7-1-1926

Seventh Biennial Report of the State Engineer of New Mexico for the 13th and 14th Fiscal Years, December 1, 1924 to June 30, 1926

Geo. M. Neel

SEVENTH BIENNIAL REPORT

OF THE

STATE ENGINEER

OF

NEW MEXICO

FOR THE 13th and 14th FISCAL YEARS
DECEMBER 1, 1924 TO JUNE 30, 1926

GEO. M. NEEL
STATE ENGINEER
SANTA FE, NEW MEXICO

New Mexico Sun Publishing Company
Santa Fe, New Mexico

TABLE OF CONTENTS

(GENERAL INDEX)

HON. A. T. HANNETT,

Governor of New Mexico.

Sir:

Transmitted herewith is the Seventh Biennial Report of the State Engineer of New Mexico, covering the period December 1st, 1924, to June 30th, 1926.

Very respectfully,

GEO. M. NEEL,
State Engineer.

Santa Fe, New Mexico,
July 1st, 1926.

SEVENTH BIENNIAL REPORT
of
STATE ENGINEER

INTRODUCTION

The following report covers the work of the Office of the State Engineer of New Mexico for the 13th and 14th fiscal years, December 1st, 1924, to June 30th, 1926.

By an Act of the Seventh regular session of the Legislature of the State the end of the fiscal year was changed from November 30th to June 30th, which makes the 13th fiscal year one of only seven months.

In addition to this it should be borne in mind that the funds under which this department operates, except those for the Water R'ghts Department and the Rio Grande Improvement, were not available from the first of February, 1926, to the end of the fiscal year. This was the result of an opinion from the Attorney General of the State of New Mexico, holding that, in view of the decision of the State Supreme Court in the case of Asplund vs. A. T. Hannett, et al., No. 3101, it was doubtful if further expenditures could be made from the appropriations from the "Water Reservo'rs for Irrigation Purposes Income Fund" and the further policy of the State Treasurer in which he refused to allow any expenditures from these appropriations after February first until the legality of such expenditures could be fully determined. It will be noted that this period of suspension is that in which the greatest amount of field work would have been accomplished in all the special invstigations to be made by this department.

PERSONNEL

The personnel of the State Engineer's Office during this biennial period has been as follows:

State Engineer	Geo. M. Neel
Assistant State Engineer	Chas. E. Perkins
Water Rights Attorney	W. A. Gillenwater
Chief Hydrographer	Mark Lambert
Field Hydrographer	Homer G. Neel
Draftsman	Sam Houston
Computer	A. M. Archer
Stenographer and Bookkeeper	Mildred M. Shimp
Stenographer and Files	Mildred Samis
Engineers in Charge of Investigations	F. M. Atkinson Hugo Marek, Jr. Earl M. Smith R. E. Kennedy F. G. Healy A. M. Easterday

NOTE: In addition to the above there have been Engineers and Geologists under government employ on co-operative projects as follows:

O. E. Meinzer, Geologist in Charge, Division of Ground Water, U. S. Geological Survey.
B. Coleman Renick, Geologist, U. S. G. S.
Kirk Bryan, Geologist, U. S. G. S.
A. G. Fiedler, Engineer U. S. G. S.
C. C. Elder, Engineer, Bureau of Reclamation.

WATER RIGHTS DEPARTMENT

The Water Rights Department is the fundamental of the State Engineer's Office. In it are deposited those records which constitute an applicant's rights to the use of water in the State. It is here also that the priority of uses and adequacy of structures and systems are examined and checked. It has been the earnest endeavor to carry on the work here with as few delays as possible and all applicants have been urged to complete the different steps in the perfection of their rights within the time limit given them.

The activities of the storage development is indicated by the fact that there have been placed under construction, during this biennial period, four dams, ranging in height from fifty-five to one hundred and twenty-five feet. Two of these dams, one on the Bluewater project and one on the Santa Cruz, and both for storage of water for irrigation districts, are horizontal arches built of concrete. One dam, on Santa Fe Creek for municipal water supply, is an earth fill with concrete and puddled core. The fourth is an earth fill of the American Metal Company of New Mexico, being built primarily for the settlement and retention of tailings in connection with their mill near Valley Ranch on the Pecos River.

During the period there has been instituted a new index and abstract of record of all filings coming into the Engineer's Office. There has also been installed a new system of files for maps to better protect and make them more accessible.

FINANCIAL STATEMENT

Thirteenth Fiscal Year

Balance in State Treasury, Dec. 1, 1924			$4,242.30
Receipts			2,197.85
Disbursements:			
Expense of Hearings and Inspections	$ 111.26		
Refunds to Applicants	216.85		
Earned Fees Transferred	1,194.70		
		$1,522.81	
Balance July 1, 1925		4,917.34	
		$6,440.15	$6,440.15

Fourteenth Fiscal Year

Balance July 1st, 1925			$4,917.34
Receipts			4,319.22
Disbursements:			
Expense of Hearings and Inspections	$ 119.48		
Refunds to Applicants	281.25		
Earned Fees Transferred	1,283.56		
Miscellaneous Expense	174.46		
		$1,858.75	
Balance June 30th, 1926		7,377.81	
		$9,236.56	$9,236.56

BOARD OF EXAMINING SURVEYORS

HON. A. T. HANNETT,
Governor of New Mexico,
Santa Fe, New Mexico.
Sir:

I transmit to you herewith report of the Board of Examining Surveyors for the 13th and 14th Fiscal Years from December 1st, 1924 to June 30th, 1926.

Respectfully,
(Signed) GEO. M. NEEL,
Secretary of Board.

Santa Fe, New Mexico,
July 1, 1926.

The Surveyor's License Law is contained in Chapter 102, Laws of 1917, approved March 13, 1917. This law defines surveying and prescribes the manner in which licenses may be issued in this State with provisions for cancellation of such licenses. Briefly stated, a license may be issued in one of three ways: (1) Upon a certificate that the applicant is the holder of a diploma of any recognized school of engineering or a member in good standing of any recognized engineering society; (2) upon certificate signed by three surveyors, licensed under this act, to the effect that he is of good moral character and competent to practice surveying; (3) upon investigation of his moral character and examination by the Board of his technical fitness to practice surveying.

The present members of the Board are:

James A. French....................President
Geo. M. Neel....................Secretary
N. Howard Thorpe....................Member

Licenses issued during this biennial period are as follows:

No.	Name	Address
225	Chas. A. Vaughn	Lubbock, Texas
226	Joe Rady	Tucumcari, N. M.
227	F. E. Devlin	Tucumcari, N. M.
228	Frank Kimball	Albuquerque, N. M
229	Louis W. Cantelou	Albuquerque, N. M.
230	Fermor Spencer Church	Otowi, N. M.
231	W. B. Wells	Amarillo, Texas
232	R. W. Keehn	Bernalillo, N. M.
233	Sam S. Coldren	Santa Fe, N. M.
234	F. E. Conway	Tucumcari, N. M.
235	Read J. Oldham	Albuquerque, N. M.
236	Allen J. Sturges	Santa Fe, N. M.
237	Chas. H. Topping	Santa Fe, N. M.
238	Henry C. Zimmerman	Santa Fe, N. M.
239	M. B. Reynolds	Santa Fe, N. M.
240	O. E. Betts	Albuquerque, N. M.
241	Earl M. Smith	Santa Fe, N. M.
242	H. W. Palmer	Taos, N. M.

No.	Name	Address
243	Hugo Marek, Jr.	Santa Fe, N. M.
244	Chas. E. Wells	Albuquerque, N. M.
245	Geo. S. Finley	Raton, N. M.
246	C. E. Perkins	Santa Fe, N. M.
247	A. M. Easterday	Santa Fe, N. M.
248	E. C. Anderson	Valley Ranch, N. M.
249	John A. Holmes	Madrid, N. M.
250	F. P. Beck	Valley Ranch, N. M.
251	H. B. Elmendorf	Las Cruces, N. M.
252	D. S. Durrin (Temporary)	Mosquero, N. M.

Financial Statement

Balance December 1st, 1924		$297.56
Receipts from Licenses issued		140.00
Balance June 30th, 1926	$437.56	
	$437.56	$437.56

CERTIFICATION BOARD

Chapter 20 of the 1925 Session Laws of the State creates the State Certification Board, the members of said Board to be composed of the Attorney General, the State Engineer and the State Bank Examiner.

Under the provisions of this act the Bluewater-Toltec Irrigation District in McKinley County made formal request to the Board that it examine and pass upon the bond issue of the District. After visiting and making a thorough inspection of the entire proposed project the Board took up the study of its feasibility and of the legality of the proceedings in connection therewith, finally approving the same. Subsequent to this approval the Board has formally considered and approved the contract which the District entered into with the contractor and it has considered all expenditures by the District which have come before it. In addition to this supervision it has, through the State Engineer, from time to time made inspections of the construction as it proceeds, both on the dam and on the canal system, it being the earnest desire of the Board to see that there will finally result to the District a completed irrigation system within the bond issue.

DRY CIMARRON HYDROGRAPHIC SURVEY

Under date of March 14th, 1923, there was received in the State Engineer's Office a copy of an Order from the Court of the Eighth Judicial District of the State of New Mexico, bearing date of March 6th, 1923, and directing the State Engineer to make and furnish a complete hydrographic survey of the Dry Cimarron Stream System.

At that time sufficient funds for the completion of such a survey and report were not available and an arrangement was negotiated with the users of water on the stream system, whereby they were to furnish such funds as could not be furnished by the State Engineer. This arrangement did not work out and the Seventh regular session of the

State Legislature appropriated $7,500.00 for the completion of such a survey.

All field work for this report has been completed and a set of maps, showing all lands irrigated from the stream system and consisting of forty-nine sheets, has been prepared. It only remains to complete the tabulation of areas and ownerships and formulate a statement of the work before the report can be submitted to the District Court in compliance with the Order as above mentioned. There have also been prepared maps of several possible storage sites in this area.

Financial Statement

(Dry Cimarron)

Appropriated by Legislature of 1925			$7,500.00
Expenditures for 13th Fiscal Year:			
Salaries	$667.00		
Subsistence	97.28		
Transportation	53.36		
Supplies	25.37	$ 843.01	
Balance June 30th, 1925		6,656.99	
		$7,500.00	$7,500.00
Balance July 1, 1925			$6,656.99
Expenditures for 14th Fiscal Year:			
Salaries	$3,997.69		
Subsistence	639.58		
Transportation	385.52		
Supplies	258.97		
Miscellaneous Expense	52.41	$5,334.17	
Balance June 30, 1926		1,322.82	
		$6,656.99	$6,656.99

VERMEJO HYDROGRAPHIC SURVEY

Under date of June 17th, 1925, an Order from the Eighth Judicial District, bearing date of June 13th, 1925, was received in the Office of the State Engineer and directed him to make a hydrographic survey of the Vermejo Stream System and furnish the same to the Court.

Because of lack of suitable engineers to place in charge of this survey and the lateness of the season when the Order was received it was planned to complete the field work during the season of 1926. The tying up of funds by the Court action brought against the expenditures from the "Water Reservoirs for Irrigation Purposes Income Fund" prevented the work from being started.

Inasmuch as the records for such a survey should cover as nearly as possible a complete irrigation season, this survey should be planned and completed during the working season of 1927.

PECOS RIVER COMPACT

Under authority of Chapter 64 of the Session Laws of 1923, entitled "An Act to Provide for the Appointment of a Commission on

Behalf of the State of New Mexico to Negotiate a Compact or Agreement Between the United States of America, the States of New Mexico and Texas, Respecting the Use, Storage and Distribution of the Waters of the Pecos River and the Rights of Said States Thereto, and Making an Appropriation Therefor," the Pecos River Compact was prepared and submitted to the Seventh regular Session of the New Mexico Legislature. This compact was approved by the legislature with certain reservations or amendments. Upon the specific request of the Pecos Water Users' Association of New Mexico and others, and the fear that the adoption of the compact in its amended form might interfere with the operation of the irrigation laws within the State of New Mexico, it was vetoed by the Governor and failed to become a law.

Since that time there has been enacted by the Congress of the United States certain legislation which impowers the Secretary of the Interior to construct a reservoir on the Pecos River at a point where it will conserve the waters of the Delaware and Black Rivers and the uses from which must necessarily be in the State of Texas. In view of this proposed construction it now appears even more desirable that there should be a definite understanding between the States of New Mexico and Texas as to a proper and equitable distribution and division of the waters of the Pecos River.

RIO GRANDE COMPACT COMMISSION

Chapter 112 of the Session Laws of 1923 provided for the appointment of a Commissioner on behalf of the State of New Mexico in conjunction with a like member from Colorado and a Federal representative, to negotiate a compact or agreement respecting the use, control and disposition of the waters of the Rio Grande.

In compliance with this act, Hon. J. O. Seth of Santa Fe, New Mexico, was appointed Commissioner for this state and Hon. Delph E. Carpenter was appointed Commissioner by Colorado. Many meetings were had by these two commissioners and the legal and engineering representatives of both states and an examination of the Rio Grande was made from near its source in Colorado to Fort Quitman in Texas.

Hon. Herbert Hoover, Secretary of Commerce, was appointed by President Harding the representative of the United States on this Commission, and the first meeting of the full commission which it was possible to secure was held at Colorado Springs, Colorado, on October 26, 1924, at which time Mr. Hoover was duly elected Chairman. At this meeting appeared Major R. F. Burges of El Paso, Texas, who protested against any further proceedings by the commission until the State of Texas should have an opportunity to appoint a representative on the commission. After a thorough discussion of this and other matters pertaining to the work to be done the following resolution was adopted:

> "That in view of the fact that the state of Texas is not represented, and has indicated a desire to be represented on this commission; that her interests will be partially affected by any action which this Commission might take; that there can be no complete determination of the problem without the

participation of Texas, therefore this Commission proposes that the Governors and legislatures of Colorado, New Mexico and Texas should have an opportunity to provide that the Commission be comprised of representatives from each of these states, together with the representatives of the Federal Government authorized to arrive at an equitable and proper division of the waters of the Rio Grande by compact for submission to the legislatures and Congress. Should the state of Texas fail to take the necessary action, then the Commission to proceed as originally outlined."

Chapter 114 of the Session Laws of 1925 provided for the continuance of the Commission and for the inclusion of the State of Texas in the negotiations. By that session also was passed Chapter 66, which provides that in the event the New Mexico Member of this Commission shall report to the Governor that this joint commission is unable to reach an agreement relative to the waters of the Rio Grande, then and in that case the Governor is authorized to take such steps as in his judgment may be necessary for the protection of rights to waters of the Rio Grande in the State of New Mexico, and this chapter appropriated from the "Water Reservoirs for Irrigation Purposes Income Fund" the sum of $25,000 to be used by the Governor for the purposes of the act.

Before the work of the commission, with members representing the three instead of two states, could be actively resumed, the Secretary of the Interior allowed certain rights-of-way in Colorado for irrigation projects and removed all restrictions on the allowance of all others, which amounted to a virtual removal of the so-called "embargo" and permitted all projects in Colorado which had theretofore been held up for lack of rights-of-way to proceed so far as this phase of their applications was concerned. In the opinion of Mr. Seth, the Commissioner for the State of New Mexico, this action of the Interior Department made impossible any agreement between the States which could properly provide water for the rights in this State having priority over those in Colorado and he so reported to the Governor, at the same time tendering his resignation as commissioner for New Mexico. Definite steps were then taken by New Mexico for the filing of an interstate suit to compel the adjudication of the waters of the Rio Grande and a final determination of the respective rights thereto in the different states. A suit, known as the Asplund vs. A. T. Hannett, et al., No. 3101, was then filed to restrain the State from using the $25,000 for the purposes of interstate litigation and the matter now stands in this condition.

LA PLATA RIVER COMPACT

The La Plata River Compact, as signed by the commissioners at Santa Fe, New Mexico, on November 27th, 1922, and ratified by the legislatures of both New Mexico and Colorado and finally approved by the United States Government, has been in effect for two irrigation seasons.

The first season's administration of this compact was not satisfactory and in order to profit by the experiences gained during the first season a conference of the State Engineers of the two States was called at Durango, Colorado, for the purpose of formulating and putting into effect a set of rules and regulations under the provisions of Article 3 of the compact.

On May 17th and 18th, 1926, this conference was held and investigations of conditions were made, at which time the engineers went over a large part of the La Plata area and talked with many of the water users. Subsequently a set of rules and regulations was duly signed by the two State Engineers. Owing to the tying up of funds which could be used by this department, New Mexico has been unable to properly supervise and administer the carrying out of the terms of the compact and the rules which had been duly adopted.

However, Mr. Chas. F. Holly, of Aztec, New Mexico, has very ably and conscientiously acted in behalf of this office on La Plata matters, and often without remuneration. The results of the second season's administration have proven to be far from satisfactory and the water users in New Mexico have not received the quantity of water to which they were entitled.

It is plainly evident that no agent of the Engineer's Office or our District Court has power to compel a compliance to the terms of the compact beyond our state line and it seems that it may be necessary, in some way, to place its administration under an agent of the Federal Court. This matter should receive serious consideration by the officials of both States and a plan worked out for a strict administration.

RIO GRANDE IMPROVEMENT

An act of the last legislature, Chapter 12, approved March 9th, 1925, appropriated $20,000.00, (or so much thereof as may be available), annually for the 14th and 15th fiscal years for the permanent improvement of the Rio Grande. Section 2 of this act sets forth that such work shall be done and performed as determined upon by the State Engineer and under his supervision, and prescribes that it "shall be such as will, in his opinion, be for the improvement of the Rio Grande or the increasing of the surface flow therein, under the provisions of the Act of Congress approved June 1, 1898, in reference thereto." It is provided that the moneys therein appropriated "shall be expended pro rata in the Counties of Rio Arriba, Taos, Santa Fe, Sandoval, Bernalillo, Valencia, Sierra, Socorro and Dona Ana according to the necessities existing or which may arise."

In carrying out the provisions of this act it has been the policy of the State Engineer, in all cases wherever possible, to require co-operation from the parties benefitted or interested in the improvement, to the extent of 50 per cent of the cost. It is the custom to cause an inspection of any needed improvement to be made, solicit the co-operation of interested parties, have an engineer outline the work to be done, make an estimate of the cost thereof, secure an agreement from the interested parties to do the work and, upon its completion, pay them one-half the cost of this work at the standard rates of pay.

The amount of money available for improvement work of this character is entirely inadequate to rectify and control the Rio Grande throughout the length of valley sections in New Mexico but the work undertaken is usually in conformity to a large scheme of improvement wherever practicable. In many localities, however, where suitable

materials are not within reach, it is impossible to do work of an entirely permanent character, but permanence is always borne in mind in planning the work and allotting funds for this purpose.

The work of river protection and rectification largely consists of bank protection by brush-and-rock riprap and rock riprap, rock jetties and rock-and-crib jetties to deflect currents and brush-and-rock deflections or diversions to divert water from unnecessary channels. Some open jetties have been tried with good effect. These are such arrangements as will lessen the velocity of the water, causing it to deposit its load of sediment along the sides of the stream, thus encouraging one main channel.

The distribution and amounts of work done during this biennial period are as follows:

13th and 14th Fiscal Year

	State	Donated	Total
Rio Arriba County:			
Espanola—1925			
Construction of current deflectors of posts, brush, rock and wire, north and south of Espanola	$ 997.70	$ 829.50	$1,827.20
Espanola—1926			
Brush, rock, wire and post constructed current deflectors and bank protection, north and south of Espanola	1,243.13	1,178.41	2,421.54
Chamita—1925			
Brush bank protection	75.00	75.00	150.00
Lyden—1925			
Jetties and rock brush deflections	172.38	172.38	344.76
Lyden—1926			
Jetties and rock brush deflections	125.00	125.00	250.00
Pilar—1926			
Jetties and rock brush deflections	210.50	210.50	421.00
San Ildefonso			
Brush rock dam to deflect branch into old channel	174.00	174.00	348.00
Velarde—1926			
Brush and rock bank protectors and stub jetties	60.00	60.00	120.00
Rio Arriba County Totals	$3,059.71	$2,824.79	$5,882.50
Sandoval County:			
Cochiti—1926			
Brush and rock bank protection and rock crib stub jetties near Cochiti steel bridge	162.50	325.00	487.50
Sandoval County Total	$ 162.50	$ 325.00	$ 487.50

	State	Donated	Total
Bernalillo County:			
Albuquerque—1925			
Extension of jetties and brush current deflections above and below Albuquerque for flood protection	$1,492.00	$8,783.89	$10,275.89
Bernalillo County Total	$1,492.00	$8,783.89	$10,275.89
Socorro County:			
San Marcial—1925			
Flood protection work	$ 300.00	$ 28.50	$ 328.50
Socorro County Total	$ 300.00	$ 28.50	$ 328.50
Taos County:			
Pilar—1926			
Bank protection on west side of river at Cieniguella	$ 210.50	$ 196.50	$ 407.00
Taos County Total	$ 210.50	$ 196.50	$ 407.00

Recapitulation

	State	Donations	Totals
Rio Arriba County	$3,057.71	$ 2,824.79	$ 5,882.50
Sandoval County	162.50	325.00	487.50
Bernalillo County	1,492.00	8,783.89	10,275.89
Socorro County	300.00	28.50	328.50
Taos County	210.50	196.50	407.00
General Expense	2,114.86		2,114.86
	$ 7,337.57	$12,158.68	$19,496.25

Financial Statement

Balance in Treasury, Nov. 30, 1924			$1,079.15
Expenditures for 13th fiscal year:			
Wages	$ 569.74		
Subsistence	22.44		
Transportation	424.97	$1,017.15	
Balance June 30, 1925		62.00	
		$1,079.15	$1,079.15
Balance July 1, 1925			$ 62.00
Appropriated, 1925 Legislature			20,000.00
Expenditures for 14th fiscal year:			
Wages	$5,735.32		
Subsistence	25.05		
Transportation	351.64		
Supplies	208.41	$ 6,320.42	
Balance June 30, 1926		13,741.58	
		$20,062.00	$20,062.00

STREAM GAGING DEPARTMENT

Agriculture must always remain an important activity in every state. New Mexico, in an arid and semi-arid section of the United States, must depend very largely upon its surface and underground water for such development. With all such waters fully utilized there will still remain large areas of otherwise agricultural land in an arid condition. The state's agricultural development, then, must be largely measured by the amount of water which can be conserved and utilized, and by the degree of economy which can be exercised in its application.

The policy of the State Legislature of New Mexico, of making investigations into the possibility of storage of its flood waters and the developments of its underground water, is a farseeing one, and one which must necessarily precede the higher development that will later follow. These investigations will take time and are a preparation for, and an invitation to prospective investors of the country. The continuation of work on the special investigations and stream gaging by the State Engineer's Office of New Mexico is one of great importance because it means the state itself is keeping open the way to development.

Some of these investigations are quite general in character, and constitute a ground work for all future and more detailed study. Others are specific, having to do with the feasibility of certain specified projects. It is doubtless true that feasibility is a comparative condition, and depends largely on economic and agricultural conditions generally. Projects found infeasible today may be decidedly attractive ten or fifteen years hence. In this manner, an investigation, which does not find immediately feasible the project under consideration, may have a decided value in pointing out and recording it as one which will be feasible under certain changed economic conditions of the future.

Few people will doubt the value to individuals and to the state of knowing how much water flows in our streams. The amount of that flow is never the same in any two years. As it is always varying in amount and character of distribution, a record of discharge over a series of years is necessary, and the longer that record the more nearly are we able to use it with confidence and safety.

Stream gaging has been carried on in New Mexico, in some degree, almost continuously since about the year 1889. Especially in the latter part of that period its scope has been extended to include more stations and more detail, and the work has kept pace with the increasing demand for such data. The early irrigation projects, when there was obviously more water in the streams than was needed for those projects, were simply built with little or no thought as to how much water there was available. Projects of today demand an accurate record of the amount of water available for numerous reasons. Among these may be mentioned the fact that we are gradually approaching the limit of what our streams will do, and also it has been found that large sums have, in some cases, been expended on projects only to find later that there is not sufficient water available. Adequacy of water supply is one of the first points on which prospective capital must be satisfied, and on this point capital is becoming more and more exacting as the years go by. With these conditions in mind, it is a great satisfaction to know that the different legislatures of the State have recognized the work of this department sufficiently to provide funds for its continuation.

One of the important points in stream gaging work is to have the records in published form for distribution to the public and it has been customary to publish them in the form of water supply papers, either yearly or once in two years. In 1918 a summary report of all runoff records up to that time was published. There was such universal

and widespread demand for this publication that the edition has been entirely exhausted.

Instead of publishing a Water Supply Paper containing the records of discharge of streams of the State during this biennial period it has been deemed of more importance and greater value to the public to publish another summary report of all records, bringing them down to the end of 1925. Accordingly all these are being assembled and will appear as a separate volume.

Financial Statement

(Stream Gaging)

Balance December 1, 1924			$ 3,591.31
Appropriation for 13th fiscal year			8,750.00
Expenditures:			
Salaries	$3,369.50		
Subsistence	638.85		
Transportation	3,026.57		
Office Exp. & Printing	1,560.83		
Equipment	306.59		
Gage Equipment & Supplies	1,225.01		
Gage Observers	2,187.00		
Miscellaneous Expense	25.92	$12,340.27	
Balance June 30, 1925		1.04	
		$12,341.31	$12,341.31
Balance July 1, 1925			$ 1.04
Appropriation for 14th fiscal year			20,000.00
Expenditures:			
Salaries	$ 3,360.00		
Subsistence	781.75		
Transportation	2,372.49		
Gage Equipment & Supplies	901.76		
Gage Observers	2,735.00		
Supplies & Equipment	580.66		
Miscellaneous Expense	114.88	$10,845.54	
Balance June 30, 1926		9,154.50	
		$20,001.04	$20,001.04

CO-OPERATION ON SPECIAL INVESTIGATIONS

It has been the policy of the State Engineer's Office to solicit and to extend co-operation in all possible cases where it can be done under a strict interpretation of the law governing those cases. Not only has the position been taken that the department should be made to serve the greatest possible number of citizens of the State, but that its work, wherever possible, should be made to correlate with activities of State and Government institutions and departments.

In conformity to this policy the government departments have been invited to participate in the special investigations that have been provided for. As a result, there have been secured not only the expert services of men long trained in their particular lines of endeavor, but the different departments and agencies have actually contributed funds to the extent of many thousands of dollars. A list of the in-

vestigations which have been benefitted by these contributions, the department or agency making them, and the amount follows:

Investigations	Agency Co-operating	Amount
San Juan Inv.	Bureau of Reclamation	$ 7,426.33
Estancia Valley Inv.	U.S.G.S. & Bur. of Rec.	181.15
Estancia Valley Inv.	State College	750.00*
Estancia Valley Inv.	Continental Oil Co.	125.00*
Hope Community	U. S. Geol. Survey	1,022.28
Ft. Sumner-Carlsbad Inv.	Bureau of Reclamation	1,953.81
De Baca County Inv.	U. S. Geol. Survey	111.86
Socorro-Torrance Inv.	U. S. Geol. Survey	238.13
San Jose-Rio Puerco Inv.	U. S. Geol. Survey	4,120.97
Roswell Artesian Inv.	U. S. Geol. Survey	4,335.66
	TOTAL	$20,265.19

NOTE: *Estimated.

Th's means that the State of New Mexico has actually received more than twenty thousand dollars from outside agencies towards the investigations for which it has appropriated its own money. This opportunity is taken to here record the splendid spirit of co-operation which has been shown by these departments.

REPORT ON INVESTIGATIONS

OF THE

ROSWELL ARTESIAN BASIN
CHAVES AND EDDY COUNTIES
NEW MEXICO

DURING THE YEAR ENDING
JUNE 30, 1926

By

ALBERT G. FIEDLER

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

AUGUST, 1926

CONTENTS

ILLUSTRATIONS

INTRODUCTION

General Features

The Roswell area of artesian flow lies in Chaves and Eddy counties, New Mexico, and extends along the Pecos River from a point five miles north of Roswell about to the mouth of Seven Rivers. In 1925 this area contained about 17,000 inhabitants, of whom 9,000 lived in Roswell, the county seat of Chaves County and the second largest city in the State. The area is served by a line of the Atchison, Topeka & Santa Fe R. R., connecting with the main line of the Santa Fe system at Clovis, New Mexico, and the Texas & Pacific R. R. at Pecos, Texas.

The climate of the region is semi-arid, the rainfall being insufficient to grow crops without irrigation. The winter and spring months are normally dry. The months of greatest precipitation are generally July and August, and during these months most of the rainfall occurs in the form of afternoon and evening showers. The chief climatic data for the area are summarized in the following table.

TABLE I.

SUMMARY OF CLIMATIC DATA FOR ROSWELL ARTESIAN AREA, NEW MEXICO

(U. S. Weather Bureau)

		Precipitation		Temperature			Snowfall	
	Elevation above sea level	Length of record	Mean annual	Length of record	Mean annual	Avg. length growing season	Length of record	Mean annual
	Feet	Years	Inches	Years	Deg. F.	Days	Yrs.	Ins.
Roswell	3,578	26	14.09	27	58.6	201	27	12.2
Artesia	3,350	15	12.58	13	61.1	203	13	8.5
Carlsbad	3,120	25	14.07	24	62.7	210	24	6.3

The rocks of the district consist mostly of limestone, but also include sandstone, shale, and gypsum, and surficial deposits of sand, gravel, clay, and silt. The high slopes west of the valley are underlain chiefly by limestone beds that dip generally toward the east or southeast beneath the valley fill. The high region to the west is the catchment area which supplies the water to the limestone beds. At lower levels where these limestone beds are tapped by deep wells they furnish water under artesian pressure.

The soil of the artesian area is chiefly loam and clay loam, and when properly watered it is very productive. The early irrigation development was mostly in the vicinity of Roswell, the water being supplied by ditches from Berrendo Creek, North Spring River, and

South Spring River. The irrigation of farm lands with artesian water was started about 1902 and has developed to such an extent that in 1925 about 45,000 acres in Chaves and Eddy counties were irrigated directly from artesian wells. At first extensive tracts were planted to apple orchards and alfalfa. Cotton was first grown in this area in 1920 but in the last few years it has become the leading crop.

