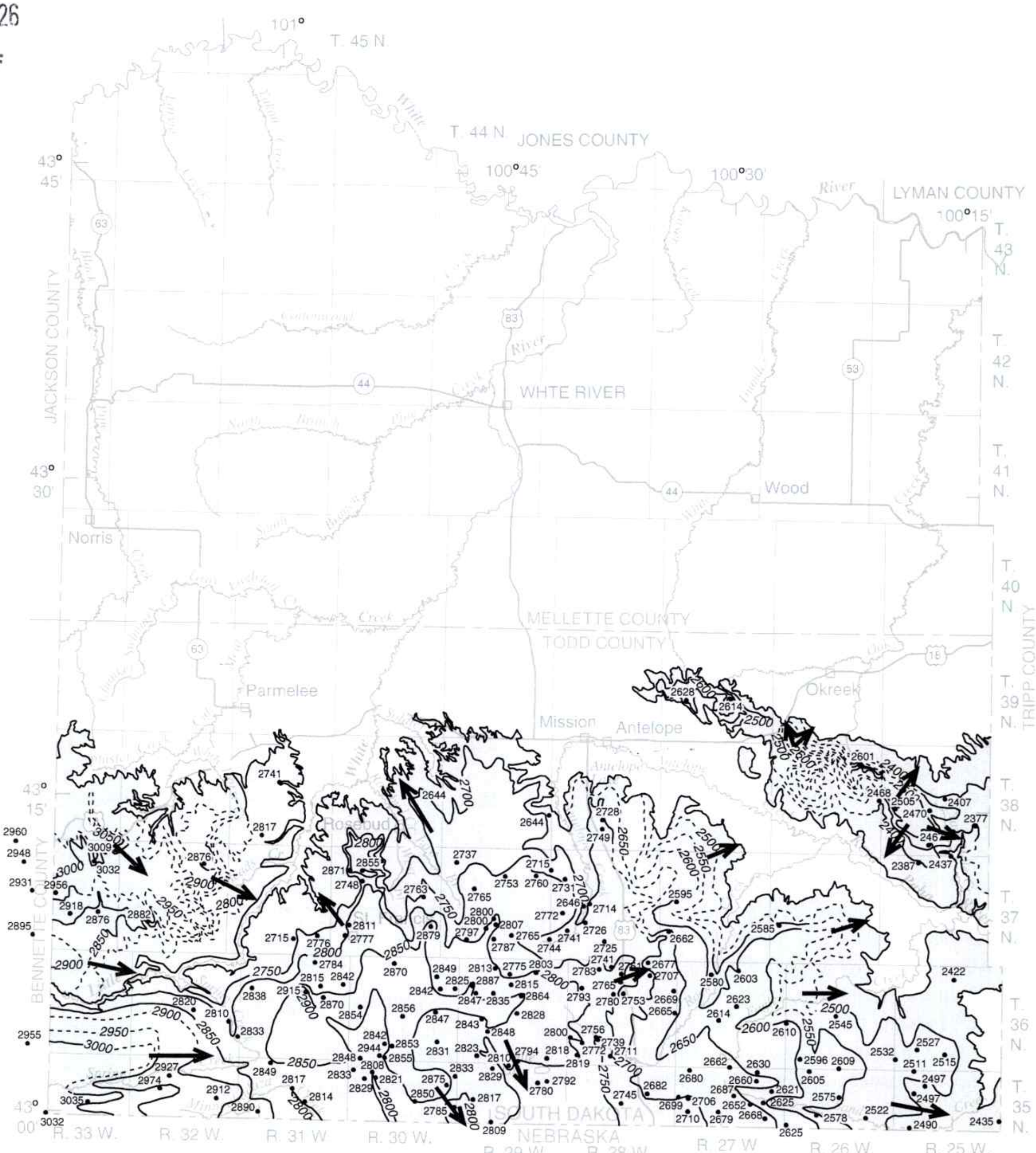
Recharge to the Ogallala aquifer primarily is by infiltration of precipitation on outcrops of the Ogallala Formation or overlying windblown sand deposits (fig. 4) and by stream loss as streams cross the outcrop of the Ogallala Formation when the stream stage is higher than the hydraulic head in the aquifer. Infiltration rates generally are greater than 2 inches/hour in the Ogallala Formation and generally are greater than 6 inches/hour in the overlying windblown sand deposits (U.S. Soil Conservation Service, 1974), so precipitation is a major source of recharge to the aquifer. Discharge from the aquifer is through withdrawals from domestic, public, stock, and irrigation wells; by loss to streams and springs; and by evapotranspiration from the aquifer where the aquifer is at or near land surface.

Transmissivity is the rate at which water of the prevailing kinematic viscosity is transmitted through a unit width of the aquifer under a unit hydraulic gradient (Lohman and others, 1972). Transmissivities of the Ogallala aquifer were estimated for the water-bearing sediments of 10 test holes along the boundary between Todd County and Nebraska; transmissivities ranged from 800 to 9,200 square feet per day, with an average of 2,800 square feet per day (Newport, 1959). Additionally, specific capacity data stored in the USGS NWIS ground-water database were available for 65 wells completed in the Ogallala aquifer. The specific capacity ranged from 2 to 2,400 square feet per day, with an average of 600 square feet per day. Hydraulic conductivity is the volume of water an aquifer will transmit under a unit hydraulic gradient, through a unit cross-sectional area, measured at right angles to the direction of flow (Lohman, 1972). Transmissivity is equal to the hydraulic conductivity times the saturated thickness of the aquifer. Average hydraulic conductivities of the Ogallala aquifer in south-central South Dakota, estimated from 205 well logs, ranged from 3.6 to 160 feet per day, with an average of 30 feet per day (Kolm and Case, 1983).

Arikaree Aquifer

The Arikaree aquifer is present throughout most of Todd County, but is present in only a small part of southwestern Mellette County. The Arikaree Formation is not present along the eastern boundary of Todd County (fig. 7). The absence of the Arikaree aquifer in eastern Todd County also is shown in the hydrogeologic section B-B' (fig. 20).

The Arikaree Formation is predominantly composed of pinkish-tan to red, clayey, tuffaceous siltstones and sandstones. The Arikaree aquifer is composed primarily of the saturated sandstones and siltstones within the Arikaree Formation. The depth to the top of the aquifer ranges from 0 to 406 feet below land surface, and the average thickness is 290 feet (table 4). The aquifer underlies approximately 1,360 square miles of the study area and contain about



Base from U.S. Geological Survey
digital data 1:100,000

0 2 4 6 MILES
0 2 4 6 KILOMETERS

EXPLANATION

APPROXIMATE AREA UNDERLAIN BY THE OGALLALA AQUIFER (modified from Ellis and others, 1971)

—2900- - · POTENTIOMETRIC CONTOUR--Shows altitude at which water would have stood in tightly cased, nonpumping wells in 1996. Dashed where inferred. Contour interval 50 feet. Datum is sea level.

• 2745 WELL--Number is altitude of water level, in feet above sea level

GENERAL DIRECTION OF GROUND-WATER FLOW

Figure 18. Potentiometric surface of the Ogallala aquifer.

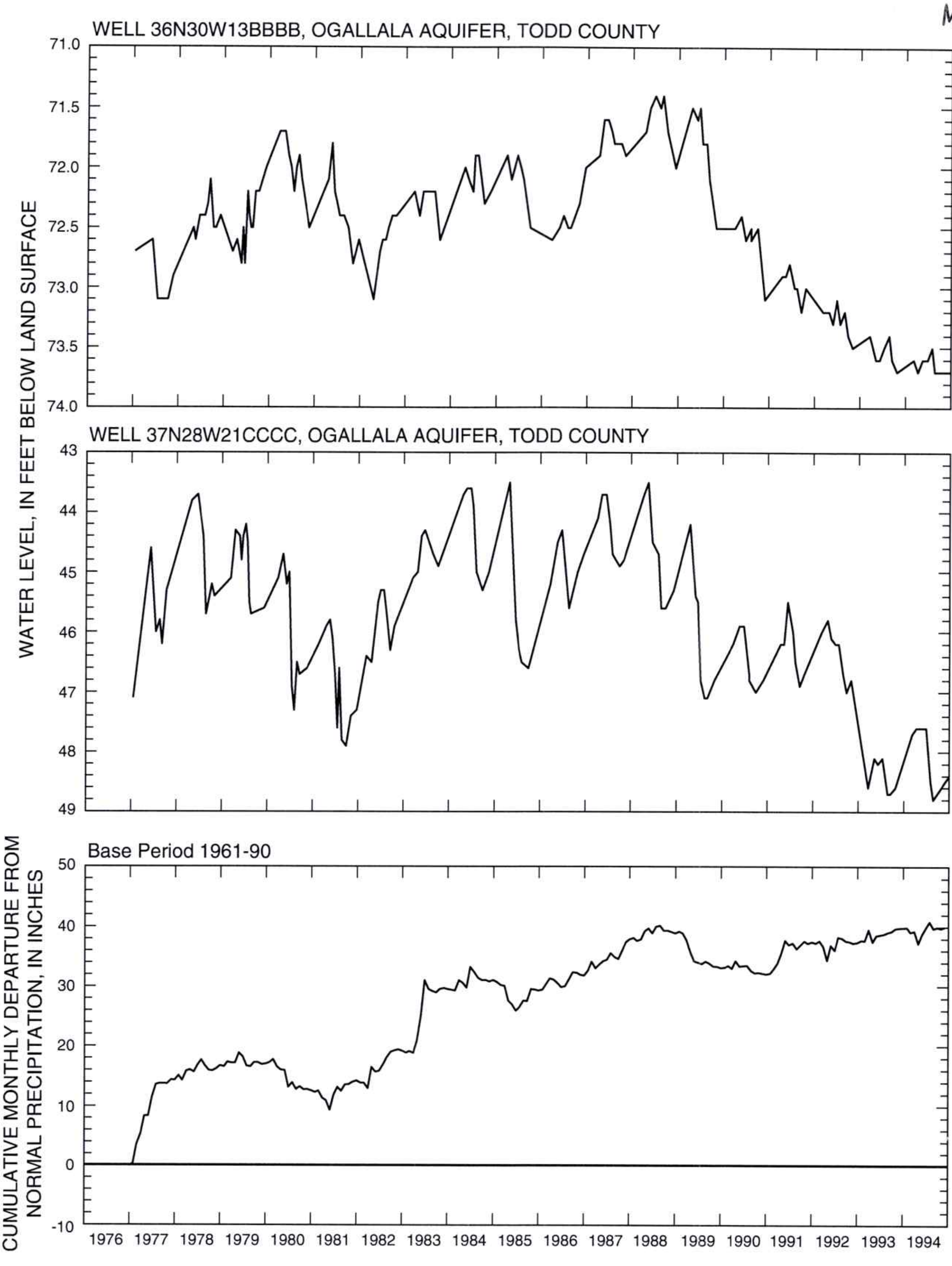


Figure 19. Water-level fluctuations in the Ogallala aquifer and cumulative monthly departure from normal precipitation at Valentine, Nebraska.

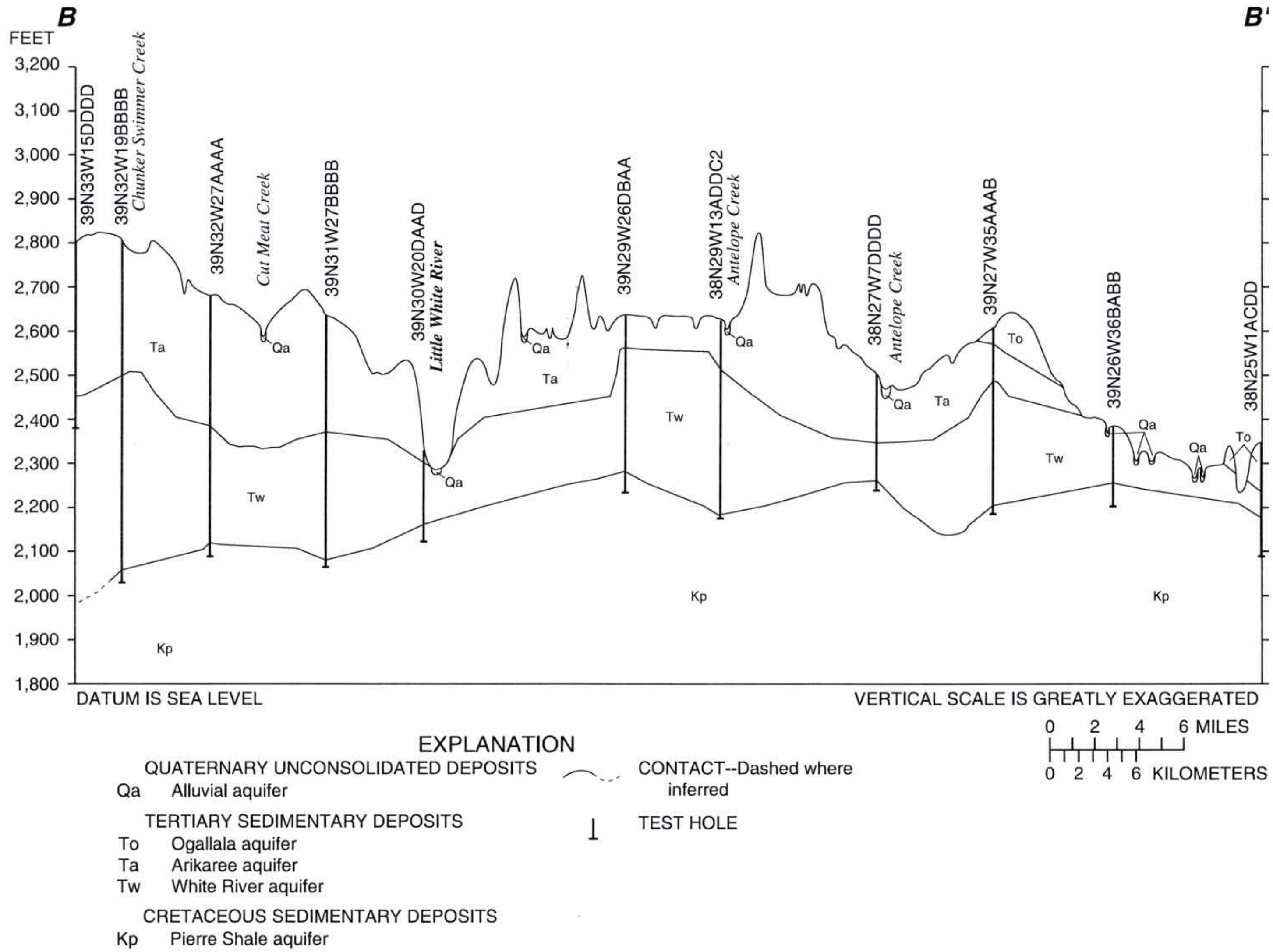


Figure 20. Hydrogeologic section B-B′ showing aquifers of Quaternary, Tertiary, and Cretaceous age in Todd County. (The location of section B-B′ is shown in fig. 2.)

50 million acre-feet of water in storage. The aquifer is thickest in southern Todd County. The potentiometric surface of the Arikaree aquifer is shown in figure 21. About one-half of the aquifer is under water-table conditions and one-half is confined. The aquifer is confined where overlain by impermeable materials in the Ogallala Formation, and the deeper part of the aquifer is under confined conditions where impermeable material exists in the upper part of the formation. Two flowing observation wells completed in the Arikaree aquifer are located at 36N33W17BACA. Water levels in the aquifer generally are within 60 feet of land surface under confined conditions, and range from 3 to greater than 150 feet under water-table conditions. Yields from the aquifer, which range from 1 to 1,005 gallons per minute (table 4), are dependent on the percentage of clay in the formation, consolidation of the materials, and well construction. Yields usually are not as great as those from the Ogallala aquifer, but are substantially greater than yields from the under-lying White River aquifer (table 4).

Records of long-term water-level fluctuations in well 40N32W21BBBB in Mellette County (fig. 22) correlate well with long-term precipitation data; records from well 37N29W22CCCC in Todd County do not correlate as well possibly because of distance from the outcrop. The Arikaree Formation is exposed at land surface at the well site in Mellette County (fig. 4), and infiltration of precipitation directly recharges the aquifer; therefore, the water-level fluctuations correlate well with precipitation data. Water-level fluctuations at both wells show the typical cyclic pattern of higher water levels during the spring due to precipitation recharge and lower water levels in the fall due to evapotranspiration and decreasing precipitation.