According to figures compiled by the Roswell Chamber of Commerce, the value of all crops grown in Chaves County in 1925, including the relatively same amounts grown outside of the artesian area, was as follows:

Cotton	$1,487,430
Alfalfa	778,550
Apples	260,000
Miscellaneous	192,309
Total	$2,718,289

According to incomplete figures furnished by the Artesia Alfalfa Growers Association the value of the crops grown in the artesian area of Eddy County is about as follows:

Cotton	$ 575,000
Alfalfa	330,000
Apples	62,000
Miscellaneous	58,000
Total	$1,025,000

DEVELOPMENT OF ARTESIAN WATER SUPPLY

The first flowing artesian well in this area was drilled in the town of Roswell in the spring of 1891 and flowed only about 1 gallon per minute. By 1900 the number of wells had gradually increased to 83, all but one of which were in Chaves County. Most of the early wells were drilled in the vicinity of Roswell and were used chiefly for domestic supplies and for watering gardens and lawns. However, the streams that cross the area furnished only enough water for the irrigation of a small part of the arable land, and hence beginning about 1902 in Chaves County and about 1904 in Eddy County, wells were drilled to obtain irrigation supplies.

Many of the early wells drilled for irrigation discharged between 500 and 1,000 gallons per minute, and a few were reported to discharge as much as 1,500 gallons per minute. The large yield of these wells naturally created much interest in this region. As no decline in discharge was at first noticed the supply was considered inexhaustible and considerable speculation in farm lands resulted.

Although 364 artesian wells were drilled in Chaves and Eddy counties up to the end of 1905 no appreciable decline in discharge had been noted up to that time except in the Artesia segment of the area. The failure of the early wells during this period was doubtless due, in part at least, to faulty construction.

The first wells drilled for irrigation were mostly either 4 or 6 inches in diameter. Most of the wells drilled from 1905 to 1920 were 8 inches in diameter, and it has only been since 1920 that 10-inch wells have been drilled to the artesian horizons. Of 61 wells drilled since 1920, 49 are 10 inches in diameter. Three wells 12½ inches in diameter have been drilled since 1923. Plate 3 shows the total number of wells drilled according to years and also the number drilled in each county.

The following table shows the number of wells drilled according to periods in the entire basin and in each county.

TABLE 2

NUMBER OF WELLS DRILLED IN THE ROSWELL ARTESIAN BASIN DURING SUCCESSIVE 5-YEAR PERIODS FROM 1900 TO 1925.

	Prior to 1900	1901-1905	1906-1910	1911-1915	1916-1920	1921-1925	Total
Chaves	107	160	330	163	8	41	809
Eddy	1	96	253	47	6	20	423
Entire Basin	108	256	583	210	14	61	1,232

Table 3 shows the per cent of total wells drilled according to periods for the entire basin and by counties.

TABLE 3.

PROPORTION OF WELLS DRILLED IN THE ROSWELL ARTESIAN BASIN DURING SUCCESSIVE 5-YEAR PERIODS FROM 1900 TO 1925, EXPRESSED IN PERCENTAGE OF THE TOTAL NUMBER OF WELLS DRILLED.

	Prior to 1900 Percent	1901-1905 Percent	1906-1910 Percent	1911-1915 Percent	1916-1920 Percent	1921-1925 Percent	Percent of total in basin Percent
Chaves County	13.2	19.8	40.8	20.1	1.0	5.1	65.7
Eddy County	.2	22.7	59.8	11.1	1.4	4.8	34.3
Entire Basin	8.8	20.8	47.3	17.0	1.1	5.0	100.0

During the five year period 1906 to 1910, 583 artesian wells, or 47.3 per cent of the total, were drilled; and during the ten-year period 1905 to 1914, 915 wells, or 74 per cent of the total, were drilled. This activity in drilling had its most noticeable effect on the west side of the artesian area, where an irrigated belt had been developed by pumping water from non-flowing artesian wells. Pumping was also done to increase the yield of flowing wells that discharged only small quantities of water by natural flow because of their small heads. As the head declined in the pumped wells at about the same rate as the flowing wells, with the rapid increase in drilling during the period 1905 to 1914 many pumping plant installations were abandoned and still other farms were forced to install expensive pumping equipment because the decline in head either caused the yield of the flowing wells to decline or stopped the flow altogether.

HISTORY AND SCOPE OF INVESTIGATION

In 1905 the Legislative Assembly of the Territory of New Mexico, realizing the need for regulations to protect the artesian water-supply, passed the first law (1) to regulate the use of the artesian water in this area. The law created the office of well supervisor, whose duty it was to keep a record of the wells drilled and to make

(1). 36th Legislative Assembly, Terr. of N. Mex., C. B. No. 20, approved Feb. 22, 1905.

measurements of the pressure and flow of the wells. In addition the supervisor was empowered to file complaints for waste of water and to see that the requirements for drilling were observed. In 1909 the Legislative Assembly repealed the law of 1905 and passed a new law (2) containing similar regulations and also prescribing the weights of casing to be used in the construction of the artesian wells. The law of 1909 was repealed in 1912 and another law (3) was enacted, which in turn was repealed by the 7th Session, New Mexico State Legislature in 1925. The 1925 session of the Legislature passed the Artesian Well Law of 1925, (4) which is still in force. The intent of all these laws was to conserve the artesian water by regulating its use. New regulations were contained in each succeeding law as the changing conditions made new restriction necessary.

An investigation of this area was made in 1904 and 1905 by C. A. Fisher of the United States Geological Survey, and upon the basis of this work a preliminary report (5) was published in 1906. The importance of a complete investigation of this area was realized by the Geological Survey as early as 1915. In 1916, O. E. Meinzer made a reconnaissance of the area and developed plans for a thorough investigation, but because of the demands of the World War and other urgent work, the investigation was not undertaken.

During 1924 and 1925 a number of prominent local citizens, through the Roswell Chamber of Commerce, took active steps to obtain an investigation of this area, and in the 7th Session of the State Legislature succeeded in obtaining the passage of a bill (6) providing an appropriation of $5,000 and instructing the State Engineer to enter into an agreement with the United States Geological Survey to investigate the artesian water supply of the area. Such a co-operative agreement was made in 1925, and resulted in the Geological Survey also providing $5,000 out of its appropriation for ground water investigations. The writer was assigned to the investigation. He started field work July 6, 1925, with headquarters at Roswell, and has spent the entire time since that date in the area studying the hydrologic problems involved. The work was done under the direction of O. E. Meinzer, geologist in charge of the division of ground water, who spent some time in the area in July and August, 1925, and again in August, 1926. Mr. Meinzer collaborated on the preparations of the section on conclusions and recommendations (pages 55 to 60).

The present preliminary report is based on work done during the period July 6, 1925 to June 1, 1926. The geologic features of the artesian basin had not at the time of writing been investigated in detail and are not discussed. During the fiscal year beginning July 1, 1926, the hydrologic investigation is to be continued by the writer and an investigation of the geology in so far as it relates to the artesian water conditions is to be made by B. Coleman Renick, geologist in the United States Geological Survey.

(2). 38th Legislative Assembly, Terr. of New Mex., H.S.H.B. No. 89, approved March 17, 1909.

(3). First Session, New Mexico State Legislature, Chap. 81, approved June 13, 1912.

(4). Seventh Session, New Mexico State Legislature, H. B. No. 97, 1925.

(5). Fisher, C. A., Preliminary report on the geology and underground waters of the Roswell Artesian Area, New Mexico: U. S. Geol. Survey Water-Supply Paper 158, 1906.

(6). Seventh Session, New Mexico State Legislature, H. B. No. 202, 1925.

ACKNOWLEDGEMENTS

The Roswell Chamber of Commerce furnished data on crop acreage and production and greatly assisted in obtaining the co-operation of the residents of the area. Especial acknowledgements are due to Dr. Austin D. Crile, President, and to Mr. Claude Simpson, Secretary, for their hearty co-operation. Through the co-operation of the County Commissioners of Chaves and Eddy counties the assistance of the county well supervisors was made available. The well supervisors furnished the results of inspections of wells, assisted in making leakage tests, and co-operated to the fullest extent in other respects. W. A. Wilson, county engineer of Chaves County, furnished much helpful information and supplied a number of maps. M. H. Hunter, consulting engineer in Roswell afforded free access to files and maps compiled by his office. L. E. Foster and J. R. Yates, of the United States Bureau of Reclamation, furnished records of stream flow and of the quantities of water used in irrigating different crops. Cleve Hallenbeck, meteorologist in charge of the Roswell office of the United States Weather Bureau, made daily measurements of the level of water in his well on the Berrendo tract, and supplied valuable climatological records. A number of petroleum geologists and water well drillers furnished helpful information, and throughout the area the work was advanced by the assistance of the residents.

HEAD OF ARTESIAN WATER

DEFINITIONS (1)

If a well is drilled anywhere in the area under consideration it will at no great depth encounter the water table, or upper surface of ground water. If, however, the well is sunk to greater depths it will eventually pass through a tight confining bed and into permeable strata that contain water under pressure. If the well is tightly cased the water from the deep strata will be raised in it by the artesian pressure to a level above that of the water table outside of the well. Such a well is called an artesian well. If the pressure is sufficient to lift the water to the surface and to cause the water to overflow the well is calld an artesian flowing well. The area in which the artesian pressure is sufficient to produce flowing wells may be called the area of artesian flow. The entire geologic structural feature in which the water is confined under artesian pressure may be called an artesian basin. The strata that contain the artesian water may together be called the artesian reservoir.

The level to which the water will rise in any tightly cased well is called the hydrostatic level, or merely the static level. If a flowing well is tightly cased and capped the artesian water will exert a pressure at the top of the well. This pressure can be measured by means

(1). Meinzer, O. E., Outline of ground-water hydrology with definitions, U. S. Geol. Survey Water-Supply Paper 494, pp. 37-40, 66, 67, 1923.

of a pressure gage, and is generally expressed in pounds per square inch. If the casing of a flowing well is extended far enough upward the water will rise in the casing to some level above the surface, determined by the artesian pressure, and will then come to rest. The pressure head, or height that the water will rise above the surface can be approximately computed in feet by multiplying the artesian pressure at the surface in pounds per square inch by 2.3.

Natural leakage from the water hor:zons and withdrawal of water from artesian wells, together with certain other factors (such as the friction of the rock channels through which the water percolates) tends to lower the artesian pressure, and it has been found that the height to which the artesian water will rise above sea level declines more or less uniformly from the intake area to the point of escape. Th's decline is known as the hydraulic gradient.

ORIGINAL HEAD

In 1904 Fisher (2) measured the pressure on a number of flowing wells in Roswell, and determined that the head was sufficient to raise the water to an elevation of 3586 feet above sea level, which near the center of Roswell would be about 15 feet above the ground level. In the present investigation Fisher's determination of the head was checked by running levels to the wells on which he had obta:ned pressures. It was not feasible in all wells to determine the exact point of reference used by Fisher, but, assuming the maximum possible error due to this cause, there are no records available that indicate that the water ever rose higher than 3590 feet above sea level. At the time that Fisher made h's observations, the water level at the head of North Spring Creek, west of Roswell, was also about 3586 feet. With the development of the artesian basin the flow of the North Springs, South Springs and Berrendo Springs declined rapidly, suggesting that these springs formed outlets which acted effectually as controlling valves for the artesian water and prevented the building up of an artesian head in the Roswell district above their own level.

HEAD IN 1925

In 1925 the artesian head varied greatly according to the location. In observation wells near the western boundary of the area of artesian flow a minimum water level of 3,563 feet above sea level was reached in the part of the area north of Roswell and a min'mum of 3,379 feet in the part south of Artesia. When the artesian basin was first tapped the water doubtless rose nearly to the same elevation in tightly cased wells regardless of the location of the wells. With the development of the basin, however, a much steeper hydraulic gradient has been created, and in 1925 the water did not rise nearly as h'gh on the eastern as on the western side of the area.

(2). Fisher, C. A. op. cit. pp. 9 and 20.

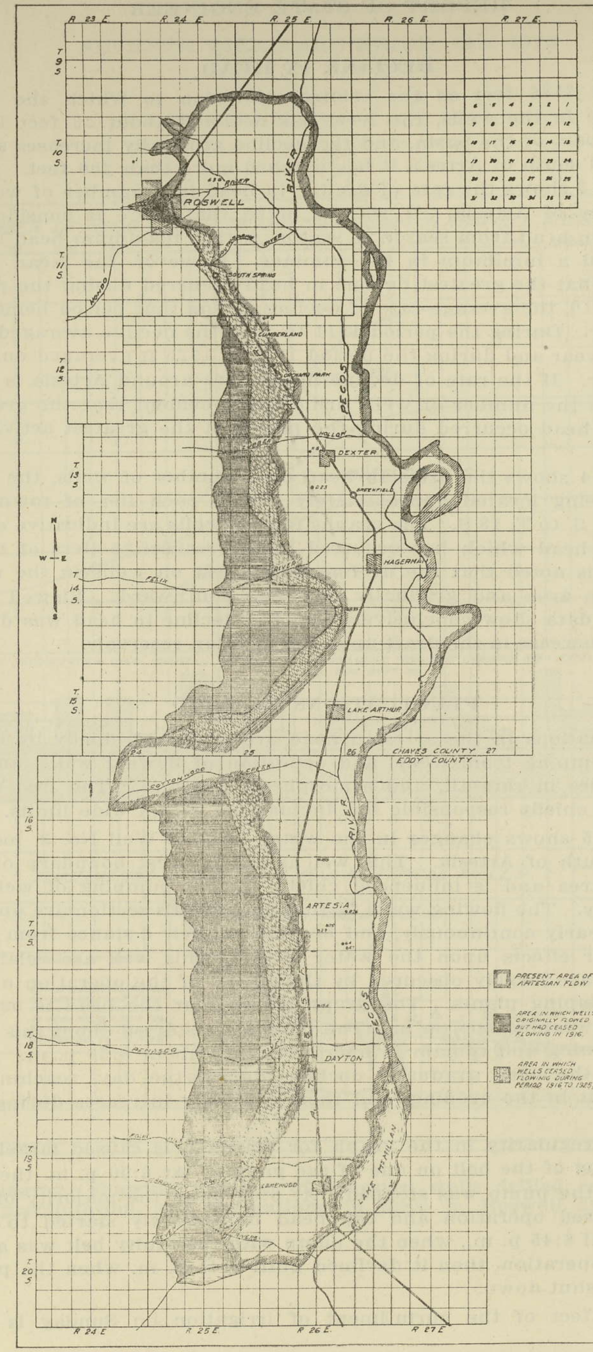


Plate 2.—Map of Roswell Artesian Area showing original area of artesian flow and areas of flow in 1916 and 1925.

DECLINE IN HEAD

Using 3586 feet as the original elevation to which the water would rise in the wells, the level has declined about 25 feet in the northern part of the basin, and the decline gradually increases southward until south of Artesia it has reached more than 200 feet.

Plate 3 shows the rate of decline in head in a number of wells in the vicinity of Artesia. It will be noted that there is considerable variation in head from season to season, with a maximum head in the winter and a minimum in the summer. However, the mean curve indicates that the greatest decline in head occurred during the period 1904 to 1910, the average rate of decline during that period being 20.5 feet a year. During the period 1911 to 1915 the decline averaged only 3.2 feet a year and during the period 1916 to 1925 it averaged only 1.5 feet a year. If the rate of decline in the area around Artesia is compared with the number of wells drilled, it is evident that the greatest decline in head occurred during the period of the greatest activity in drilling.

Plate 4 shows the artesian head on a number of wells, the wells selected being located approximately one in each tier of townships from T. 10 S. to T. 18 S. The graphs for the wells are indicative of the decline in head which has occurred in the respective tiers of townships. It is noted that the decline is smallest on wells in the north end of the area and gradually increases southward. Viewed as a whole the data show conclusively that the decline in head was due to the large increase in the draft upon the artesian reservoir.

FLUCTUATIONS IN HEAD

Fluctuations in the artesian head are produced chiefly by intermittent pumping from wells, and operation of flowing wells, and by irregularities in rainfall, and atmospheric pressure. The first three causes are chiefly responsible for fluctuations within wide limits.

Plate 5 shows changes in the water level in Well No. 3, located 3 miles south of Artesia. This well is on the west boundary of the irrigated area and is influenced chiefly by the pumping of wells in this vicinity. The flowing wells farther east in this section are operated more nearly continuously, and because of their distance from Well No. 3 their effects upon the water level in this well are relatively small and are largely obscured by the effects of the operation of the nearby pumping plants. The graph shows that the head is usually highest between 5 and 7 a. m. The pumps are started about this time in the morning and remain in operation until about 6:30 p. m. Consequently, the head gradually declines during the day, reaching its lowest point in the evening, and then gradually increases during the night.

The irregularity in the graph for March 9 is caused largely by the breaking of the belt on one of the pumps. At 6:00 p. m. the belt broke and the pump was stopped. At 8:00 p. m. the majority of the pumps ceased operation and the head immediately started to rise. It rose until 8:45 p. m., when the pump with the faulty belt was again placed in operation, then it declined until 9:45 p. m. when the pump was again shut down.

The effect of the curtailment of irrigation on Sunday is well

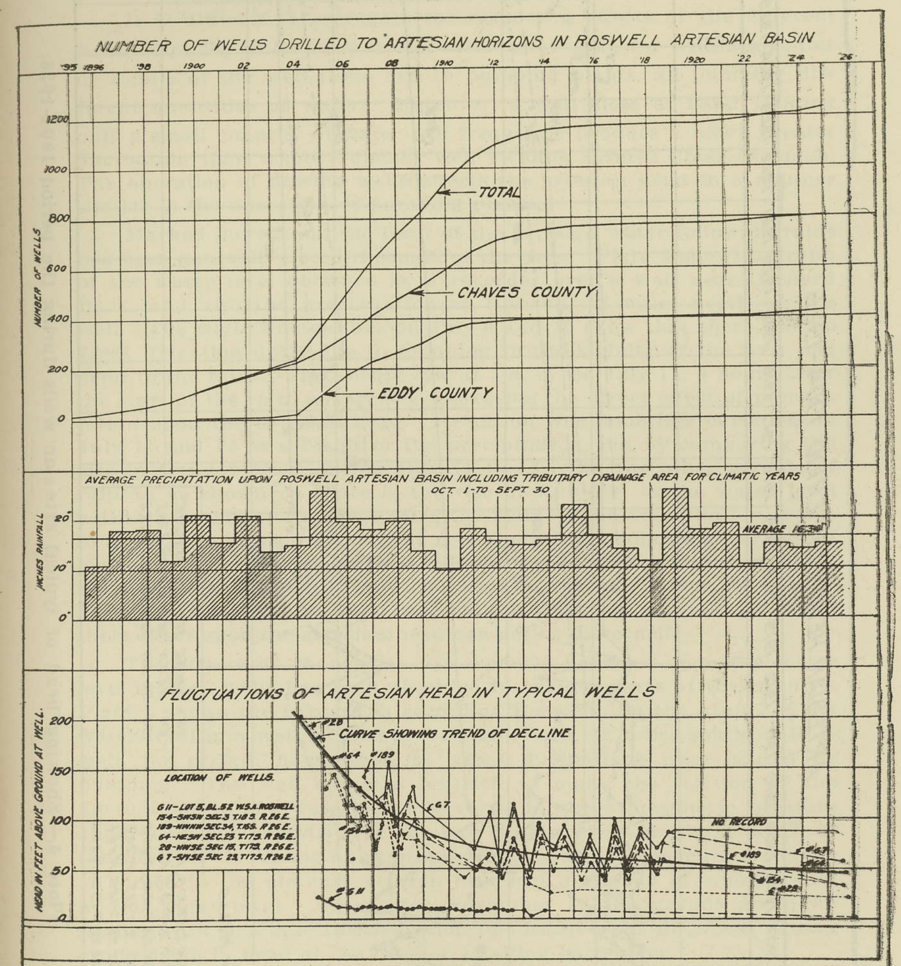


Plate 3.—Diagram showing number of artesian wells drilled each year, average annual precipitation, and fluctuations in head in Roswell artesian basin.

PLATE 4.

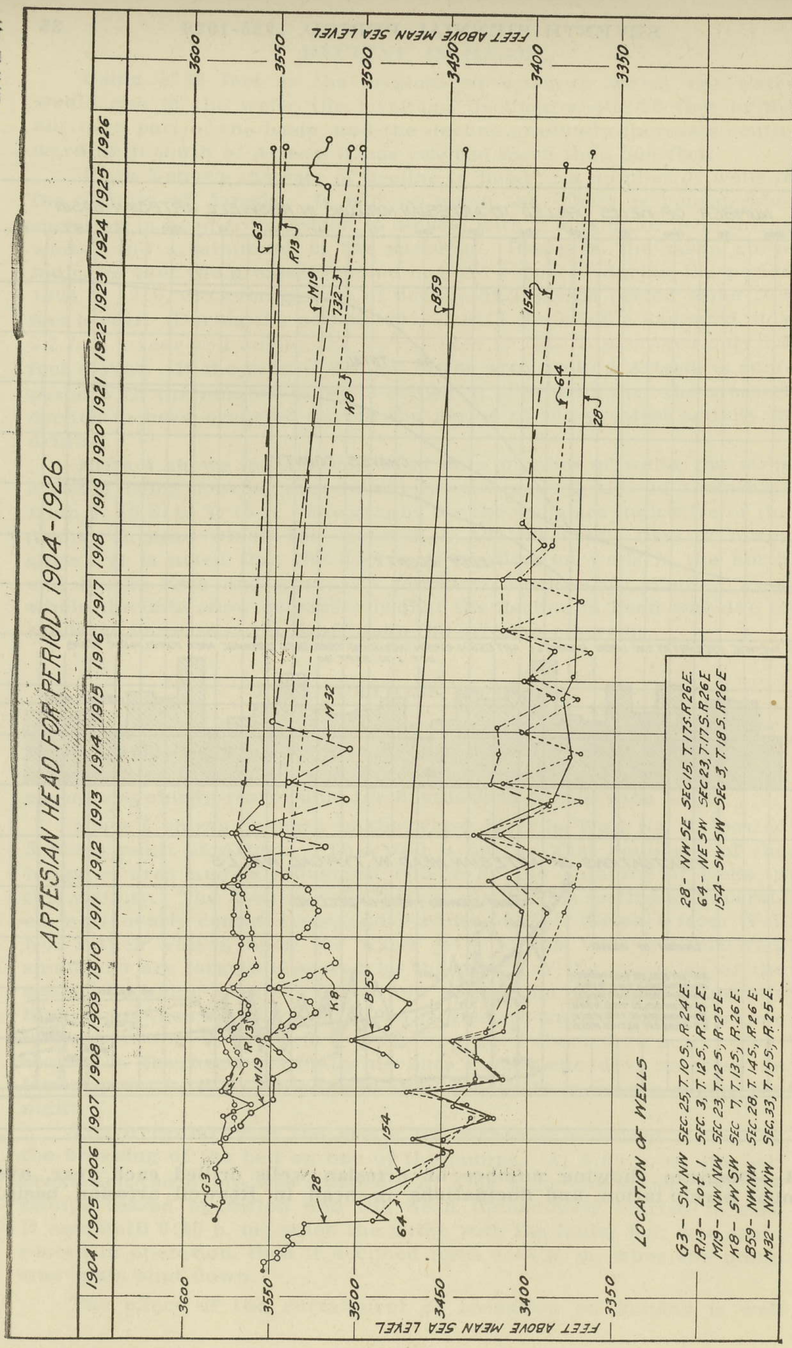


Plate 4.—Showing head of typical artesian wells during the period 1904-1926.

shown in the graph for March 7 and 14. Practically no pumping was done on March 7 while on March 14 only about a quarter of the pumps were operated.

It is difficult to segregate the respective effects of the different wells upon the water level in the observation well, for within a radius of 1 mile of the well there are 10 pumping plants, all pumping different quantities of water. Moreover, a well close at hand yielding only a small quantity of water will frequently produce a much greater fluctuation than a more distant well yielding several times as much. The operation of flowing wells affects the artesian head in a manner similar to the operation of pumping plants.

Marked increase in the head of the artesian water following rains has been generally noted throughout the area. Plate 6 shows a graph of the water level obtained by a recorder over a well near Orchard Park, and also the precipitation at Roswell, 12 miles north of this well. The slight fluctuations on July 9 and 10 show that there was no great irrigation draft due to pumping in the vicinity of the well just prior to the rains. The abrupt rise at 3 a. m. on July 11, 4 hours after the start of the rain, apparently represents the direct effect of precipitation upon the artesian head. Irrigation was doubtless curtailed on July 11 and 12 as a result of the precipitation, but by comparing the rise in artesian head during July 11 to 13, with the other periods of rainfall as shown on Plate 8, the rise of 5.90 feet in the water level within a period of 69 hours after the start of the precipitation seems to show that a large amount of recharge occurs following periods of heavy rainfall. The water that falls during light rains largely evaporates or is lost through the transpiration of plants. Hence the contributions of the light rains to the artesian reservoir are negligible and their effect upon the artesian head can not be discerned.

The effects of changes in atmospheric pressure upon the water level in deep wells has been observed in various parts of the country. Plate 7 shows the barograph record at Roswell and the graph of the water level in a well located at Orchard Park, 12 miles south of Roswell, for certain days when no great fluctuations were caused by pumping. The well curve is inverted to make the relation of the fluctuations in the water level to those in the atmospheric pressure apparent. The similarity of the two graphs gives ample evidence of the effect of the changing atmospheric pressure. In general a change of 1 inch in the mercury column produces a change of about 1 foot in the water level. Except for November 23 the graphs are quite similar. On this date the operation of distant wells doubtless caused gradual fall in head at the time of a falling barometer.

Since the initial period of decline in head there have been changes in head from season to season, as is shown by the observations made by the County well supervisors during many years. To obtain reliable records of these changes Au drum-type water-stage recorders were installed on two wells, one located near Orchard Park and the other 3 miles south of Artesia. In addition, daily observations were made on a well located in the Berrendo tract, north of Roswell. Plate 8 shows the graphs for these wells. The mean daily levels for wells Nos. 2 and 3 were determined by inspection of the recorder graphs, or,

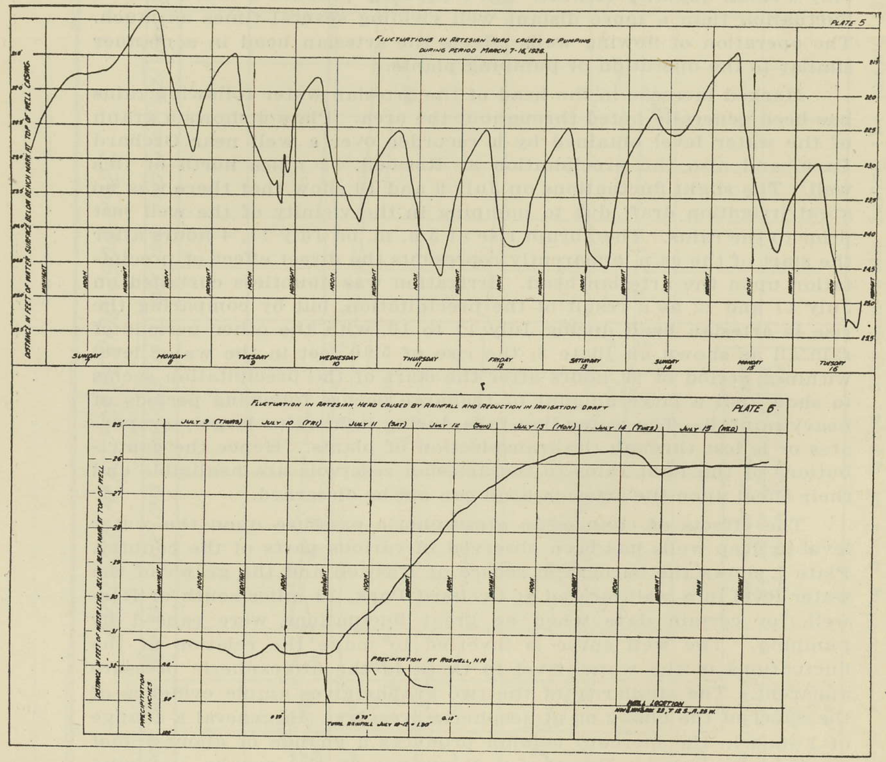


Plate 5.—(Upper) Graph showing fluctuations in artesian head caused by pumping.
Plate 6.—(Lower) Graph showing fluctuations in artesian head caused by rainfall and consequent reduction in irrigation draft.

for days of wide fluctuation, by averaging the level for hourly or other regular periods.

It has been impossible to obtain a reliable record of irrigation draft during the period. Some of the flowing wells are open continuously, and others only at times of irrigation, while pumping plants are operated according to the needs of irrigation. The operation of a well affects the water level of nearby wells that obtain their water from the same horizon.

Records were obtained on wells Nos. 1 and 3 (Plate 8) before rains of any consequence had occurred in this region. The records of the Weather Bureau at Roswell showed that no measurable quantity of rain had fallen during a period of 98 days prior to May 5, 1925, and only a total of 0.78 inch in scattered showers from May 5 to July 21. Because of the deficient precipitation and heavy drafts for irrigation upon the artesian reservoir the water level in wells Nos. 1 and 3 was undoubtedly at the lowest points of the year and probably at the lowest point that had even been reached in the history of the area. Observations on Well No. 2 were not started until July 23 and because of the rain of July 21 and 22 the initial observation did not represent the lowest stage in this well.

With the copious rains of late July and early August the irrigated demand was greatly curtailed and a rise in the water level of 7.4 feet occurred in well No. 2 during the period July 23 to August 13. A similar rise doubtless occurred in well No. 3 though records are not available. The level of the water in well No. 1 rose 2.2 feet during the same period. This fluctuation is typical of the result caused by rainfall and the consequent curtailment of the irrigation demand. The rapid rise in head is due both to the reduction in the use of water and to recharge of the artesian reservoir. The rise due to curtailment of irrigation is strikingly shown in the graph of well No. 3 during the period January 25 to March 10, during which time no rainfall of consequence occurred and the water level was generally higher on Sundays than on other days of the week. The usual rise on Sundays has been generally observed and accounts for the flowing of many wells on Sunday which do not flow during the remainder of the week. The belt of Sunday flowing wells is constantly shifting with the seasonal changes in the artesian head. During the winter when the artesian head is at its highest this condition is noted in the wells on the western edge of the area of artesian flow. As the head is lowered with the increased draft upon the reservoir these wells cease to flow and wells farther eastward exhibit this same characteristic until the further decline in head has brought the border line of non-flowing wells still further eastward.

The fall in the water level or artesian head during the latter part of August was caused by the increase in draft upon the basin. During September the continuation of beneficial rains and the harvesting of crops in the northern part of the basin reduced irrigation, and hence, the head gradually increased in wells Nos. 1 and 2. In the Artesia segment of the area, however, there was little or no rain during this period and consequently there was no marked increase in head in well No. 3. During October irrigation generally ceased and the artesian head rose notably in all of the wells. The maximum head was

reached in well No. 1 on December 13-15, in well No. 2 on November 9, and in well No. 3 on November 26.

From the lowest point recorded in July, 1925, to the high point in the winter the range in stage was 6.17 feet in well No. 1, 13.36 feet in well No. 2 and 19.52 feet in well No. 3. The differences in the seasonal range in the different parts of the area are similar to the rates at which the decline in head has progressed. In the northern part of the area the head has declined the least and the seasonal range in head is also relatively small, whereas farther south the decline in head has been much greater and the seasonal range in head reaches a maximum.

Irrigation is normally started in January, especially for alfalfa and on ground that is to be plowed. Its effect is shown by the gradual decline in head during January in well No. 2 and the marked decline in well No. 3. The head in well No. 1, located on the Berrendo tract, was well sustained at high levels until the latter part of February. This in a large measure is due to the fact that most of the pumps in this area are operated by electric motors and because of a minimum monthly charge based on installed horsepower, there is considerable incentive to delay placing the pumps on the line until such time as pumping for extended periods is required. Marked fluctuations in head occur due to periods of rain in April, May and June, a peak head usually occurring several days after the rain.

In well No. 1, the head was well maintained and the lowest level reached during the 1926 season up to the end of July was about 1 foot higher than the low level reached in July, 1925. The initial observation made in well No. 2 was undoubtedly 3 or 4 feet above the lowest level reached in 1925 but even making due allowance for the rise caused by the first rains in July, 1925, the head on this well reached a level about 2 feet lower in July, 1926. The low level in July, 1926, on well No. 3 is about 2 feet lower than the low level of July, 1925. This decline in head occurred in spite of beneficial rains which were well distributed throughout the spring irrigation season for holding the irrigation draft at a minimum. This lowering of the head in well No. 2 was largely caused by the increased draft of six 10-inch wells and one 12½-inch well which were drilled in this part of the basin since January 1, 1926. The average flow during the spring months of these new wells amounted to 15,750 gallons per minute, or 35 second-feet. The decline in well No. 3 is likewise probably caused by additional draft in the Artesian segment of the area.

The two largest wells completed in the Roswell artesian basin were the 10-inch well of H. D. King, in the SW¼ Sec. 14, T. 11 S., R. 25 E., and the 12½-inch well of the Oasis Cotton Co., in the NW¼ Sec. 22, T. 11 S., R. 25 E. The former flowed 3,190 gallons per minute, or 7.1 second-feet, and the latter 5,700 gallons per minute, or 12.7 second-feet, when measured on April 21, 1926.

The greatest danger confronting the farmers of the artesian area at present is that of further lowering of the head by drilling of large wells on low land to bring new tracts under irrigation. The most urgent immediate need, therefore, is for legislation that will prevent further irrigation developments with artesian water except as it may

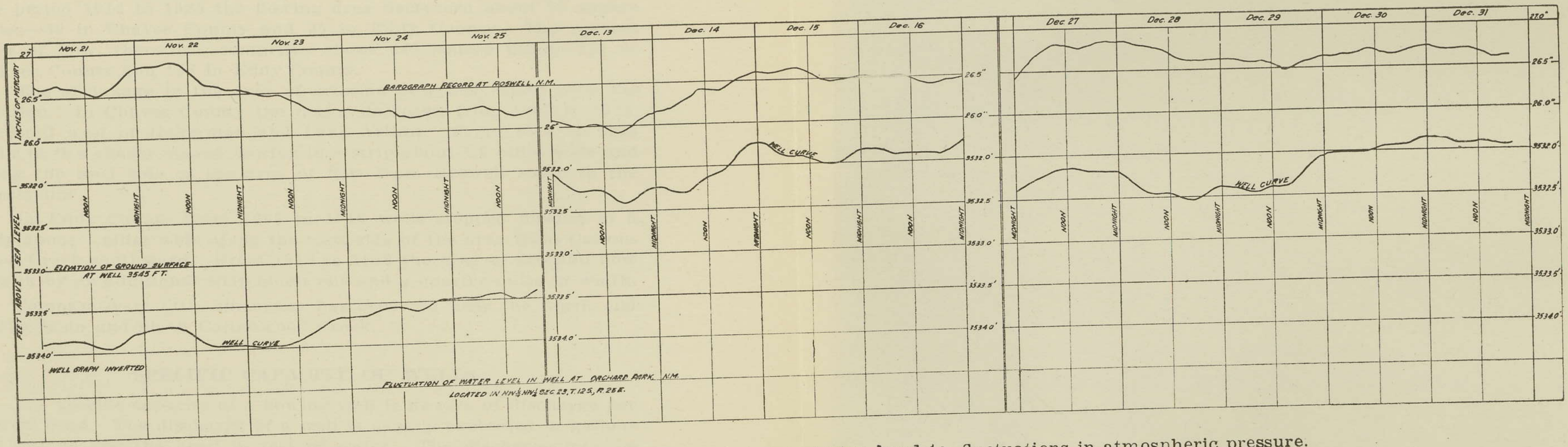


Plate 7.—Graphs showing relation of fluctuations in artesian head to fluctuations in atmospheric pressure.

be conclusively proved that such developments will not injure the water rights of the present irrigator by lowering the artesian head.

AREA OF ARTESIAN FLOW

With the decline in head the size of the area of artesian flow has decreased. The original area in which flowing wells could be obtained comprised about 670 square miles (Plate 2). Fisher (1) estimated the area at 650 square miles, but since his report was published the area was found to extend slightly farther west along Cottonwood and slightly farther north in the Berrendo tract than is shown on his map. By 1916 the area of flow had decreased about 165 square miles—62 in Chaves County and 103 in Eddy County. During the period 1916 to 1925 the flowing area decreased about 75 square miles—40 in Chaves County and 35 in Eddy County. The present area of flow, therefore, comprises about 430 square miles—272 in Chaves County and 158 in Eddy County.

The shrinkage in the area of artesian flow has varied with the location. In Chaves County the major decrease, from 1905 to 1916, occurred west of Hagerman and Lake Arthur. From 1916 to 1925 wells in this county ceased flowing in a strip about 1.5 miles wide and along the west side of the area of flow from Roswell south to the county line.

In Eddy County from 1905 to 1916 wells stopped flowing in a strip about 4 miles wide along the west side of the area from Cottonwood Creek southward. From 1916 to 1925 the area of artesian flow shrank by an additional strip about one and a quarter miles in width.

Comparatively little shrinkage has occurred near the north end of the basin and along Cottonwood Creek.

SPECIFIC CAPACITY OF WELLS

The specific capacity of a flowing well is its rate of discharge per unit of head. The discharge of a well is usually expressed in gallons per minute and the head in feet of water. The discharge may be measured with a weir or a current meter and the head with a pressure gage when the well is not flowing. Each pound of pressure per square inch produces a head of 2.3 feet. The specific capacity of an artesian well is important because, as is shown by Plate 9, the discharge of the well varies practically as the head. Thus the flowing wells deliver much smaller quantities of water in summer than in winter because during the summer the head is greatly reduced by the draft upon the artesian reservoir.

Plate 9 shows the specific capacity of four wells. The observations were made by the County well supervisors over a period of years, and hence gave a considerable range in head and discharge for each well. As is to be expected, the individual observations deviate somewhat from the mean for each well, which doubtless is due chiefly to inaccuracies in determining the discharge. The two 6-inch wells yielded an average of 9 gallons per minute for each foot of head and the two 8-inch wells an average of 20 gallons per minute for each foot of head. Single observations on two 10-inch wells drilled in

(1). Fisher, C. A., op. cit., p. 9.

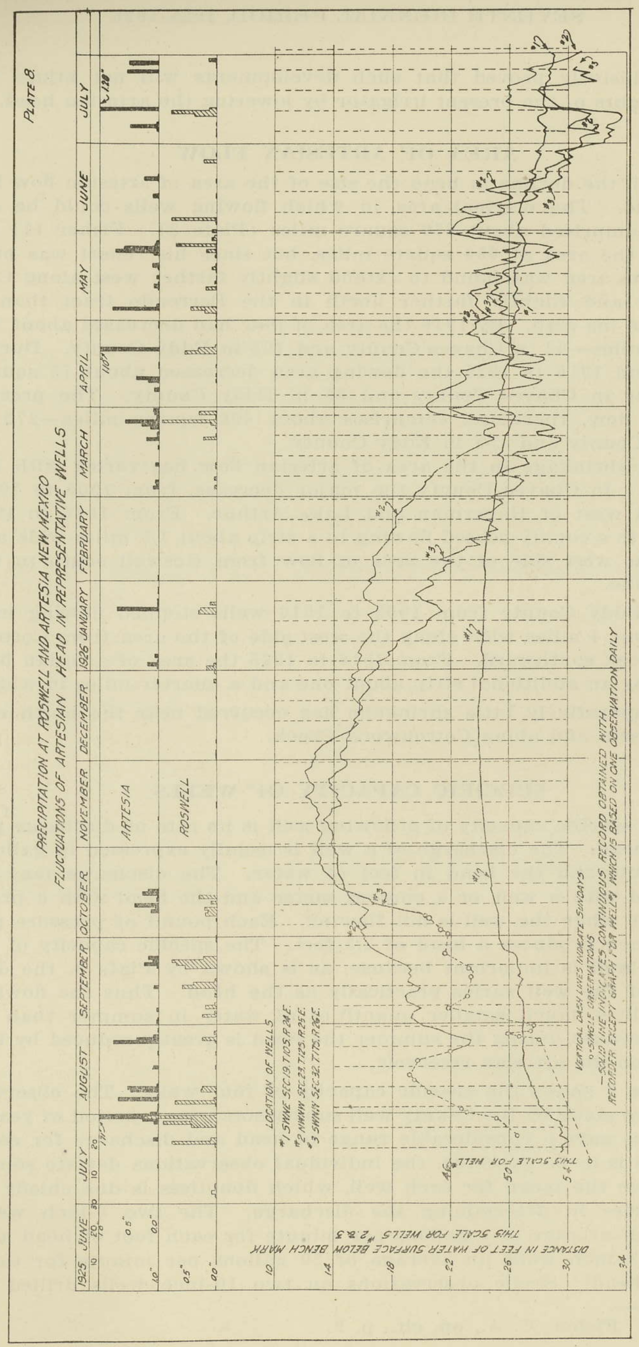


Plate 8.—Graph showing artesian pressure in typical wells from July 1925 to July, 1926, and diagrams showing daily precipitation at Roswell and Artesia during same period.

1926 gave a discharge of 53 gallons per minute for each foot of head from one well and 57 gallons from the other. A single observation on a new 12½-inch well gave a specific capacity of 89 gallons per minute.

The close agreement in the specific capacities of the wells of the same diameter indicates that the wells were in like condition and tapped water-bearing formations about equally permeable. There are, however, great differences in the specific capacities of the wells in different parts of the area. These differences may be due to obstruction of the casing by corrosion and cementation or the growth of algae, or to the clogging of the interstices of the water-bearing rock near the wells, or to original differences in the permeability of the water-bearing rock. For this reason it must not be assumed that wells of the same diameter and head necessarily yield the same quantity of water.

QUANTITY OF WATER DISCHARGED BY ARTESIAN WELLS

Aggregate Capacity of Artesian Wells.

As shown in Plate 10, the number of wells used for irrigation in the Roswell artesian basin, including both flowing wells and pumped artesian wells, amounted to about 29 in 1900, about 226 in 1905, about 735 in 1910, about 839 in 1915, and about 593 in 1925. The estimates for 1900, 1905, 1910 and 1915 are based on a study of the records of the county well supervisors; the estimate for 1925 on a survey made in connection with the present investigation. No estimate could be made for 1920 because very few records were obtained by the well supervisors between 1916 and 1925. It will be noted that whereas Plate 3 shows the total number of artesian wells drilled up to the end of each successive year, Plate 10 shows only the number of wells in use for irrigation in each year and does not include the wells that had been abandoned because of the drop in head or for other reasons.

Plate 10 also shows the aggregate and average capacities of the irrigation wells in successive years, based on a study of the records of the county well supervisors and on the survey made in 1925. For each of the years 1900, 1905, 1910, 1915 and 1925 an estimate was made of the capacity, or yield, of each well that was in use in that year. These estimates were partly obtained from the records of discharge and partly computed from the more accurate records of head and data or assumptions as to the specific capacity. The estimate for each well is an average of the estimated yield in the summer, when the head was low, and that in the winter when it was relatively high. The records for intervening years were also used to some extent. Thus, in making the study for 1910 the records for 1908, 1909, 1911 and 1912 were used for many wells that did not have any satisfactory records for 1910. The results for 1925 are, of course, much more accurate than those for the preceding years.

According to this study, the aggregate capacity of all the flowing and pumped wells used for irrigation amounted to about 21 second-feet in 1900, 293 second-feet in 1905, 837 second-feet in 1910, 870 second-feet in 1915, and 634 second-feet in 1925. The peak capacity doubtless was reached before 1915, probably in 1913, when the marked

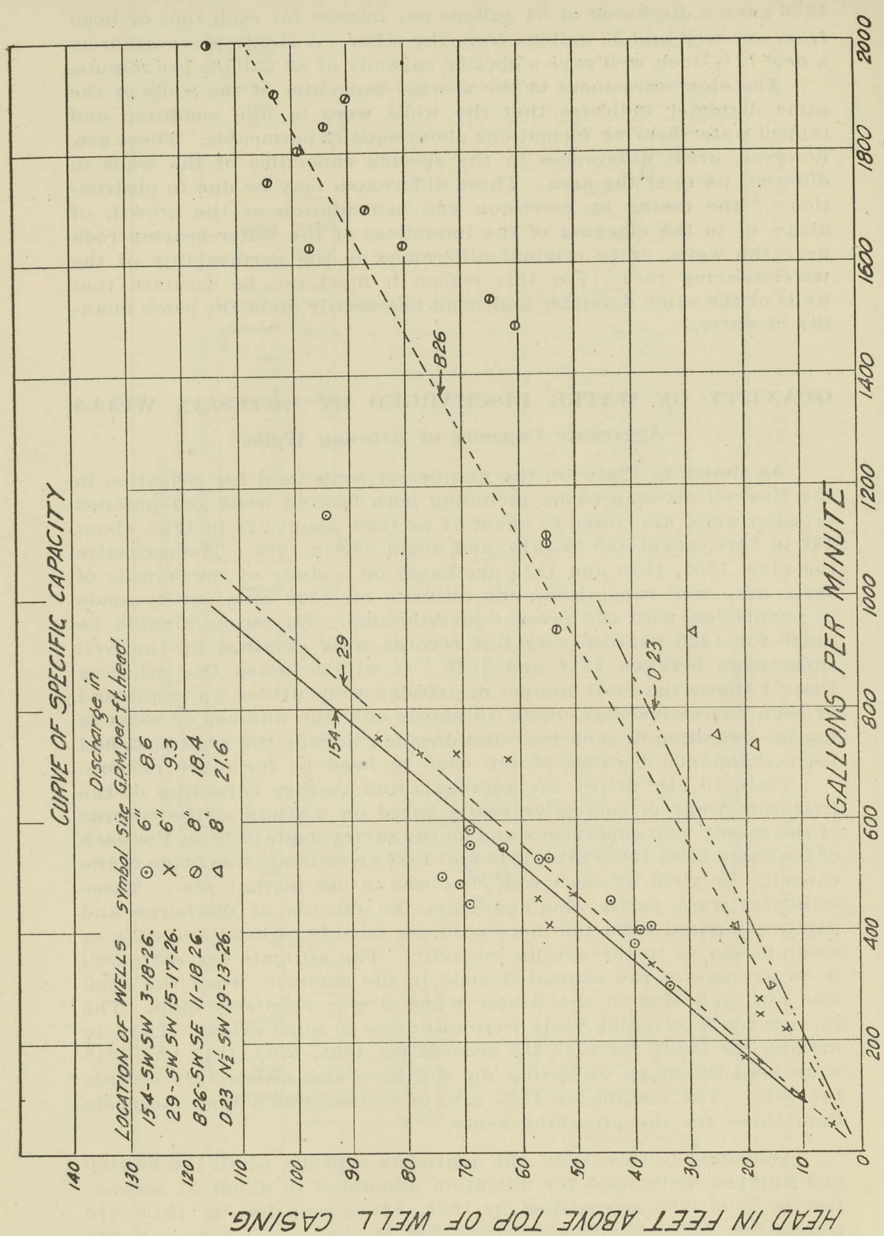


Plate 9.—Diagram showing specific capacity of four artesian wells.

development occurred in the Berrendo tract, north of Roswell. The peak in Chaves County occurred about this time but the peak in Eddy County was probably reached in 1908.

The average capacity of the irrigation wells, either by natural flow or by pumping has declined only moderately in the last 20 years. It is estimated that an average well yielded about 580 gallons a minute in 1905 and about 480 gallons a minute in 1925.

The average capacity of the wells in Chaves County increased until about 1910, owing to the drilling of wells of larger diameter after the first years of the development, but declined from 1910 to 1915, due to the great lowering in the head. The average capacity in 1925 was nearly the same as in 1915, the decrease in the yield of the old wells due to the lowering of the head being offset by the copious yield of new wells of larger diameter.

The greatest average capacity of the wells in Eddy County occurred some time prior to 1905. The average capacity dropped rapidly from 1905 to 1910 as a result of the great activity in drilling during these years and the consequent rapid drop in head. However, the average capacity was slightly larger in 1925 owing chiefly to the drilling of a number of wells of larger diameter between 1920 and 1925. It must be remembered that, throughout the entire period, in both counties, wells were constantly being drilled while others were being abandoned. Hence, while the capacity of most wells declined from year to year, the average capacity of all the wells declined less rapidly and actually increased during parts of the period.

In 1925 the capacity of all the wells in Chaves County averaged about 470 second-feet, of which about 240 second-feet was discharged by flowing wells and 230 second-feet by pumped wells. On wells used primarily for irrigation there are 128 pumps operated by gas engines and 57 by electric motors. The capacity of all the wells in Eddy County averaged about 205 second-feet, of which 150 second-feet was discharged by flowing wells and 55 second-feet by pumped wells. Forty-four gas-engine pumping plants were in operation for irrigation in Eddy County in 1925. The total capacity for the area was about 675 second-feet, of which 390 second-feet was discharged by flowing wells and 285 second-feet by pumped wells. For the reason already stated, these estimates may be subject to considerable error.

REQUIREMENTS FOR IRRIGATION

Statistics as to the areas irrigated with artesian water in 1925 are given in the following table. They are based chiefly on data compiled by the Roswell Chamber of Commerce, the Artesia Alfalfa Growers Association, and the County Assessors. According to the available data, about 45,000 acres was irrigated in 1925 with water obtained directly from artesian wells, either by natural flow or by pumping. About two-thirds of this area lies in Chaves County and about one-third in Eddy County. In addition to this area of 45,000 acres irrigated directly by the artesian water, about 13,200 acres within the artesian area was supplied by water from tributary streams, waste

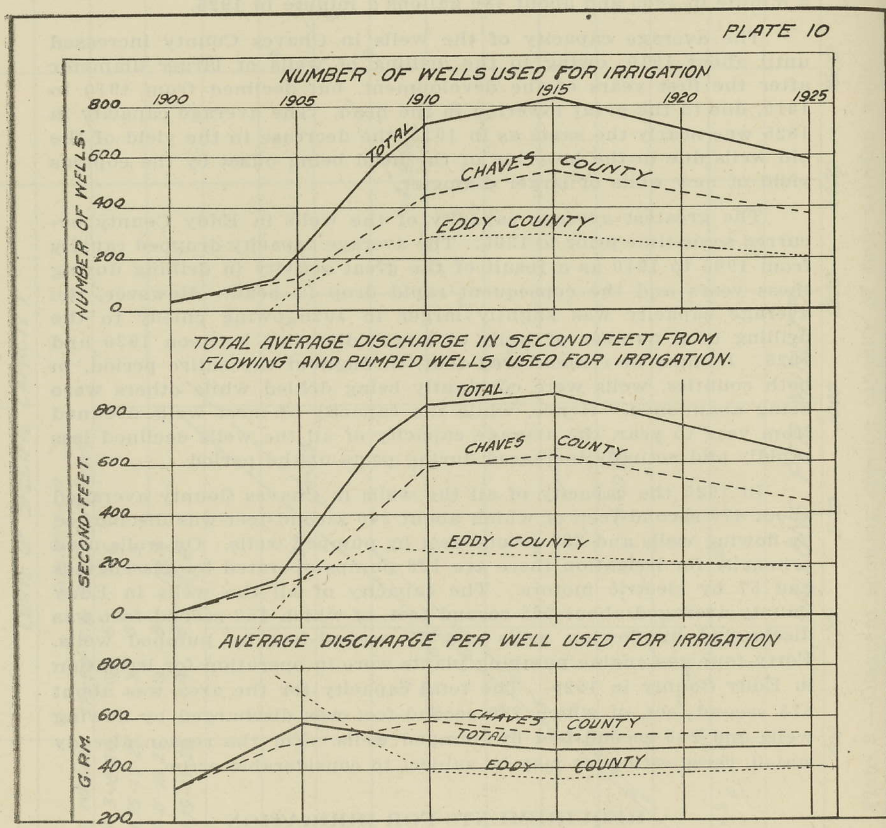


Plate 10.—Diagram showing for the period 1900 to 1925, the number of flowing and pumped wells used for irrigation, and total and average capacity of these wells.

water from wells. and water reclaimed by drainage ditches. About 9,500 of the 13,200 acres thus irrigated are supplied by the Northern Canal, which directly or indirectly derives its water chiefly from the artesian reservoir.

TABLE 4.

AREAS DEVOTED TO DIFFERENT CROPS IRRIGATED BY WATER OBTAINED DIRECTLY FROM ARTESIAN WELLS IN THE ARTESIAN BASIN DURING 1925.

	Area irrigated by artesian wells	Percent of total area	Cotton: Area	Cotton: Percent of total	Alfalfa: Area	Alfalfa: Percent of total	Orchard: Area	Orchard: Percent of total	Misc. Crops: Area	Misc. Crops: Percent of total
	Acres		Acres		Acres		Acres		Acres	
Chaves	29,600	66	13,950	47	10,300	35	1,810	6	3,540	12
Eddy	15,400	34	7,610	49	5,490	36	530	3	1,770	12
Total	45,000	100	21,560	48	15,790	35	2,340	5	5,310	12

Table 5 shows the net requirements of water for irrigation of the different crops, based on experiments made by Bloodgood and Curry at the Agricultural Experiment Station near Mesilla Park, New Mexico. (1) It does not include the water that is lost by seepage and evaporation from the reservoirs and ditches.

TABLE 5.

NET REQUIREMENTS OF WATER FOR IRRIGATION OF DIFFERENT CROPS SUPPLIED DIRECTLY FROM ARTESIAN WATER IN THE ROSWELL ARTESIAN BASIN DURING 1925.

	Required for Cotton 1 2-3 A.F. per acre	Required for Alfalfa 3 A.F. per acre	Required for Orchard 3 A.F. per acre	Required for Miscl. 2½ A.F. per acre	Total
Chaves	23,160 A.F.	30,900 A.F.	5,430 A.F.	8,850 A.F.	68,340 A.F.
Eddy	12,630 "	16,470 "	1,590 "	4,250 "	34,940 "
Total	35,790 "	47,370 "	7,020 "	13,100 "	103,280 "

According to the duties assumed for the respective crops, based on the work of Bloodgood and Curry, the average net requirement for the land irrigated directly from artesian wells in 1925 was about 2⅓ acre-feet to the acre. Assuming a loss of 20 per cent from the wells to the land, 2⅞ acre-feet to the acre, or a total of approximately 130,000 acre-feet would have to be drawn from the wells to supply the

(1). Bloodgood, D. W., and Curry, A. S., Net requirements for crops for irrigation water in Mesilla Valley, New Mexico: N. Mex. Agric. Exper. Sta. Bull. 149, 1925.

acreage with the respective amounts of water assumed. On the Carlsbad project, where conditions as to soil and climate are similar to those in the artesian area, an average of 2.44 acre-feet per acre was delivered to the farms during a period of 13 years, according to the records of the United States Bureau of Reclamation, but this quantity has not always been adequate for the requirements of the crops. The artesian well law of 1925 permits 3.5 acre-feet to the acre. Considering the type of crops cultivated in the artesian area an average of 3 acre-feet to the acre delivered at the land is, however, believed to be ample.

In most cases a farm is supplied by one or more wells on the farm. The amount of water supplied to the land varies on the different farms with the discharge of the well, the "head" of water available for irrigation, the nature of the soil, and the methods of irrigation. It is generally less where the water has to be pumped than where flowing wells are used. Because of these variations it is almost impossible to pick out representative farms on which to make accurate determinations of the quantity used. On the other hand, to determine the total amount of water used by obtaining records of discharge and the hours each well is used would require a vast amount of work quite beyond what can be attempted with the funds available for this investigation.

The principal irrigation season is considered to extend from April 1 to October 1. Many flowing wells, especially those with small discharge are, however, in operation continuously throughout the year. In other sections where the discharge is larger the flowing wells are operated almost continuously for 6 to 7 months. Pumped wells are operated from 4 to 6 months, many being in use for 24 hours of the day during the irrigation season.

It is roughly estimated that during 1925 an average of 3.25 acre-feet to the acre was used for the area under irrigation from artesian wells, including the losses from reservoirs and ditches. This would make a total of 146,250 acre-feet. Assuming an average discharge of 634 second-feet from all the wells used primarily for irrigation this quantity of water will be discharged in 185 days of 15 hours operation.

SURFACE WASTE OF ARTESIAN WATER

In general the waste of water during the irrigation season is not excessive and is doubtless no greater than on the average irrigation project. On lands irrigated by wells which are pumped, waste is at a minimum though in some cases too much water is applied to the land. Irrigation from wells of small discharge can not readily be practiced with economy. Many of the smaller wells discharge into reservoirs ranging in capacity from 6 to 25 acre-feet, but there are still a number of relatively small wells which are not so equipped. In general it might be stated that any irrigation well with a discharge of less than 300 gallons per minute should be equipped with a reservoir so that the irrigation "head" might be augmented by water stored during the night. Losses from ditches and laterals are in some cases large, and improvement in distributing systems is possible on many

farms by puddling with clay, lining with concrete, or replacing with tile.

The largest waste of water in the area occurs during the winter when irrigation is at a minimum. During the winter of 1925-1926 there were 225 wells in the artesian area which either had no valves or valves in such condition that the discharge could not be controlled. The wells that were thus defective were about equally divided between the two counties, but the aggregate discharge of such wells was about 35 second-feet in Chaves County and about 65 second-feet in Eddy County. Throughout most of the winter this water was placed to no beneficial use.

It is estimated that 25,000 acre-feet were wasted by these wells during the winter of 1925-1926. A large portion of this waste might be eliminated by the installation of valves, and would be available later in the year through increased discharge of the wells. Besides the loss of water through lack of beneficial use, large areas are water-logged and made unfit for cultivation because of the rise in the water table.

Smith (1) states in a discussion of winter irrigation of alfalfa that "3 acre-feet of water applied in the months when alfalfa is dormant may be no more effective than 1 acre-foot in the growing season." Winter irrigation of crops in an area where the water would otherwise go to waste and where the irrigation does not produce water-logging may serve a beneficial purpose, but in the Roswell artesian area there is no reason why winter irrigation should be indiscriminately practiced. It would therefore be desirable to eliminate all winter irrigation, at least from November 15 to February 15, except for orchards which may be benefitted by earlier irrigation. The results to be obtained by such a policy of conservation would be in the best interests of the area.

The closing of the artesian wells causes an increase in the artesian head. This has been clearly shown in the graphs in Plate 8 by the rise in head on Sundays when irrigation is curtailed. The elimination of the waste of 25,000 acre-feet during the winter would produce a like result. In addition, it would largely arrest the progressive decline in head from year to year and might eliminate further decline altogether. Pumping costs would also be reduced since the pumping lift would be lessened by the increase in the artesian head. In flowing wells the benefits of winter conservation would be derived through the increased discharge of the well.

DISCHARGE IN 1925 AT THE SURFACE

It has been roughly estimated that during 1925 about 3.25 acre-feet to the acre, or a total of 146,250 acre-feet, was applied to the area under irrigation directly from artesian wells. It has also been roughly estimated that about 25,000 acre-feet of water discharged by flowing wells was wasted, chiefly in the winter months. In addition the draft

(1). Smith, G.E.P., Ground-water supply and irrigation in Rillito Valley: Univ. Ariz. Agric. Exper. Sta. Bull. 64, p. 97, 1910.

for domestic and stock use, for the city supplies of Roswell and Artesia, and for other miscellaneous uses is roughly estimated at 15,000 acre-feet. The total withdrawal from artesian wells, not including the waste underground, is therefore estimated at present to be around 200,000 acre-feet a year.

UNDERGROUND WASTE OF ARTESIAN WATER

The underground waste of artesian water caused by insufficient or defective casing can be determined either by the pressure method or the meter method. In using the pressure method, the shut-in pressure of a well is determined with a pressure gage and this pressure is compared with that of other wells in the vicinity with proper allowance for the difference in elevation of the wells compared. This method is very satisfactory for preliminary tests. The meter method of determining leakage is, however, the most reliable. By this method both the location of the leak and the quantity of water wasting are determined.