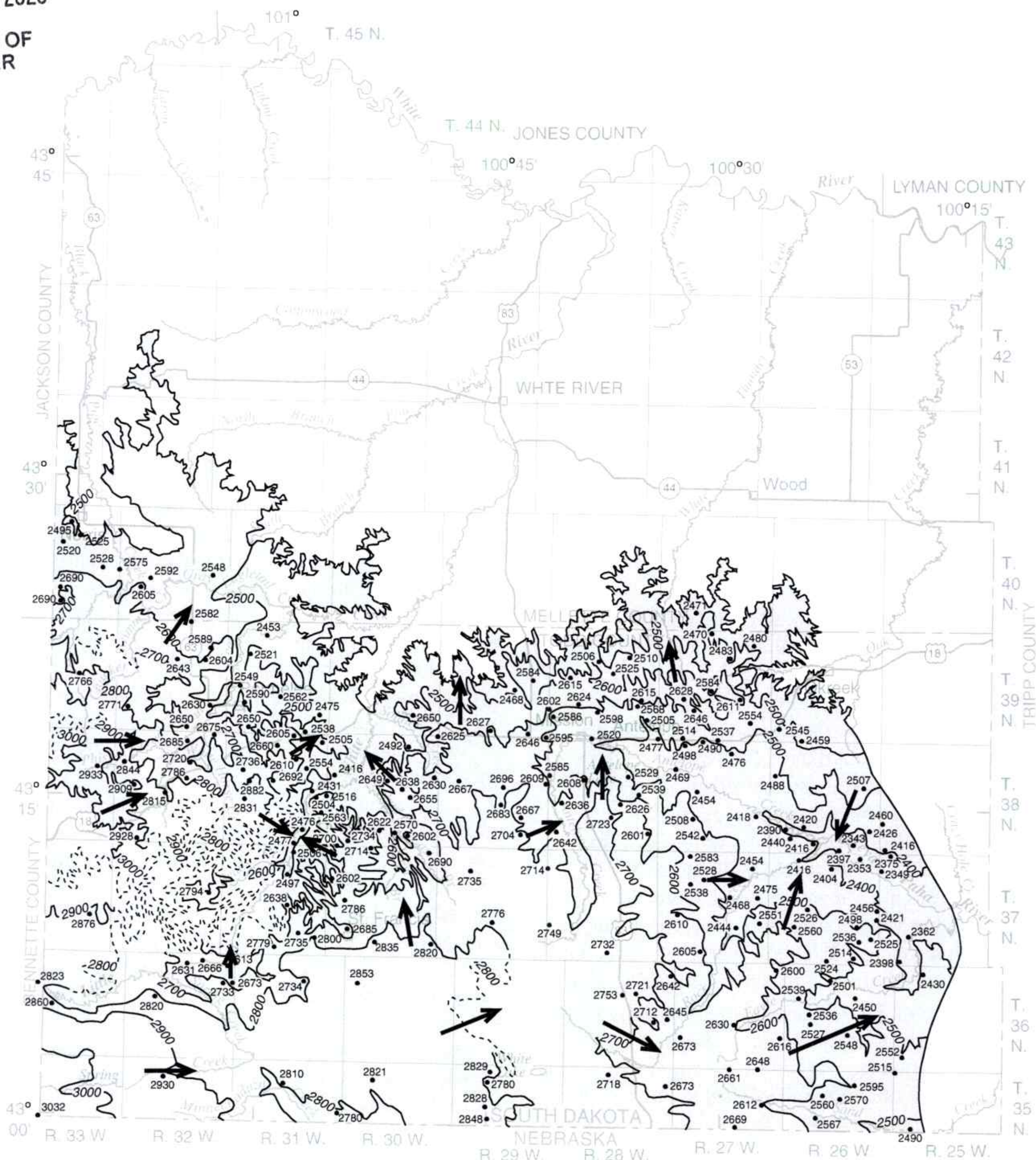
Recharge to the Arikaree aquifer primarily is by infiltration of precipitation on the outcrops of the Arikaree Formation (fig. 4) and by stream loss as streams cross the outcrop of the Arikaree Formation when the stream stage is higher than the hydraulic head in the aquifer. The greatest recharge to the aquifer occurs during the spring after snowmelt and during storm events. Infiltration rates generally range between 0.6 and 1.2 inches/hour (U.S. Soil Conservation Service, 1974, 1975). Discharge from the aquifer is through withdrawals from domestic, stock, and irrigation wells; by evapotranspiration where the aquifer is at or near land surface; and by discharge from springs to alluvial aquifers and streams when the hydraulic head in the Arikaree aquifer is higher than the hydraulic head in the alluvial aquifers or stage in the streams.

Specific capacity data stored in the USGS NWIS ground-water database for 184 wells completed in the Arikaree aquifer ranged from 2 to 2,000 square feet per day, with an average of 90 square feet per day. Analyses of four aquifer tests conducted near Pine Ridge, South Dakota, by Greene and others (1991) yielded a hydraulic conductivity of 13 feet per day and a transmissivity of 1,250 square feet per day in the unconfined Arikaree aquifer. In the confined Arikaree aquifer, the hydraulic conductivity was reported as 1 foot per day and the transmissivity was 300 square feet per day (Greene and others, 1991). A core sample from the Arikaree Formation in Nebraska had a hydraulic conductivity of about 2 feet per day (Bradley, 1956).

White River Aquifer

The White River aquifer is present throughout most of Todd County and in western and south-central Mellette County. The White River aquifer is used as a water source in northern Todd County where the Ogallala and Arikaree aquifers are not present. The aquifer is used in Mellette County where present because it is usually the shallowest source of water. A hydrogeologic section (C-C') from the northwestern boundary of Mellette County to the south-central part of Todd County (fig. 23) shows the White River aquifer where present.

The White River aquifer consists predominantly of the saturated, poorly consolidated siltstones and claystones and interbedded sand layers within the White River Group. The depth to the top of the aquifer ranges from 0 to 789 feet below land surface, and the average thickness is 229 feet (table 4). This aquifer underlies approximately 1,720 square miles of the study area and contains about 50 million acre-feet of water in storage. The White River aquifer is thickest in western Todd County and southwestern Mellette County. The potentiometric surface of the aquifer is shown in figure 24. The aquifer is under water-table conditions where it is at or near the land surface, and is confined where overlain by the Ogallala Formation and/or the Arikaree Formation (fig. 4). Thus, most of the aquifer is confined in the study area. One observation well (107 feet deep) completed in the aquifer at 37N25W24BCBB currently flows. Two shallower observation wells (less than 60 feet deep) completed in the aquifer at this same location do not flow, but water levels in both wells are within 10 feet of land surface. Water levels in the aquifer generally are less than 100 feet below land surface under both water-table and confined conditions, but water-level depths exceeding



Base from U.S. Geological Survey digital data 1:100,000

0 2 4 6 MILES
0 2 4 6 KILOMETERS

EXPLANATION

APPROXIMATE AREA UNDERLAIN BY THE ARIKAREE AQUIFER (modified from Ellis and others, 1971)

—2900- - - POTENTIOMETRIC CONTOUR--Shows altitude at which water would have stood in tightly cased, nonpumping wells in 1996. Dashed where inferred. Contour interval 100 feet. Datum is sea level.

• 2749 WELL--Number is altitude of water level, in feet above sea level

⟶ GENERAL DIRECTION OF GROUND-WATER FLOW

Figure 21. Potentiometric surface of the Arikaree aquifer.

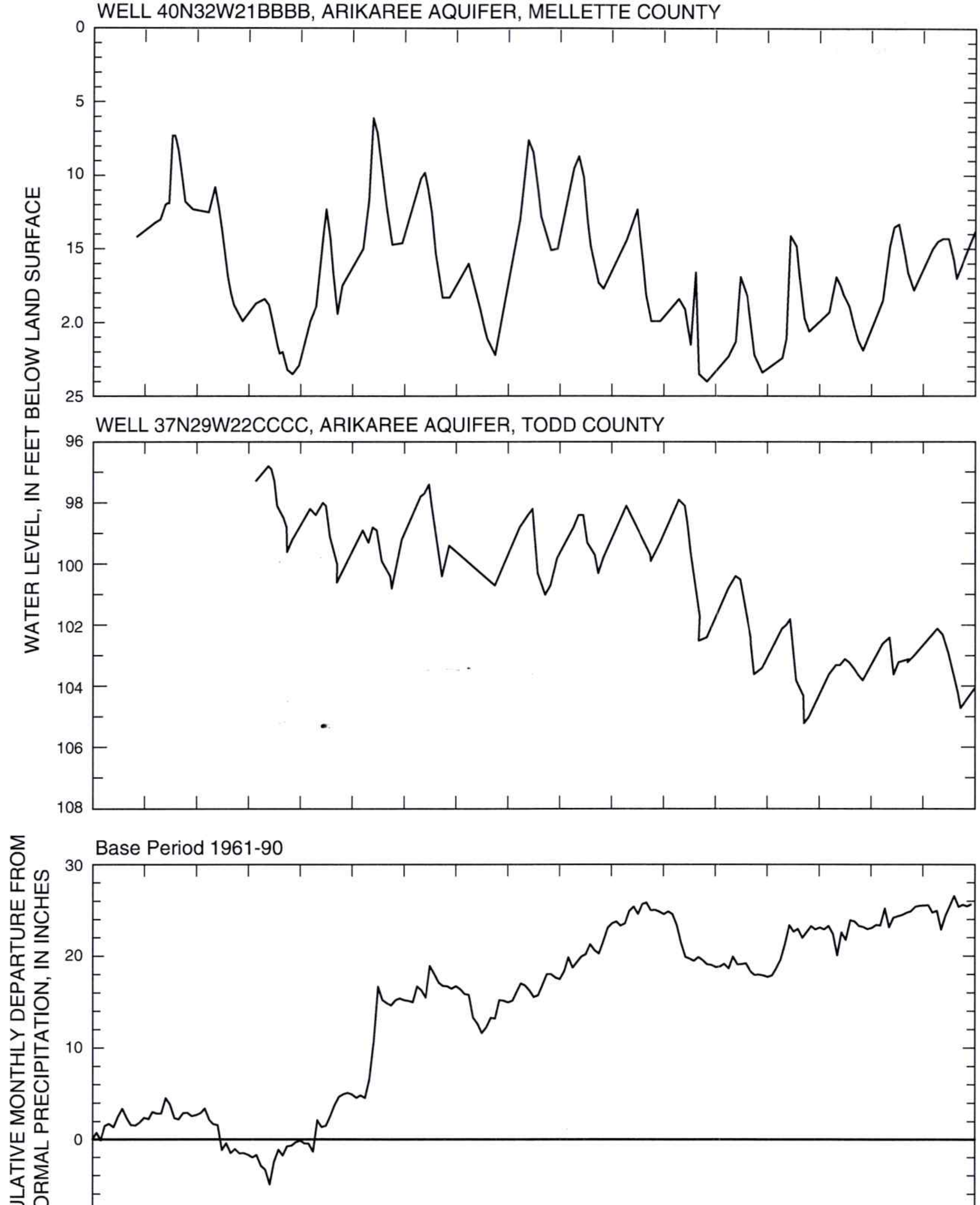
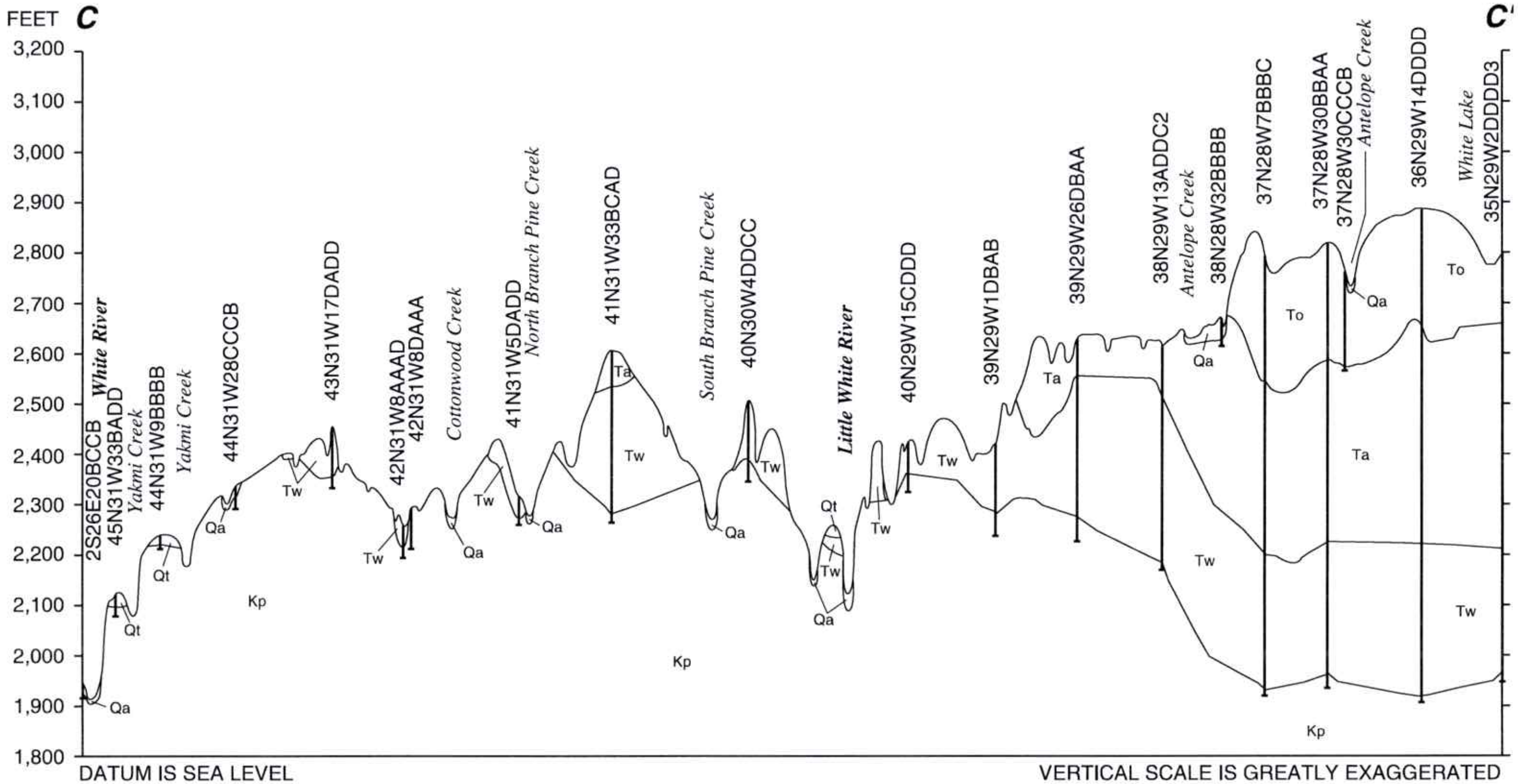


Figure 22. Water-level fluctuations in the Arikaree aquifer and cumulative monthly departure from normal precipitation at Valentine, Nebraska.



EXPLANATION

QUATERNARY UNCONSOLIDATED DEPOSITS
- Qa Alluvial aquifer
- Qt Terrace deposit

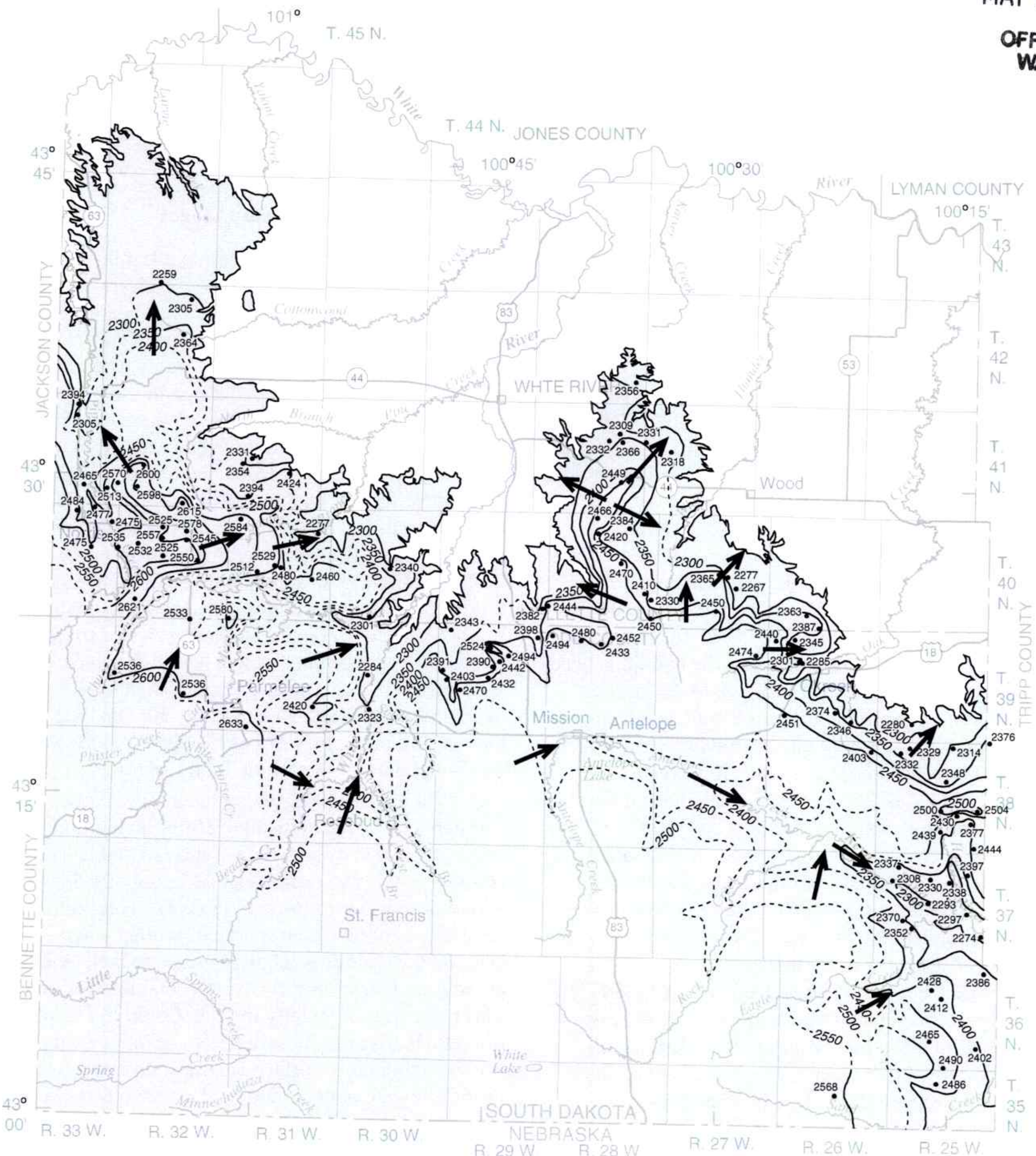
TERTIARY SEDIMENTARY DEPOSITS
- To Ogallala aquifer
- Ta Arikaree aquifer
- Tw White River aquifer

CRETACEOUS SEDIMENTARY DEPOSITS
- Kp Pierre Shale aquifer

CONTACT

TEST HOLE

Figure 23. Hydrogeologic section C-C′ showing aquifers of Quaternary, Tertiary, and Cretaceous age in Mellette and Todd Counties. (The location of section C-C′ is shown in fig. 2.)