The Price current meter, which is used by the United States Geological Survey in gaging streams, has given valuable results when used in exploring artesian wells in Hawaii, but it is not properly designed for this type of service. A new meter (1) was therefore designed especially for use in the wells of the Roswell artesian basin and it has been used successfully in the exploration of a number of wells in this area.

The principles involved in the use of the meter method of determining leakage are very simple. The fundamental hydraulic expression of water rising in a well is **Q equals AxV**, where Q equals the quantity of water per unit of time; A equals the cross-section area, and V equals the velocity of the water passing the section. It is apparent that for a given quantity of water flowing from a pipe in a unit of time, the water has a certain mean velocity. Any increase in the quantity of water discharged per unit of time from a given pipe must be due to an increase in the mean velocity of the water. The water passing upward in an artesian well that is in good condition has a comparatively uniform velocity at all points along which the well casing is of the same nominal diameter, although minor variations are caused by slight irregularities in the cross-section area of the casing. Should a leak occur in the casing the velocity of the water above this point will be decreased because a portion of the flow will be leaving the casing and wasting into permeable strata that are not filled with water or contain water under low head. The current meter is used to determine variations in velocity at different depths and thereby to locate underground leaks out of the well. The same principle is involved in the exploration of the uncased lower portion of the well to determine whether the casing has been inserted to a sufficient depth

(1). McCombs, John, and Fiedler, A.G., Methods of exploring and repairing leaky artesian wells on the Island of Oahu, Hawaii, and The Au deep-well current meter and its use in the Roswell artesian basin, New Mexico: U. S. Geol. Survey Water Supply Paper ———, 1926. (In process of publication.)

to prevent waste of water from the well into a permeable stratum that contains water under low head.

The Au deep-well current meter is essentially a turbine wheel mounted within a cylindrical brass case which is suspended in a 3-inch pipe and is lowered and removed from the well by means of a cable and reel. The meter is provided with a mechanism for making and breaking an electric circuit either at every revolution or at every fifth revolution. When the meter is lowered into the well it is attached to an insulated electric cable so that the electric impulse made by interrupting the circuit may be recorded in a telephone receiver in a manner similar to that of an ordinary current meter. The meter is rated for different sizes of pipe and different velocities of water and a table is prepared showing the number of revolutions per second corresponding to a certain velocity.

In exploring a well, the meter is let down a little at a time and velocity observations are made at regular intervals to determine when a leak is passed. In a non-flowing well no velocity will be noted until a leak is encountered, while in a flowing well a leak is indicated by an increase in velocity. If a waterbearing stratum which supplies water to the well is passed the speed of the turbine wheel will decrease. After the meter has passed below the end of the casing variations in the velocity will occur due to the irregularities in the size of the hole. As long as no consistent change is noted these variations are disregarded.

The investigation of underground leakage has been greatly handicapped by the fact that it was impossible to insert the meter into many of the wells. Many wells were found obstructed by foreign material which has been thrown in more or less maliciously, others were filled with sand and still others had undoubtedly collapsed. On many of the flowing wells the pressure method could not be used because the casing at the ground or the valve was in such condition that the well could not be shut in. Without this information or evidence that water was coming up around the casing it is practically impossible to determine that a well is leaking underground for the specific capacity varies so greatly that the discharge alone is not a positive indication.

In a number of wells definite evidence of leakage was found and the leaks were located, but, the information obtained thus far is too meager to warrant an estimate of the total underground leakage that occurs in the area. It would seem, however, from the information thus far obtained, that the underground leakage is not at the present time excessive. Considerable work will be done during the present year with the deep-well meter to determine the condition of as many wells as possible.

RECHARGE

The water bearing formations in the Roswell artesian basin crop out in successive zones on the high land west of the area of artesian flow and receive their water supply by downward percolation of the

water which falls as rain or snow upon this high land. The area which contributes to the artesian supply comprises in all about 4,000 square miles (1) and extends about to the crests of the Capitan, Sierra Blanca, and Sacramento mountains. The precipitation over the area either runs off in surface streams, evaporates, is given off by plant growth, or is contributed to the groundwater supply by percolation through the cavernous and creviced limestone. The chief tributary streams which cross the catchment area are the Hondo, Felix, Penasco and Seven Rivers, and a large portion of their run-off is also contributed to the artesian supply through seepage losses. After the water enters the permeable rocks it migrates eastward, down the slope, and eventually becomes confined under impervious layers of limestone and clay.

During the year ending September 30, 1925, an average of about 15 inches of precipitation fell upon the catchment area that furnishes the artesian supply. This amount of precipitation is equivalent to 3,200,000 acre-feet of water. During the same period it is estimated that 200,000 acre-feet of water, not including underground loss, was withdrawn from the artesian reservoir for irrigation and other purposes. This quantity represents but 6¼ per cent of the total quantity of water which fell upon the catchment area. The cavernous condition of the limestone underlying most of the catchment area and the behavior of the artesian wells give good evidence that a large quantity of water is contributed to the artesian reservoir each year.

METHODS OF REPAIRING AND PLUGGING WELLS

The chief requirements for the successful repair or sealing of a defective artesian well are drillers of experience and skill with adequate equipment. Considering the number of wells which have been drilled in the artesian area comparatively few have been repaired or sealed, not because such work was unnecessary but because the general practice has been to abandon an old well that has become defective and to drill a new well near by. Such a policy may frequently be the most economical at the time, but, in view of the large loss of investment in the area that was formerly within the area of artesian flow, it can hardly be questioned that the practice has been a most expensive one. Because of this policy there has been little incentive on the part of the drillers operating here to become thoroughly familiar with the methods of repairing and plugging wells and to develop a real technique for this type of work.

A few repair jobs have been successful, particularly where the defect was near the surface, but most of them have been total failures. No well of which the writer has information has been effectively sealed from top to bottom, and doubtless many of the wells that have been plugged are leaking underground into porous formations. An instance of such a method of plugging was discovered in the vicinity of Artesia. Some years ago this well was condemned because it was leaking and was plugged by having a wooden plug inserted

(1). Fisher, C. A., op. cit., p. 24.

several hundred feet below the top of the casing. In 1925 water was coming up on the outside of the casing and hence an attempt was made to examine the well with the current meter to locate the leak. However, it was found that the meter could only be inserted to a depth of 10 feet, at which point a wooden plug was lodged in the casing. It was authoritatively learned that the plug had been inserted several hundred feet down in the well, and it, therefore, appears that the outer part of the plug rotted away and that the rest of the plug was then dislodged and carried upward to a constriction in the casing 10 feet from the top. This case illustrates how ineffective such crude methods may be in stopping the flow when the water is under considerable pressure.

In experiments conducted by the United States Geological Survey on the repair and sealing of artesian wells on the Hawaiian Islands, effective methods of procedure have been devised which have been very successful. (1) It is the writer's opinion that similar methods would be successful in this area if the work were done in the proper manner. The fact can not be overlooked, however, that such repair and plugging work is expensive. According to the information available it would seem that the underground leakage in the Roswell basin is not excessive at the present time. To repair or seal all of the defective wells properly in the basin would involve an expense which would be burdensome regardless of whether the work were done at public or private expense. It is therefore suggested that the survey of underground leakage be continued, especially with a view that further study of the problem may lead to the development of less expensive methods of repair and sealing.

While it is not considered the best policy to undertake the repairing or sealing of all the defective wells at this time, nevertheless, permits for the drilling of wells even to supply land now under irrigation should be issued only upon the condition that defective wells upon the property be repaired or sealed. Such a policy is recommended in justice to the present irrigators, for unless the defective wells on a farm are first repaired or sealed a new well will involve an additional draft on the artesian reservoir and will endanger the economic existance of other irrigators.

CONCLUSIONS AND RECOMMENDATIONS

The first flowing well was drilled in the Roswell artesian basin in 1891 but there was not much development of the artesian water-supply for irrigation until about 1904. The most active period of drilling was between 1904 and 1910. During these years much land was placed under irrigation with artesian water and the artesian head dropped rapidly. The total decline in artesian head to 1916 ranged from only 20 feet in the vicinity of Roswell to a maximum of about 185 feet in the south end of the basin. Since 1916 the decline in head has proceeded at a much slower rate. In the 10-year period from 1916

(1). McCombs, John, Methods of exploring and repairing leaky artesian wells on the Island of Oahu, Hawaii: U. S. Geol. Survey Water-Supply Paper ———, 1926. (In process of publication.)

to 1925 it has been only about 5 feet in the vicinity of Roswell but has been somewhat greater in other parts of the basin, reaching about 15 feet around Artesia.

The artesian reservoir is supplied by rain and snow that fall on the upland area of about 4,000 square miles lying west of the area of artesian flow. Much of the rain and snow water sinks through the cavernous limestone that underlies this upland and finds its way into the artesian reservoir. Thus the artesian water-supply is replenished in large quantities every year and can never be wholly exhausted. So long, however, as the quantity of water annually withdrawn from the artesian reservoir exceeds the annual recharge the head will decline, the area of artesian flow will shrink, and, other things being equal, the area within which pumping for irrigation is profitable will likewise be diminished. Even if the decline each year is so slight that it is hardly observed by the farmers, the aggregate decline in a period of years may cause serious damage. The future welfare of the community and of the individual farmers requires that the quantity of water withdrawn from the artesian wells be held down to such an extent that the decline in head will be stopped.

The area of artesian flow originally covered about 670 square miles but it decreased to about 505 square miles by 1916 and to about 430 square miles by 1925. Thus the shrinkage in the area of artesian flow amounted to about 165 square miles prior to 1916 and to about 75 square miles in the 10-year period since 1916. Much good land lying about the present area of flow was in 1925 and 1926 irrigated by pumping. However, as the water level in the non-flowing wells declines at about the same rate as the head in the flowing wells, the fact remains that by the gradual decline in head land suitable for agriculture is eliminated from the area of profitable irrigation. In view of the fact that the entire irrigated acreage amounts at present to only about 90 square miles and that this includes most of the good land in the area of flow, it is evident that even slow decline in the future may cause serious shrinkage of the irrigated area. The situation obviously demands that all useless withdrawal of water from wells be stopped in order to prevent further decline in head.

In 1925 about 45,000 acres of land in the Roswell artesian basin was irrigated with water obtained directly from artesian wells, and about 11,500 acres under the Northern Canal and Cottonwood Creek were supplied directly or indirectly chiefly from the artesian reservoir. A total of 593 wells were in use for irrigation, of which 364 yielded their water by artesian flow and 229 were pumped. If an average of 3¼ acre-feet of water was used per acre a total of about 150,000 acre-feet of water was withdrawn during the year for the irrigation of lands directly supplied by artesian wells. The total value of the crops produced in land irrigated directly from artesian wells in this basin in 1925 is estimated at about $3,000,000.

During the year covered by the present investigation measurements of head were made on numerous wells, daily measurements were made on one well and continuous records were obtained with automatic water-stage recorders over two wells. These records indicate that in the vicinity of Roswell and in the Berrendo tract north

of Roswell the equilibrium between recharge and withdrawal has virtually been reached and that unless additional land is brought under irrigation the head will in the future decline very slowly if at all. The records, however, indicate that in the rest of the basin the equilibrium between recharge and withdrawal has not yet been reached and gradual decline in head is still taking place. It must be remembered, however, that the effect of increased underground leakage may virtually be the same as placing an increased acreage under cultivation. It is very desirable that continuous records should in the future be obtained with water-stage recorders on several typical wells in different parts of the basin in order that reliable information may be at hand as to the decline or recovery of the head from year to year and from season to season. The aim should be to stop all further decline in head.

In 1904 and 1905 a general investigation of the Roswell artesian basin was made by the Geological Survey and in 1906 a report on this investigation was published as Water-Supply Paper 158. In this report attention was called to the waste of the artesian water and a policy of conservation was recommended. In 1905 the Legislative Assembly of the Territory of New Mexico enacted an artesian water law which prohibited waste of artesian water. This law was revised and strengthened by additional legislation in 1909, 1912 and 1925. In 1916 the Geological Survey made a second investigation of the area and determined the extent of the decline in the area of artesian flow that had occurred up to that time. In spite of these efforts by the Federal and State governments the years following 1904 were marked by excessive drilling activity and great waste of artesian water. The result was that by 1916 when the Geological Survey made its second investigation many irrigation farmers had been ruined and the irrigation area had been reduced from both sides, from the west because of the great drop in head and consequent high lifts and from the east because of the water-logging of the low lands, which later was partly relieved by drainage systems installed at heavy cost.

Although the artesian water laws were never fully enforced, the fact should not be overlooked that great good was accomplished by the saving of artesian water that resulted from even the partial enforcement of the laws and from various efforts to educate the farmers as to the value of conservation. It is safe to estimate that if in 1925 all efforts at conservation had been abandoned and all wells had been allowed to flow through the year, at least 100,000 acre-feet of water would have been wasted, which in fact was held in the artesian reservoir for future use. If no valves had ever been placed in any wells and no effort had at any time been made to prevent waste, many farms which are at present productive would by this time have been abandoned either because of excessive lifts or because of water-logging. If there had been no artesian water laws and no effort made to prevent waste, the value of the crops raised in the basin in 1925 would certainly have been a few hundred thousand dollars less than the value of the crops that were actually raised in that year. It is quite possible that the results of the past efforts at conservation have produced results, measured in present crop values, of more than half a million dollars a year. The past efforts at preventing waste have certainly been worth while.

The greatest waste of artesian water occurs during the winter from wells that are not equipped with valves in good condition and from wells whose valves are left open. It is estimated that during the winter of 1925-26 about 25,000 acre feet of water was wasted from wells that were not closed when the water was not used. If this waste were prevented it would go far toward stopping further decline in the artesian head and improve the productivity of the cultivated land that is more or less damaged by waterlogging. The survey made during the past year shows that 225 wells are not provided with valves to properly control the flow. It is urged that the law be strictly enforced requiring that wells be tightly finished at the top and provided with valves and which requires that the valves be closed when the water is not used.

In general the irrigation practice followed in the Roswell artesian basin compares favorably with that in other irrigation districts. The largest waste of water during the irrigation season is due to poor ditches and reservoirs. The farmers should be encouraged, for their own benefit as well as that of the community, to place their distribution systems in better condition. In much of the winter, irrigation should be discouraged in order to conserve the water for a higher duty. The artesian well law allows a use of 3½ acre-feet per acre each year. This allowance is certainly ample and application of water in excess of this amount should not be permitted.

In some of the old wells the casing has become corroded and allows artesian water to leak out of the wells without coming to the surface. Two methods are available for determining whether an artesian well loses water by leakage,—the meter method and the pressure method. The most satisfactory is the meter method in which a current meter is lowered into the well. By this method the depths at which leakage occurs can be determined and also the approximate amount of leakage in gallons per minute at each depth. A special deep-well current meter was designed and constructed by the Geological Survey for this investigation and has been successfully used in exploring a number of wells in this basin. The pressure method consists of obtaining the closed pressure of the well under investigation and comparing this pressure with the normal pressure for this vicinity. This method is valuable as a preliminary test and on wells that are obstructed so that the meter can not be used. The leakage survey has not yet been carried far enough to make it possible to estimate the loss of artesian water by underground leakage but the results thus far obtained indicate that the loss by leakage is not at the present time excessive. Much good has resulted from the use of the heavy type of casings which are specified in the artesian well law and strict enforcement of this section of the law is recommended.

The law requires that leaky wells should be repaired or plugged. The Geological Survey has for several years conducted experiments on recasing and sealing leaky artesian wells in the Hawaiian Islands and has developed effective methods of recasing and sealing. It was found, however, that both processes are expensive if the work is to be properly done, and the conclusion can not be avoided that any effort adequately to recase or seal all the defective wells in the basin would involve very heavy costs which would be burdensome whether the work were done at private or public expense. It is therefore recommended that no drastic action be taken in this matter but that the leakage survey be carried further and that study be made of methods and costs of recasing and sealing and of the relative value of the benefits to be derived by applying these methods.

It is however, recommended that whenever a permit is requested for drilling a new well to supply water for land already under irrigation it should be required that all defective wells on the property for which the permit is desired be placed in good condition either by recasing or by making other adequate repairs, or be effectively sealed from the bottom to a point above the water horizons. Unless this is done a new well drilled even to supply old acreage will cause a new draft on the artesian reservoir and will constitute an encroachment on the water rights of the other farmers. By enforcing the law to this extent the menace of progressive increase in waste by underground leakage can largely be overcome without undertaking a drastic and excessively expensive program.

In spite of the gradual decline in the artesian head since 1916 there has been a marked improvement in agricultural conditions and in the total value of the crops produced. This improvement has been due in part to the installation of more efficient pumping machinery, a reduction in the price of electric current used for power, and the draining of some of the low-lying waterlogged lands, but still more largely it has been due to the introduction of cotton, which has proved to be a very valuable crop. This very prosperity, however, constitutes the greatest menace to the water rights of the present irrigation farmers because it is encouraging the drilling of wells to put new lands under irrigation that is not now cultivated. It is probable that no new land can be brought under irrigation with artesian water drawn from the present known artesian horizons without infringing on the water rights of existing irrigators and even threatening the economic existence of some of them who already have high lifts. As a matter of elemental justice to the present irrigators the drilling of wells to supply new acreage should be prohibited except as it may be demonstrated that some additional developments can be made without lowering the head. The drilling of additional wells on lower lands is considered especially harmful because good agricultural lands at higher levels will in consequence be abandoned because of the increased lifts and insufficient water-supply with present pumping plants, whereas the new developments will place under irrigation land of poorer quality which will be subject to water logging and will shortly require extensions of the drainage systems to maintain its productivity. New legislation will probably be required to prevent new developments with artesian water that will infringe on the water rights of existing irrigators, and the speedy enactment of such legislation is strongly recommended.

Restrictions on further drilling should not include the drilling of relatively shallow wells that will not tap the artesian reservoir but will yield ground water by pumping. Some of the waterbearing beds near the surface will probably yield considerable water to properly con-

structed pump wells, and irrigation developments on low lands by recovering this water are to be encouraged.

The following recommendations are made for the conservation program of the immediate future:

1. Only competent hydraulic engineers should be appointed as county well supervisors.

2. Continuous records of the fluctuations in the artesian head should be obtained by the operation of automatic water-stage recorders on several representative wells in different parts of the basin.

3. The artesian water law in so far as it relates to surface waste should be strictly enforced.

4. Permits for the drilling of artesian wells to supply acreage now under cultivation, should be issued with the understanding that all defective wells on the property for which the permit is desired will be effectively repaired or sealed.

5. New legislation should be enacted at the earliest possible date to prohibit further irrigation developments with artesian water except as it is shown that such developments will not injure present irrigators.

SAN JOSE-RIO PUERCO INVESTIGATION

Chapter 74 of the 1925 Session Laws makes an appropriation of $10,000 and directs the State Engineer to make surveys for the location of ditches and reservoir sites and to ascertain the capacity thereof and to investigate the prospects for artesian wells in San Jose and Rio Puerco Drainage Basin within Sandoval County, New Mexico.

In this, as well as in all other special investigations which the State Engineer is directed to make, which involve the study and determination of the feasibility of artesian wells or other ground water conditions, the assistance of the United States Geological Survey has been enlisted, in order that any test wells might be intelligently located.

In this case a thorough study has been made by the Geological Survey and a preliminary report is herewith included. From the field work done and the study given this subject there will be a detailed report produced, which will be published by the Survey as a government Bulletin entirely at the expense of the Government, and which will be available to the public within the near future. On this cooperative work the Government has expended of its own funds $4,120.97.

The Preliminary Report by Mr. B. Coleman Renick follows:

THE GEOLOGY AND ARTESIAN WATER PROSPECTS

IN THE SAN JOSE-RIO PUERCO VALLEY IN SANDOVAL COUNTY, NEW MEXICO

By

B. COLEMAN RENICK

UNITED STATES GEOLOGICAL SURVEY

CONTENTS

ILLUSTRATIONS

INTRODUCTION

HISTORY AND SCOPE OF THE INVESTIGATION

During the summer of 1924 the author spent about six weeks in making an investigation of the ground-water conditions in western Sandoval County. At the conclusion of this work a preliminary report (1) was prepared in which it was pointed out that there are prospects for obtaining flowing artesian wells in parts of Sandoval County. Accordingly, the State Legislature, during the following winter, enacted a law directing the State Engineer to "investigate the feasibility of irrigation development, flood control, and the prospects for artesian wells in the San Jose and Rio Puerco drainage basin within Sandoval County" (S. B. No. 94; approved March 17, 1925.)

The State Engineer, George M. Neel, then made a co-operative arrangement with the United States Geological Survey whereby the Geological Survey was to complete the survey of the artesian water prospects in that part of the San Jose-Rio Puerco drainaage basin that lies in Sandoval County. The author was assigned to complete this investigation and spent about ten weeks during the summer and fall of 1925 in additional field work in the area. After completing the field work, the following recommendations for the drilling of several wells in this drainage basin to test the artesian water prospects were submitted to the State Engineer (pp. 65-67).

In the present report the essential features of the geology and the artesian water prospects in the San Jose-Rio Puerco drainage basin only are described. It should be understood that this report is preliminary in nature and is to be followed by a more comprehensive report embracing a considerably greater area in Sandoval County, which is now in the process of preparation (2). In the final report the artesian prospects along the Rio Salado and its tributaries will also be described. In this connection it should be noted that in drilling for oil in the lower part of the valley of Arroyo Cachana—a tributary to the Rio Salado—a flowing artesian well was obtained during the spring of 1926.

All of these investigations were made under the general direction of O. E. Meinzer, geologist in charge of the division of ground water.

RECOMMENDATIONS TO THE STATE ENGINEER FOR DRILLING TEST WELLS

The field investigation pertaining to artesian water possibilities of the Rio Puerco-San Jose drainage basin, Sandoval county, New Mexico, was completed on December 3, 1925, and on the basis of this work recommendations for the drilling of three test wells are herewith made.

It will be desirable if these wells are finished at the bottom with

---

(1) Renick, B. C., Ground water in Sandoval County, N. M., U. S. Geol. Survey Press Notice No. 18059.

(2) Renick, B. C., The geology and ground water resources of western Sandoval County, N. M., U. S. Geol. Survey Water-Supply Paper (in preparation).

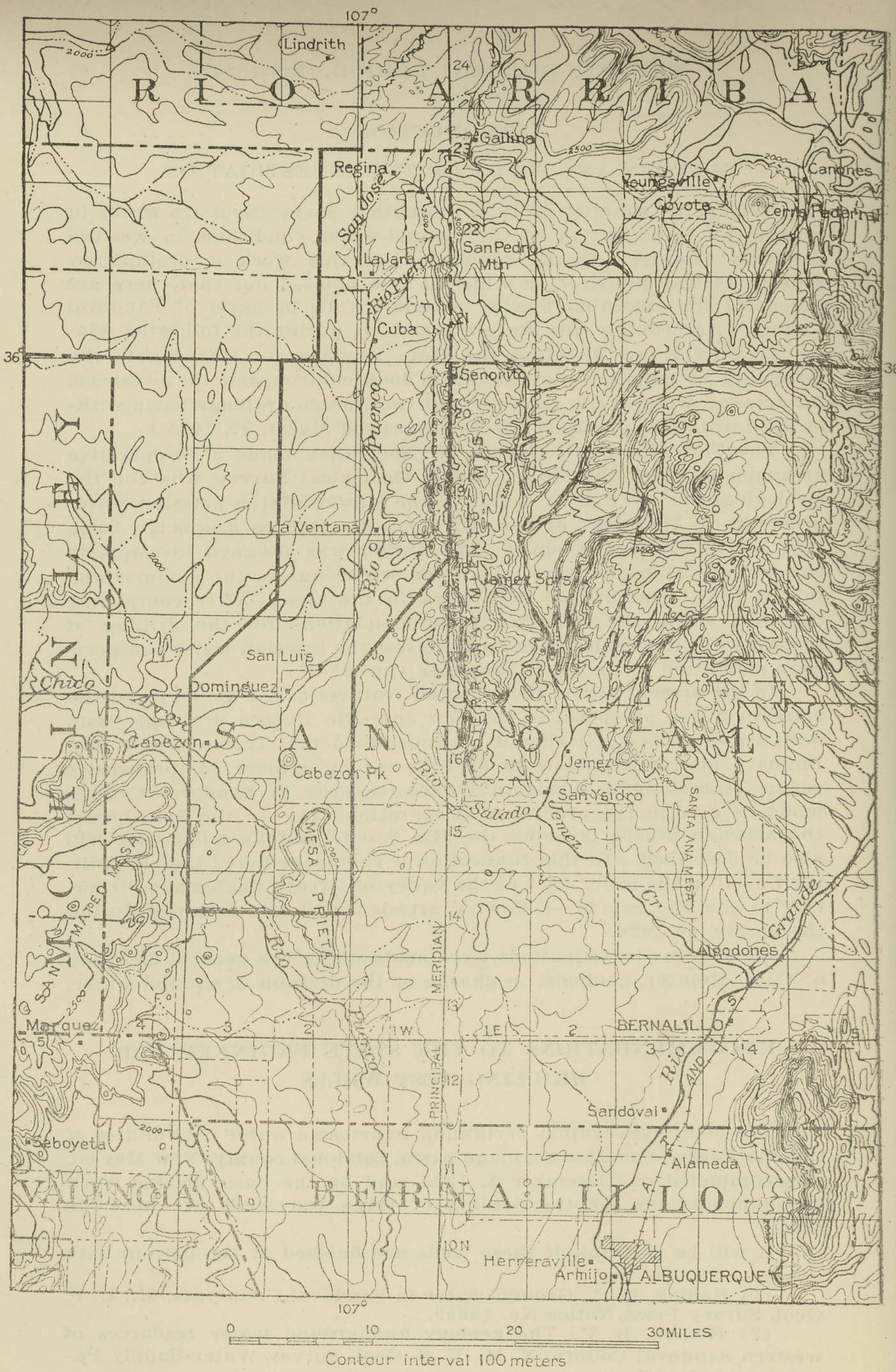


Figure 1.—Map of western Sandoval County and adjoining territory showing area described in this report.

a diameter not less than 4 inches and preferably not less than 5 3-8 inches. In all wells it will be necessary to case off the highly mineralized ground water near the surface and it is very probable that in all the wells this can be successfully done at a depth of less than 100 feet, and probably less than 50 feet. Inside of this casing it will be necessary to insert a casing of smaller diameter. This latter casing should extend to the water-bearing formation and it should either be set in cement or attached to a packer that tightly fits against the walls of the hole. It is recommended that these wells be drilled in the order named, that is, No. 1 first; No. 2, second; No. 3, third.

Well No. 1.—This well is to be located along the flat bordering San Jose River somewhere within the tract embracing the S. 1-2, Sec. 22 N., R. 1 W., and the N. 1-2 of Sec. 6, T. 21 N., R. 1 W. Here the basal sandstone of the Wasatch formation and the sandstones at the top of the Torrejon formation will be tested. The maximum depth recommended for this test is 500 feet. If a flow of water of sufficient magnitude to be of economic importance for irrigation is obtained at a depth less than 500 feet, the well should be finished in the formation in which the flow is obtained. If, on the other hand, small, inadequate flows are obtained at depths less than 500 feet, drilling should continue to the maximum depth or until a flow of economic importance is obtained.

Well No. 2.—In the town of Cuba the prospects for obtaining a flowing well at any depth less than 1,600 to 1,800 feet are slight, and the cost of drilling to this depth to reach the mesaverde formation is prohibitive with the appropriation available and with success not assured. However, the prospects of obtaining ground water nearer the surface in the vicinity of Cuba should be tested, especially as the people of Cuba are very much in need of a water supply for domestic use. It is, therefore, recommended that a well not to exceed 300 feet in depth be drilled in the town—on the School House property located along the main thoroughfare between the Catholic Church and Young's Store. If the highly mineralized ground water near the surface is effectively cased off, there are good prospects of obtaining a potable water supply from a well drilled into the sand or sandstone strata near the base of the Puerco formation within a depth of 300 feet or less. Any water obtained from these strata will doubtlessly rise to a considerable height in the well.

Well No. 3.—This well should be located on the flat along the Rio Puerco within the tract embracing the S.W. 1-4, Sec. 17, S.E. 1-4 Sec. 18, N.E. 1-4 N.E. 1-4 Sec. 19, N.W. 1-4 Sec. 20, T. 19 N., R. 1 W. Here the water-bearing possibility of the Mesaverde formation may be tested, and this locality is regarded as favorable for prospecting for a flowing well. The maximum depth recommended for this test is 800 feet. If a flow of water of sufficient magnitude to be of economic importance for irrigation is obtained at a depth less than 800 feet, the well should be finished in the formation in which the flow is obtained. If, on the other hand, small, inadequate flows are obtained at depths less than 800 feet, drilling should be continued to the maximum depth or until a flow of economic importance is obtained.

INHABITANTS, ROADS, AND RAILROADS

The western part of Sandoval County is semi-arid and sparsely inhabited. The principal town is Cuba, which has several hundred inhabitants. There are, however, several other villages, including Cabezon, La Ventana, San Luis, La Jara, and Regina.

The principal automobile road from Albuquerque to Cuba and points farther north goes up the Rio Grande Valley to Bernalillo and from there follows Jemez Creek to San Ysidro. It then leads around the south end of the Sierra Nacimiento and thence northward to Cuba. Another road leaves the Rio Grande Valley near Alameda and goes to Cabezon. From Cabezon this road leads to La Ventana where it joins the main Albuquerque-Cuba road.

A standard gage logging railroad connects Bernalillo with San Ysidro and extends 15 miles, or more, northward from the latter town. A railroad is projected to extend from San Ysidro to La Ventana and thence across the San Juan basin to Farmington, and at the time this investigation was being carried on most of the grading from San Ysidro to La Ventana had been completed.