Base from U.S. Geological Survey digital data 1:100,000

0 2 4 6 MILES

0 2 4 6 KILOMETERS

EXPLANATION

APPROXIMATE AREA UNDERLAIN BY THE WHITE RIVER AQUIFER (modified from Ellis and others, 1971)

—2900- - - POTENTIOMETRIC CONTOUR--Shows altitude at which water would have stood in tightly cased, nonpumping wells in 1996. Dashed where inferred. Contour interval 50 feet. Datum is sea level.

• 2912 WELL--Number is altitude of water level, in feet above sea level

Figure 24. Potentiometric surface of the White River aquifer.

200 feet below land surface have been recorded in northwestern Todd County and southwestern Mellette County. Yields from the aquifer range from 1 to 30 gallons per minute (table 4), and are dependent on the percentage of clay in the formation, consolidation of the siltstones and sandstones, thickness of the siltstones and sandstones, and well construction. Yields generally are sufficient for domestic and stock-watering purposes.

Records of long-term water-level fluctuations in well 40N32W32BBBB in Mellette County and in well 37N25W23ADAD in Todd County (fig. 25) correlate reasonably well with long-term precipitation data. However, the below-normal precipitation during 1974-76 does not correlate with water-level fluctuations in the Todd County well, and the cause of the water-level decline in the Mellette County well in 1979 is not known. Both wells show an increase in water levels due to above-normal precipitation beginning in 1992-93 through the end of the period shown.

Recharge to the White River aquifer primarily is by infiltration of precipitation on the outcrops of the White River Group (fig. 4), and by stream loss as streams cross the outcrop of the White River Group when the stream stage is higher than the hydraulic head in the aquifer. The greatest recharge to the aquifer occurs during the spring after snowmelt and during storm events. Infiltration rates range from less than 0.06 to 0.6 inches/hour (U.S. Soil Conservation Service, 1974, 1975). Discharge from the aquifer is through withdrawals from domestic and stock wells, by evapotranspiration where the aquifer is at or near land surface, and by discharge from springs to alluvial deposits and streams when the hydraulic head in the aquifer is higher than the hydraulic head in the alluvial deposits or the stage in the streams.

Specific capacity data stored in the USGS NWIS ground-water database were available for 26 wells completed in the White River aquifer. The specific capacity ranged from 2 to 2,500 square feet per day, with an average of 160 square feet per day.

Bedrock Aquifers

The bedrock aquifers in the study area include the Pierre Shale, Dakota Sandstone, Inyan Kara, and Minnelusa and Madison aquifers. The Pierre Shale aquifer, which is the shallowest bedrock aquifer in the study area, generally is used only in Mellette County as a source of ground water. Few wells have been completed in the deeper aquifers because of cost and because water usually can be obtained from a shallower aquifer or from other sources. Most of the available bedrock-aquifer information in the study area is from wells located in northern Mellette County. Test drilling for this study usually stopped just below the upper contact of the Pierre Shale. Therefore, other than the Pierre Shale, the deeper bedrock aquifers were not penetrated during the test drilling.

Pierre Shale Aquifer

The Pierre Shale aquifer is present throughout the study area. The upper part of the Pierre Shale generally is weathered and fractured. The Pierre Shale typically is not considered an aquifer in South Dakota, except in localities like Mellette County where individuals rely on the aquifer because it is the shallowest source of ground water available. Where the Pierre Shale is used to supply water, wells usually are completed in the weathered shale. The shale is exposed at the land surface throughout most of Mellette County and is overlain by the Tertiary deposits throughout most of Todd County (fig. 4). A hydrogeologic cross-section (D-D') from north to south along the eastern edge of Mellette and Todd Counties (fig. 26) shows that the Pierre Shale aquifer is the shallowest water source in eastern Mellette County, except where alluvial deposits are present. In eastern Todd County, the Pierre Shale is overlain by the White River Group and Ogallala Formation. As previously discussed, the Arikaree Formation is not present in eastern Todd County.

The Pierre Shale predominantly is a black shale. The depth to the top of the Pierre Shale in the study area ranges from 0 to greater than 1,200 feet (table 4). The aquifer contains an estimated maximum of 1.5 million acre-feet of water in storage (table 4). This aquifer generally is not a viable source of ground water because the aquifer is relatively impermeable, yields are low, and water usually can be obtained from shallower aquifers, especially in Todd County. The potentiometric surface of the aquifer is shown in figure 27. The potentiometric surface for the aquifer throughout most of Todd County could not be drawn because of insufficient data. Because the aquifer is used as a water source mainly in Mellette County, where the formation generally is present at or near the land surface, the aquifer is under water-table conditions. The general direction of ground-water flow in the Pierre Shale aquifer is to the north. Yields from the aquifer ranged from 1 to 8 gallons per minute (table 4) and are dependent on the amount of fracturing and the percentage of clay and sand present in the shale. No long-term water-level records were available for wells completed in the Pierre Shale.

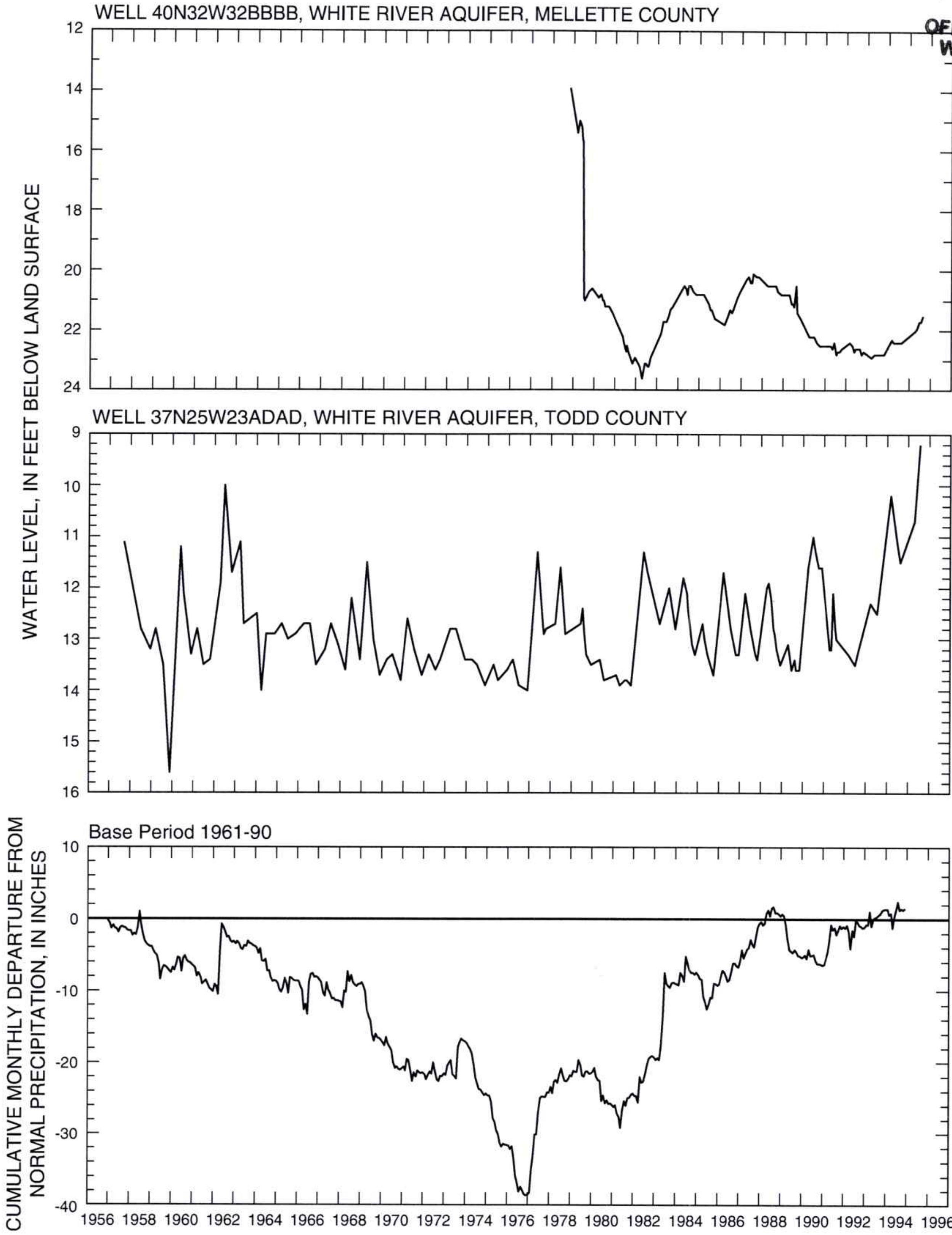


Figure 25. Water-level fluctuations in the White River aquifer and cumulative monthly departure from normal precipitation at Valentine, Nebraska.

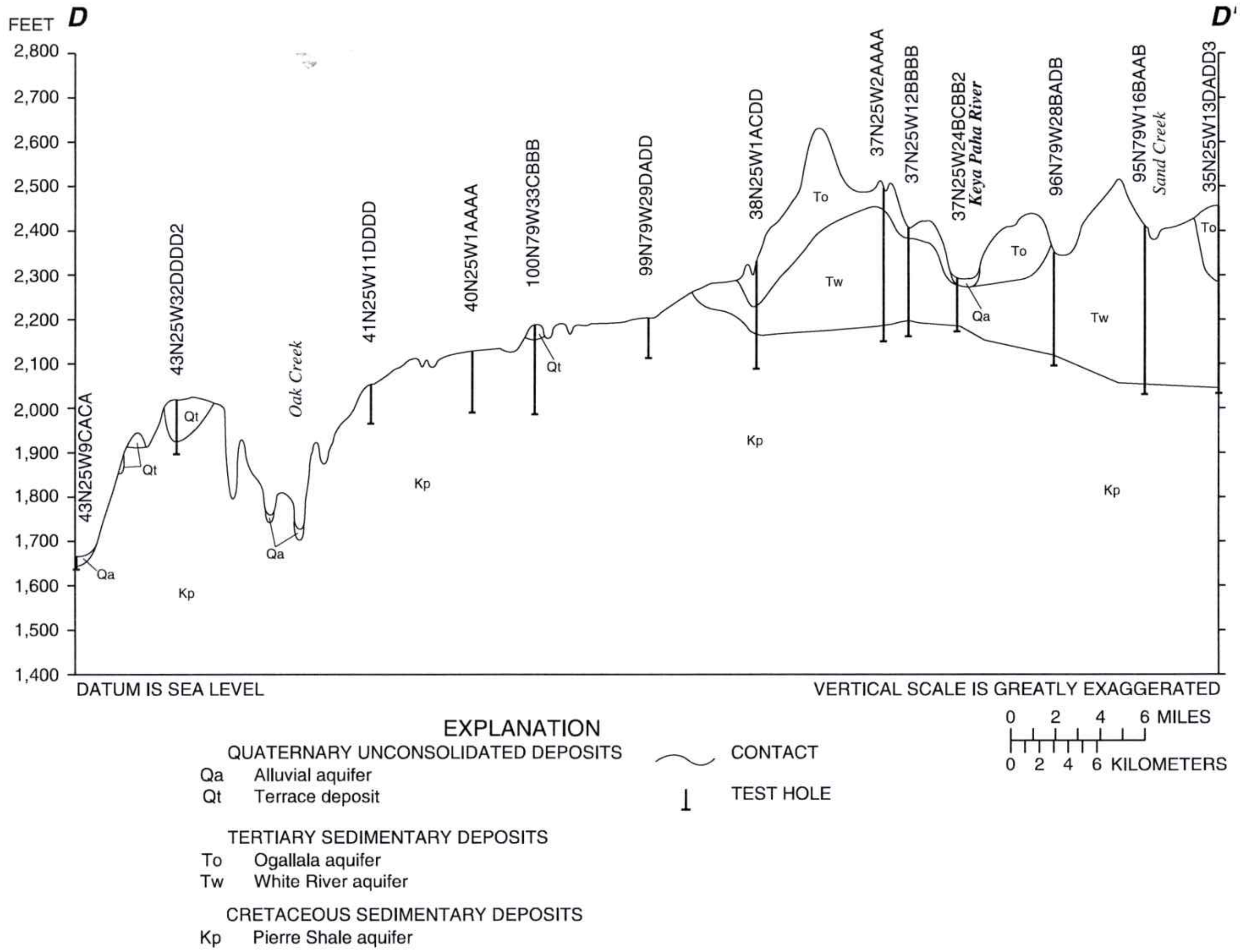


Figure 26. Hydrogeologic section D-D′ showing aquifers of Quaternary, Tertiary, and Cretaceous age in Mellette and Todd Counties. (The location of section D-D′ is shown in fig. 2.)

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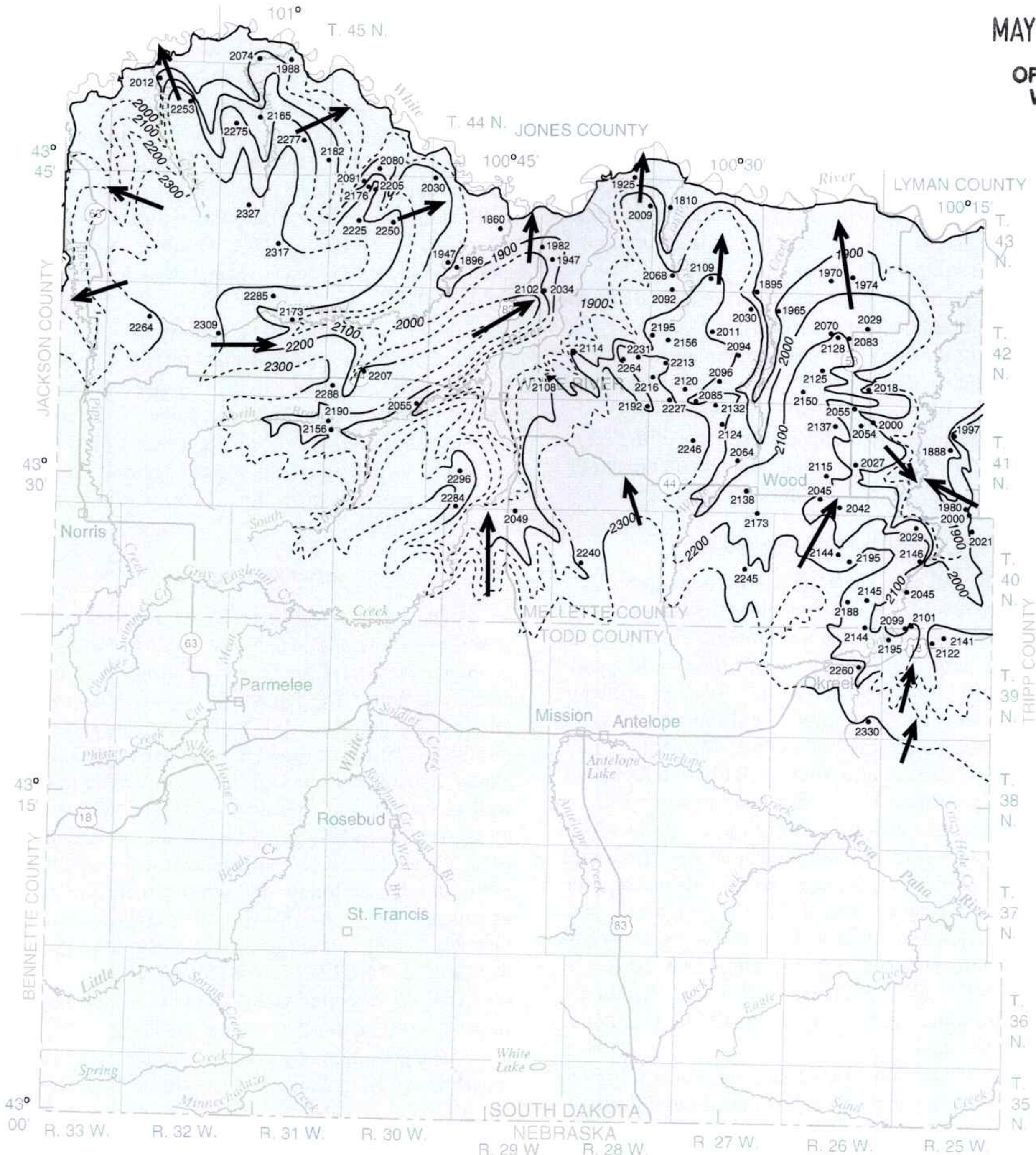

Base from U.S. Geological Survey digital data 1:100,000

EXPLANATION

APPROXIMATE AREA UNDERLAIN BY THE PIERRE SHALE AQUIFER (modified from Ellis and others, 1971)

—2300- - - POTENTIOMETRIC CONTOUR--Shows altitude at which water would have stood in tightly cased, ninpumping wells in 1996. Dashed where inferred. Contour interval 100 feet. Datum is sea level.