PHYSIOGRAPHY AND DRAINAGE

The Rio Puerco rises in the San Pedro Mountains several miles northeast of Cuba, and flows in a general southward direction, emptying into the Rio Grande about 20 miles southwest of Albuquerque. Its principal headwater tributary is the Arroyo San Jose, which rises near the northern boundary of Sandoval County. The Rio Puerco is sometimes referred to as the Rio Puerco East to distinguish it from the Rio Puerco West, which flows through Gallup and belongs to the drainage system of Colorado River.

East of the Rio Puerco there is a prominent mountain range with north-south trend, the summit of which extends 10,000 feet above sea-level in many places. Although this range is continuous, the southern part is known as the Sierra Nacimiento, and the northern part as the San Pedro Mountains.

The San Jose Valley, near its headwaters, has an elevation of 7,500 feet and the Rio Puerco, near the southern end of the area, has an elevation of about 6,000 feet. The Rio Puerco flows almost due southward parallel to the mountain range, as far south as La Ventana, but here it turns southwestward away from the range, and south of the village of Cabezon it flows between the San Mateo Mesa on the west and the Mesa Prieta on the east.

GEOLOGY

STRATIGRAPHY

Introductory Statement

The geologic section outcropping in this part of Sandoval County includes rocks of pre-Cambrian, Pennsylvanian, Permian, Triassic, Jurassic (?), Cretaceous, Tertiary, Pleistocene, and Recent age. Most of the strata are upturned along the western slope of the Sierra Nacimiento and San Pedro Mountains, and here the thicknesses and character of the several formations can be determined. Although at the time this investigation was made no deep wells had been drilled in the San Jose-Rio Puerco Valley, it was possible by studying the rocks at the surface to determine with considerable certainty the order and thickness of the formations that will be encountered in drilling wells in the valley.

PRE-CAMBRIAN ROCKS

The oldest rocks in this region are of pre-Cambrian age. The principal pre-Cambrian rock is a coarse-grained granite-porphyry prevailingly pinkish red to red brown. Associated with the granite are some basic intrusive rocks and a few small areas of schist. The pre-Cambrian rocks occupy the central core of the San Pedro Mountains and Sierra Nacimiento.

CARBONIFEROUS SYSTEM

Pennsylvanian Series

Magdalena group (1).—This group of rocks consists chiefly of limestone which in most places is fossiliferous, but it also contains considerable red and yellow sand and shale and basal beds of arkosic conglomerate. The arkosic beds are generally confined to the lower 10 feet of the group, but locally occur as much as 200 feet above the base. The entire thickness of the Magdalena group is not represented at any place along the San Pedro Mountains or the Sierra Nacimiento owing to the fact that the rocks have been partly removed by erosion prior to the deposition of the overlying Permian beds. The maximum observed thickness of the Magdalena group exceeds 450 feet.

PERMIAN SERIES

Abo sandstone (2).—The Abo sandstone was measured northwest of San Ysidro, which is east of the area under consideration. There it was found to be 320 feet thick. This is the approximate thickness at the south end of the Sierra Nacimiento, but northward, along the San Pedro Mountains, it thins and in some places is entirely absent, having been removed before the deposition of the overlying Yeso member of the Chupadera formation. The Abo sandstone generally rests on the Magdalena, but where the Magdalena had been removed by erosion, it rests on the granite. The color of the Abo sandstone is maroon to madder brown. It consists of coarse grit, sandstone, and shale. Sandstone generally predominates, but in some places the formation consists chiefly of shale.

---

(1) Gordon, C. H., Notes on the Pennsylvanian formation of the Rio Grande Valley, New Mexico, Jour. Geol., vol. 15, pp. 805-816, 1907.

(2) Herrick, C. L., Geology of the white sands of New Mexico; Jour. Geol., vol. 8, pp. 112-128, 1900; Univ. New Mexico Bull., vol. 2, 17 pp., 1900.

Yeso member (1) of the Chupadera formation (2).—The rocks mapped as the Yeso member of the Chupadera formation in this region are composed of two parts, the lower beds consisting mostly of brilliant scarlet sandstone and grit, much of the sandstone being shaly, and the upper beds consisting of light buff to gray, massive cliff-forming sandstone. In the southern part of the region the lower beds are about 530 feet thick and the upper beds about 260 feet thick. Here the Yeso member rests on the abo sandstone, but in places in the northern part of the region it rests on the Magdalena group or on the granite, showing that there is an unconformity at its base.

The San Andres limestone, which is the upper member of the Chupadera formation and which is widespread in other parts of New Mexico, is not present in this region.

TRIASSIC SYSTEM

Poleo sandstone.—The formation known as the Poleo sandstone consists of massive gray sandstone with lenticular beds of quartzose conglomerate, the latter in general being connned to the lower part. It ranges in thickness from 260 feet to less than 100 feet, and rests unconformably on the Yeso member of the Chupadera formation, the intervening Moenkopi formation apparently not being present in this region. The water from the artesian well in the valley of Arroyo Cachana comes from the Poleo sandstone. The Poleo sandstone is probably the equivalent of the Shinarump conglomerate of Utah and western New Mexico.

Chinle (?) formation.—The rocks here tentatively correlated with the Chinle formation, aggregate 600 to 900 feet in thickness and rest on the Poleo sandstone. They are essentially shale but also contain some sandstone and limestone conglomerate. They vary in color from pinkish red to purplish maroon.

JURASSIC (?) SYSTEM

Wingate sandstone.—The Wingate sandstone, about 240 feet thick, overlies the Chinle (?) formation. The upper part of the formation is white, yellow, tan, and the lower part pink to scarlet. The Wingate in this region is a soft argillaceous sandstone and does not readily withstand erosion.

Todilto formation.—Throughout this part of Sandoval County there is a massive bed of white gypsum, 60 to 110 feet thick, which rests on the Wingate sandstone. Darton (3) correlates this bed with the Todilto formation on the west side of the San Juan basin. This gypsum bed contains thin limestone layers at the top and bottom, and in the lower one-third of the bed there are lenses of shaly limestone. The upper part of the formation consists chiefly of very pure gypsum.

---

(1) Lee, W. T., and Girty, G. H., The Manzano group of the Rio Grande Valley: U. S. Geol. Survey Bull. 389, 1909.

(2) Darton, N. H., Geologic structure in parts of New Mexico: U. S. Geol. Survey Bull. 726, p. 254, 1921.

(3) Darton, N. H., Geologic structure of parts of New Mexico; U. S. Geol. Survey Bull. 726, p. 184, 1922.

CRETACEOUS (?) SYSTEM

Lower Cretaceous (?) Series

Morrison formation.—The Morrison formation rests on the Todilto formation. A measured section in Los Bancos shows that it is there about 710 feet thick. It consists of two parts. The lower part is about 180 feet thick and is made up mostly of maroon colored soft sandy shale with thin beds of white and gray sandstone. The upper part consists of alternating beds of resistant sandstone and soft shale, the prevailing colors being green, buff, lavender, white, tan, and maroon.

CRETACEOUS SYSTEM

Upper Cretaceous Series

Dakota (?) Sandstone.—The Dakota (?) sandstone is present throughout this region and varies in thickness from 30 to about 200 feet. It rests uncomformably on the Morrison formation and is conglomeric at the base. In the northern part of the area, where it is thickest, it consists of an upper and lower sandstone member and a middle shale member.

Mancos shale.—The Mancos is essentially a shale formation, but it contains throughout the section lenticular beds of sandstone. The shale is generally dark gray, but on the weathered surface it is tan. The average thickness of the Mancos shale is about 2,000 feet.

Mesaverde formation.—The Mesaverde formation consists of massive and shaly sandstone, shale, some of which is carbonaceous, and coal, of which there are several workable beds. It is a fresh-water deposit, in which respect it contrasts with the Mancos shale, which is of marine origin. Several miles north of Cuba the Mesaverde is about 100 feet thick, and in the vicinity of La Ventana it is over 800 feet thick.

Lewis shale.—The Lewis shale rests on and grades into the Mesaverde formation. It is a dark gray marine shale, similar to the Mancos, but differs from the latter in that it does not contain sandstone except in the lower part. Its maximum measured thickness is 1,500 feet.

TERTIARY SYSTEM

Eocene Series

Nacimiento group (Puerco and Torrejon formations (1)).—The Nacimiento group, which comprises the Puerco and Torrejon formations, is about 830 feet thick and in this region rests unconformably on the Lewis shale. It consists of alternating beds of sandstone, shale, and sandy shale. The sandstones are prevailingly light gray to buff or brown, and the shales are generally dark gray. The Puerco and Torrejon formations each contain a distinctive vertebrate fauna.

---

(1) Gardner, J. H., The Puerco and Torrejon formations of the Nacimineto group: Jour. Geol., vol. 18, pp. 702-741, 1910.

Wasatch formation.—The base of the Wasatch formation is marked by a conglomeratic sandstone which is variable in thickness but probably averages about 300 feet. Overlying it are several hundred feet of variegated sandy shales and shaly sands. The entire thickness of the Wasatch is not represented in the area under consideration.

MIOCENE AND PLIOCENE SERIES

Santa Fe formation.—This formation which overlies the Wasatch formation, from which it is separated by an erosional unconformity, is not present in the part of the Rio Puerco Valley that is under consideration, but it occurs on the plain called La Ceja, several miles southwest of the Rio Puerco. It consists of conglomerate and sand, most of which is poorly cemented.

PLIOCENE (?) IGNEOUS ROCKS

The Mesa Prieta and the San Mateo Mesa are covered with basalt. Here the basalt rests on the Mesaverde formation and the Mancos shale and its age can not be definitely determined. However, in the Santa Ana Mesa, along Jemez Creek, 20 miles or more southwest of the Mesa Prieta, basalt of similar character overlies the Santa Fe formation. It is therefore probable that the basalt along the Rio Puerco is also younger than the Santa Fe formation. In the Rio Puerco Valley, between the San Mateo Mesa and the Mesa Prieta, there are several peaks of varying height. These doubtless represent plugs and dikes that were former conduits through which the basalt was erupted.

QUATERNAY SYSTEM

Pleistocene and Recent Series

The surficial deposits of this region consist chiefly of alluvial gravel, sand, and silt that mantle the mountain slopes and underlie the stream channels and valley floors. The alluvium-covered slopes at the foot of the mountains and the stream terraces are considered to be of Pleistocene age whereas the alluvial deposits adjacent to the streams are of Recent age.

STRUCTURE

The geologic structure along the west slope of the San Pedro Mountains is too complicated to be described in detail in this report. Along the west face of the Sierra Nacimiento and San Pedro Mountains the sedimentary beds stand on end or are overturned and dip towards the east, the more resistant beds thus forming hogback ridges. This structural condition is brought about by the presence of a large fault that parallels the west front of mountains.

The field work of the past season definitely established the fact that the fault along the northern part of the range is an overthrust and that in some places there is more than one fault plane. The strike of the rocks adjacent to the mountains is approximately north-south, but southward the strike of each formation, beginning with the youngest, changes to northeast and the dip becomes northwest and of considerably less magnitude than adjacent to the mountains. This change of strike and decrease in dip cause the outcrop of each formation to widen and to swing westward across the Rio Puerco. As one descends the San Jose-Rio Puerco Valley, he therefore in turn crosses the Wasatch formation, Puerco and Torrejon formations, Lewis shale, Mesaverde formation, and Mancos shale, the last named formation being at the surface in the southern part of the area described in this report.

The regional structure is modified by several minor flexures which show an eastward dip. These occur chiefly along the Rio Puerco south of La Ventana.

ARTESIAN CONDITIONS

General Principles

The geology of western Sandoval County is favorable for producing artesian conditions in parts of the San Jose-Rio Puerco Valley. Several of the sandstone formations that have been described are doubtless sufficiently porous and permeable to be good waterbearing rocks. They are interbedded with shaly formations that are relatively watertight and doubtless serve as confining beds. The sandstones crop out on the west slope of the mountains, high above the valley, and receive their water supply from the precipitation on the mountains. West of the mountains, where they pass under the valley, they are covered by shale beds which, it is believed, confine the water in the sandstones under artesian pressure. Wells drilled in certain parts of the valley into the sandstones will obtain water that will rise to a considerable height in the wells, and in some localities will doubtless rise above the surface, thus producing flowing artesian wells.

PROBABLE SOURCES OF ARTESIAN WATER IN THE SAN JOSE - RIO PUERCO VALLEY

The sandstones which may be expected to yield artesian flows within a reasonable depth in the San Jose-Rio Puerco Valley are (1) sandstones in the Wasatch formation, especially the basal bed; (2) sandstones in the Nacimiento group; (3) sandstones in the Mesaverde formation; (4) the Dakota(?) sandstone; and (5) the sandstones in the Morrison formation. The Poleo sandstone is known to be a waterbearing bed of considerable importance, but as supplies can probably be obtained at less depth from overlying formations, it would be inadvisable at present to drill to the Poleo.

PROSPECTIVE AREAS OF ARTESIAN FLOW

It was explained on page 73 that the youngest geological formations are at the surface in the upper part of the San Jose-Rio Puerco Valley, and that as one descends the valley southward successively older strata are crossed. The geologic section that will be encountered in drilling will depend on the location of the well. It is, therefore, desirable to describe the artesian prospects along several different stretches of the San Jose-Rio Puerco Valley. (See Figure 1).

San Jose Valley.—The valley of the Arroyo San Jose, from a point about 2 1-2 miles north of Cuba, northward about to the Rio Arriba-Sandoval line, is regarded as a prospective area of artesian flow. The middle of the valley in the vicinity of La Jara store is regarded as probably the most favorable place for testing the artesian prospects. Here the basal sandstone of the Wasatch formation is close to the surface, and this sandstone and those in the underlying Nacimiento group may be tested within a depth of 900 feet. Water will probably be obtained at a depth of less than 500 feet.

It has been recommended (p. 67) that the artesian prospects of the San Jose Valley be tested in the vicinity of La Jara by drilling one of the State wells near there. The shaly sands above the basal sandstone of the Wasatch formation are probably not as good water-bearing beds as the basal sandstone, and northward from La Jara store the depth to the latter increases.

Vicinity of Cuba.—At Cuba the rocks of the Nacimiento group are at the surface. Here the westward dip is probably insufficient to produce a flowing well, but water of satisfactory quality can doubtless be obtained by drilling 200 feet, or more, into the basal beds of this group.

A flowing well might perhaps be obtained at Cuba by drilling to the Mesaverde formation. In order to test this possibility it would be necessary to drill through the Nacimiento group and through about 1,500 feet of impervious Lewis shale before the Mesaverde would be reached. This would require at least 1,800 feet of drilling, and with only the present appropriation available a test well of this depth is not considered advisable.

Rio Puerco Valley above La Ventana.—From a point near the mouh of Arroyo Los Pinos northward for about 10 miles, the Rio Puerco Valley is regarded as favorable for testing the Mesaverde formation for artesian water supplies. A well drilled in the valley of the Rio Puerco about half a mile north of the mouth of Arroyo Los Pinos would test the entire section of Mesaverde rocks within a depth of 900 feet. Ground water would probably be obtained at much less depth and there are good prospects that this water would rise to the surface by artesian pressure. It has been recommended that the third test will be drilled at this place (p. 67). Along the Rio Puerco northward from the mout of Arroyo Los Pinos the depth to the Mesaverde rocks increases.

Rio Puerco Valley below La Ventana.—At La Ventana and southward in the Rio Puerco Valley the Mancos shale is at the surface and the first prospective waterbearing bed is the Dakota (?) sandstone. At La Ventana this sandstone is about 1,900 feet below the surface, and from this point the depth gradually decreases southward along the Rio Puerco to Casa Salazar, which marks the southern limit of the area covered in this report. It is very probable that flowing wells can be obtained at some places along the Rio Puerco within this stretch. The Morrison formation, which lies below the Dakota (?) sandstone, is also doubtless water-bearing in this stretch.

Piedra Lumbre Valley.—In the country immediately bordering the Piedra Lumbre, in Secs. 21, 22, 28, 29, 32 and 33, T. 19 N., R. 2 W., and even southward into the next township, artesian water can probably be obtained by drilling a few hundred feet into the sandstones of the Mesaverde formation. These sandstones dip northwestward beneath the valley and the abundance of springs within the area of their outcrop shows that they are water-bearing.

Financial Statement

San Jose-Rio Puerco Investigation

Appropriation by 1925 Legislature			$10,000.00
Expenditures 13th fiscal year:			
Equipment	$151.30	$ 151.30	
Balance June 30, 1925		9,848.70	
		$10,000.00	$10,000.00
Balance July 1, 1925			$ 9,848.70
Expenditures 14th fiscal year:			
Salaries	$1,118.88		
Subsistence	360.85		
Transportation	492.77		
Equipment and Supplies	29.23		
Miscellaneous Expense	46.28	$ 2,048.01	
Balance June 30, 1926		7,800.69	
		$ 9,848.70	$ 9,848.70

SOCORRO - TORRANCE INVESTIGATION

Chapter 69 of the 1925 Session Laws makes an appropriation and directs the State Engineer to investigate the feasibility of supplying reservoirs for irrigation puposes from artesian wells or pumping plants on State lands within the Counties of Socorro and Torrance.

As a preliminary step arrangements were entered into with the United States Geological Survey for the necessary geological studies of this area and a reconnaissance was made by Kirk Bryan, a report of which is included herewith.

Because of the tying up of funds the final or detailed studies have not been made.

GROUND WATER RECONNAISSANCE
IN SOCORRO COUNTY
NEW MEXICO

By
KIRK BRYAN

GEOLOGIST IN THE
UNITED STATES GEOLOGICAL SURVEY

SEPTEMBER, 1926

CONTENTS

INTRODUCTION

Socorro County, in the south-central part of the State of New Mexico, has extreme dimensions of 100 miles from east to west and 75 miles from north to south, and contains approximately 5,400 square miles. The mere exploration of its broad plains and bold mountain ranges would require much time, and a complete study of the water resources of the area is a large undertaking. The present report summarizes a brief reconnaissance of parts of the county made by the writer from June 26 to July 9, 1925, for the purpose of learning the kind and extent of work necessary to determine the ground-water possibilities of the region. This reconnaissance was made at the expense of the State in carrying out an agreement between George M. Neel, State Engineer, and the United States Geological Survey for the ground-water survey of Socorro County under the provisions of Senate Bill No. 131, section 2, passed by the Seventh Legislature of New Mexico. From July 4 to 9, Mr. O. E. Meinzer, chief of the Ground Water Division, accompanied the writer and participated in the observations with his mature skill in ground-water work.

GEOGRAPHY

Rio Grande Valley

The dominant feature of the county is the broad north and south depression formed by the flood plain and terraces of the Rio Grande. In the northern part of the county this depression is 6 to 7 miles wide, but in the southern part its width is about 15 miles and its boundaries are less well defined. In the northern part it is bounded sharply on the west by the small but precipitous Socorro Mountains, and on the east it merges more gradually with the ragged hills and plateaus that lie south of Los Pinos Mountains. Further south it is bounded on the west by the rugged San Mateo Mountains, and merges to the east with the Jornada del Muerto. Below the general level of this depression and enclosed by the dissected terraces known as the "foot hills," is a verdant flood plain of the river, from 1 to 3 miles wide, to which the term "valley" is often restricted. The elevation of this flood plain ranges in the county from about 4,550 to about 3,950 feet above sea level, and the river has a grade of about 5 feet to the mile. The southern 20 miles is included in the Elephant Butte Reservoir. The land of the flood plain is irrigated by ditches heading at numerous points on the river, or consists of river channel, overflow land, swamp, and meadow. Here are the principal settlements and the main routes of travel, both road and railroad. The numerous small streams which drain the tributary area have dissected the terraces into gulches of the most intricate form. This detailed carving has produced a region of steep slopes which an adequate rainfall and a gravelly soil make unfavorable for the growth of vegetation. The land is of little value even for grazing. The numerous outcrops in the deep gulches afford, however, unusual opportunities for studying

the nature of the valley fill, which in most other valleys is generally concealed and known only imperfectly from well records.

The slopes of the ridges between the gulches are not uniform and are apparently divided into two main groups: 1. remnants of an extensive erosion surface, or pediment, capped with gravel deposited during the erosive process; 2. remnants of a lower, less extensive erosion surface forming a discontinuous terrace on each side of the river flood plain and narrow benches along the principal tributary gulches. The earlier erosion surface was formed when the Rio Grande flowed at a level 350 to 450 feet higher than its present bed. The later erosion surface indicates, by its position, that during its formation the river flowed at a height only 200 to 250 feet above its present level. Below these remnants lie dissected alluvial fans and vaguely defined remnants of a still lower terrace. These terraces testify to a long sequence of geologic events which are as yet only imperfectly known.

JORNADA DEL MUERTO

The great plain which because of its inhospitable character gained at the time of the Spanish conquest the name "Jornada del Muerto" (Day's journey of death) forms the greater part of the eastern section of Socorro County. In this county it is bounded on the east by the Chupadera Mesa and the Oscura Mountains. It extends in a southwesterly direction to the county line and thence southward for many miles between the San Andreas Mountains on the east and the Fra Cristobal Mountains and Sierra Caballo on the west.

In this great plain the dra nage is feeble. The water that is occasionally shed from the adjacent mountains pours in floods upon the plain, where it is largely lost by evaporation and seepage into the cavernous gypseous soil. The excess water finds its way through tortuous channels, blocked here and there by sand dunes, into the Rio Grande near the south boundary of the county.

PLAIN BETWEEN THE SOCORRO AND MAGDALENA MOUNTAINS

Between the Socorro and Magdalena mountains lies a plain about 6 miles wide and 20 miles long. It merges to the south with the expanded upland in which the valley of the Rio Grande has been cut, and to the north with the rough and dissected country of the lower part of the Rio Salado. The larger part of this plain consists of smooth gravelly slopes fairly well covered with grass and suitable for grazing.

SAN AUGUSTIN PLAINS

The important feature of the western part of the county is the great enclosed basin known as the San Augustin Plains. This basin is bordered on the north by the Bear, Gallinas, and Datil mountains, on the west by the Tularosa Mountains and the more subdued elevations known as the Continental Divide, on the south by an almost continuous belt of mountains including O Bar O, Pelona, and Tuera mountains, and on the east by the Magdalena Mountains and adjacent hills. This basin is 60 miles long from northeast to southwest, and tapers from a width of 20 miles at the northeast end to about 6 miles at the southwest. The drainage is feeble and many of the ephemeral streams that head in the mountains occasionally give rise to floods which spread out over the plain and eventually are lost by seepage into the gravelly soil.

During heavy floods the water reaches two small playas, White Lake, in T. 1 S., R. 7 W., and North Lake, in T. 1 S., R. 8 W., and a much more extensive playa at the siuthwest end of the basin. This large playa is part of the floor of an ancient lake whose waters reached an elevation slightly above the present 6,900-foot contour line and at least 120 feet above the lowest part of the lake floor. The shore features of this ancient lake are well displayed at the south end of the hills south of Horse Springs, T. 5 S., R. 13 and 14 W., as wave-cut cliffs with gravel beaches. A definite and well-defined gravel beach was observed east of the Gutierrez Ranch, on which stands the Geological Survey's bench mark 6903. When the water stood at this elevation the lake was about 25 miles long and 7 miles wide. It seems most suitable that this old lake should be called Lake San Augustin since it lies in the San Augustin Plains. The floor of the old lake is covered in large part by luxuriant greasewood, a bush known in New Mexico as chico. A large part of the old lake bottom lies in Catron County. The part of the San Augustin Plains that lies in Socorro County consists largely of gravelly grass-covered slopes suitable for grazing and with arable soil on which dry farming has been attempted.

WATER-BEARING FORMATIONS OF THE PLAINS AREAS

GENERAL STATEMENT

In the brief time that was spent in this preliminary examination of the water resources of Socorro County it was impossible to see much of the mountainous and hilly areas, where, however, water-bearing rocks occur. In general water supplies in these areas of rough topography are valuable only for stock, but there are numerous small valleys and plains within the hilly country in which, if water could be obtained cheaply enough, crops could be grown to advantage. Moreover, an adequate number of good water supplies for stock would increase the value of the range contiguous to farming areas. For these reasons a systematic study ought to be made of the ground-water conditions in the hilly country.

The plains areas on which some information was gathered are the Rio Grande Valley, the Jornada del Muerto, the plains between the Socorro and Magdalena mountains, and the San Augustin Plains, all of which have been briefly described. The valley of the Rio Salado and adjacent plains and valleys, the open valleys near Que-

mado, and the Palomas drainage area were not visited, although doubtless valuable water supplies can be found in these localities.

RIO GRANDE VALLEY

Unconsolidated deposits consisting chiefly of gravel, sand, and clay underlie the Rio Grande Valley and adjacent upland to very great depths and are well exposed in the gulches tributary to the river. The deposits on the east side of the river are variable in character, ranging from sand to boulder beds, but are predominantly coarse. They consist largely of beds of loosely cemented, reddish gravel that dip 2 to 5 degrees toward the west. Irregular fragments of gray limestone derived from the Chupadera formation which crops out immediately to the east are most common, but pebbles of many other types of rock occur. Due to its open and porous texture this material is well adapted to absorb and transmit water. The material on the west side of the valley is of much finer grain, including fine sand and clay with interbedded basaltic lava flows. These beds are generally though not consistently tilted gently toward the west. At several localities near the foot of the Socorro Mountains the beds are much disturbed. Obviously the materials on both sides of the Rio Grande Valley were deposited in a large ancient valley. The coarse gravel on the east side was deposited on the alluvial slopes of the valley and the fine sand and clay on the west side were deposited in the central areas, in which lakes may have existed. This ancient valley has its center line near the east front of the Socorro Mountains. The uplift of this range cut off the deposits that once lay farther west, and these deposits have either been eroded away or now lie buried in the plain west of the mountains. The coarse permeable beds that prevail on the east side of the valley are more or less imbedded with and partly buried in the finer and more impervious beds that characterize the west side of the valley. This condition, together with the general tilt of the valley fill toward the west holds out hope that artesian conditions may exist in limited areas, such as the slope west of Limitar. However, the details of the arrangement of the beds and their attitude from place to place have not yet been adequately observed, and definite recommendations as to localities in which test wells should be sunk can not be made until further field work has been done.

The main body of valley fill is overlain by thin sheets of gravel of various ages which were deposited on erosional plains and terraces. Similarly in the verdant river bottom, a considerable body of alluvium, perhaps as much as a hundred feet thick, overlies the main valley fill. On the flood plain or bottom lands of the Rio Grande water is close to the surface, and in many places the ground is swampy and alkaline. The underlying deposits for a considerable depth are open and porous, and yield water freely to shallow wells. The water is, however, somewhat mineralized and water of better quality is in demand. On the secondary alluvial slopes between the first terrace and the irrigation ditches, locally called "la ladera," water supplies are needed for household use and for irrigation. Larger supplies are also needed for the growing towns of the valley. In many places wells less than 100 feet deep give adequate supplies, but in other places shallow wells yield little water. The prospects for obtaining supplies by drilling deeper into the main body of valley fill depend on the character in depth of that material. The same studies required to solve the question of artesian supply will also answer these questions—a proper solution of which is of considerable economic importance.

JORNADA DEL MUERTO

Near the middle of the northern part of the Jornada del Muerto there are shallow wells which yield water of so poor a quality, because of its mineral content, that it is valuable only for stock. On the margins of the plain it is necessary to drill deeper for water, and even deep wells are not always successful. With respect to possible irrigation the questions to be answered are whether deeper wells in the shallow-water belt along the center line of the plain will yield better water that will overflow or rise close to the surface, and whether rules can be formulated by which sites for flowing wells or successful pump wells can be selected near the margin of the plain.

The great plain of the Jornada is in its northern part underlain by bedded rocks of various ages. Whether artesian water can be obtained depends on the order and character of the rocks and their attitude. The general structure appears to be synclinal (1) and therefore somewhat favorable, but it has yet to be determined whether pervious beds occur and whether they lie effectively confined between impervious beds. Farther south, in this same valley, a faulted and deformed valley fill may be present similar to that in the Rio Grande Valley at Socorro. South of the county line a number of deep wells have been sunk which seem to show that artesian water can not be expected. Within this county, however, further geological work may show that the requisite conditions for an artesian basin occur.

PLAIN BETWEEN THE SOCORRO AND MAGDALENA MOUNTAINS

In this broad area a number of wells have been sunk which encountered water in moderate quantities at depths of 100 to 300 feet. The possibility of artesian water at reasonable depths seems on the basis of these tests alone to be rather remote. Preliminary examination indicates that this valley is underlain, at depths ranging up to 200 or 300 feet by a deformed valley fill. This ancient fill is covered by younger valley fill composed of materials brought down by the streams from the Magdalena Mountains since their uplift. The process of uplift is still going on, as is shown by the fact that on the east side of these mountains a recent fault scarp, about 40 feet high, can be traced for several miles. A well recently drilled between the mountains and this scarp found water at a level about 100 feet higher than is found in wells out on the plains. This fact indicates that further study may bring to light a valuable shallow-water zone near the mountains.

SAN AUGUSTIN PLAINS

Numerous wells have been drilled in various parts of the broad

(1). Darton, N. H., Geologic structure of parts of New Mexico: U. S. Geol. Survey Bull. 726, pp. 229-232, 1922. Fig. 31, and Pl. XLII.

San Augustin Plain. Most of these wells penetrate relatively unconsolidated alluvium. Water stands at depths ranging from 140 to 250 feet throughout most of the eastern part of the plains, but water at a depth of less than 10 feet from the surface occurs in the floor of ancient Lake San Augustin, at the west end of the basin. The prospects are not good for locating a shallow-water belt of considerable size except at the western border of the county within the old lake shore.

The greater part of the lake floor is a smooth plain largely covered by greasewood. Around the borders of this flat swamps and springs occur and the presence of the greasewood, a well known phreaophyte, indicates that water is shallow throughout the whole area. Evidently large quantities of ground water reach this old lake bed, there to evaporate or to be transpired by the greasewood. At White Lake and North Lake the depth to ground water, as indicated by wells, is more than 100 feet, and there is apparently no loss of ground water by evaporation or transpiration. Most of the water that is absorbed in this part of the basin probably percolates to the old lake floor at the southwest end of the basin. Most of this shallow-water area lies in Catron County, but since this is the place where the ground water emerges a study of the loss of water from the flat by evaporation and transpiration is necessary to evaluate the ground-water supplies of the Socorro County portion of the basin.