• 2912 WELL--Number is altitude of water level, in feet above sea level

⟶ GENERAL DIRECTION OF GROUND-WATER FLOW

Figure 27. Potentiometric surface of the Pierre Shale aquifer.

Recharge to the Pierre Shale aquifer primarily is by infiltration of precipitation on the outcrops of the Pierre Shale (fig. 4). The greatest recharge to the aquifer occurs during the spring after snowmelt and during storm events. Infiltration rates generally are less than the lowest rate (0.06 inches/hour) measured by the U.S. Soil Conservation Service (1974, 1975). Discharge from the aquifer is through withdrawals from domestic and stock wells and by evapotranspiration where the aquifer is at or near land surface.

Based on modified slug tests conducted at a site in central South Dakota, the horizontal hydraulic conductivity of the unweathered Pierre Shale aquifer ranges from about 10^{-5} to 10^{-6} feet per day (Bredehoeft and others, 1983). Bredehoeft and others (1983) suggested that the hydraulic conductivity of the Pierre Shale aquifer decreases with depth, and that much of the flow in the shale occurs through fractures.

Dakota Sandstone Aquifer

The Dakota Sandstone aquifer underlies the entire study area and contains more than an estimated 81 million acre-feet of water in storage. However, only a few test holes and wells penetrate the Dakota Sandstone in the study area, and all but two were drilled in Mellette County. The Dakota Sandstone consists of interbedded sandstones and shales. The depth to the top of the aquifer ranges from 1,270 to 2,348 feet below land surface (table 4). Because the formation is overlain by at least five formations primarily composed of shale (table 1), the aquifer is under confined conditions, and wells completed in the Dakota Sandstone aquifer are likely to flow when drilled in topographically low areas, such as near streams. Known flowing wells completed in the Dakota Sandstone aquifer are located at 42N28W22, 43N27W14, and 43N27W3. Reported yields from the aquifer range from 10 to 100 gallons per minute (table 4).

The potentiometric surface was not constructed for the Dakota Sandstone aquifer because of insufficient data. Regional potentiometric maps of the aquifer (Schoon, 1971) approximate the hydraulic head altitude to range from 2,150 feet above sea level along the western boundary of Mellette and Todd Counties to 1,950 feet along the eastern boundary. The contours generally trend north-south; therefore, the general direction of ground-water flow in the Dakota Sandstone aquifer is from west to east in the study area.

Records of long-term water-level fluctuations in wells completed in the Dakota Sandstone aquifer located at 41N26W30DDCB and 43N30W8BBCD in Mellette County (fig. 28) correlate poorly with long-term precipitation data. Water levels in the two observation wells have declined 31 to 50 feet since 1963 because discharge has exceeded recharge.

The major sources of recharge to the Dakota Sandstone aquifer are infiltration of precipitation on outcrops of the Dakota Sandstone (mostly in the Black Hills area) and leakage from other aquifers (Schoon, 1971; Miller and Rahn, 1974). Discharge from the aquifer in the study area is through withdrawals from stock wells.

Miller and Rahn (1974) reported a hydraulic conductivity from a single-well aquifer test at Box Elder, South Dakota, of about 1 foot per day and a transmissivity of about 200 square feet per day for the Dakota Sandstone. Bredehoeft and others (1983) calculated an average hydraulic conductivity of about 5 feet per day from approximately 500 drilling records in South Dakota.

Inyan Kara Aquifer

The extent of the Inyan Kara Group in the study area is not known. The only test holes and wells that penetrate the Inyan Kara Group are located in northern Mellette County. The depth to the top of the Inyan Kara Group is greater than 1,900 feet below land surface (table 4). The Inyan Kara Group consists predominantly of sandstones and siltstones containing loose to well-cemented sand. Because the formation is overlain by the Dakota Sandstone and five shale formations (table 1), the aquifer is confined, and wells completed in this aquifer are likely to flow when drilled in topographically low areas. Known flowing wells completed in the aquifer are located in Mellette County in 42N28W22, 42N30W12, 43N26W33, and 45N32W36. Reported yields from the aquifer range from 9 to 160 gallons per minute (table 4).

The potentiometric surface was not constructed for the Inyan Kara aquifer because of insufficient water-level data. The potentiometric surface of the Inyan Kara aquifer in northern Mellette County is presented in Ellis and others (1971). The altitude of the potentiometric surface ranges from 2,250 feet above sea level in northwestern Mellette County to 2,150 feet in central Mellette County. The potentiometric contours generally trend east-west; therefore, the general direction of ground-water flow in the aquifer is from north to south (Ellis and others, 1971). No long-term water-level records were available for wells completed in the Inyan Kara aquifer in either Mellette or Todd County.

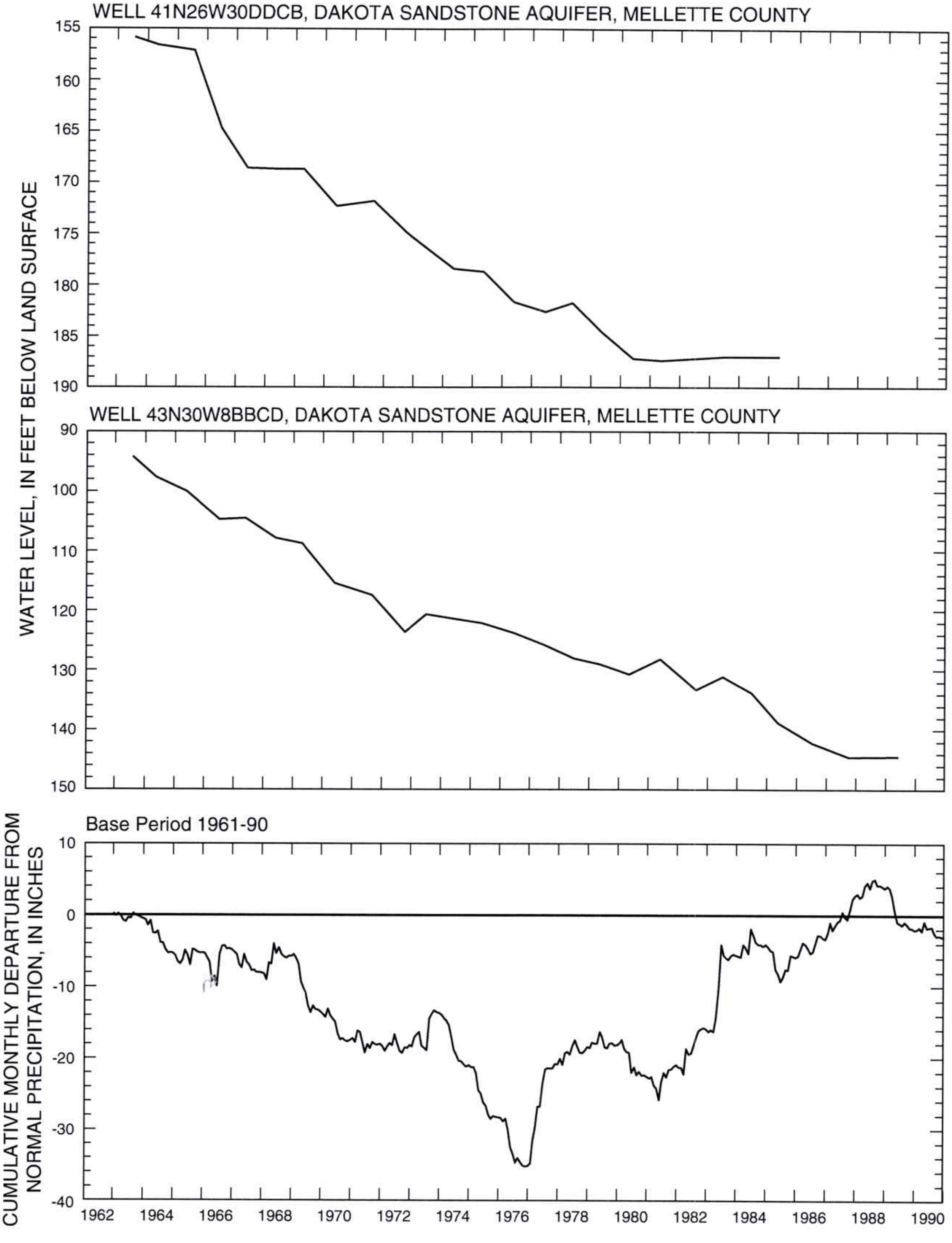

Figure 28. Water-level fluctuations in the Dakota Sandstone aquifer and cumulative monthly departure from normal precipitation at Valentine, Nebraska.

The major source of recharge to the aquifer is by infiltration of precipitation on outcrops of the Inyan Kara Group (mostly in the Black Hills area), ground-water inflow mostly from Wyoming and North Dakota, and leakage from underlying units (Case, 1984). Discharge from the Inyan Kara aquifer in the study area is through withdrawals from stock wells.

No specific-capacity or aquifer-test data were available for wells completed in the Inyan Kara aquifer in or near the study area. Aquifer properties of hydraulic conductivity and transmissivity possibly are similar to those in the Dakota Sandstone aquifer based on conductivity values compiled by Case (1984).

Minnelusa and Madison Aquifers

The Minnelusa Formation and Madison Limestone are combined for purposes of this report because almost all wells at this depth are completed in both the Minnelusa and Madison aquifers. The extent of the Minnelusa and Madison Formations in the study area is not known. The Minnelusa Formation consists primarily of interbedded sandstone, siltstone, limestone, dolomite, anhydrite, and shale. The composition of the Madison Limestone varies from pure limestone to pure dolomite with combinations of the two. The aquifers are confined because they are overlain by many confining deposits. Wells completed in the Minnelusa and/or the Madison aquifers are likely to flow when drilled in topographically low areas. Known flowing wells are located in Mellette County at 42N28W22, 42N28W30, 42N25W32, and 42N26W34. Yields from the aquifers range from 25 to 40 gallons per minute (table 4).

The major source of recharge to the Minnelusa and Madison aquifers is infiltration of precipitation and streamflow on outcrops of the these formations in the Black Hills area (Peter, 1985). Discharge from the aquifers in the study area is through withdrawals from stock wells and leakage to other aquifers (Case, 1984).

The potentiometric surface for the Minnelusa and Madison aquifers was not drawn because of insufficient water-level data. Ellis and others (1971) approximate the potentiometric surface of the Minnelusa and Madison aquifers throughout most of Mellette County. The altitude of the potentiometric surface in Mellette County ranges from 2,400 feet above sea level in the northwest to 2,150 feet in the southeast. The general trend of the contours is southwest-northeast; therefore, the general direction of ground-water flow in the aquifers is from the northwest to the southeast (Ellis and others, 1971). No long-term water-level measurements were available for either aquifer in the study area.

Although the hydraulic properties of the Minnelusa and Madison aquifers have been studied extensively in the Black Hills area, no known information exists for these aquifers in areas in or near the study area. Because the hydraulic properties determined in the Black Hills would not be comparable to those in this study area due to the uplift and karstification in the Black Hills, no hydraulic properties are given in this report for the Minnelusa and Madison aquifers.

Water Quality

The chemical quality of water in the aquifers in the study area varies widely, both within and between aquifers. The chemical quality among the aquifers of Tertiary age is the most similar. A summary of chemical analyses of water for each aquifer, based on data stored in the USGS NWIS water-quality database, is presented in table 5.

In the following discussions, hardness and salinity are used to characterize the quality of water from the aquifers. Water that has a hardness less than 61 mg/L (milligrams per liter) is considered soft; 61 to 120 mg/L, moderately hard; 121 to 180 mg/L, hard; and more than 180 mg/L, very hard (Heath, 1983). Salinity is based on the dissolved solids concentrations. Water that has a dissolved solids concentration less than 1,000 mg/L is considered fresh; 1,000 to 3,000 mg/L, slightly saline; 3,000 to 10,000 mg/L, moderately saline; 10,000 to 35,000 mg/L, very saline; and more than 35,000 mg/L, briny (Heath, 1983).

The quality of water in the alluvial aquifers varies greatly between locations and is dependant on the deposits that underlie the unconsolidated deposits. The alluvial aquifers generally yield water that has low concentrations of dissolved solids, is fresh, and is soft to moderately hard where underlain by the Ogallala and Arikaree Formations; has moderate concentrations of dissolved solids, is slightly saline, and is hard where underlain by the White River Group; and has high concentrations of dissolved solids, is slightly saline, and is very hard where underlain by the Pierre Shale. Because of this variation, calcium and bicarbonate generally are the dominant species in the alluvial water where underlain by the deposits of Tertiary age, and sodium and chloride generally are the dominant species where underlain by the Pierre Shale (fig. 29).

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Table 5. Summary of chemical analyses for ground water

[Results based on data stored in USGS NWIS water-quality database. Results in milligrams per liter except as indicated. One milligram per liter (mg/L) is approximately equal to one part per million. One microgram per liter (µg/L) is approximately equal to one part per billion; µS/cm, microsiemens per centimeter at 25° Celsius; --, not analyzed or not determined; <, less than indicated detection limit; ND, specifically analyzed for but not detected, and detection limit unknown]

Property or dissolved constituent	Alluvial aquifers				
	Number of samples	Mean	Median	Minimum	Maximum
Specific conductance (µS/cm)	46	1,580	1,210	229	4,600
pH (standard units)	51	7.3	7.5	6.6	8.3
Carbon dioxide	20	12	9.9	1.7	24
Hardness, as $CaCO_3$	52	518	273	77	2,060
Solids, residue at 180° C	48	1,140	724	175	3,820
Solids, sum of constituents	43	1,200	1,040	177	3,440
Calcium	52	156	94	25	527
Magnesium	52	31	14	2	196
Sodium	50	152	81	8.1	570
Potassium	47	14	13	6.5	33
Bicarbonate	26	326	317	117	600
Alkalinity	25	323	318	107	668
Sulfate	52	478	194	ND	2,000
Chloride	52	28	13	ND	160
Fluoride	49	0.5	0.4	0.1	4
Silica	36	33	31	12	60
Nitrogen, nitrate	40	1.0	0.3	ND	9.2
Phosphorus, orthophosphate	11	0.04	0.04	ND	0.12
Aluminum (µg/L)	4	--	<5	<5	7.5
Arsenic (µg/L)	17	13	7	<1	44
Barium (µg/L)	5	127	124	12	330
Boron (µg/L)	17	409	354	20	940
Cadmium (µg/L)	9	--	<1	<1	2.4
Chromium (µg/L)	9	--	<1	<1	<10
Cobalt (µg/L)	0	--	--	--	--
Copper (µg/L)	6	6.2	<1	4.5	18
Iron (µg/L)	29	627	60	ND	3,200
Lead (µg/L)	9	--	<1	<1	2
Lithium (µg/L)	0	--	--	--	--
Manganese (µg/L)	23	597	250	<1	4,400
Mercury (µg/L)	7	--	<1	<1	<1
Molybdenum (µg/L)	3	2.4	2	1.8	3.4
Nickel (µg/L)	0	--	--	--	--
Selenium (µg/L)	16	7.7	2	<1	60
Silver (µg/L)	2	--	31	<1	60
Strontium (µg/L)	0	--	--	--	--
Vanadium (µg/L)	3	2.1	2.1	1.1	3.2
Zinc (µg/L)	9	38	29	<3	120

Table 5. Summary of chemical analyses for ground water—Continued

Property or dissolved constituent	Ogallala aquifer				
	Number of samples	Mean	Median	Minimum	Maximum
Specific conductance (µS/cm)	150	397	361	227	911
pH (standard units)	157	7.5	7.5	6.8	8.4
Carbon dioxide	93	10	8.6	0.8	33
Hardness, as $CaCO_3$	143	171	164	21	415
Solids, residue at 180° C	70	280	256	180	619
Solids, sum of constituents	126	237	210	134	632
Calcium	143	55	52	7.3	130
Magnesium	143	8.0	8.0	ND	42
Sodium	142	12	6.0	ND	180
Potassium	139	8.6	8.0	1.0	24
Bicarbonate	102	217	215	109	453
Alkalinity	41	183	174	129	340
Sulfate	142	9.2	4.0	ND	145
Chloride	147	7.0	3.6	ND	220
Fluoride	54	0.4	0.3	0.2	4.6
Silica	45	60	59	50	73
Nitrogen, nitrate	92	5.5	1.3	<0.1	44
Phosphorus, orthophosphate	28	0.06	0.02	<0.01	2.3
Aluminum (µg/L)	2	--	<5	<5	<5
Arsenic (µg/L)	20	4.8	3.8	1.0	12
Barium (µg/L)	8	166	115	98	360
Boron µg/L)	30	94	40	ND	780
Cadmium (µg/L)	8	--	<1	<1	3.5
Chromium (µg/L)	8	1.0	1.0	<1	2.9
Cobalt (µg/L)	0	--	--	--	--
Copper (µg/L)	3	4.0	5.0	ND	7.0
Iron (µg/L)	47	40	8	<0.1	320
Lead (µg/L)	8	2.7	1.0	<1	13
Lithium (µg/L)	0	--	--	--	--
Manganese (µg/L)	29	2	0.3	<1	20
Mercury (µg/L)	4	--	<0.1	<0.1	<0.1
Molybdenum (µg/L)	0	--	--	--	--
Nickel (µg/L)	0	--	--	--	--
Selenium (µg/L)	23	1.2	<1	<1	10
Silver (µg/L)	4	--	<1	<1	<2
Strontium (µg/L)	0	--	--	--	--
Vanadium (µg/L)	0	--	--	--	--
Zinc (µg/L)	6	24	20	12	54

Table 5. Summary of chemical analyses for ground water—Continued

Property or dissolved constituent	Arikaree aquifer				
	Number of samples	Mean	Median	Minimum	Maximum
Specific conductance (µS/cm)	68	510	425	238	1,730
pH (standard units)	80	7.6	7.6	7.1	8.5
Carbon dioxide	20	7.9	6.9	2.2	25
Hardness, as $CaCO_3$	73	104	91	10	499
Solids, residue at 180° C	67	357	300	172	1,200
Solids, sum of constituents	67	347	299	140	1,180
Calcium	78	34	31	3.6	170
Magnesium	78	4.0	2.9	ND	19
Sodium	74	68	66	4.1	170
Potassium	71	11	10	1.1	26
Bicarbonate	44	243	234	122	587
Alkalinity	52	211	192	109	534
Sulfate	75	31	20	ND	170
Chloride	77	9.6	3.9	<0.1	110
Fluoride	58	0.7	0.5	<0.1	3.1
Silica	57	64	65	31	77
Nitrogen, nitrate	45	2.1	1.1	<0.05	39
Phosphorus, orthophosphate	26	0.24	0.09	0.007	1.1
Aluminum (µg/L)	7	--	<5	<5	39
Arsenic (µg/L)	46	29	13	2	110
Barium (µg/L)	3	110	140	39	150
Boron µg/L)	25	141	105	30	630
Cadmium (µg/L)	26	--	<1	<1	<1
Chromium (µg/L)	26	0.7	<1	<1	2
Cobalt (µg/L)	0	--	--	--	--
Copper (µg/L)	23	4.1	2	<1	17
Iron (µg/L)	51	24	<3	ND	230
Lead (µg/L)	26	--	<1	<1	2.0
Lithium (µg/L)	0	--	--	--	--
Manganese (µg/L)	44	31	7	ND	500
Mercury (µg/L)	25	--	<0.1	<0.1	0.6
Molybdenum (µg/L)	15	2.2	1.4	<1.0	5.3
Nickel (µg/L)	0	--	--	--	--
Selenium (µg/L)	42	1.7	1.0	<1.0	20
Silver (µg/L)	0	--	--	--	--
Strontium (µg/L)	0	--	--	--	--
Vanadium (µg/L)	15	25	12	6	150
Zinc (µg/L)	26	71	11	<3	960

Table 5. Summary of chemical analyses for ground water—Continued

Property or dissolved constituent	White River aquifer				
	Number of samples	Mean	Median	Minimum	Maximum
Specific conductance (μS/cm)	22	1,010	764	296	3,280
pH (standard units)	22	7.2	7.4	6.7	8.0
Carbon dioxide	3	12	11	7.1	16
Hardness, as $CaCO_3$	20	187	137	19	1,130
Solids, residue at 180° C	20	659	471	211	2,450
Solids, sum of constituents	19	653	466	215	2,310
Calcium	20	64	46	6.4	360
Magnesium	20	6.7	3.6	0.1	55
Sodium	20	154	103	5.1	650
Potassium	20	9.6	9.1	1.4	20
Bicarbonate	10	309	316	161	469
Alkalinity	17	310	288	137	589
Sulfate	20	97	17	<1	1,300
Chloride	20	93	9.8	1	860
Fluoride	20	0.5	0.4	<0.1	1.7
Silica	20	42	45	11	65
Nitrogen, nitrate	18	1.5	0.7	<0.005	7.6
Phosphorus, orthophosphate	13	0.2	0.05	0.02	0.8
Aluminum (μg/L)	3	--	<5	<5	8.3
Arsenic (μg/L)	9	6.5	7	<1	14
Barium (μg/L)	2	195	195	120	270
Boron μg/L)	10	784	110	20	2,170
Cadmium (μg/L)	2	--	<1	<1	1
Chromium (μg/L)	2	--	1.5	<1	2
Cobalt (μg/L)	0	--	--	--	--
Copper (μg/L)	0	--	--	--	--
Iron (μg/L)	9	32	11	<3	92
Lead (μg/L)	2	--	<1	<1	<1
Lithium (μg/L)	0	--	--	--	--
Manganese (μg/L)	9	98	9	<1	810
Mercury (μg/L)	2	--	<0.1	<0.1	<0.1
Molybdenum (μg/L)	0	--	--	--	--
Nickel (μg/L)	0	--	--	--	--
Selenium (μg/L)	9	1.2	<1	<1	5
Silver (μg/L)	0	--	--	--	--
Strontium (μg/L)	0	--	--	--	--
Vanadium (μg/L)	0	--	--	--	--
Zinc (μg/L)	2	7.5	7.5	4	11

Table 5. Summary of chemical analyses for ground water—Continued

Property or dissolved constituent	Pierre Shale aquifer				
	Number of samples	Mean	Median	Minimum	Maximum
Specific conductance (µS/cm)	21	2,350	1,740	530	6,200
pH (standard units)	21	7.0	7.1	6.6	8.0
Carbon dioxide	2	9.2	9.2	7.3	11
Hardness, as $CaCO_3$	24	739	484	25	2,230
Solids, residue at 180° C	24	1,870	1,380	336	5,990
Solids, sum of constituents	20	1,720	1,170	331	4,940
Calcium	24	216	160	7.6	582
Magnesium	24	49	27	0.9	280
Sodium	24	277	190	13	830
Potassium	21	15	12	4.3	33
Bicarbonate	2	368	368	278	457
Alkalinity	19	335	326	122	550
Sulfate	24	886	565	<1	3,000
Chloride	24	93	34	4.5	790
Fluoride	24	0.6	0.4	<0.1	2.5
Silica	21	23	21	11	45
Nitrogen, nitrate	23	4.1	0.7	<0.1	40
Phosphorus, orthophosphate	5	0.05	0.02	0.01	0.12
Aluminum (µg/L)	0	--	--	--	--
Arsenic (µg/L)	5	--	<1	<1	5
Barium (µg/L)	5	87	27	18	280
Boron µg/L)	2	195	195	130	260
Cadmium (µg/L)	5	--	<1	<1	2
Chromium (µg/L)	5	--	<1	<1	2
Cobalt (µg/L)	0	--	--	--	--
Copper (µg/L)	0	--	--	--	--
Iron (µg/L)	6	319	60	5	1,700
Lead (µg/L)	5	--	<1	<1	<1
Lithium (µg/L)	0	--	--	--	--
Manganese (µg/L)	7	188	100	<1	500
Mercury (µg/L)	5	--	<0.1	<0.1	<0.1
Molybdenum (µg/L)	0	--	--	--	--
Nickel (µg/L)	0	--	--	--	--
Selenium (µg/L)	6	4.7	3.5	<1	10
Silver (µg/L)	0	--	--	--	--
Strontium (µg/L)	0	--	--	--	--
Vanadium (µg/L)	0	--	--	--	--
Zinc (µg/L)	5	171	55	10	390

Table 5. Summary of chemical analyses for ground water—Continued

Property or dissolved constituent	Dakota Sandstone aquifer				
	Number of samples	Mean	Median	Minimum	Maximum
Specific conductance (µS/cm)	15	2,880	2,780	2,440	4,080
pH (standard units)	13	7.7	7.7	7.1	8.6
Carbon dioxide	7	27	12	4	107
Hardness, as $CaCO_3$	13	92	43	19	400
Solids, residue at 180° C	12	1,910	1,890	1,450	2,900
Solids, sum of constituents	12	1,870	1,870	1,450	2,780
Calcium	13	27	13	6	130
Magnesium	13	6	2	1	19
Sodium	13	640	650	390	970
Potassium	13	12	11	7	20
Bicarbonate	11	700	670	260	1,000
Alkalinity	1	303	303	303	303
Sulfate	13	652	620	120	1,200
Chloride	13	170	100	39	440
Fluoride	11	3	4	2	5
Silica	11	23	22	12	30
Nitrogen, nitrate	8	0.07	<0.1	ND	0.25
Phosphorus, orthophosphate	2	--	0.02	<0.01	0.03
Aluminum (µg/L)	1	10	10	10	10
Arsenic (µg/L)	2	--	<1	<1	<1
Barium (µg/L)	2	--	<100	<100	<100
Boron µg/L)	10	3,100	3,300	510	5,000
Cadmium (µg/L)	2	--	<1	<1	<1
Chromium (µg/L)	2	--	<1	<1	<1
Cobalt (µg/L)	1	--	ND	ND	ND
Copper (µg/L)	1	--	ND	ND	ND
Iron (µg/L)	6	330	80	20	1,500
Lead (µg/L)	2	--	<1	<1	<1
Lithium (µg/L)	1	170	170	170	170
Manganese (µg/L)	5	--	ND	ND	130
Mercury (µg/L)	1	<0.1	<0.1	<0.1	<0.1
Molybdenum (µg/L)	1	<1	<1	<1	<1
Nickel (µg/L)	1	--	ND	ND	ND
Selenium (µg/L)	3	--	<1	<1	10
Silver (µg/L)	1	--	ND	ND	ND
Strontium (µg/L)	1	530	530	530	530
Vanadium (µg/L)	1	15	15	15	15
Zinc (µg/L)	2	--	<20	<20	<20

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Table 5. Summary of chemical analyses for ground water—Continued

Property or dissolved constituent	Inyan Kara aquifer				
	Number of samples	Mean	Median	Minimum	Maximum
Specific conductance (µS/cm)	3	4,130	4,320	2,480	5,590
pH (standard units)	3	7.5	7.9	7.2	7.9
Carbon dioxide	3	15	15	13	18
Hardness, as $CaCO_3$	3	473	160	130	870
Solids, residue at 180° C	3	3,090	3,060	2,140	4,070
Solids, sum of constituents	3	2,940	3,000	1,960	3,860
Calcium	3	136	51	18	340
Magnesium	3	34	7.1	3.2	93
Sodium	3	824	1,050	131	1,290
Potassium	3	16	17	9.8	20
Bicarbonate	3	580	740	130	870
Alkalinity	3	478	607	108	718
Sulfate	3	1,400	1,300	1,100	1,800
Chloride	3	207	180	180	260
Fluoride	3	3.7	3.9	2.8	4.4
Silica	3	30	30	28	32
Nitrogen, nitrate	3	0.2	0.1	0.1	0.4
Phosphorus, orthophosphate	0	--	--	--	--
Aluminum (µg/L)	0	--	--	--	--
Arsenic (µg/L)	0	--	--	--	--
Barium (µg/L)	0	--	--	--	--
Boron µg/L)	3	1,437	1,900	210	2,200
Cadmium (µg/L)	0	--	--	--	--
Chromium (µg/L)	0	--	--	--	--
Cobalt (µg/L)	0	--	--	--	--
Copper (µg/L)	0	--	--	--	--
Iron (µg/L)	3	2,733	1,300	1200	5,700
Lead (µg/L)	0	--	--	--	--
Lithium (µg/L)	0	--	--	--	--
Manganese (µg/L)	3	183	140	140	270
Mercury (µg/L)	0	--	--	--	--
Molybdenum (µg/L)	0	--	--	--	--
Nickel (µg/L)	0	--	--	--	--
Selenium (µg/L)	1	ND	ND	ND	ND
Silver (µg/L)	0	--	--	--	--
Strontium (µg/L)	0	--	--	--	--
Vanadium (µg/L)	0	--	--	--	--
Zinc (µg/L)	0	--	--	--	--

Table 5. Summary of chemical analyses for ground water—Continued

Property or dissolved constituent	Minnelusa and Madison aquifers				
	Number of samples	Mean	Median	Minimum	Maximum
Specific conductance (µS/cm)	2	2,060	2,060	1,510	2,610
pH (standard units)	2	7.2	7.2	7.1	7.3
Carbon dioxide	0	--	--	--	--
Hardness, as $CaCO_3$	3	970	810	800	1,300
Solids, residue at 180° C	3	1,560	1,270	1,190	2,220
Solids, sum of constituents	3	1,440	1,170	1,160	1,990
Calcium	3	287	250	240	370
Magnesium	3	63	48	47	94
Sodium	3	60	35	27	119
Potassium	3	15	13	11	21
Bicarbonate	3	143	140	140	150
Alkalinity	3	118	114	114	125
Sulfate	3	817	680	670	1,100
Chloride	3	104	42	40	230
Fluoride	3	1.5	1.7	1.0	1.7
Silica	3	34	39	24	40
Nitrogen, nitrate	2	--	0.3	ND	0.5
Phosphorus, orthophosphate	1	<0.01	<0.01	<0.01	<0.01
Aluminum (µg/L)	1	20	20	20	20
Arsenic (µg/L)	1	3	3	3	3
Barium (µg/L)	1	<100	<100	<100	<100
Boron µg/L)	3	140	170	70	180
Cadmium (µg/L)	1	<2	<2	<2	<2
Chromium (µg/L)	1	ND	ND	ND	ND
Cobalt (µg/L)	0	--	--	--	--
Copper (µg/L)	1	ND	ND	ND	ND
Iron (µg/L)	3	2,413	890	450	5,900
Lead (µg/L)	1	3	3	3	3
Lithium (µg/L)	1	60	60	60	60
Manganese (µg/L)	3	90	50	30	190
Mercury (µg/L)	1	3.4	3.4	3.4	3.4
Molybdenum (µg/L)	1	3	3	3	3
Nickel (µg/L)	0	--	--	--	--
Selenium (µg/L)	1	<1	<1	<1	<1
Silver (µg/L)	0	--	--	--	--
Strontium (µg/L)	1	4,600	4,600	4,600	4,600
Vanadium (µg/L)	0	--	--	--	--
Zinc (µg/L)	1	330	330	330	330

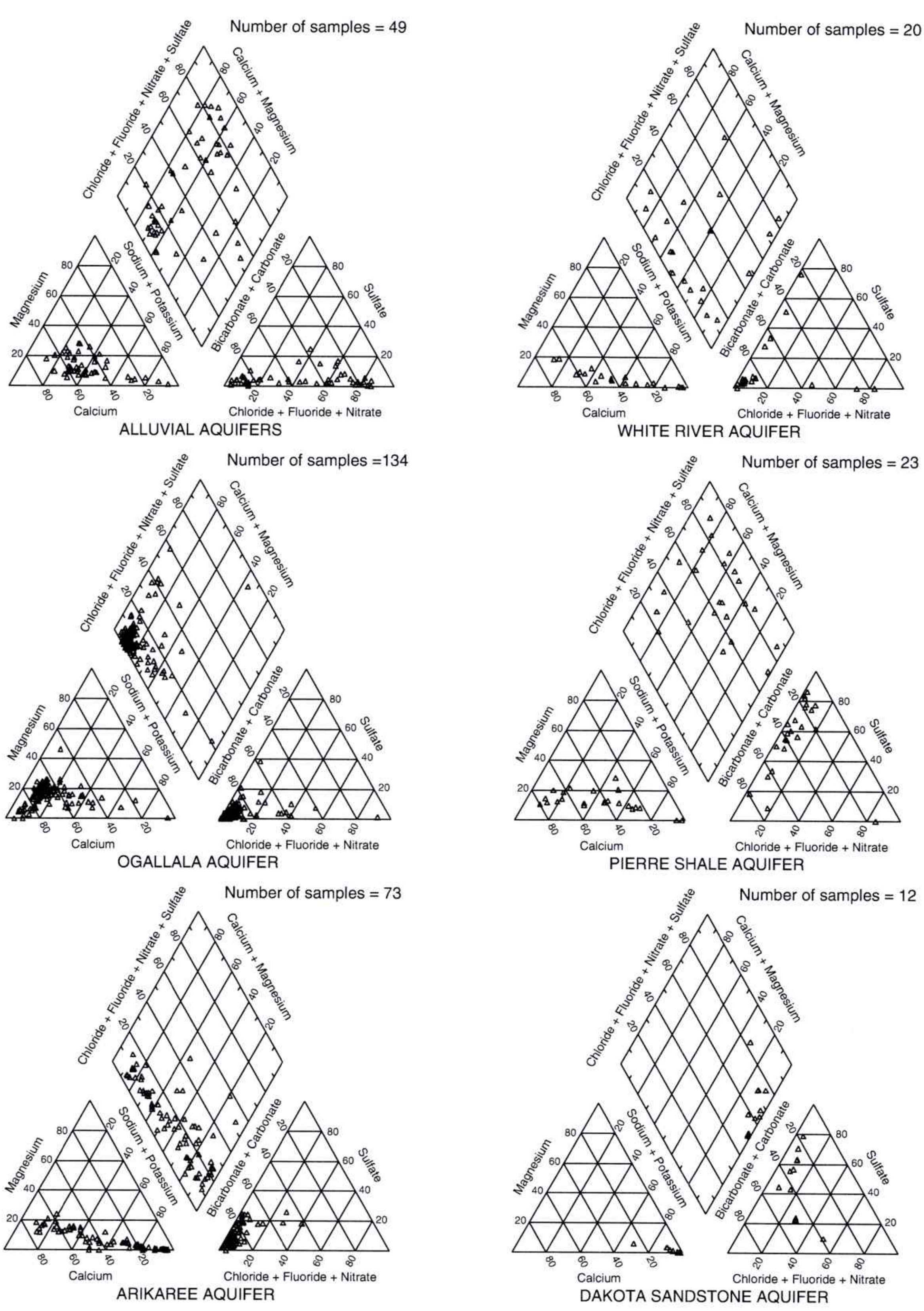

Figure 29. Trilinear diagrams showing proportional concentrations of major ions in ground-water samples.