Prospects for artesian water rest largely on the nature of the unconsolidated deposits which fill the basin. Obviously these beds are for the most part much older than the ancient lake. If they have been deformed, like the valley fill that underlies the Rio Grande Valley, artesian structure may exist. The brief reconnaissance that was made has not brought forth any tangible evidence on th's question.

SUMMARY

The preliminary survey indicates that more detailed investigation of the ground-water conditions would be justified in several areas which have some promise for future development. Moreover, as such an 'nvestigation would proceed other localities of equal promise might be found. The characteristics of these areas are listed below:

1. In the Rio Grande Valley the low alluvial fans, locally known as "la ladera," between the foot of the terraces and the river flood plain, form discontinuous narrow strips of cultivable land in which shallow pump wells will doubtless y eld valuable supplies of water to supplement the river water of the ditches or to irrigate independently small tracts. 2. Similar areas near Limitar may prove on further study to be underlain by deformed valley fill that will yield artesian water. 3. In the northern part of the Jornada del Muerto the rocks have a synclinal structure but it rema'ns to be determined whether there are confining beds that are effective in holding ground water under artesian pressure. Further study will throw light on this question, and even if the results should prove disappointing as to the prospects for artesian flows, much information will be obtained as to the proper location of wells for watering stock. 4. The San Augustin Plains, a large intermountain basin, suitable for grazing and possibly for dry

farming, are underlain by a large body of ground water that is only partly developed for stock water. The shallow-water area, some of which may eventually be irrigated by pumping from wells, lies chiefly in Catron County, but extends into the western part of Socorro County.

Financial Statement

Socorro-Torrance Investigation

Appropriation by 1925 Leg'slature			$20,000.00
Expenditures for 13th fiscal year:			
Equipment	$302.59	$ 302.59	
Balance June 30, 1925		19,697.41	
		$20,000.00	$20,000.00
Balance July 1, 1925			$19,697.41
Expenditures for 14th fiscal year:			
Salaries	$196.65		
Subsistence	82.35		
Transportation	56.24		
Equipment and Supplies	5.25	$ 340.49	
Balance June 30, 1926		19,356.92	
		$19,697.41	$19,697.41

DE BACA COUNTY INVESTIGATION

Chapter 124 of the 1925 Session Laws makes an appropriation and directs the State Engineer to investigate the water supply available for State or private wells in De Baca County, New Mexico, by drilling or d'gging wells or otherwise as he may deem best.

Here also arrangements were made for the detailed geological studies and which was interfered with.

Herewith is given the Reconnaissance by Mr. Kirk Bryan covering this area.

GROUND WATER RECONNAISSANCE IN DE BACA COUNTY

NEW MEXICO

BY
KIRK BRYAN

GEOLOGIST IN THE UNITED STATES
GEOLOGICAL SURVEY

SEPTEMBER, 1926

GENERAL STATEMENT

DeBaca County lies in the plains of east-central New Mexico. It is laid out on the Government land lines and is nearly square, extending about 50 miles east and west and about 40 miles north and south. The area is about 2,100 square miles.

Three days were spent in August, 1925, in travel by automobile from Roswell to the county, in travel within it, and in return. Mr. O. E. Meinzer accompanied the writer on this trip. The trip was a reconnaissance preliminary to a geologic investigation, that was to be made of the artesian-water prospects of the county in accordance with House Bill No. 189, passed by the Seventh Legislature of New Mexico. As the funds appropriated for this purpose became unavailable, the investigation has not been made but the following statement of the general conditions is presented on the basis of available information.

TOPOGRAPHY

The principal feature of the county is the broad terraced valley of Pecos River, whose course lies from north to south in the eatern third of the area. To the east of the river the land rises rapidly to a well marked escarpment which lies from 1 to 2 miles within the county boundary and which marks the beginning of the High Plains, here known as the Llano Estacado. On the west there is a more gentle rise to the extensive plains characteristic of this part of the State.

The principal route of travel is the Atchison, Topeka and Santa Fe Railroad, which crosses the county from east to west in the northern third. Fort Sumner, located where the railroad crosses the Pecos River, is the county seat and principal settlement. Near this town there is considerable land irrigated by water derived from the Pecos River. A good road parallels the railroad from east to west, and fair roads lead north from Fort Sumner to Santa Rosa on the east side of the river and south to Roswell on the west side.

WATER-BEARING FORMATIONS

In general the county is underlain by rocks of the Chupadera formation, but near Guadalupe, on Pecos River and eastward to Taiban, beds of the Dockum group crop out. Along the escarpment of the High Plains, sand, clay, and gravel of Tertiary age overlie the older rocks. Adjacent to Pecos River sand and gravel occur on terraces and the flood plain of the river is underlain with alluvium. A thin cover of soil, wind-blown sand and caliche masks the underlying rocks over large parts of the county.

The Chupadera formation and associated beds dip gently eastward throughout the county. There are, however, numerous local variations from the regional dip, by which low domes and terraces are formed in which the hopes of oil prospectors are centered. Since the lower beds lie at the surface to the westward at elevations of 5,000 to 6,000 feet and pass below the valley of Pecos River, which has an elevation of 4,500 feet, it is obvious that the beds have the right attitude for an artesian basin. However, unless certain beds are per-

meable and are overlain by impervious beds it is impossible for water to be confined under pressure so as to produce artesian flows. The Chupadera formation in this region consists largely of limestone, sandstone, and gypsum. A well (1) 3,200 feet deep, 5 miles south of Buchanan, penetrated beds of red shale and limestone with much gypsum between 200 and 600 feet, and 200 feet of salt between 2,105 and 2,460 feet. These data indicate that the Chupadera formation in its upper part at least is unlikely to have impervious beds suitable for confining artesian water. However, the general thickness is thought to be between 1,000 and 1,200 feet, and since the material is highly variable, more favorable conditions may exist in other places. Below the Chupadera formation the Abo sandstone, about 800 feet thick, rests on limestone of the Magdalena group or on the underlying crystalline rocks. Near the outcrop the Abo sandstone are generally tightly cemented and unfavorable for water. Similarly the Magdalena rock is generally a heavy bedded limestone likely to be sealed and impervious at depth. In places in eastern New Mexico also, as shown by Darton (2), the Magdalena is wholly or nearly absent.

Thus there are a number of indications that the details of the order and thickness of formations in this area are unfavorable for obtaining flowing wells. Moreover, the water in deep wells may be of poor quality. Yet the fact of the favorable dip of the beds remains as an incentive for a thorough study of the area and a reconsideration of the results of drilling in the past before reaching unfavorable conclusions as to the possibility of obtaining artesian flows.

The flood plain of Pecos River and the adjacent lower terraces are underlain by alluvium that is water-bearing. Much of this material consists of relatively coarse gravel. Wells suitably located should yield freely, and pumping for irrigation should prove economical if the water is used as a supply supplemental to the ditch water.

In the plains country, both east and west of the valley of Pecos River, the problem of securing sufficient water for domestic and stock purposes is difficult. Where the surficial deposits of sand, caliche, and other materials are thick, shallow wells may be successful and a considerable amount of time could well be spent in locating and studying such possibilities, since the full development of the area as a stock-raising and dry-farming country is dependent on adequate and well distributed water supplies. Water supplies adequate in quantity and quality for stock use can be obtained in deep wells in some parts of the county where the supplies would not be adequate and the head would be too low for irrigation use. A geologic survey of the county should give valuable information as to water supplies available for stock and general use from deep sources.

(1). Darton, N. H., Geologic structure of parts of New Mexico: U. S. Survey Bull. 726, p. 199, 1922.
(2). Darton, N. H., op. cit., p. 195.

Financial Statement

De Baca County Investigation

Appropriation by 1925 Legislature			$7,500.00
Expenditures 13th fiscal year:			
Equipment	$151.30	$ 151.30	
Balance June 30, 1925		$7,348.70	
		$7,500.00	$7,500.00
Balance July 1, 1925			$7,348.70
Expenditures 14th fiscal year:			
Salaries	$119.81		
Subsistence	17.20		
Transportation	3.66	$ 140.67	
Balance June 30, 1926		7,208.03	
		$7,348.70	$7,348.70

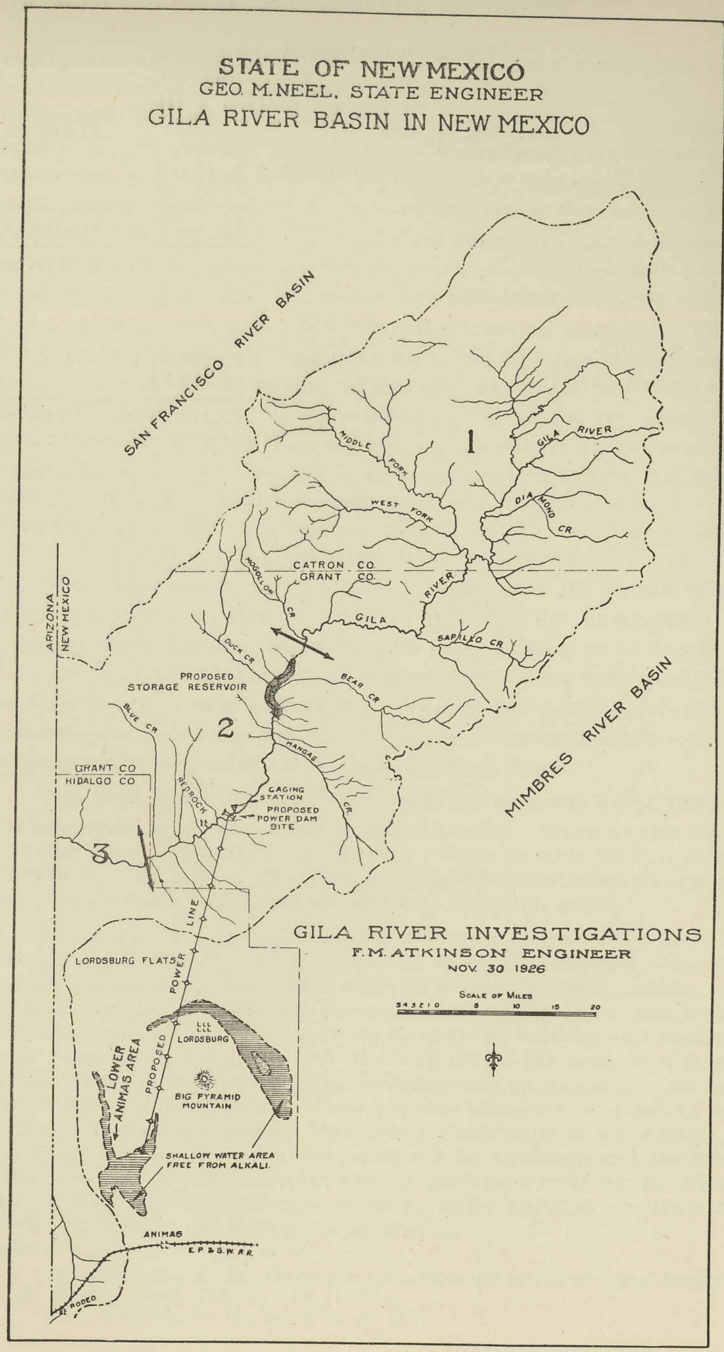


Plate 1.—General map showing location of Gila Investigation.

GILA RIVER INVESTIGATION

Preliminary Report

INTRODUCTION

Chapter 92 of the 1925 Session Laws of New Mexico appropriated $10,000 for the purpose of investigating reservoirs, canals, damsites, and the underflow of the Gila River within Grant and Hidalgo Counties, New Mexico. In compliance therewith this investigation was assigned to Mr. F. M. Atkinson as Engineer in Charge and the following preliminary report is submitted and the final detailed report, with maps, graphs and illustrations, will be completed and placed in the files of the State Engineer's Office.

The demand for irrigation engineering data in regard to the possibilities of using the waters of the Gila River within New Mexico became urgent upon the decision of the Federal Government to construct the San Carlos Irrigation Project in Arizona.

The San Carlos Project contemplates the irrigation of about 80,000 acres in Pinal and Maricopa Counties and in the White Mountains Indian Reservation with some in the neighborhood of Florence and Casa Grande, all in Arizona.

DESCRIPTION OF WATERSHED

The Gila River rises in T. 10 S. on the west side of the Continental Divide, flows in a general southwesterly direction across Catron, Grant and Hidalgo Counties New Mexico, thence across the State of Arizona into the Colorado River at Yuma.

That portion of the Gila basin within New Mexico, about 4,040 square miles in extent, of which 3,500 square miles is tributary to the Red Rock gaging station, may be divided into three distinct districts topographically. From the source the first seventy miles of the channel is through rough mountainous country within which there is about 600,000 acres of commercial timber, ranging in elevation from 5,000 to 8,000 feet. The second or middle district begins at Mogollon Creek and extends some 42 miles to a point about 14 miles above the Arizona State line through an area which contributes none but an irregular flood runoff, ranges in elevation from 5,000 to 4,150 feet above sea-level and supports only a scant desert vegetation. The third district may be designated as the agricultural section for here the river enters the long, narrow, fertile valley where a great variety of crops are successfully raised. Only a small portion, about 3,000 acres, of this farming land lies within the State of New Mexico, for the valley floor is but a mile wide while farther downstream, across the line, the width increases considerably. The elevation of this district ranges from 4,150 to 3,800 feet and the gradient of the stream is 12 to 17 feet to the mile.

WATER SUPPLY

The best record of the run-off at any section is that at the gaging station near Red Rock in Sec. 23, T. 18 S., R. 18 W., established in

1908 by the United States Geological Survey and now maintained by the State of New Mexico. All the following data refer to that station. As these records are not continuous from the date of establishment an estimate was made of the run-off for the time the records are missing and inserted after a study of the relation between the rainfall and the run-off was made.

Graphical studies indicate that a continuous annual draft of 160,000 acre-feet can be had from this stream with a net storage of 212,000 acre-feet. The 18-year period of record, from January 1, 1908 to December 31, 1925, shows at least one cycle of dry and wet years. Assuming a full reservoir January 1, 1908, a gradual draw-down of the reservoir supply would take place until July 1, 1914, when it would increase till the full capacity had been reached March 1, 1915, and a waste of 373,000 acre-feet result through the following 26 months to May 1, 1917. During the year 1925 there would be a period of shortage, the extent of which is unknown until further records become available. One reasonable shortage in 18 years is allowable and within the limits usually placed when calculating storage, however, the draft in actual practice would likely be less than the figure above used, thus obviating the indicated shortage.

RUN-OFF OF THE GILA RIVER AT RED ROCK, NEW MEXICO
(In Acre-Feet)

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
1908	5,000*	8 000*	4,800*	3,800*	2,700*	2,100*	12,000*	19,000*	3,900*	1,000*	3,600*	3,680	69,600
1909	3,130	10,100	42,200	20,300	13,000	2,870	7.260	18.900	15,200	5,610	5,850	9,100	154,000
1910	9,960	5,830	5,350	5 190	3,440	2,640	2 430	2 740	2.660	3.480	4,500	5,740	54,000
1911	28,500*	26,600*	15,400*	3,900*	4,000*	29,000*	41 600*	33,000*	12,000*	12,000*	3,900*	3,900*	214,000
1912	2,800*	16 700*	44,400*	26,400*	12,000*	7,400*	21,400*	6,100	5,550	5 340	5,120	5,060	158,000
1913	4,920	4 720	17,800	22,600	9,720	4,190	3.010	8 240	8,210	11.900	14,500	9,590	119,000
1914	10,800	13,300	16,400	11 900	7,990	4,860	48,600	27,200	16,800	29,800	24,200	78,100	290,000
1915	52,000*	34,300	77,500	81,200	33,800	13,400	28.900	22,700	12,100	9,250	6,840	8,220	380,000
1916	55,500*	35,000*	32,000*	17,100*	14,500*	5,200*	19,000*	34,000	50,600	50 000*	9,920	9,240	332,000
1917	18,200*	19,600	32,900	24 000	13,500	6,600	4,910	4,670	3,550	3,470	3,380	3,980	139,000
1918	5,130	5,200*	14,000*	4,330	4,240	3,320	2 460	5 230	2,790	6,300	6,320	9,700	69,000
1919	8,020	15 600	43,900	59,100	22,700	8,460	31,300	17,100	10,300	6,470	7,850	12,400	243,000
1920	15,800	56,400	24,200	17,500	20,300	9,870	4,210	11,000	6,550	4 270	10,100	4,740	185,000
1921	5,360	2,810	6,380	3 950	4,940	5,620	15,800	35,400	9,240	2 150	4,030	3,460	99,100
1922	5,650	6,220	5,200	4,000	2,960	2,510	7 730	2,990	3,710	3,190	3,330	6,290	53,800
1923	4,650	5 450	18,500	11,900	7,110	2,330	9.780	37,700	32,900	6,330	7,650	18,760	163,000
1924	22,100	12,800	14,800	45,700	23,600	6,410	15,230	2,360	2,370	3,610	4,100	4,400	157,000
1925	4,300	3,610	3,670	2,520	2,460	3,380	6 150	10,100	4,130	11,700*	6,800*	5,890	64,700

NOTE: *Partly estimated or estimated.

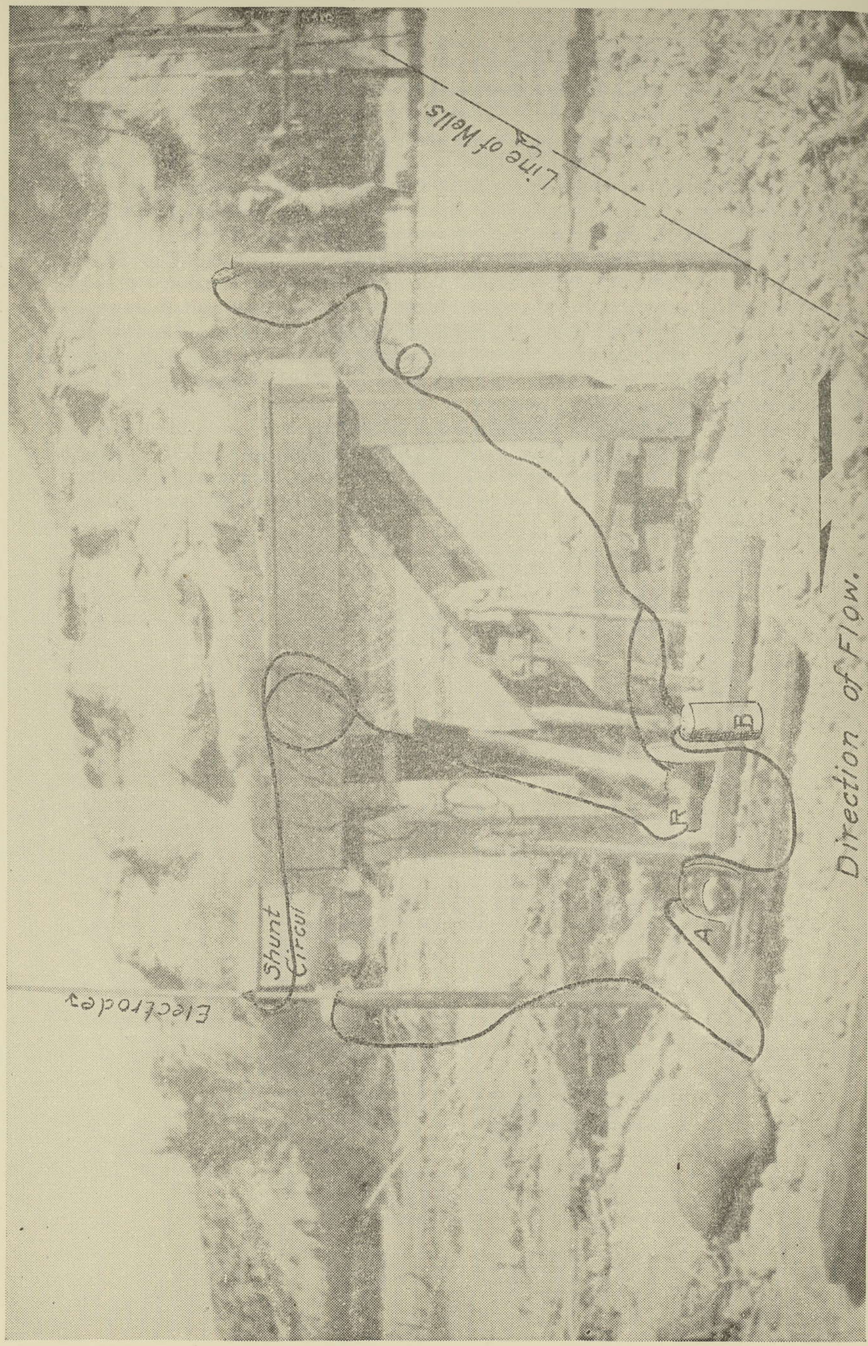


Plate 2.—Showing general arrangement of equipment for electrical determination of underground water velocity.

CLIMATIC CONDITIONS AND RAINFALL

In the upper mountainous district the annual ra'nfall amounts to from 16 to 20 inches and more and the melting snow in March is often noticeable in the run-off. Mild temperatures prevail, the mean maximum at Silver City, just on the border of the basin, being 65.5 degrees. In the middle district desert conditions prevail with a mean maximum temperature of 77.4 degrees at Lordsburg just below the southern boundary of the basin and where temperatures considerably over 100 degrees are often recorded. The Arizona type of rainfall is characteristic here during the months of July and August. This is felt in the sudden heavy showers covering small areas. During the remaining months the precipitation is of a more moderate variety, falling at a lower rate and covering greater areas. The mean annual precipitation at Lordsburg is about 10 inches. These sudden summer rains usually fall on dry soil, thus causing sudden rises in the stream but giving usually a small quantity of run-off. High winds occur usually in the spring and early summer months. The annual evaporation is here used as five feet in depth on the calculated reservoir, which quantity is based on records taken at Deming. The climate and rainfall conditions in the third or farming districts are essentially the same as those in the second district.

UNDERFLOW INVESTIGATIONS

One of the two main points to be determined under the legislative act is the quantity of underflow in the bed of the Gila River in the third district. As a first step, electrical tests were made to measure the veloc'ty of the water through the sands, at a section near the logical diversion point on the river that would supply the entire third district. These tests show that the velocity is less than four feet per day. With this velocity, and the sectional area through which percolat'on can take place, and taking into consideration the porosity of the materials, it is concluded that the underflow could not possibly exceed two second-feet, an amount of little or no consequence for a water supply for the areas under consideration.

SURVEYS TO DETERMINE THE FEASIBILITY OF IRRIGATION ON THE LORDSBURG FLATS

The remaining primary object occasioning this investigat'on was that of reaching a decision on the question as to the feasibility of irrigation on the fertile area north and northwest of the town of Lordsburg. This is undoubtedly an excellent tract of land, the fertility of which is unqeustioned and the extent of which is far in excess of any area that can be irrigated by the quantity of water available.

Divers'on of water above the Red Rock Box, at the gaging station, is believed impracticable on account of the rough and broken character of the country. Consequently, surveys were made from this point to seek possible canal lines which would carry water to the Lordsburg Flats. No canal locations, either with or without tunnels, were found that would accompl'sh this object. The elevation

of the normal water surface of the river at the Red Rock Box is 4,085 at the outlet of the ten mile canyon. The elevation of the barrier ridge is from 4,300 to 4,600, while that of the proposed irrigable land is 4,250 and greater.

POWER FOR PUMPING

This stream system through the development of its power resources will likely contribute much to the advancement of the State of New Mexico. The cheap transportation of high tension power from power dams on the Gila across the high rough intervening country to the fertile Animas and Playas Valleys, undr which there are valuable supplies of water of sufficient purity and at sufficiently shallow depths, will materially aid in the development of an attractive 30,000-acre or larger pumping project in these land-locked basins.

Storage of flood waters will be of first importance, the most economic site for which is believed to be the "Cliff Site." The provision for the generation of auxiliary power will be an important factor in the design of this dam. The discussion of this pumping project presupposes co-operat on of the Arizona water users and the proposed users in the Animas Valley. One arrangement might be that the Arizona users be allowed to claim the entire flood water supply over and above the quantity now used and needed by residents of New Mexico and build their own storage in this State while the Animas and Playas users benefit by use of all the power developed.

From prel minary studies it is found, in all probability, there is a feasible project in these valleys which would utilize the shallow water existing there and the power which can be developed on the Gila River and considerable study has been and is being given these phases of the matter.

PROPOSED IRRIGATION BY PUMPING

Free use is here made of the Un ted States Geological Survey Water Supply Paper No. 422, "Ground Water in the Animas, Playas, Hachita, and San Luis Basins, New Mexico." The above mentioned paper states that there is an area, exclusive of areas covered by lava beds, sand dunes and alkali flats and other areas where the soils conta n excessive quantities of alkali, in excess of 26,000 acres in the Lower Animas valley in southern Hidalgo County where the underground water table is within 50 feet of the surface and where the soil is suitable for general farming. This statement has been verified by examination on the ground. Other smaller, shallow-ground-water areas nearby would bring the total ava lable acreage of such land to a figure much beyond the 30,000 acres here used in this calculation. This land will be very valuable for agricultural purposes if sufficient power for pumping can be supplied at a reasonable figure.

The power dam site considered is the one at the Red Rock Box for here a h gh dam can be constructed at low cost, which would impound a relatively small quantity of water, thus interfering with the operation of the lower irrigation project less than were the reverse conditions to hold.

In these calculations free use has also been made of U. S. Geological Survey, Water Supply Paper No. 396.

STORAGE RESERVOIR

The Cliff Dam s'te for the storage reservoir is located in Sec. 21, T. 16 S., R. 17 W., N. M. P. M. The maximum height used here is 225 feet, effective height 175 feet, including 50 feet below the surface for foundation which is largely problematical, top length 1,070 feet, bottom length 430 feet, volume 107,000 cubic yards of masonry.

Capacity Table

Contour	Acres	Capacity in Acre-Feet
4,600	2,259	
		178,400
4,500	1,308	
		82,600
4,450	343	
		19,250
4,425	42	
Total acre-feet		280,250

According to the above mentioned Water Supply Paper No. 396, this reservoir would flood Sections 15, 16, 10, 9, 4, and somewhat farther up the channel. This area includes no expensive highways, railroads or other features that would complicate the securing of the right-of-way.

The accumulation of silt in this reservoir is not expected to reach such proportions that the effective capacity would be greatly impaired. However, should silt become troublesome, a method of its control is outlined in Frank H. Olmstead's report on Gila River Flood Control.

POWER DAM

The power dam site is located in the E. 1-2 of Sec. 23, T. 18 S., R. 18 W. The maximum height here figured is 290 feet including eighty feet to bed rock (this also is problematical as no data are at hand on this depth). Top length is 650 feet, bottom length 127 feet, volume 72,000 cubic yards of masonry.

Reservoir Capacity Table

Contour	Area Acres	Capacity in Acre-Feet
4,300	581	
		35,300
4 200	125	
		7,800
4,100	31	
Total Acre-Feet		43,100

The backwater from this dam would reach a point about ten miles upstream, but would flood no property of value as the channel

in this reach is in canyon. Parts of Sections 23 and 13, T. 18 S., R. 18 W. and Sections 18, 7 and 5, T. 18 S., R. 17 W. and Sections 33 and 28, T. 17 S., R. 17 W. would be submerged.

CONCLUSIONS

From the work that has been done and studies that have been made, up to the present time, on the Gila River Investigations, the following conclusions may be recorded:

(a) That the subterranean underflow beneath the surface of the river channel which might be secured can not exceed two second-feet and is not sufficient to materially change calculations of water supply.

(b) That the direct diversion of water from the Gila River, either at stream elevation or at any reasonable height above the stream, because of excessively rough country intervening and the relatively high elevation of the land which it is desired to irrigate, is impracticable.

(c) That with an effective storage capacity of 212,000 acre-feet the Gila River, during an eighteen-year period, could have been made to support an annual draft of 160,000 acre-feet with but one comparatively inconsequential shortage occurring in 1925.

(d) That it is feasible to build storage on the Gila River in New Mexico for the purpose of insuring better water supplies for valley areas now under cultivation and for new areas which could thereby be irrigated.

(e) That there is more than thirty thousand acres of good agricultural land in the Animas and Playas Valleys under which there is an ample supply of good water for irrigation purposes at depths not to exceed fifty feet.

(f) That it appears feasible to develop a pumping project for those areas by the generation of hydroelectric power on the Gila River with a system in which the irrigation rights in the valley areas on the river would pay for the most, if not all, the necessary storage.

(g) And that the studies and investigations to determine such feasibility should be continued at least so far as is possible under the present appropriation.

Financial Statement

Gila River Investigation

Appropriation by 1925 Legislature			$10,000.00
Expenditures 14th fiscal year:			
Salaries	$2,980.21		
Subsistence	453.40		
Transportation	817.44		
Equipment	1,464.53		
Supplies	599.66		
Drilling	301.05		
Miscellaneous Expense	167.51	$ 6,783.80	
Balance June 30, 1926		3,216.20	
		$10,000.00	$10,000.00

CANADIAN RIVER INVESTIGATION

The Canadian Investigation, authorized by Chapter 93 of the 1925 Session Laws, directs the determination of the feasibility of storage and irrigation on the Canadian River System in San Miguel, Harding and Quay Counties. It is known to be a fact that there are large quantities of water which leave the State unused in the Canadian River every year, and that there are large areas of land in that vicinity, which, if supplied with water, would be highly productive and add millions to the wealth of the State.

To put water from the Canadian River on lands of that valley is a big and expensive undertaking, but it is hoped, by combining flood control for the lower area with irrigation for the upper, a feasible plan may be found. Toward this end a coalition of the interests in New Mexico, Oklahoma, Texas and even further down has been sought. There is always a chance that this big plan will not be realized, and, on the other hand, New Mexico dare not do less than bend every effort to that end.

While the work being done in connection with this investigation is primarily for the storage and application of water on lands within the State of New Mexico, it is not being forgotten that we have in this State storage sites that can serve admirably for flood protection to the lower reaches of the stream. With this in mind we are endeavoring to find reservoir sites of greater capacity than might be the case if irrigation alone were being considered.