The Ogallala aquifer is a calcium-bicarbonate water type, and the Arikaree aquifer is a calcium sodium bicarbonate water type (fig. 29). Generally, the Ogallala and Arikaree aquifers yield water that has low concentrations of dissolved solids, is fresh, and is soft to moderately hard. The dominant species in the White River aquifer generally are calcium, sodium, and bicarbonate (fig. 29). The water quality of the White River aquifer varies and is dependent on depth and proximity of the aquifer to the Pierre Shale. Like the alluvial aquifers, the closer the water-bearing deposits of the White River Group are to the Pierre Shale, the higher in dissolved solids concentrations, more saline, and harder the water.

The bedrock aquifers generally yield hard, saline water with high concentrations of dissolved solids. The dominant species in the Pierre Shale aquifer vary from calcium to sodium and from bicarbonate to sulfate (fig. 29). In the Dakota Sandstone aquifer, the dominant species generally are sodium and sulfate (fig. 29). The Dakota Sandstone aquifer generally is the only bedrock aquifer that yields soft to moderately hard water with a mean concentration of 92 mg/L (table 5). Water from all other bedrock aquifers generally is hard to very hard with means ranging from 473 to 970 mg/L (table 5). The water type of the Inyan Kara aquifer generally is a sodium or calcium sulfate type and the water type of the Minnelusa and Madison aquifer generally is a calcium sulfate type (Ellis and others, 1971). Although the concentrations of dissolved solids in the Minnelusa and Madison aquifers are lower than the other bedrock aquifers, the water is very hard ranging from 800 to 1,300 mg/L (table 5).

Boxplots are presented in figure 30 for the alluvial, Ogallala, Arikaree, White River, and Pierre Shale aquifers for each of the constituents listed in table 5 that had a minimum of 10 analyses in samples from at least two aquifers. The Inyan Kara, Minnelusa, and Madison aquifers were not included in the boxplots because the maximum number of analyses for each constituent was three. The boxplots not only show the variations of the constituents within each aquifer, but also allow a comparison of the general water-quality characteristics between the aquifers. For example, the highest nitrate concentrations were detected in the Ogallala aquifer and the highest arsenic concentrations in the Arikaree aquifer.

The significance of the chemical and physical properties of water and, if applicable, the U.S. Environmental Protection Agency (USEPA) Maximum Contaminant Level (MCL) and Secondary Maximum Contaminant Level (SMCL) are presented in table 6 and shown in figure 30. The MCL's are established for contaminants that, if present in drinking water, may cause adverse human health effects; MCL's are enforceable health-based standards (U.S. Environmental Protection Agency, 1994a). The SMCL's are established for contaminants that can adversely affect the odor or appearance of water and result in discontinuation of use of the water; SMCL's are nonenforceable, generally non-health-based standards that are related to the aesthetics of water use (U.S. Environmental Protection Agency, 1994a).

Water samples collected from wells completed in alluvial aquifers exceeded the USEPA MCL's for the following regulated constituents: 1 sample out of 49 analyzed for fluoride exceeded the MCL of 4.0 mg/L, and 1 sample out of 16 analyzed for selenium exceeded the MCL of 50 μg/L (micrograms per liter). The median concentrations for dissolved solids and manganese exceeded the SMCL's for these constituents. Almost one-half of the samples collected from alluvial wells exceeded the SMCL for sulfate and about one-third exceeded the SMCL for iron.

Two constituents analyzed in samples collected from the Ogallala aquifer exceeded the respective MCL's: 1 sample out of 54 exceeded the fluoride MCL, and 13 samples out of 92 exceeded the nitrate MCL of 10 mg/L. Only a few samples exceeded the SMCL's for dissolved solids (5 out of 70 samples) and iron (1 out of 48 samples). The Rosebud Sioux Tribe reported high nitrate concentrations in the Ogallala aquifer in a small area of Todd County (Huq, 1989). An investigation of ground-water quality, with emphasis on nitrate concentrations, in shallow aquifers (including the Ogallala, Arikaree, and White River aquifers) in parts of Mellette and Todd County was conducted by Hammond (1994). This investigation concluded that both point and non-point sources of contamination were impacting the ground water in Todd County, and that point sources of contamination were impacting the ground water in Mellette County. The USGS also investigated nitrate concentrations in a small area of Todd County that had high concentrations in the Ogallala aquifer; the data from this investigation is presented by Carter (1997).

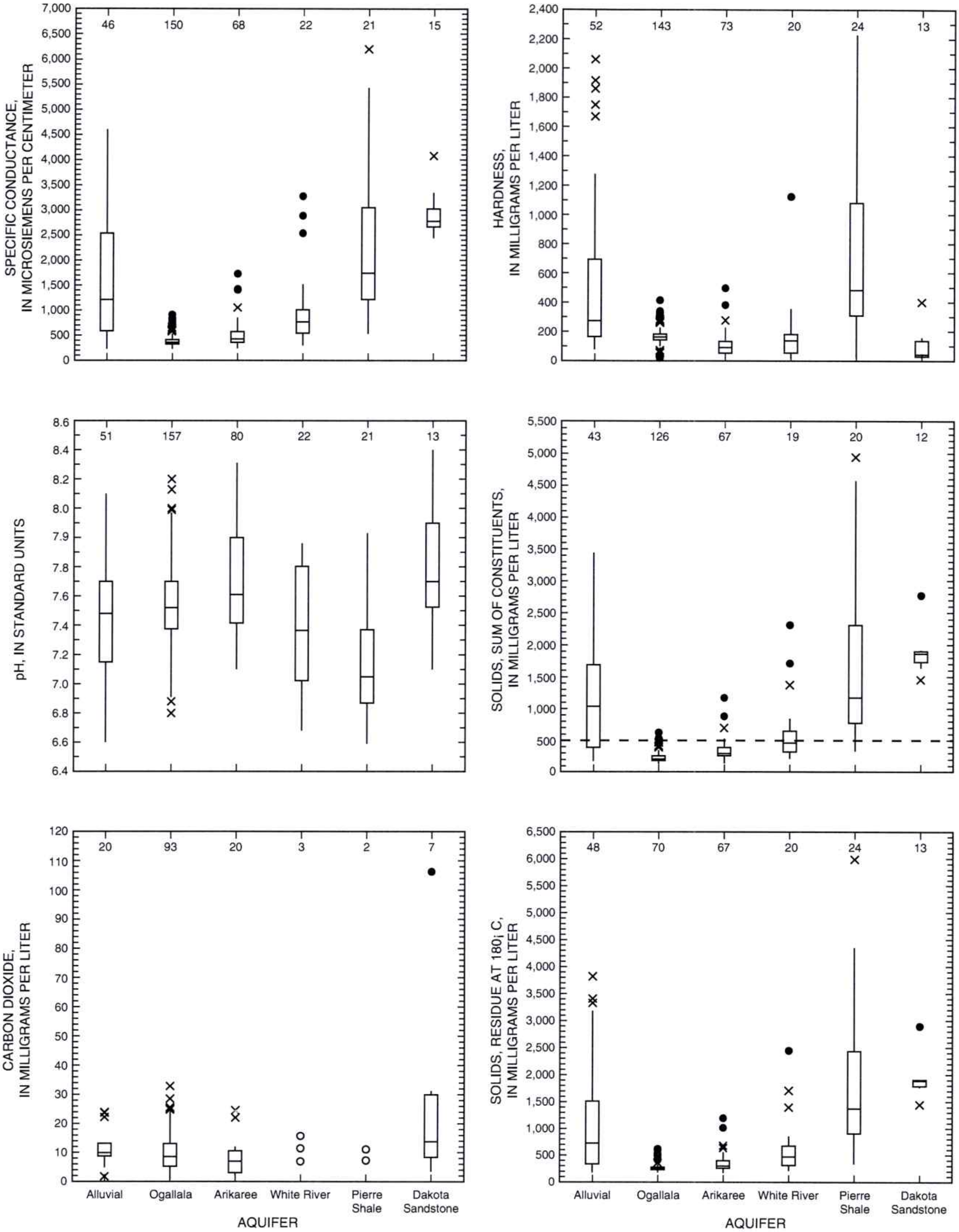

Figure 30. Boxplots of chemical constituents in ground-water samples.

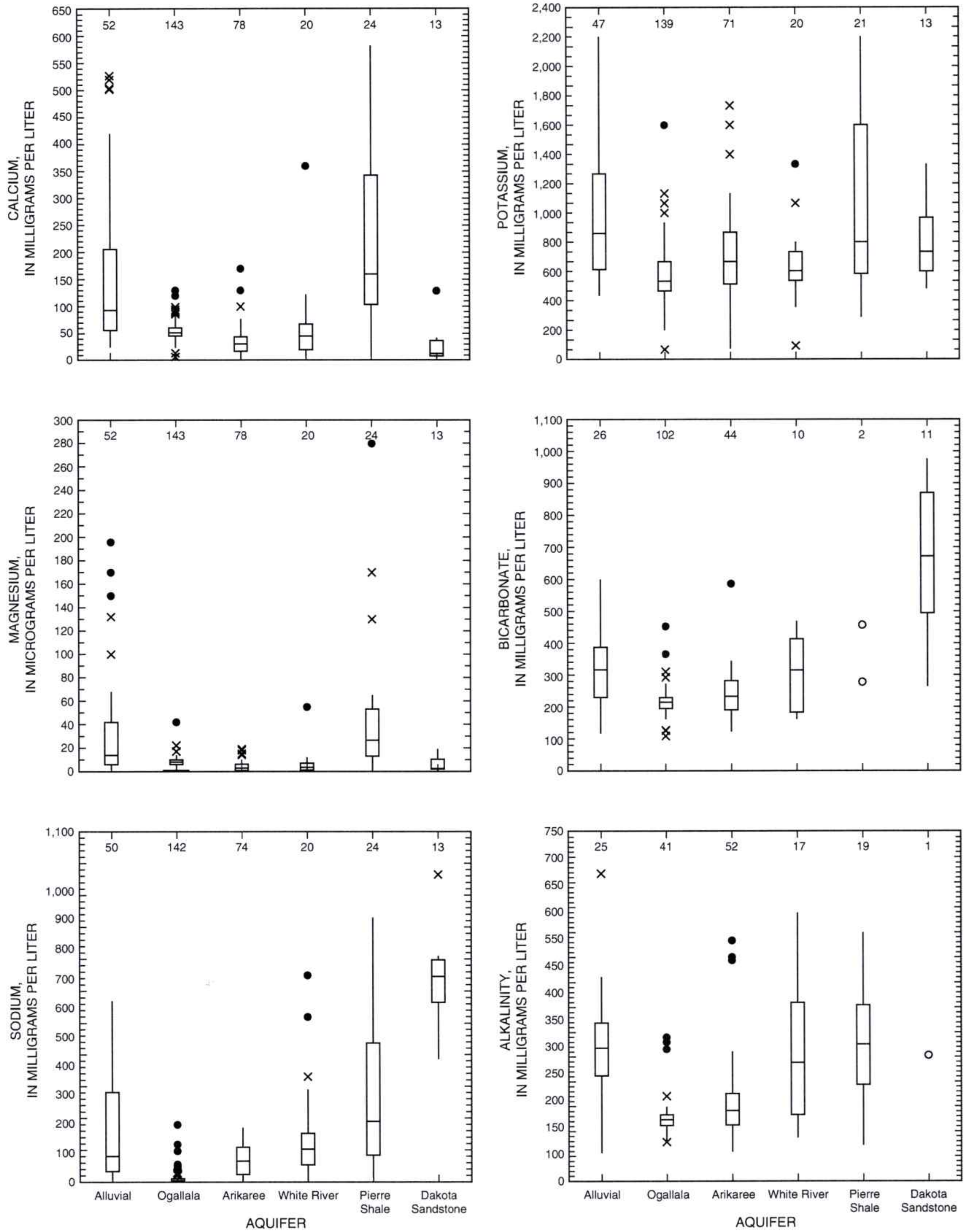

Figure 30. Boxplots of chemical constituents in ground-water samples.--Continued

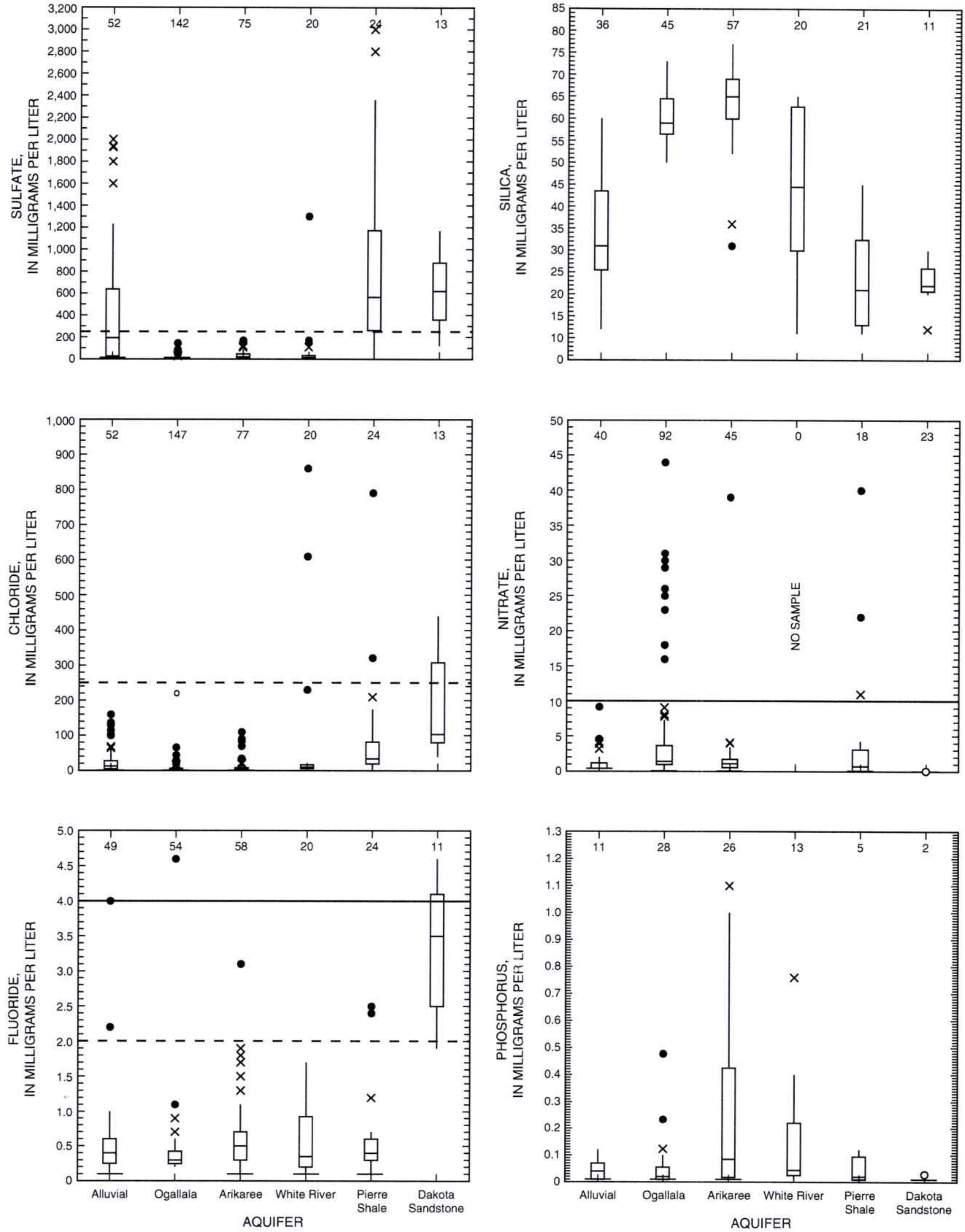

Figure 30. Boxplots of chemical constituents in ground-water samples.--Continued

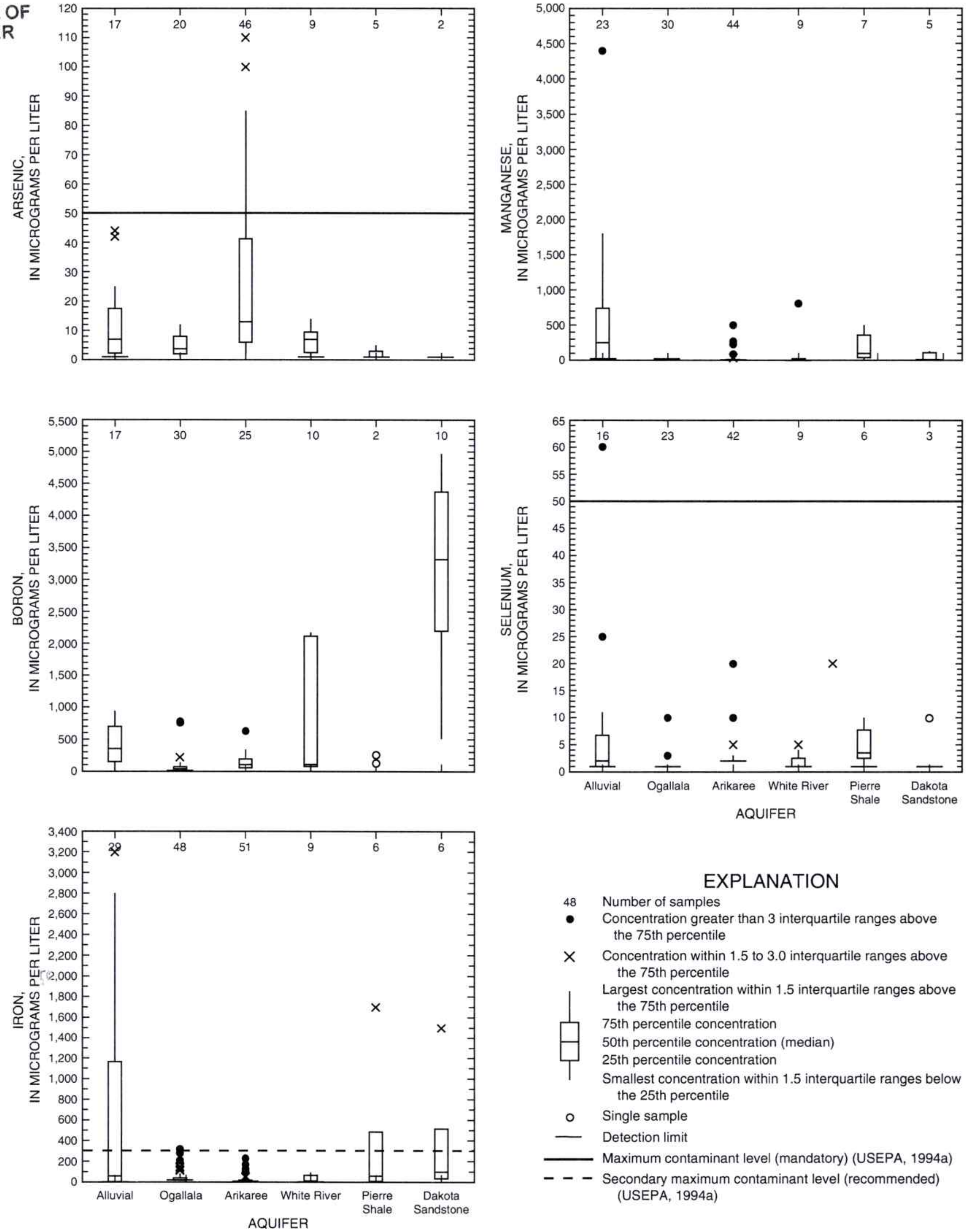

Figure 30. Boxplots of chemical constituents in ground-water samples.--Continued

Table 6. Significance of chemical and physical properties of water

Constituent or property	Limit	Significance
Specific conductance		A measure of the ability of water to conduct an electrical current; varies with temperature. Magnitude depends on concentration, kind, and degree of ionization of dissolved constituents; can be used to determine the approximate concentration of dissolved solids. Values are reported in microsiemens per centimeter at 25° Celsius.
pH	6.5-8.5 units (recommended)	A measure of the hydrogen ion concentration; pH of 7.0 indicates a neutral solution, pH values less than 7.0 indicate acidity, pH values greater than 7.0 indicate alkalinity. Water generally becomes more corrosive with decreasing pH; however, excessively alkaline water also may be corrosive.
Temperature		Affects the usefulness of water for many purposes. Generally, users prefer water of uniformly low temperature. Temperature of ground water tends to increase with increasing depth to the aquifer.
Hardness (as $CaCO_3$)		Related to the soap-consuming characteristics of water; results in formation of scum when soap is added. May cause deposition of scale in boilers, water heaters, and pipes. Hardness equivalent to the bicarbonate and carbonate in water is called carbonate hardness; hardness in excess of this concentration is called noncarbonate hardness. Water that has a hardness less than 61 mg/L is considered soft; 61-120 mg/L, moderately hard; 121-180 mg/L, hard; and more than 180 mg/L, very hard (Heath, 1983).
Calcium plus magnesium		Cause most of the hardness and scale-forming properties of water (see hardness).
Sodium plus potassium		Large concentrations may limit use of water for irrigation and industrial use and, in combination with chloride, give water a salty taste. Abnormally large concentrations may indicate natural brines, industrial brines, or sewage.
Percent sodium		Ratio of sodium to total cations in milliequivalents per liter expressed as a percentage. Important in irrigation waters; the greater the percent sodium, the less suitable the water for irrigation.
Sodium-adsorption ratio (SAR)		A ratio used to express the relative activity of sodium ions in exchange reactions with soil. Important in irrigation water; the greater the SAR, the less suitable the water for irrigation.
Bicarbonate		In combination with calcium and magnesium forms carbonate hardness.
Sulfate	250 mg/L (recommended)	Sulfates of calcium and magnesium form hard scale. Large concentrations of sulfate have a laxative effect on some people and, in combination with other ions, give water a bitter taste.
Chloride	250 mg/L (recommended)	Large concentrations increase the corrosiveness of water and, in combination with sodium, give water a salty taste.
Fluoride	4.0 mg/L (mandatory) 2.0 mg/L (recommended)	Reduces incidence of tooth decay when optimum fluoride concentrations present in water consumed by children during the period of tooth calcification. Potential health effects of long-term exposure to elevated fluoride concentrations include dental and skeletal fluorosis (U.S. Environmental Protection Agency, 1994b).
Silica (as SiO_3)		Forms hard scale in pipes and boilers and may form deposits on blades of steam turbines. Inhibits deterioration of zeolite-type water softeners.
Dissolved solids	500 mg/L (recommended)	The total of all dissolved mineral constituents, usually expressed in milligrams per liter. The concentration of dissolved solids may affect the taste of water. Water that contains more than 1,000 mg/L is unsuitable for many industrial uses. Some dissolved mineral matter is desirable, otherwise the water would have no taste. The dissolved solids concentration commonly is called the water's salinity and is classified as follows: fresh, 0 to 1,000 mg/L; slightly saline, 1,000 to 3,000 mg/L; moderately saline, 3,000 to 10,000 mg/L; very saline, 10,000 to 35,000 mg/L; and briny, more than 35,000 mg/L (Heath, 1983).
Nitrite (as N)	1 mg/L (mandatory)	Commonly formed as an intermediate product in bacterially mediated nitrification and denitrification of ammonia and other organic nitrogen compounds. Thus it often, though not always, may indicate pollution by sewage, feedlot or barnyard drainage, or some similar source. Nitrite has a toxic effect similar to that of nitrate, but stronger for given concentrations.

Table 6. Significance of chemical and physical properties of water–Continued

Constituent or property	Limit	Significance
Nitrate (as N)	10 mg/L (mandatory)	Concentrations greater than local background levels may indicate pollution by feedlot runoff, sewage, or fertilizers. Concentrations greater than 10 mg/L, as nitrogen, may be injurious when used in feeding infants.
Phosphate		Essential to plant growth. Concentrations greater than local background levels may indicate pollution by fertilizer or sewage.
Aluminum	0.05-0.2 mg/L (recommended)	No known necessary role in human or animal diet. Nontoxic in the concentrations normally found in natural water supplies. Elevated dissolved aluminum concentrations in some low pH waters can be toxic to some types of fish (Hem, 1985).
Arsenic	50 µg/L (mandatory)	No known necessary role in human or animal diet, but is toxic. A cumulative poison that is slowly excreted. Can cause nasal ulcers; skin cancer; damage to the kidneys, liver, and intestinal walls; and death.
Barium	2,000 µg/L (mandatory)	Toxic; used in rat poison. In moderate to large concentrations can cause death; smaller concentrations cause damage to the heart, blood vessels, and nerves.
Boron		Essential to plant growth, but may be toxic to crops when present in excessive concentrations in irrigation water. Sensitive plants show damage when irrigation water contains more than 670 µg/L and even tolerant plants may be damaged when boron exceeds 2,000 µg/L. The recommended limit is 750 µg/L for long-term irrigation on sensitive crops (U.S. Environmental Protection Agency, 1986).
Cadmium	5 µg/L (mandatory)	A cumulative poison; very toxic. Not known to be either biologically essential or beneficial. Believed to promote renal arterial hypertension. Elevated concentrations may cause liver and kidney damage, or even anemia, retarded growth, and death.
Chromium	100 µg/L (mandatory)	No known necessary role in human or animal diet. In the hexavalent form is toxic, leading to intestinal damage and to nephritis.
Copper	1,000 µg/L (recommended)	Essential to metabolism; copper deficiency in infants and young animals results in nutritional anemia. Large concentrations of copper are toxic and may cause liver damage. Some people can detect the taste of as little as 1 to 5 mg/L of copper.
Iron	300 µg/L (recommended)	Forms rust-colored sediment; stains laundry, utensils, and fixtures reddish brown. Objectionable for food and beverage processing. Can promote growth of certain kinds of bacteria that clog pipes and well openings.
Lead	50 µg/L (mandatory) 15 µg/L (recommended)	A cumulative poison, toxic in small concentrations. Can cause lethargy, loss of appetite, constipation, anemia, abdominal pain, gradual paralysis in the muscles, and death. If 1 in 10 samples of a public supply exceed 15 µg/L, the USEPA recommends treatment to remove lead and monitoring of the water supply for lead content (U.S. Environmental Protection Agency, 1991).
Lithium		Reported as probably beneficial in small concentrations (250 to 1,250 µg/L). Reportedly may help strengthen the cell wall and improve resistance to genetic damage and to disease. Lithium salts are used to treat certain types of psychosis.
Manganese	50 µg/L (recommended)	Causes gray or black stains on porcelain, enamel, and fabrics. Can promote growth of certain kinds of bacteria that clog pipes and well openings.
Mercury	2 µg/L (mandatory)	No known essential or beneficial role in human or animal nutrition. Liquid metallic mercury and elemental mercury dissolved in water are comparatively nontoxic, but some mercury compounds, such as mercuric chloride and alkyl mercury, are very toxic. Elemental mercury is readily alkylated, particularly to methyl mercury, and concentrated by biological activity. Potential health effects of exposure to some mercury compounds in water include severe kidney and nervous system disorders (U.S. Environmental Protection Agency, 1994b).
Molybdenum		In minute concentrations, appears to be an essential nutrient for both plants and animals, but in large concentrations may be toxic.
Nickel	100 µg/L (mandatory)	Very toxic to some plants and animals. Toxicity for humans is believed to be very minimal.

Table 6. Significance of chemical and physical properties of water–Continued

Constituent or property	Limit	Significance
Selenium	50 µg/L (mandatory)	Essential to human and animal nutrition in minute concentrations, but even a moderate excess may be harmful or potentially toxic if ingested for a long time (Callahan and others, 1979). Potential human health effects of exposure to elevated selenium concentrations include liver damage (U.S. Environmental Protection Agency, 1994b).
Silver	100 µg/L (recommended)	Causes permanent bluish darkening of the eyes and skin (argyria). Where found in water is almost always from pollution or by intentional addition. Silver salts are used in some countries to sterilize water supplies. Toxic in large concentrations.
Strontium		Importance in human and animal nutrition is not known, but believed to be essential. Toxicity believed very minimal--no more than that of calcium.
Vanadium		Not known to be essential to human or animal nutrition, but believed to be beneficial in trace concentrations. May be an essential trace element for all green plants. Large concentrations may be toxic.
Zinc	5,000 µg/L (recommended)	Essential and beneficial in metabolism; its deficiency in young children or animals will retard growth and may decrease general body resistance to disease. Seems to have no ill effects even in fairly large concentrations (20,000 to 40,000 mg/L), but can impart a metallic taste or milky appearance to water. Zinc in drinking water commonly is derived from galvanized coatings of piping.

Water samples collected from wells completed in the Arikaree aquifer did not exceed the USEPA MCL's for any regulated constituent with the following exceptions: 1 sample out of 45 analyzed for nitrate exceeded the MCL, and 11 samples out of 46 analyzed for arsenic exceeded the MCL of 50 µg/L. In samples from the Arikaree aquifer, 1 out of 58 samples exceeded the SMCL for fluoride, 7 out of 67 samples for dissolved solids, and 4 out of 44 samples for manganese. An investigation of high arsenic concentrations in the Arikaree aquifer in the Grass Mountain area, located about 5 miles northwest of Rosebud in Todd County, was conducted by the USGS in cooperation with the Rosebud Sioux Tribe and the South Dakota Geological Survey during 1991-96. The results of the investigation indicate that the source of arsenic is natural and probably sourced by volcanic ash in the Arikaree Formation (Carter and others, 1998). Arsenic may be high in the aquifer in other parts of Mellette and Todd Counties because two of the samples with arsenic concentrations that exceeded the MCL were not collected near the Grass Mountain area but were located in eastern Todd County (Carter, 1997).

No water samples collected from wells completed in the White River aquifer exceeded the USEPA MCL's for any regulated constituent, although almost one-half of the samples exceeded the SMCL for dissolved solids. A few samples also exceeded the SMCL's for sulfate (4 out of 20 samples), manganese (1 out of 9 samples), and chloride (3 out of 20 samples).

The only constituent concentration that exceeded an MCL in samples collected from the Pierre Shale aquifer was nitrate (3 out of 23 samples). The median concentrations for dissolved solids, sulfate, and manganese exceeded the SMCL's for these constituents. Some samples from the Pierre Shale aquifer also exceeded the SMCL's for chloride (2 out of 24 samples), fluoride (2 out of 24 samples), and iron (1 out of 7 samples).

Water samples collected from wells completed in the Dakota Sandstone aquifer exceeded the USEPA MCL's for fluoride. Of the 11 samples analyzed for fluoride, 5 equalled or exceeded the MCL and 10 exceeded the SMCL. The median concentrations for dissolved solids and sulfate exceeded the SMCL's for these constituents. Concentrations from some of the samples collected from the Dakota Sandstone aquifer also exceeded the SMCL's: 4 out of 13 for chloride, 1 out of 6 for iron, and 2 out of 5 for manganese.

In samples collected from the Inyan Kara aquifer, the MCL for fluoride was exceeded in 1 of the 3 samples, and the SMCL for fluoride was exceeded for all 3 samples. For the 3 samples collected, the minimum concentrations for dissolved solids, sulfate, iron, and manganese exceeded the SMCL's for these constituents. One sample exceeded the SMCL for chloride.

The MCL for mercury was exceeded in one sample collected from the Minnelusa and Madison aquifers. The minimum concentrations of the three samples exceeded the SMCL's for dissolved solids, sulfate, and iron. Two of the 3 samples exceeded the SMCL for manganese.

The general suitability of water for irrigation from the aquifers in the study area can be determined by using the South Dakota irrigation-water diagram (fig. 31). The diagram is based on South Dakota irrigation-water standards (revised January 7, 1982) and shows the State's water-quality and soil-texture requirements for the issuance of an irrigation permit. Generally, most water from the Ogallala and Arikaree aquifers is suitable for irrigation. The quality of water from alluvial aquifers and the White River aquifer generally is suitable for irrigation, but yields probably are not sufficient in most areas. Limited irrigation may be supported by alluvial aquifers in areas where the permeability is very high and in areas where the aquifer is hydraulically connected to a perennial stream. A few wells completed in the White River aquifer are used to support irrigation in Mellette County. The Pierre Shale, Dakota Sandstone, and Inyan Kara aquifers are unsuitable for irrigation because of high sodium-adsorption ratios coupled with high specific conductances. Water from the Minnelusa and Madison aquifers can be used for irrigation under certain soil conditions (fig. 31), although currently no irrigation-use data have been reported for either aquifer in Mellette and Todd Counties.

Water from eight aquifers in the study area generally is suitable for livestock watering. Suitability of water for domestic and municipal purposes is limited in the bedrock aquifers because of high dissolved solids. Generally, water from the shallow aquifers (alluvial, Ogallala, Arikaree, and White River aquifers) is suitable for all water uses, except where constituent concentrations exceed the MCL's.

WATER USE

Withdrawal of water during 1995 for use in Mellette and Todd Counties was about 10,560 acre-feet (table 7). The withdrawal was about 1,220 acre-feet in Mellette County and about 9,340 acre-feet in Todd County. Surface-water withdrawal was about 780 acre-feet in Mellette County, of which 54 percent was used for livestock and 46 percent for irrigation. Surface-water withdrawal was about 630 acre-feet in Todd County, of which 59 percent was used for livestock and 41 percent for irrigation. About 60 percent of the water used for stock watering in both counties was derived from surface-water sources and 40 percent from ground-water sources. In Mellette County, 86 percent of the water used for irrigation was derived from surface-water sources and 14 percent from ground-water sources. In Todd County, only 3 percent of the water used for irrigation was from surface-water sources, and 97 percent was from ground-water sources. Ground water was the source of all water used for municipal and rural-domestic purposes in both counties.

Table 7. Ground- and surface-water withdrawals in Mellette and Todd Counties during 1995
[From F.D. Amundson, U.S. Geological Survey, written commun., 1997]

Source	Total		Municipal		Rural-domestic		Livestock		Irrigation	
	Acre-feet	Percent	Acre-feet	Percent	Acre-feet	Percent	Acre-feet	Percent	Acre-feet	Percent
Mellette County										
Ground water	437	4.1	45	0.4	56	0.5	280	2.7	56	0.5
Surface water	784	7.4	0	0	0	0	426	4.0	358	3.4
Todd County										
Ground water	8,713	82.5	123	1.2	582	5.5	246	2.3	7,762	73.5
Surface water	627	5.9	0	0	0	0	370	3.5	257	2.4
Total, both counties	10,561	[1]100	168	1.6	638	6.0	1,322	12.5	8,433	[1]79.9

[1]Total percentage may not equal sum of components because of rounding.