There have been appointed commissioners representing New Mexico, Oklahoma, Texas, and possibly other states, who are endeavoring to work out an interstate compact or agreement under which the Canadian River and its tributaries will be developed in accordance with one large plan, and there is a possibility that such a plan might place some of the burden of construction, which would be beneficial to irrigated areas in New Mexico, upon areas in the lower States which would be benefitted by flood protection.

The work on this investigation was actively begun in August, 1925, and since that time there have been preliminary surveys on a large number of reservoir sites and several hundred miles of preliminary canal lines for the determination of feasible locations which will reach the lands to be irrigated. Among the storage sites already investigated are the Canon Largo, Lagarita, Conchas-Canadian, La Cinta, The Angostura, The Narrows, and the Bell Ranch. It is found that these sites will impound from two hundred thousand acre-feet up to one and one-half million acre-feet with dams which are not beyond reason.

In addition to the preliminary location surveys which have been made, considerable time has been given to the study and classification of the lands which it is hoped to irrigate and it has been finally determined that there is a great deal more land available than can possibly be irrigated from the Canadian River, even if all of its waters were conserved. Out of this mass of preliminary data must be selected the most feasible plan, or plans, which can be devised.

The funds for this work, along with others, were tied up on the first of February, but the people in and around Tucumcari furnished

sufficient money to carry on for about a month later. A preliminary report covering the work accomplished by Mr. Robt. E. Kennedy, engineer in charge, is on file in this office.

Financial Statement

Canadian River Investigation

Appropriation by 1925 Legislature			$30,000.00
Expenditures 14th fiscal year:			
Salaries	$3,706.11		
Subsistence	940.61		
Transportation	1,462.38		
Equipment	491.18		
Supplies	255.87		
Miscellaneous Expense	73.26	$ 6,929.41	
Balance June 30, 1926		23,070.59	
		$30,000.00	$30,000.00

HOPE, FORT SUMNER, CARLSBAD INVESTIGATION

Chapter 49 of the Session Laws of 1925 appropriates $10,000 for defraying the cost of making surveys, investigations and tests to determine the feasibility of increasing the water supply for the Hope Community Ditch and it also appropriates $4,000 for the purpose of making surveys, investigations and tests to determine the feasibility of increasing the water supply for lands in the vicinity of Fort Sumner and for lands in the vicinity of Carlsbad.

In compliance with the first investigation provided for in this chapter an arrangement was entered into with the United States Geological Survey whereby they were to furnish to this department a complete geologic study and report treating of the possible underground water supplies along the Penasco River. With this report at hand it was planned to make the necessary engineering studies to determine the feasibility of increasing the water supply of the Hope Community Ditches. This would involve, of course, the consideration of developing the underground supplies and in storing any surplus water that might be available for storage and also in determining a practical means of delivering all such water through stretches of the river which are known to have excessive losses.

The Geological Report has been completed and submitted and is presented herewith but the engineering work is yet to be done. The government funds expended on this investigation amounted to $1,022.28.

GEOLOGY *and* GROUND WATER RESOURCES

OF THE

DRAINAGE BASIN OF THE RIO PENASCO ABOVE HOPE, NEW MEXICO

By

B. COLEMAN RENICK

WITH AN INTRODUCTION

BY

O. E. MEINZER

UNITED STATES GEOLOGICAL SURVEY

MARCH, 1926

CONTENTS

ILLUSTRATIONS

INTRODUCTION

By O. E. Meinzer

The report by Mr. Renick transmitted herewith relates to the development of an additional water supply for irrigation at Hope, New Mexico. It is based on a field investigation which was made at the request of the State Engineer of New Mexico, who was charged by the State Legislature with the duty of making investigations and tests to determine the feasibility of increasing the water supply of the Hope Community (S. B. No. 16; approved March 16, 1925.) The report describes the unusual hydrologic conditions that exist in the drainage basin of the Rio Penasco above Hope and gives specific recommendations in regard to drilling wells to test the possibility of utilizing more fully the water in the natural underground reservoirs in this basin.

The main body of ground water in the entire region about Hope lies hundreds of feet below the surface. In this region deep water is not under much head but remains at great depths in the wells that are drilled to it. The deep water affords some valuable water supplies for live stock but it is not available for irrigation because the cost of pumping it would be much greater than its value for irrigation.

Springs and shallow wells are found in several localities along the Rio Penasco and its tributaries above Hope. These springs and shallow wells are fed by bodies of perched ground water that occur near the surface, far above the main body of ground water. The perched water is supplied by the rain and snow water that falls on the drainage basin of the Penasco and that percolates into the crevices of the limestone in large quantities. It is doubtless held up in each of these particular localities by some tight bed which forms, as it were, the bottom of a natural reservoir in that locality situated high above the main body of ground water. Wherever it has been possible to make observations, this underlying tight bed has been found to be a stratum of shale interbedded with the limestone. Each year these perched reservoirs receive new supplies of water from the rain and snow, and each year they lose water through springs at the surface and doubtless by the water spilling underground at some points or leaking downward through the shale beds. In that part of the drainage basin of the Penasco above Mayhill there is evidently a large body of ground water that appears at the surface in some localities. No data from deep wells are available to determine to what extent this water is perched. However, as it moves eastward down the slope, some of it evidently cascades underground to the main water table that is known to occur many hundreds of feet below.

The water from the springs flows down the stream channels and is largely used for irrigation. Some of it reaches the Hope community and is there diverted for irrigation. A part of the spring water, however, seeps into the underlying creviced limestone where there is no shale bed to uphold it and sinks to the main body of ground water. Fortunately, the spring water precipitates large amounts of lime carbonate, and this is believed to have an important function in cementing the gravelly stream channels and making them relatively water-

tight. It was reported by some of the local people who have watched the water conditions carefully that the seepage losses in the river are especially great after heavy floods, and that less water reaches the Hope community at these times than is usual; also that the river loses water at the Y-O crossing on account of the gravel being churned up by the vehicles that ford it. Apparently the explanation is that the turbulent flood waters and also the vehicles that ford the stream break up the matrix of silt and cement in the channel gravel which otherwise tends to make the gravel bed more or less water tight. The valley sides in most places are formed by cavernous limestone. Hence if a dam were built across the Penasco it would be likely to force the water into the crevices of the limestone, through which it would sink to great depths and be lost to the Hope community.

There is no definite information as to the quantity of perched ground water that sinks to the main body of ground water without appearing at the surface. However, the quantity is probably large and may be much larger than the quantity of water that appears at the surface in springs. If additional ground-water supplies are to be developed for irrigation in this drainage basin it must be by bringing to the surface the shallow ground water that would otherwise sink to great depths without appearing at the surface. It is possible that shallow flowing wells could be obtained in certain favorable places, as was the case in the deep well, known as the Manning well No. 1, that was drilled on the Rio Felix, in the shallow-water tract just above the springs. However, pumping from wells will probably be necessary if much water is to be recovered, especially if the wells are to be located far enough from the springs so that they will not interfere seriously with the flow of the springs.

Several serious practical problems present themselves in connection with any plan to obtain an additional irrigation supply for the Hope community from wells: (1) The limits of the areas of shallow water are not definitely known and it is not known whether any of them will yield enough water to be of practical importance. Considerable drilling and pumping will have to be done to get information as to the yield of the wells and the extent and quantity of the available water. (2) Unless strong flowing wells should be obtained it will be necessary to pump, and the cost of pumping may be prohibitive. (3) A considerable part of the water recovered from wells will be lost on its way to the irrigated lands. This loss will increase the unit cost of the water actually available for irrigation. A supply developed in the shallow-water area of Bluewater Creek could not be profitably brought to the Penasco unless the supply were very large and were obtained at low cost. (4) The wells must either be located at points where they will not interfere with existing water rights or else these rights must be purchased by the Hope community or some adequate guarantees must be given to the owners of these rights. As in general the best prospects are in the localities of the large springs, this restriction places a serious handicap upon the enterprise. It is probable that if a large quantity of water were obtained from a well situated near one of the springs in this region, either by artesian flow or by pumping, the flow of the spring would be reduced but that the aggregate quantity of water recovered from the spring and the well together would be greater than could be obtained from the spring alone.

The following localities have been considered by Mr. Renick for test drilling: (1) The shallow-water area of the Upper Penasco, (2) the shallow-water area of the Lower Penasco, (3) the valley area that lies between the Upper and the Lower Penasco, which for convenience he calls the Middle Penasco, (4) the shallow-water area along Bluewater Creek, and (5) the synclinal area below the Y-O crossing. He recommends that the first test drilling be done in the area between the Upper and the Lower Penasco. He does not recommend drilling at present in either the Upper or the Lower Penasco area because of the danger of interfering with established water rights and the legal complications that are likely to arise, nor in the Bluewater Creek area because of the probable impracticability of bringing the water to the Hope community, nor in the synclinal area below the Y-O crossing because, in the absence of any known shallow-water conditions, the hazards are necessarily great. In the stretch between the C A Bar ranch and the Cady ranch wells could probably be drilled without interfering with existing rights to springs. It is not known just how far down-stream shallow water will be found but the prospects of developing a practicable supply in this stretch do not appear very encouraging.

No adequate information was obtained as to whether shallow-water conditions extend through the Middle Penasco area from the Upper to the Lower Penasco, but this should be determined by the test drilling. If it is found that the shallow-water tracts are closely restricted to the vicinity of the springs and that little or no shallow water occurs in the intermediate area between the Upper and the Lower Penasco, the prospects of making any practicable development will be poor and it would not seem advisable to drill close to the springs in order to find water. If, on the other hand, it is found that ground water occurs near the surface and that wells with good yield can be obtained throughout the Middle Penasco area, there will be good reason to expect that a large additional supply can be developed. In this case the conditions should be thoroughly tested with an adequate number of wells and by prolonged pumping if strong artesian flows are not obtained. If encouraging results are obtained in this area it may be desirable to extend the test drilling to the other areas that have been considered, but not without first making provision for protecting existing water rights.

If the conditions in the Middle Penasco are favorable water will probably be encountered near the surface and the well will tend to keep filled with water to a high level. Under these conditions it will be advisable to continue drilling, because of the prospects of obtaining an artesian flow, until a depth of several hundred feet is reached or until the water drops, as it did in the Manning well. If the water drops to any great extent the drilling should be stopped and the well should be plugged at the bottom to prevent downward escape of the water. If a depth of a few hundred feet is reached without striking water or if the water level in the well goes lower and lower as the drilling progresses the prospects are poor and deep drilling can not be encouraged.

It is doubtful whether pumping from wells can be made profitable

under any circumstances but if wells are obtained with water levels not more than 50 feet below the surface and with only moderate draw-down under heavy pumping the possibil ties of pumping should be carefully considered. If it should be demonstrated by heavy and prolonged pumping that a large supply of good water is perennially available, consideration might be given to a project for installing a hydro-electric plant which would develop power from the enlarged flow of the Penasco for use in pumping the ground water.

The question may be raised whether the recovery of perched ground water on the Penasco would affect adversely the artesian supply in the Pecos Valley. The exact source and direction of movement of the artesian water has not been determined. Doubtless the artesian water is derived from the great body of deep ground water that underlies the vast upland region west of the Pecos Valley, including the area under consideration. Whether the withdrawal of perched water through wells for irrigation of land near Hope would tend to increase or to decrease the artesian supply is a debatable question. However, it is not likely that any development which the Hope community can make will have an important effect on the artesian supply. It appears obvious that the irrigators along the Penasco would be well within their rights in attempting to develop and equalize their water supply by means of wells so long as they do not interfere with one another.

RECOMMENDATIONS

By B. Coleman Renick

It must be understood that in order for a well to be successful it must be either (1) an artesian well or (2) the water must rise to within about 50 feet of the surface in order that it may be pumped with profit.

It is recommended that a well be drilled to a depth of 500 feet on the bottom land along the stretch of the river between the Upper and the Lower Penasco, which in this report is called the Middle Penasco. The well should be located in the western half of T. 16 S., R. 15 E., preferably near the center of the township.

As one goes westward along the Middle Penasco the probable water-bearing beds come nearer the surface, and hence a relatively shallow well is likely to produce the same results as would a deeper well farther east. Therefore the western half of T. 16 S., R. 15 E. is regarded as the most favorable area for prospecting along the Middle Penasco. If the first test well proves satisfactory there is ample room for extending the development by sinking wells to the east or west and thereby increasing the total water supply without interfering with water supplies now being utilized by others. The Middle Penasco is considered to be the most logical place to begin development with the view of increasing the water supply of the Hope community.

Wells drilled near the springs of the Upper and Lower Penasco would in all probability affect them adversely, and drilling at such localities is not recommended unless satisfactory arrangements are made with the owners of the land on which the springs are located and w th the persons that utilize the water for irrigation.

The syncline between the Y-O overthrust and the Black Hills anticline may be regarded as a prospect but it is a much less favorable locality than the Middle Penasco. If a well is ever drilled on this syncline for a water supply the water-bearing possibilities will not be completely tested until the Yeso member of the Chupadera formation is reached with the drill at a probable depth of about 1,000 feet. It is possible, however, that a water supply might be obtained at less depth from some perched body of ground water.

GEOLOGY AND GROUND-WATER RESOURCES OF THE DRAINAGE BASIN OF THE RIO PENASCO ABOVE HOPE, N. MEX.

By B. Coleman Renick

THE HOPE COMMUNITY

Hope, New Mexico, is located in the NW¼ Sec. 30, T. 17 S., R. 23 E., in the center of an agricultural community known as the Hope community, which has a maximum radius of 6 miles. It is connected by a good highway with Artesia, about 21 miles to the east on the Atchison, Topeka and Santa Fe Railway. The total population of the town of Hope was about 1,000 in 1920 and about 600 in 1923, but the population of the entire Hope community was about 1,200 in (1) 1923.

The soil in the vicinity of Hope is a sandy loam which is very fertile and productive when adequately watered. There are splendid orchards of apples, pears, and plums, and good vegetable gardens. Alfalfa and cotton are leading crops. The products are hauled by motor truck or wagon to Artesia.

CLIMATE

There is considerable change in the climatic conditions as one goes westward from Artesia, in the Pecos Valley, to Cloudcroft, near the top of the Sacramento Mountains. The climatic data for this strip of country are tabulated below:

(1). Teeter, E. E., Report on preliminary investigations for the Penasco River project: U. S. Bureau of Reclamation; manuscript report, 1924.

CLIMATIC DATA FOR THE AREA FROM CLOUDCROFT TO ARTESIA, NEW MEXICO

		Precipitation		Temperature Degrees			Snowfall	
	Elevation above sea level	Lenth of record	Mean annual	Lenth of record	Mean annual	Average length of growing season	Lenth of record	Mean annual
	Feet	Years	Inches	Years	F.	Days	Years	Inches
Cloudcroft	8,650	21	23.25	18	44	140	18	75.9
Weed	7,200	7	22.17					
Elk	5,800	19	20.19	12	55	185	12	17.6
Hope	4,085	6	16.15	5	58	204		
Artesia	3,350	15	12.15	13	61	204	13	8.5

ACKNOWLEDGEMENTS

Acknowledgements are due the following members of the United States Geological Survey: O. E. Meinzer, geologist in charge, division of ground water, under whose direction this work was done, for helpful suggestions and critical review of the manuscript; G. H. Girty, for the identification of the fossils and for helpful discussion regarding the stratigraphy; C. S. Howard, for the analysis of two water samples; and W. D. Collins, for review of the section on quality of water; also to George M. Neel, State Engineer of New Mexico for his co-operation throughout the course of this investigation.

The co-operation of R. A. Coffin, chief geologist of the Mid-West Refining Co., is greatly appreciated. He put at the disposal of the author a detailed structural contour map by K. S. Ferguson and J. W. Hunter, of the Mid-West Refining Co., of the structure west of the Y-O overthrust. Paul MacCune, also of the Mid-West Refining Co., greatly facilitated the work by affording free access to certain geologic data and by helpful discussion. To Arthur Rich, consulting geologist at Artesia, New Mexico, acknowledgements are due for supplying certain geologic data, including a structural map of the so-called Black Hills dome. Throughout this area the work was materially advanced by the ready assistance and hospitality of the residents. J. D. Josey, one of the water commissioners of the Hope community, was especially helpful. Free use has been made of the report of E. E. Teeter, of the Bureau of Reclamation.

HISTORY AND PURPOSE OF INVESTIGATION

The people of this agricultural community obtain their water supply for irrigation from the Penasco River. The water is diverted from the Penasco by a dam in the S.E.¼ Sec. 14, T. 17 S., R. 20 E. The total irrigable land in the vicinity of Hope is much greater than that for which water is available. The community has suffered considerable hardship in recent years partially because of droughts but largely on account of over-expansion and attempting to irrigate more land than could be irrigated with the water available. Teeter's (1) report states that when the Hope community ditch association was formed in 1895 there was 1,000 acres under irrigation and that in 1923 there was 8,004 acres being irrigated. It is evident that the total acreage under ditch far exceeds the available water supply of the Penasco, which in the early spring of 1924 had a mean discharge at the diversion dam of only 24 second-feet.

The feasibility of building dams for storing water has been considered for over a score of years. In 1903 W. M. Reed, (2), an engineer of the United States Reclamation Service, made a reconnaissance survey of the country west of Hope. He examined four reservoir sites and concluded that "while all the work done is of a very preliminary nature, the conditions are such that it is not thought necessary to make further surveys, and it is not believed that the proposition, as a whole, is worth further consideration."

The four dam sites examined were located as follows: (1) Across the Penasco, below the Cady Ranch, in SE¼ Sec. 35, T. 16 S., R. 17 E.; (2) Across Eagle Draw, in the SE¼ Sec. 22, T. 16 S., R. 20 E.; (3) Across Eagle Draw, in the eastern part of Secs. 30 and 31, T. 16 S., R. 21 E.; (4) At Antelope Lake, southeast of Hope, mostly in Sec. 23, T. 18 S., R. 22 E. The two proposed reservoirs on Eagle Draw were to be filled by diverting the water from the Penasco through a tunnel at the Y-O crossing leading into the upper reservoir, and by another tunnel about 4½ miles down-stream from the Y-O crossing leading into the lower reservoir on Eagle Draw. Antelope Lake is a sinkhole in red beds and gypsum. None of these sites has been successfully developed though attempts have been made. The history of the failures is recorded by Teeter in his report.

In 1923 $5,000 was appropriated by the Bureau of Reclamation for the investigation of possible reservoir sites for storage of water for the Hope community, and during 1923 and 1924 E. E. Teeter was engaged in making an investigation. He surveyed and mapped in detail four damsites on the Rio Penasco. These were (1) the Penasco No. 1 site, in SE¼ Sec. 35, T. 16 S., R. 17 E.; (2) the Penasco-Cherry site, in NW¼NE¼ Sec. 8, T. 17 S., R. 18 E.; (3) the Benson site, in NE¼ Sec. 9, T. 17 S., R. 19 E., and (4) the Penasco-Quevo site, in the NE¼ NW¼ Sec. 21, T. 17 S., R. 20 E. Tetter's report contains the following conclusion regarding these sites:

> "There are no sites for the economical storage of water on the Penasco. The chief reason is that the river falls from 28 to 90 feet per mile, with no wide basin of large storage capacity.

(1). Op. cit., P. 29.
(2). Reed, W. M., Surveys on Eagle Draw and Penasco River; 2d Ann. Rept. Reclamation Service, 1902-1903, pp. 389-393. 1904.

The water supply is not sufficient to take in the additional land necessary to reduce the per acre cost to a reasonable figure. The unit cost of storage will run from $100 to $125 per acre-foot, which on a safe requirement basis will cost from $200 to $400 per acre. The owners of the present rights to the continuous flow can not afford to pay this additional cost for storage. Water records are extremely meager and incomplete. Data are insufficient on which to make reliable estimates of acreage which the total flow may safely irrigate." (1).

In 1925 the Legislature of New Mexico appropriated $10,000 for further investigations, and the State Engineer requested the United States Geological Survey to co-operate by making an investigation as to the possibility of developing additional supplies by drilling wells. The author was assigned to make this investigation and spent several weeks between the dates of August 4 to 20 and December 4 to 12 in making a study of the geology and ground water conditions near Hope and for a considerable distance to the west of Hope. Mr. Meinzer spent several days in the field with the author during August. The following report which contains the results of this field study was prepared in Washington after returning from the field.

PHYSIOGRAPHY

SACRAMENTO MOUNTAINS

The summit of the Sacramento Mountains in the vicinity of Cloudcroft is about 9,000 feet above sea level, and from this elevation the range gradually slopes eastward until it coalesces with the Pecos River Valley, which at Artesia is at an elevation of about 3,300 feet. The west face of the Sacramento Mountains which borders the Tularosa basin, is very precipitous, rising from an elevation of about 4,500 feet at Alamogordo to about 9,000 feet near Cloudcroft.

In this west face a section of rocks from Pre-Cambrian to Permian are exposed including Cambrian, Ordovician, Silurian, and Carboniferous. (2).

These rocks dip eastward towards the Pecos Valley.

RIO PENASCO

The Rio Penasco, which drains the region described in this report, rises near the crest of the Sacramento Mountains and flows eastward, down the slope, emptying into Pecos River about 7 miles south of Artesia, its total length being about 115 miles. In its upper part this stream has cut a valley deep into the plateau which it drains, but in its lower course the valley is less pronounced. Stream terraces occur high above the present river channel.

The valley of the Penasco may be divided for purposes of discussion into several segments, as follows: the Upper Penasco, the Middle Penasco, the Lower Penasco, the Canyon section, and the Valley section. The limits and characteristics of each of these segments are described on subsequent pages.

The principal tributaries of the Upper Penasco are Bear Creek

(1). Teeter, E. E., op. cit., p. 4.

(2). Darton, N. H., A comparison of Paleozoic sections in Southern New Mexico: U. S. Geol. Survey Prof. Paper 108, p. 50. 1917.

and the streams flowing in Curtis and James canyons. The principal tributaries of the Middle Penasco are Aqua Chiquita, Burned, and Elk creeks, all of which in their lower courses are ephemeral streams or dry washes. The Lower Penasco has no tributaries of importance, and the only important tributaries between the upper end of the Canyon Section and Hope are Cherry, Little Cuevo, and Big Cuevo or Bluewater creeks. Cherry and Little Cuevo are ephemeral streams. Bluewater is an intermittent stream, near its head (see map, Pl. I) but farther east, nearer its junction with the Penasco, where it is known as the Big Cuevo, it is dry except in times of flood.

SACRAMENTO CUESTA

On October 6, 1925, the author, in company with Lieut. G. H. Gale, of the Army Air Service, had the pleasure of making a flight from Fort Bliss, near El Paso, Texas, eastward to the Guadalupe Mountains, thence northward almost to the latitude of Roswell, thence west and southwest over the south end of the Sacramento Mountains, and across the Tularosa Basin, back to El Paso. From the airplane the vast eastward sloping surface of this region was strikingly displayed as far as the eye could reach.

The summit of the Sacramento Mountains at Cloudcroft is capped by a massive limestone considered to be the San Andreas limestone. This limestone which dips eastward toward the Pecos Valley defines an eastward sloping cuesta here designated as the Sacramento Cuesta. In general, the surface of this cuesta conforms to the dip of the San Andreas limestone but toward the Pecos Valley successively younger beds of San Andreas limestone outcrop at the surface.

The tilting of this surface towards the east is accounted for by the upward faulting of the Sacramento Mountains on the east side of the Tularosa basin. This faulting probably started during the late Tertiary and continued into the Pleistocene and possibly into recent time for on the east side of the Tularosa basin Meinzer found that the valley fill as well as the older rocks have been deformed by faulting. Since the plain was tilted the streams have cut deeply into it.

The continuity of this eastward sloping plain between the crest of the Sacramento Mountains and Pecos River is interrupted by several narrow northward and northeastward trending ridges. One of these is the Y-O overthrust, which is shown on the map, Pl. 1, and another is the ridge crossing the highway about 25 miles west of Roswell (not shown on Pl. 1.) Both of these ridges are the result of deformation of the rocks underlying the peneplain. This deformation probably occurred during the upfaulting of the west front of the Sacramento Mountains.

Stream gravels were observed at high levels and these gravels doubtless were deposited by the Rio Penasco in an earlier geologic age when the present upland was still a lowland and the river had not yet cut its deep valley.

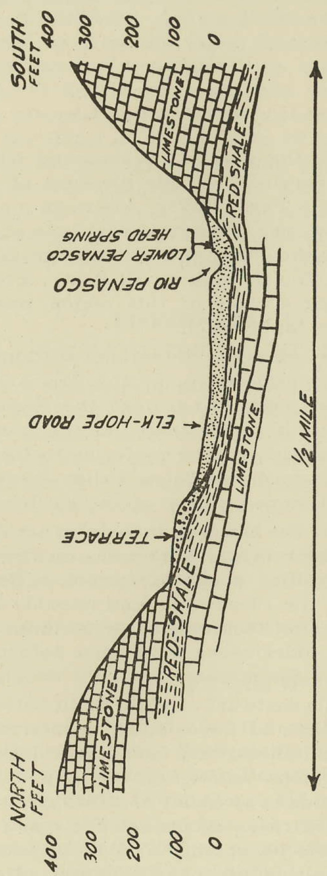


Figure 1.—Diagrammatic geologic cross-section in Sec. 3, T. 16 S., R. 16 E., showing the relation of the Lower Penasco Head Spring to the red shale bed. The ground water flows along the upper contact of the red shale and enters the alluvium coming to the surface on the edge of the Rio Penasco channel.

GEOLOGY

STRATIGRAPHY

Chupadera Formation.—The rocks underlying this region are probably all Permian in age and belong to the Chupadera formation. The Chupadera formation, as defined by Darton (1) includes the Yeso formation and San Andreas limestones of Lee and Girty (2). In this region the San Andreas and Yeso are not easily distinguished from each other, and not much time could be spent in determining the contact between them.

Along the Cloudcroft-Mayhill road, about 6 miles southwest of Mayhill and westward toward Cloudcroft, beds come to the surface that are believed to be the stratigraphic equivalent of the Yeso member of the Chupadera formation. These beds consist of limestone interbedded with red sand, shale, and sandstone, and yellowish green shale and sandstone. Westward from the junction of the Mayhill-Cloudcroft road, with the Weed-Cloudcroft road, as one goes down the geologic section, the proportion of limestone decreases and the red and yellowish green sandstones and shales increase. Thus most of the thick massive limestone beds are apparently in the upper part of the succession of rocks assumed to be Yeso.

Overlying these beds that are considered to be the equivalent of the Yeso, are several hundred feet of limestone which in some places contains thin beds or lentils of red sandy shale and yellow sandstone. Certainly over 95 per cent of these upper beds are limestone. Most of the limestone is dark gray to black, but there are some light gray beds. This limestone is probably the equivalent of the San Andreas limestone of Lee and Girty, (3) and may be called the San Andreas limestone member of the Chupadera formation.

The log of the well that was drilled near Dunken, in the SW¼ Sec. 29, T. 17 S., R. 18 E., shows that about 674 feet of limestone was penetrated. This limestone is believed to be the equivalent of the San Andreas.

---

(1). Darton, N. H., Geologic structure in parts of New Mexico: U. S. Geol. Survey Bull. 726, pp. 181-182, 1922.

(2). Lee, W. T., and Girty, G. H., The Manzano group of the Rio Grande Valley, N. M., U. S. Geol. Survey Bull. 389, p. 12, 1909.

(3). Lee, W. T., and Girty, G. H., op. cit.

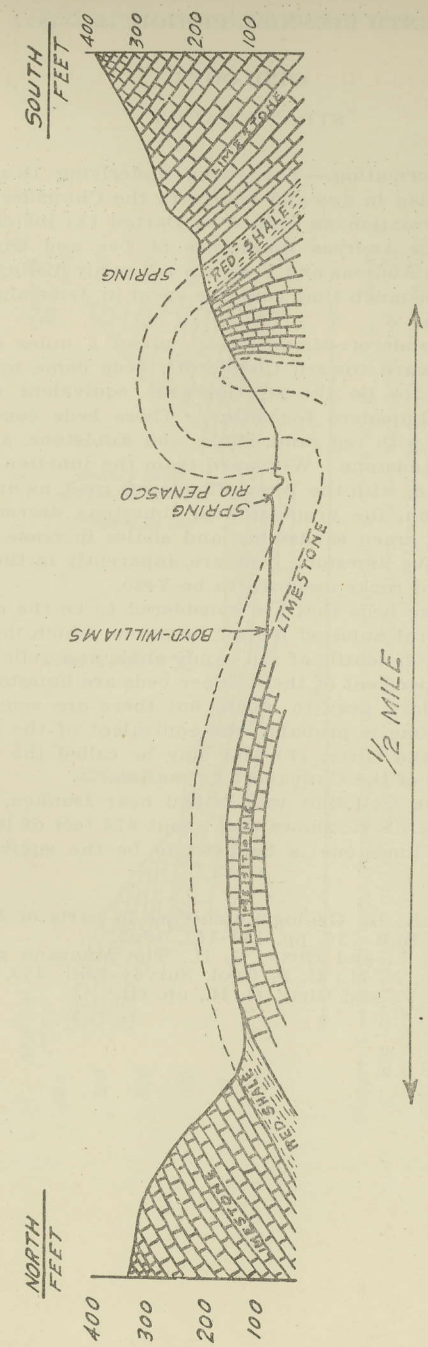


Figure 2.—Diagrammatic geologic cross-section of Sec. 11, T. 16 S., R. 16 E., showing relation of Boyd Williams Springs to red shale bed and the geologic structures. The springs occur near the upper contact of the red shale.

LOG OF DEEP WELL DRILLED NEAR DUNKEN, NEW MEXICO, IN SW¼ SEC. 29, T. 17 S., R. 18 E.