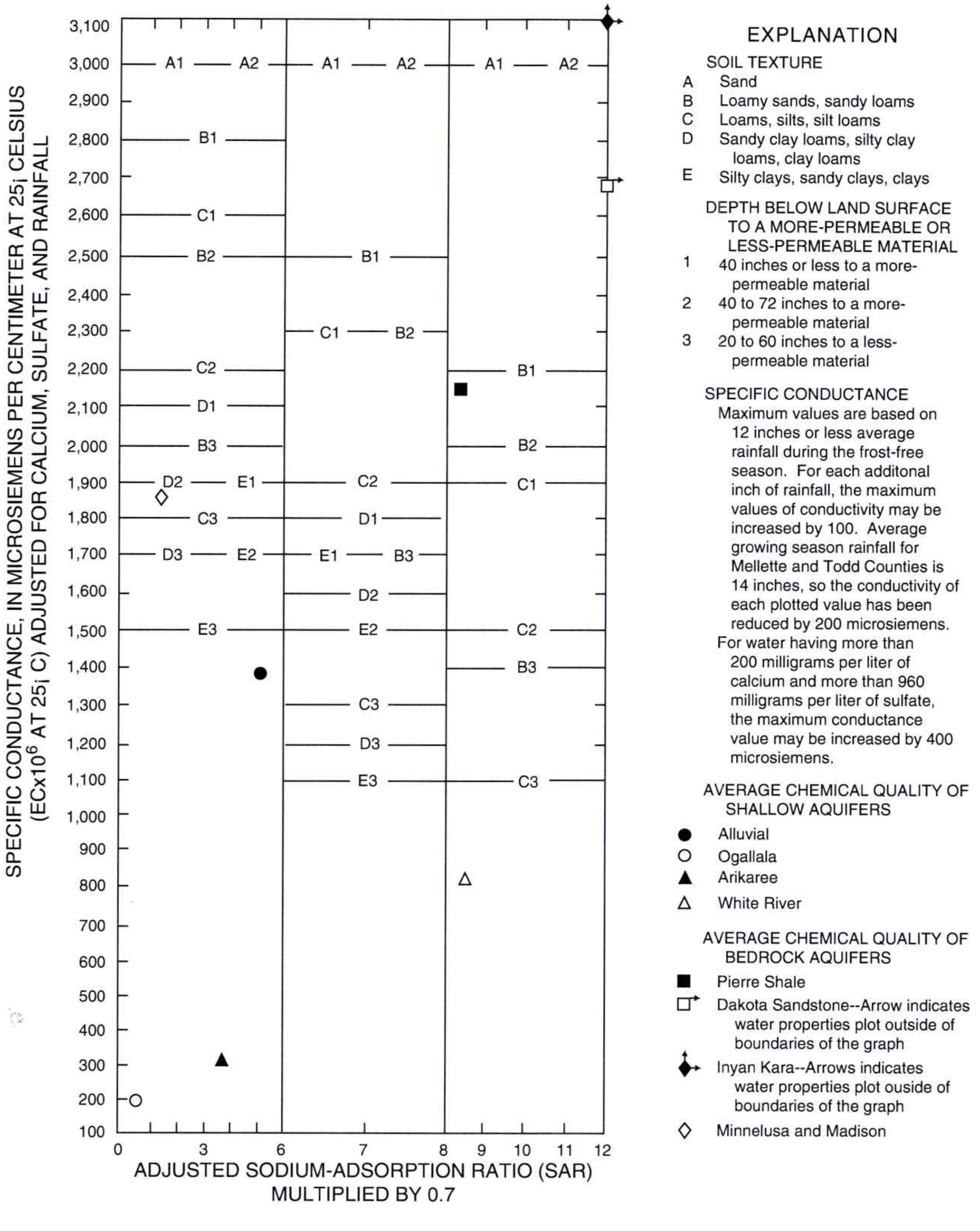

Figure 31. South Dakota irrigation-water classification diagram (based on South Dakota standards (revised Jan. 7, 1982) for maximum allowable specific conductance and adjusted sodium-adsorption-ratio values for which an irrigation permit can be issued for applying water under various soil-texture conditions. Water an be applied under all conditions at or above the plotted point, but not below it, provided other conditions as defined by the State Conservation Commission are met (from Koch, 1983)).

Withdrawal of ground water in Mellette County during 1995, summarized in table 8, was almost 440 acre-feet. Aquifer withdrawals were estimated from available water-use data in the USGS NWIS ground-water database. About 66 percent of the ground water used was supplied by shallow aquifers, and about 34 percent was supplied by bedrock aquifers. Most of the ground water was supplied by alluvial aquifers (about 31 percent) and the Pierre Shale aquifer (about 24 percent). The deeper bedrock aquifers only supplied about 9 percent of the ground water. Most of the ground water used in Mellette County was for stock-watering purposes (64 percent).

Withdrawal of ground water in Todd County during 1995, summarized in table 9, was about 8,710 acre-feet. Almost 100 percent of the ground water used was supplied by shallow aquifers. The Ogallala aquifer supplied about 84 percent of the ground water used in Todd County. Other than the Pierre Shale, no bedrock aquifers supply water in Todd County. Most of the ground water (89 percent) was used for irrigation.

Table 8. Estimated withdrawal of ground water in Mellette County during 1995

Source	Total		Municipal		Rural-domestic		Livestock		Irrigation	
	Acre-feet	Percent	Acre-feet	Percent	Acre-feet	Percent	Acre-feet	Percent	Acre-feet	Percent
Shallow aquifers										
Alluvial	134	30.7	31	7.0	11	2.5	73	16.7	19	4.3
Arikaree	73	16.7	3	0.7	25	5.7	20	4.6	25	5.7
White River	83	19.0	4	1.0	8	1.8	59	13.5	12	2.7
Subtotal	290	66.4	38	8.7	44	[1]10.1	152	[1]34.8	56	[1]12.8
Bedrock aquifers										
Pierre Shale	106	24.2	0	0	10	2.3	96	22.0	0	0
Dakota Sandstone	26	5.9	7	1.6	2	0.5	17	3.9	0	0
Inyan Kara	10	2.3	0	0	0	0	10	2.4	0	0
Minnelusa and Madison	5	1.1	0	0	0	0	5	1.1	0	0
Subtotal	147	[1]33.6	7	1.6	12	[1]2.7	128	[1]29.3	0	0
Total, all aquifers	437	100	45	10.3	56	12.8	280	64.1	56	[1]12.8

[1]Total percentage may not equal sum of components because of rounding.

Table 9. Estimated withdrawal of ground water in Todd County during 1995

Source	Total		Municipal		Rural-domestic		Livestock		Irrigation	
	Acre-feet	Percent	Acre-feet	Percent	Acre-feet	Percent	Acre-feet	Percent	Acre-feet	Percent
Shallow aquifers										
Alluvial	44	0.5	0	0	38	0.4	6	0.1	0	0
Ogallala	7,355	84.4	41	0.5	125	1.4	102	1.2	7,087	81.3
Arikaree	1,228	14.1	82	0.9	357	4.1	114	1.3	675	7.8
White River	81	0.9	0	0	59	0.7	22	0.2	0	0
Subtotal	8,708	[1]100	123	1.4	579	6.6	244	2.8	7,762	89.1
Bedrock aquifers										
Pierre Shale	5	0	0	0	3	0	2	0	0	0
Subtotal	5	0	0	0	3	0	2	0	0	0
Total, all aquifers	8,713	100	123	1.4	582	[1]6.7	246	2.8	7,762	89.1

[1]Total percentage may not equal sum of components because of rounding

SUMMARY AND CONCLUSIONS

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Mellette and Todd Counties, located in south-central South Dakota, have a combined area of 2,694 square miles. The main source of income is ranching. The average annual precipitation is about 19 inches. The White River forms the northern boundary of Mellette County and the South Dakota-Nebraska border forms the southern boundary of Todd County. The major water resources of the counties are surface water and ground water from shallow and bedrock aquifers.

The major rivers in Mellette and Todd Counties are the White, Little White, and Keya Paha Rivers. All of Mellette County and 51 percent of Todd County is drained by the White River, in Nebraska, and its tributaries; 49 percent of Todd County is drained by the Niobrara River and its tributaries, which include the Keya Paha River. The average flow of the Little White River is about 56 cubic feet per second as the river enters Todd County, and the average flow of the Little White River is 131 cubic feet per second at the most downstream streamflow-gaging station in Mellette County. The Keya Paha River near Keyapaha (just outside Todd County) has an average flow of about 39 cubic feet per second. The average annual runoff for the counties ranges from 0.94 to 2.36 inches and averages 1.62 inches based on records from nine gaging stations in and near the counties. Bicarbonate, calcium, and sulfate are the dominant chemical species in the water of the Little White River. Surface-water quality varies seasonally with volume of streamflow. Generally, the concentrations of dissolved constituents increase from upstream to downstream.

The geology of Mellette and Todd Counties consists mostly of marine, fluvial, and eolian deposits. The major shallow aquifers in the counties are the alluvial, Ogallala, Arikaree, and White River aquifers. The bedrock aquifers include the Pierre Shale, Dakota Sandstone, Inyan Kara, and Minnelusa and Madison aquifers.

In Todd County, ground water generally can be obtained from shallow wells completed in the alluvial, Ogallala, Arikaree, or White River aquifers. In Mellette County, the Pierre Shale is present at the land surface throughout most of the county, which means that the Ogallala, Arikaree, and White River aquifers are not present. Because shallow ground-water sources in Mellette County often are not available, deep bedrock aquifer wells, often greater than 1,000 feet, are sometimes installed.

The boundaries of four shallow aquifers (alluvial, Ogallala, Arikaree, and White River) and one bedrock aquifer (Pierre Shale) were delineated for this study. Alluvial aquifers are present in both Mellette and Todd Counties; however, the water has high concentrations of dissolved solids, is saline, and is very hard in Mellette County where the alluvial deposits are underlain by the Pierre Shale. Also, deposits overlying the Pierre Shale are relatively impermeable and may not yield an adequate supply of water. The major alluvial aquifers are located along the Keya Paha, Little White, and White Rivers. The average thickness of the alluvial aquifers is 29 feet. Alluvial aquifers underlie about 440 square miles of the study area and store an estimated 1.6 million acre-feet of water. Recharge to the alluvial aquifers is by infiltration of precipitation, stream loss, and discharge from springs originating in the Tertiary deposits. Discharge from the alluvial aquifers is through withdrawals from domestic and stock wells and by evapotranspiration from the aquifer. Water from the alluvial aquifers primarily is used for stock-watering and rural-domestic purposes; however, it can be used to support irrigation in some areas of Mellette County.

The Ogallala aquifer is present throughout most of Todd County, but not in Mellette County. The aquifer underlies 950 square miles in Todd County and contains an estimated 17 million acre-feet of water in storage. The depth to the top of the Ogallala aquifer ranges from 0 to 164 feet below land surface, and the average thickness is 137 feet. The aquifer is thickest in central Todd County, and is under water-table conditions except in southwestern Todd County, where it is confined. Recharge to the Ogallala aquifer is by infiltration of precipitation on the outcrops of the Ogallala Formation or overlying windblown sand deposits and by stream loss. The primary discharge from the aquifer is through withdrawals from domestic, public, stock, and irrigation wells; by loss to streams and springs; and by evapotranspiration. The aquifer has the highest yield potential of the eight aquifers in the study area; the maximum reported well yield is 1,250 gallons per minute.

The Arikaree aquifer is present throughout most of Todd County, although it is absent in the eastern part of the county. The Arikaree is present in only a small part of southwestern Mellette County. The Arikaree aquifer underlies about 1,360 square miles in Mellette and Todd Counties and contains an estimated 50 million acre-feet of water in storage. The depth to the top of the aquifer ranges from 0 to 406 feet below land surface, and the average thickness is 290 feet. About one-half of the aquifer is under water-table conditions and one-half is confined. Yields from the Arikaree aquifer range from 1 to 1,005 gallons per minute and generally are not as high as those from the Ogallala aquifer, but yields are often sufficient to support irrigation. Recharge to the Arikaree aquifer is by infiltration of precipitation on the outcrops of the Arikaree Formation and by stream loss. Discharge is through withdrawals from domestic, stock, and irrigation wells; by evapotranspiration; and by discharge from springs to alluvial aquifers and streams.

The White River aquifer is present throughout most of Todd County and in western and south-central Mellette County. Other than alluvial aquifers, the White River aquifer, where present, is the shallowest source of ground water in Mellette County. In Todd County, the White River aquifer is used mostly where the Ogallala and Arikaree aquifers are not present. The White River aquifer underlies approximately 1,720 square miles of the study area and contains an estimated 50 million acre-feet of water in storage. The depth to the top of the White River aquifer ranges from 0 to 789 feet below land surface, and the average thickness is 229 feet. Most of the aquifer is confined. Although the water quality of the White River aquifer generally is suitable for irrigation purposes, well yields are not sufficient. The reported yields of the White River aquifer in the counties range from 1 to 30 gallons per minute. Recharge to the aquifer is by infiltration of precipitation on outcrops of the White River Group and by stream loss. Discharge from the aquifer is by withdrawals from domestic and stock wells, evapotranspiration, and discharge from springs to alluvial deposits and streams.

The Pierre Shale is the shallowest bedrock aquifer and is exposed at the land surface throughout most of Mellette County. Although the Pierre Shale is present throughout both counties, it is used as an aquifer only in Mellette County to supply rural-domestic and stock wells. The aquifer contains an estimated maximum of 1.5 million acre-feet of water in storage; however, it is not a viable source of ground water because water can usually be obtained from shallower aquifers, yields are low, and the aquifer is relatively impermeable. Reported yields from the Pierre Shale aquifer range from 1 to 8 gallons per minute. The depth to the top of the Pierre Shale ranges from 0 to greater than 1,200 feet in the study area. The Pierre Shale aquifer, where used, is under water-table conditions. Recharge to the aquifer is primarily by infiltration of precipitation on outcrops of the Pierre Shale, and discharge is through withdrawals from domestic and stock wells and by evapotranspiration.

Little is known about the deeper bedrock aquifers (Dakota Sandstone, Inyan Kara, and Minnelusa and Madison) because few test holes and wells penetrate below the Pierre Shale. All but two of the deeper test holes and wells are located in Mellette County so the extent of some of the bedrock aquifers in Todd County is not known. Recharge to all of the deeper bedrock aquifers primarily is by infiltration of precipitation on outcrops of the formations, which occurs mainly in the Black Hills. In the study area, discharge from the bedrock aquifers is through withdrawals from stock wells.

The Dakota Sandstone aquifer underlies both counties and contains more than 81 million acre-feet of water in storage. The depth to the top of the Dakota Sandstone ranges from 1,270 to 2,348 feet below land surface. Reported yields from the Dakota Sandstone aquifer range from 10 to 100 gallons per minute.

The areal extent of the Inyan Kara, and Minnelusa and Madison aquifers in Todd County is not known. The depth to the top of these aquifers generally is at least 1,900 feet below land surface. The Minnelusa and Madison aquifers are the only bedrock aquifers that generally are suitable for irrigation. Reported yields from the Inyan Kara aquifer range from 9 to 160 gallons per minute, and yields from the Minnelusa and Madison aquifers range from 25 to 40 gallons per minute.

The chemical quality of water in the aquifers in the counties varies widely, both within and between aquifers. The chemical quality among the aquifers of Tertiary age is the most similar. The quality of water from the alluvial aquifers is dependant on the underlying deposits; the water generally has low concentrations of dissolved solids, is fresh, and is soft to moderately hard where underlain by the Ogallala and Arikaree Formations; has moderate concentrations of dissolved solids, is slightly saline, and is hard where underlain by the White River Group; and has high concentrations of dissolved solids, is saline, and is very hard where underlain by the Pierre Shale. Calcium and bicarbonate generally are the dominant species in alluvial water where underlain by the Tertiary deposits, and sodium and chloride are the dominant species where underlain by the Pierre Shale. One out of 49 samples from the alluvial aquifers exceeded the

USEPA Primary Drinking-Water Regulations Maximum Contaminant Level (MCL) for fluoride, and 1 out of 16 samples exceeded that MCL for selenium.

Calcium and bicarbonate are the dominant species in water from the Ogallala aquifer; calcium, sodium, and bicarbonate are the dominant species in water from the Arikaree aquifer. The water of both the Ogallala and Arikaree aquifers generally has low concentrations of dissolved solids, is fresh, and is soft to moderately hard. In samples collected from the Ogallala aquifer, 1 out of 54 exceeded the MCL for fluoride, and 13 out of 92 exceeded the MCL for nitrate. In samples collected from the Arikaree aquifer, 1 out of 45 samples exceeded the MCL for nitrate, and 11 out of 46 samples exceeded the MCL for arsenic.

The dominant species in water from the White River aquifer are calcium, sodium, and bicarbonate. The water quality from this aquifer is dependant on depth and proximity of the aquifer material to the Pierre Shale. The water is higher in dissolved solids, more saline, and hard where the water-bearing deposits are close to the Pierre Shale.

The bedrock aquifers generally yield a hard water with high concentrations of dissolved solids. The Dakota Sandstone aquifer yields the softest water of the bedrock aquifers. Concentrations of dissolved solids in the bedrock aquifers are lowest in the Minnelusa and Madison aquifers, which would allow water from these aquifers to be used for irrigation.

Withdrawal of water during 1995 in Mellette and Todd Counties was about 10,560 acre-feet. More surface water than ground water was used by Mellette County, although all water used for municipal and rural-domestic purposes was from ground water. Most of the ground water used in Todd County (89 percent) was for irrigation.

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