		Thickness Feet	Depth Feet
San Andreas	Limestone	674	674
?	Sandstone	26	700
	Sandy shale	2	702
	Sandstone	10	712
Yeso	Limestone	44	756
	Yellow shale	20	776
	Red and brown shale	77	853
	Blue and yellow shale	23	876
	Limestone	7	883
	Sandstone	10	893
	Limestone	44	937
	Shelly lime and blue shale	11	948
	Limestone	27	975
	Limestone and blue shale	37	1,012

Gravel Deposits.—Much of the upland surface east of the line between ranges 21 and 23 is covered by gravel or conglomerate. The pebbles and cobbles in this gravel or conglomerate consist almost entirely of sedimentary rock, and limestone constitutes over 95 per cent. There is generally a matrix of sand and silt but in many places the gravel has been cemented by lime carbonate into a firm conglomerate. For several miles west of the continuous gravel deposits there are small patches and outliers of gravel. The relation of these gravels to those of the Pecos Valley has not been studied. They were obviously laid down before this part of the upland was deeply dissected by the streams, but apparently at a time when the region to the west was sufficiently elevated to furnish coarse gravel to the streams.

TRAVERTINE DEPOSITS ALONG THE RIO PENASCO

Travertine is a material consisting mostly of lime carbonate and in most places where it occurs it has been deposited by mineralized thermal springs. Along the Penasco there are extensive accumulations of travertine which produced natural dams that were formerly effective in impounding at least a part of the flow of the stream. There is good reason to believe that there was formerly a travertine dam across the Penasco near the center of the western half of Sec. 13, T. 16 S., R. 16 E. Upstream from this travertine accumulation there is a broad floodplain which, in its lower part near the former dam, is underlain by an accumulation of 10 to 20 feet of fine gravel and evenly laminated alluvium. The Penasco in gradually cutting its channel headward has deeply dissected the deposit of alluvium above the dam. There is no spring near this former dam in section 13 at the present time, but a fault close by to the east may have at an earlier geologic date given rise to such a spring.

Along the flood plain of the Penasco at many places there are

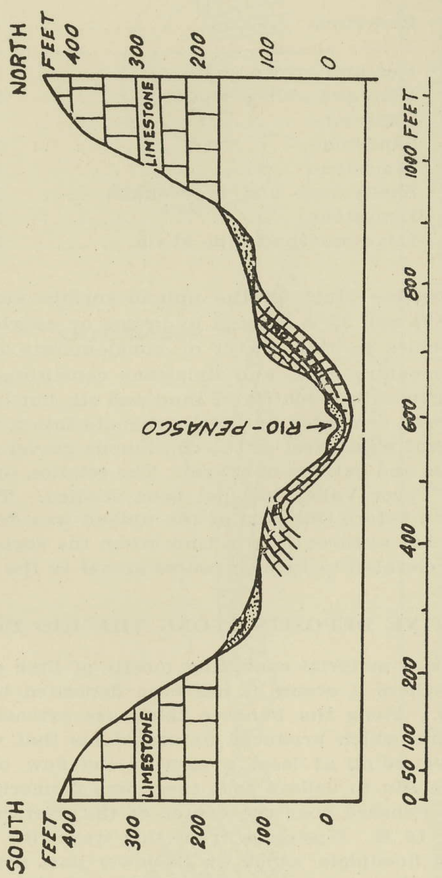


Figure 3.—Diagrammatic sketch showing structural relations along the Upper Penasco near the center of Sec. 9, T. 17 S., R. 14 E.

large pieces of porous travertine that have been broken from spring accumulations and carried downstreams. In the stretch from the north line of Sec. 1, T. 17 S., R. 17 E., downstream, at least as far as the Penasco-Cherry damsite, in NW¼ Sec. 9, T. 16S., R. 18 E., there are deposits of travertine in place. In some places this travertine rests on limestone in the creek valley and in other places on recent alluvium, thus showing that it is relatively young. There are several localities in this stretch where dams were formed resulting in a basin in which silt and gravel were deposited by the river. It is very likely that this cementing of the channel by travertine and the accumulation of silt above travertine dams have helped to prevent underground leakage in the Penasco channel.

STRUCTURE

In this region there are structures of two types: (1) those that have resulted from earth movements, and (2) those that have resulted from solution. In considering the ground water, and especially the artesian conditions, it is important to know which type of structure is being dealt with. In a region of alternating permeable and impermeable beds where the folds have resulted from earth movements and have beneath them interbedded permeable and impermeable beds, prospecting for artesian water may be carried on in a very intelligent manner, but in a region where the folds have resulted from solution it is extremely difficult to make predictions regarding artesion conditions.

STRUCTURE RESULTING FROM SOLUTION

The Permian strata in southeastern New Mexico, especially those above the Chupadera formation, contain a great amount of salt and gypsum. These beds, as well as certain of the limestones, including those of the Chupadera formation, are relatively soluble. Ground water, therefore, easily removes these soluble beds and allows the less soluble overlying unsupported beds to slump and cave. This process commonly produces small, irregular structural features with high angles of dip, which, however, in many places are difficult to distinguish from structures that have resulted from more deep-seated earth movements. (1). In the Pecos Valley, north of Carlsbad, the author has observed many of these structural features, and they have been found as far west as a locality about 6 miles west of Hope. Some of the folds in the area described in this paper, especially those in the Upper Penasco, may be of this type. Most of the folds are, however, believed to be of the more ordinary type formed by deep-seated earth movements.

STRUCTURAL FEATURES RESULTING FROM EARTH MOVEMENTS

Y-O Overthrust.—One of the most conspicuous folds in this area is an overthrust that extends in a general northeast-southwest direc-

(1). Lee, W. T., Erosion by solution and fill: U. S. Geol. Survey Bull. 760, pp. 107-121, 1925.

tion and is well exposed in the bluffs of the Penasco near the Y-O crossing. The beds on the west side have been thrust over those on the east side, and in places they have been broken giving rise to an overthrust fault of slight displacement. Although it is a mere buckle in the rocks it persists for many miles as a conspicuous topographic ridge that is easily recognized either on the ground or from the air.

Black Hills Anticline.—East of the Y-O overthrust, mostly in the southwest corner of T. 17 N., R. 20 E., is an anticline known as the Black Hills or Cuevo anticline. Structural contour maps show that the axis of this anticline extends about N. 60 deg. E., from near the middle of the west line of section 31 beyond the Penasco, at least as far north as Sec. 14, T. 17 S., R. 20 E.

Syncline Between Y-O Overthrust and Black Hills Anticline.—The axis of the syncline between the Y-O overthrust and the Black Hills anticline apparently crosses the Penasco near the southeast corner of Sec. 12, T. 17 S., R. 19 E., and trends approximately N. 50 deg. E.

Dunken Dome.—On the west side of the Y-O overthrust, is a fold known as the Dunken dome. Its axis trends almost north-south along the east line of Secs. 29 and 30, T. 17 S., R. 18 E.

Bluewater Anticline.—The village of Dunken is situated on the western limb of the Dunken dome. The valley just west of Dunken is in a syncline, and west of this syncline, in Sec. 32, T. 17 N., R. 17 E., the rocks dip eastward from an anticline the axis of which trends north-south across Bluewater Creek, near the middle of Sec. 34, T. 17 N., R. 16 E. The west margin of this anticline, here called the Bluewater anticline, is near the line between Secs. 32 and 33, where the limestone dips sharply westward, in places at angles of as much as 40°.

Rock Folds Along the Lower Penasco.—Other prominent structural features occur west of the latitude of Dunken but are not shown on the map Pl. 1. Some of these along the Lower Penasco are shown in the geologic cross section, Figs. 1 and 2.

Structure Along the Upper Penasco.—Unusual structural conditions are found southwest of Mayhill, along the Mayhill-Cloudcroft road, at least as far west as the junction of this road with the Weed-Cloudcroft road. From a horizon 100 to 200 feet above the Penasco, up to the top of the bluffs bordering the valley, 500 feet above the stream, are some massive limestones with a regional eastward dip not exceeding 2°. Below this limestone is a group of highly deformed rocks consisting mostly of limestone, but including interbedded sandstone and shale. Some of the beds dip at angles as high as 60°. Figure 3 shows the structural relations that were observed. The top of this lower, deformed group of rocks generally forms a bench or terrace 100 to 200 feet above the Penasco.

The author spent a short time in collecting fossils from these two groups of rocks, which, on account of the marked discordance of dip between them, suggested the presence of an important structural uncomformity. Some time later a few hours were spent in company with the geologists R. A. Coffin and Paul McCune, of the Mid-West Refining Co., and Max Ball, of the Argo Oil Co., in inspecting these

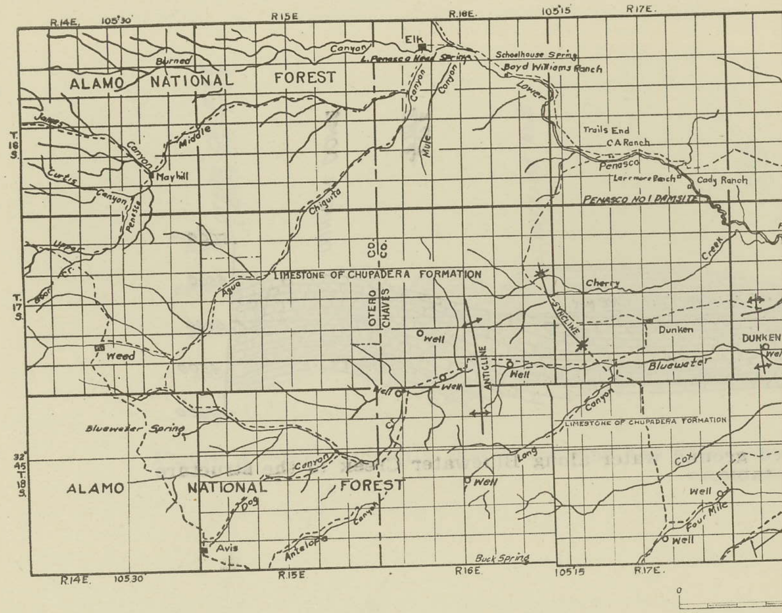


Plate 1.—Map of a part of the Rio Penasco drainage basin, N

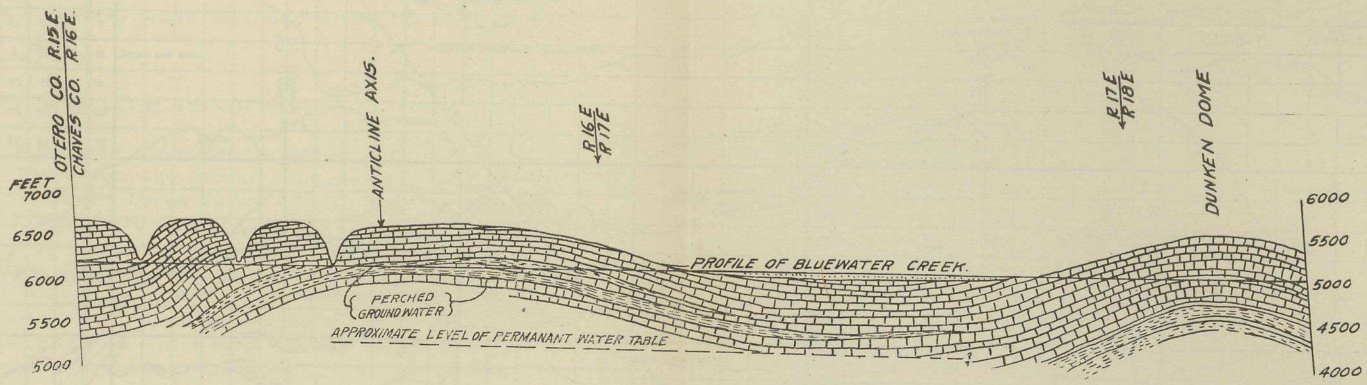


Figure 4.—Diagrammatic sketch showing the relations of the perched ground water along Bluewater Creek to the structure and permanent water table.

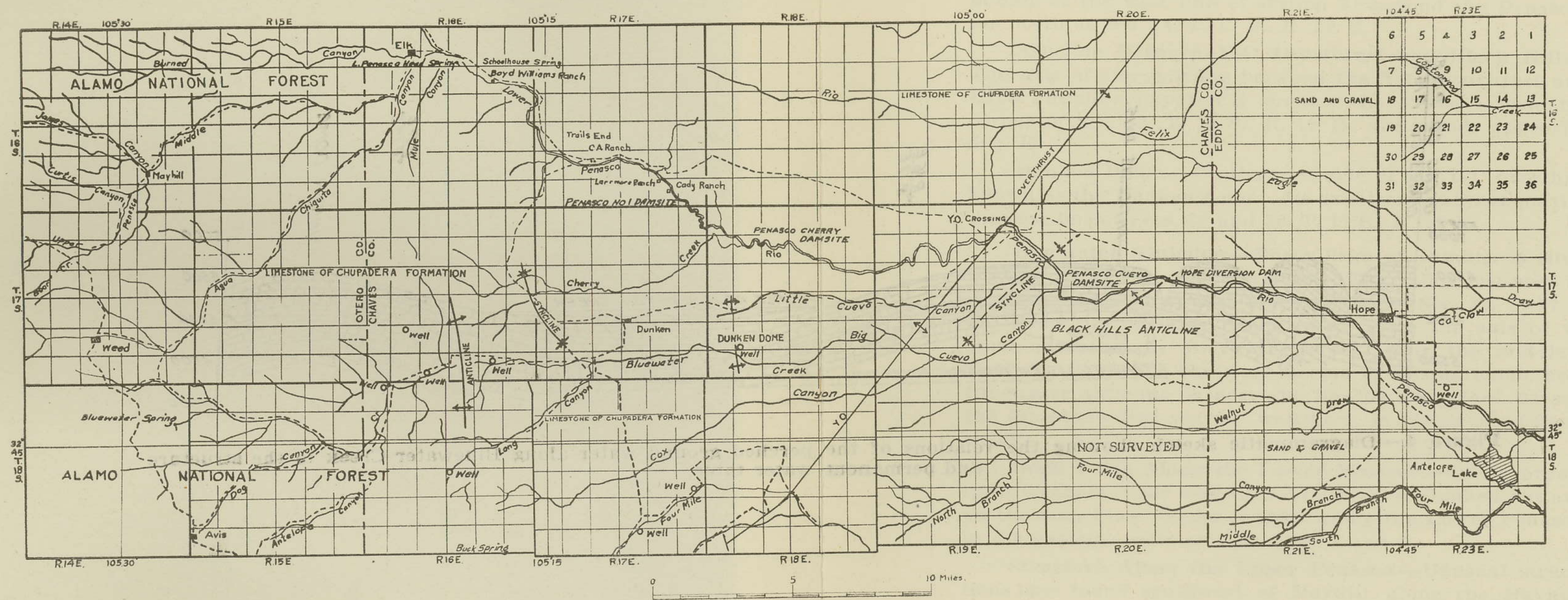
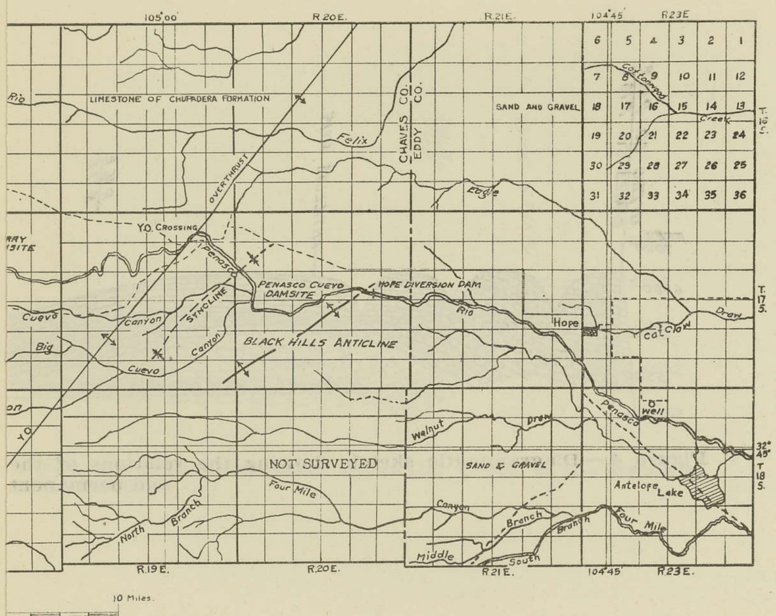


Plate 1.—Map of a part of the Rio Penasco drainage basin, New Mexico, showing geologic structure and ground-water conditions.



exico, showing geologic structure and ground-water conditions.

exposures. Two explanations of the relation between the lower highly deformed and the upper eastward dipping beds suggest themselves: (1) that there is a structural unconformity between these two groups of rocks, and (2) that the underground and surface flow of the Penasco has dissolved certain soluble beds and let down the overlying beds, thus giving rise to the deformed beds immediately adjacent to the stream. In the short time that was devoted to this problem it was impossible to arrive at a definite solution, but the tentative conclusion was in favor of the second explanation. Fossils collected from both groups of rocks were examined by G. H. Girty (1) who reported that they are of essentially the same age. At all places where the rocks were seen the contact was concealed by talus and slope wash, but by more intensive work places might be found where the contact is exposed.

PERCHED WATER CONDITIONS

Ground Water.—In this region the normal water table is generally between 500 and 1,000 feet below the surface, the depth gradually decreasing in the direction of the Pecos Valley. There are, however, several localities, as along Bluewater west of Dunken, along the Upper and Lower Penasco, and in the vicinity of the head spring of the Rio Felix, where the water table is close to the surface and springs exist. This condition is brought about by the presence of impervious shale beds within this great thickness of limestones of the Chupadera formation. Melting snow and rain water seep into the limestones at the surface but in some places its down-progress is arrested by the presence of an impervious shale which holds the water closer to the surface and above the main body of ground water. This water is, therefore, said to be perched. It flows as an underground stream or sheet of water over this impervious bed. If the impervious bed crops out the perched ground water is likely to appear as a spring. If the impervious bed continues underground the ground water will remain perched until the impervious bed grades into limestone or is broken or otherwise interrupted, when the perched water will sink to a greater depth to join the main body of ground water. The springs along the Lower Penasco (see Figs. 1 and 2) illustrate the first condition, where the impervious bed comes to the surface, and the perched condition along Bluewater Creek, west of Dunken (see Fig. 4 and p. 129 illustrates the second condition.

Streams.—The streams in this region are also perched. They are held up by impervious beds and by the tightly packed and partly cemented silt in the stream channels. Wherever these perched streams cross a stretch where there is no impervious bed and where the channel is not waterproof, it loses water by seepage.

East of the Otero-Chaves County line all the streams shown on Plate I, except the Penasco, are dry washes or ephemeral streams. Table 1, p. 135, taken from Teeter's report, shows that the mean loss of the Penasco over a period of 40 days during the irrigation season was 25 per cent between the Cady ranch and the Y-O crossing. Tee-

(1). Memorandum from G. H. Girty.

ter ascribes this loss to evaporation but part of it is in all probability due to seepage.

In the upper parts of the Rio Felix and Bluewater Creek there is water that has been contributed by springs, but before these streams flow many miles they are entirely dry, most of the water being lost by seepage, though, of course, some is lost by evaporation. This perched condition of the ground water and the streams is important in relation to the development of water supplies and reservoir sites.

RELATION OF PERCHED CONDITIONS TO WATER SUPPLY

In attempting to develop a ground water supply for the Hope community it will obviously be desirable to find a supply that may be led directly into a perennial stream that is known to have a relatively impervious bottom with a minimum of leakage. The Penasco is the only stream that answers these requisites.

The possibility of reclaiming the flow that was obtained in the Manning well No. 1, described later in this report, and delivering this water to Hope has been considered, but is probably not feasible. If this water were to be delivered at Hope by gravity it would be necessary to take it from the Rio Felix over the divide into Eagle Draw and thence to let it flow for some distance down this draw before it could be diverted into the Penasco. The drainage basins of both the Rio Felix and Eagle Draw are hundreds of feet above the water table, the channels of these streams are gravelly and lose water readily, and the country between Felix and Eagle Draw and between Eagle Draw and the Penasco is underlain by creviced limestone or permeable alluvium. The water from the Manning well would therefore probably be entirely lost before it could be delivered to Hope unless it were carried in a concrete ditch or a pipe line, either of which would be excessively expensive.

RELATION OF PERCHED CONDITIONS TO RESERVOIR SITES

The present investigation did not include an examination of the reservoir sites. However, it is considered desirable to point out that the ground water conditions along the Rio Penasco are unfavorable for obtaining reservoirs that will hold water.

Where the confining walls of a reservoir are composed of cavernous, permeable limestone and the water table is many hundred feet below the surface the resrvoir will not be watertight because the water will leak through the joints and solution channels in the limestone and will sink to the water table. Teeter, in his report, regards several reservo r sites as unfavorable on account of economic reasons but all of these reservoir sites are unfavorable also because of the cavernous character of the rocks and the depth to the water table. Heavy leakage will undoubtedly occur in any reservoir that may be constructed along the Penasco and the water thus lost will not return to the Penasco above the lands of the Hope community.

UPPER RIO FELIX

MANNING WELL NO. 1

While the author was in the field the Arkansas Fuel Oil Co. was engaged in drilling a well in the NW¼ Sec. 14, T. 15 S., R. 17 E., on what is known as the Manning dome. This well, which is north of the area shown on Plate I, is located on a bench 15 feet or so above the dry channel of Rio Felix. Mr. C. F. Barrett, superintendent of drilling, stated that water was obtained at a depth of about 7 feet. At a depth of 275 feet he struck an artesian flow, at 310 feet he struck much more water, and the flow increased down to a depth of 400 feet. Mr. Ward reports that the water from this well flowed 4.5 inches over a 2-foot rectangular wier, indicating a flow of about 665 gallons a minute, or about 1.5 second-feet. It is reported that at some level between 400 and 415 feet the drilling tools dropped into a crevice and the well immediately stopped flowing, all the water going into this crevice and carrying the drill cuttings with it. The water obtained in this flow was undoubtedly perched being held up by a blue shale bed that exists between 375 and 400 feet. The basal or main water table in this region is 600 feet or more below the surface.

It is the opinion of several geologists of this region who are familiar with the stratigraphy that this flow was obtained near the top of the Yeso formation. If oil is not found in this well it would be feasible to plug it with cement between 375 and 400 feet and then reclaim the flow of artesian water, which might be utilized to good advantage for irrigation along the Upper Felix. It is explained elsewhere in this report that it would not be practicable to deliver by gravity into the Penasco any water that might be developed in this vicinity.

HEAD SPRING OF RIO FELIX

Less than one-quarter mile downstream from the Manning well, near the middle of the west line of Sec. 13, T. 15 S., R. 17 E., there is a spring flowing from the alluvium along the Rio Felix. This spring doubtless represents a perched ground water, but the geologic conditions that account for its presence are not apparent. The estimated discharge of this spring is less than one second-foot. The chemical character of the water is shown in the table below.

WELLS IN THE VICINITY OF THE MANNING WELL NO. 1

About ⅝-mile west of the Manning Well No. 1, Sec. 15, T. 15 S., R. 17 E., on the ranch of E. Joy and Sons, there is a dug well 60 feet deep in which water was found to stand at 49.5 feet below the surface. Also along the Felix, in Sec. 16, there is a dug well 60 feet deep in which the water level is about 50 feet below the surface. The foregoing data regarding these wells and the presence of the Rio Felix head spring near the Manning Well No. 1 all point to the presence of a body of perched ground water in the vicinity of this well, a condition which is entirely compatible with the large flow that was obtained in the Manning Well No. 1 between the depths of 275 and 400 feet. In

fact a large flow, such as that which was obtained, would not be expected in a region where the main body of ground water is far below the surface unless there was a perched body of ground water.

GROUND WATER DESCRIBED BY LOCALITIES

UPPER PENASCO

The portion of the Penasco above a point about 2 miles east of Mayhill has for many years been referred to as the Upper Penasco. In this stretch the river flows through a narrow V-shaped valley bordered by steep bluffs that rise 400 to 600 feet above the stream. Most of the country along this stretch is covered with a good stand of pine timber. The Upper Penasco is characterized by the presence of numerous springs and by a perennial stream of water, in which respect it differs from the stretch between the Upper and Lower Penasco. Most of the narrow strips of bottom land along the Upper Penasco are cultivated. The farmers in this locality are favored by a plentiful supply of water but are hampered by a shorter growing season than obtains farther downstream. There are numerous springs and seeps along the Upper Penasco. It is significant that all of these springs occur within an area where the rocks in proximity to the stream are highly deformed (see Fig. 3) and it is believed that the distribution of the springs is largely controlled by this structure and by the presence of more or less impervious beds. Near the mouth of James Canyon, in the SW¼ Sec. 26, T. 16 N., R. 14 E., a large green algae-covered pool marks the presence of a spring of considerable importance, and in the NE¼ Sec. 35, of the same township, on the west side of the creek, there is a spring with an estimated flow of about 1 second-foot. In addition to these two large springs there are many smaller ones. All of these that were inspected come from alluvium, and the exact relation of any particular spring to the bed rock geology is difficult or impossible to determine. Figure 4 shows in a general way the relation of the springs to the rock structure. Obviously these springs issue from a large body of ground water.

Ground water supplies could probably be obtained by drilling wells along the Penasco in this stretch and the total flow of the Penasco could probably be increased by developing a supply from wells. However, the withdrawal of water from wells, either by artesian flow or by pumping, would be likely to diminish the flow of some of the springs. Hence, the drilling of wells in this stretch is not recommended unless satisfactory arrangements can be made with the people who use the spring water, guaranteeing them an adequate supply.

MIDDLE PENASCO

The designation Middle Penasco is not, so far as is known, used by the inhabitants along the Rio Penasco but the name is here applied to the stretch between the Upper and Lower Penasco. It extends from a locality about 2 miles below Mayhill to the head spring of the Lower Penasco, about 2 miles below Elk. In this stretch of about 11 miles the eastward dip of the rocks is greater than the gradient of the stream and the strata that are near stream level at Elk are several hundred feet above the stream at Mayhill.

From the spring-fed stretch that constitutes the Upper Penasco the stream originally flowed into a marshy tract or cienega which extended about to the head spring of the Lower Penasco, a distance of about 11 miles. Mr. R. E. Bates, who lives near Elk, in the NW¼ Sec. 8, T. 16 S., R. 16 E., informed the author that when he settled at this location in September, 1881, there was no water flowing in the present stream channel of the Penasco and that he and other settlers along this stretch constructed a ditch through this marshy tract in an attempt to drain the cienega and to bring water down from the Upper Penasco. At first only small amounts of water flowed as far as his ranch and this was used only for stock. The quantity of water gradually increased, however, and by 1884 some of the settlers began to use small amounts for irrigation. From a few years after up to the present time the water so obtained has been used extensively by the inhabitants along the Middle Penasco for irrigation purposes. It appears that this increase in the flow of the Middle Penasco was produced by the trenching which collected the water into one definite channel.

So far as is known the ground-water conditions along the Middle Penasco have not been tested by drilling wells. However, there are several reasons why this stretch should be considered favorable for developing ground water supplies. In the upper part of the Sacramento Mountains there is relatively heavy precipitation, springs are abundant, and a large body of ground water seems to be relatively near the surface. As one ascends the Penasco the region where the water table is many hundred feet below the surface is apparently left behind and a region where there is a permanent body of shallow ground water is approached.

The strata, regarded as the Yeso member of the Chupadera formation, which contain impervious shale beds that tend to hold up the ground water, come closer to the surface as one ascends the Penasco and they appear at the surface just above Mayhill. Shale beds would doubtless be encountered at a depth of less than 500 feet in the upper part of the Middle Penasco and ground water would be expected on top of these impervious strata and in the interbedded permeable strata. Owing to the eastward dip of the rocks, the water in the interbedded strata would rise in a well drilled to them unless it has free means of underground escape toward the east. Thus it is possible that flowing wells could be obtained in this stretch. If a ground-water supply is developed in the proper locality along the Middle Penasco it will be virtually a net gain and will not interfere appreciably with the springs that are already utilized. It is, therefore, considered that the lowland along the Middle Penasco is the best locality for drilling test wells to develop a water supply for the Hope community.

The part of the valley of the Penasco that lies in the western half of T. 16 S., R. 15 E., is considered the best tract for drilling the first well. If this well gives promising results there will be ample territory for drilling additional wells in this tract.

LOWER PENASCO

The stretch known as the Lower Penasco begins at the head spring on the Cleve ranch, in the SW¼ Sec. 3, T. 16 S., R. 16 E., and extends downstream several miles. The lower limit so far as the author knows is not exactly defined but extends at least as far downstream as Trails End at the C. A. Bar ranch.

In the upper part of the Lower Penasco there are several important springs, for example, the head spring on the Cleve ranch; the Schoolhouse spring, in the NW¼ NW¼ Sec. 11, T. 16 S., R. 16 E., and two springs on the ranch of Mr. Boyd in Sec. 11, T. 16 S., R. 16 E. The origin of all of these springs is similar. Interbedded with the limestone in this region is a bed of impervious red shale. The ground water that accumulates in the limestone beds above the shale encounters this impervious bed and can not sink deeper. Where the shale bed comes to the surface it gives rise to a spring. Thus all these springs along the upper part of the Lower Penasco occur at or near the contact of this red shale with the overlying cavernous limestone (see Figs. 1 and 2). In this region the main body of ground water is several hundred feet below the surface and the water of these Lower Penasco springs is a perched ground water held above the main water table by the bed of red shale.

Lower Penasco Head Spring.—The springs at the head of the Lower Penasco on the Cleve ranch, in the SW¼ Sec. 3, T. 16 S., R. 16 E., are the largest springs along the Lower Penasco. This water comes to the surface through several openings in the alluvium along the south bank of the Penasco near the bed of the stream, but the location of the springs is obviously determined by the presence of the above-mentioned bed of red shale which goes under the stream at this place. A sample of water (analysis No. 3) was collected at the head springs.

Between the head spring and Boyd William's upper spring (see below) there are a number of small springs and seeps, the water coming out of the alluvium adjacent to the bed of the stream. The flow of the river increases considerably in this stretch.

Boyd Williams' Springs.—Near the center of section 11, in Mr. Williams' pasture, there is a spring of good water flowing out of the alluvium in the northeast bank of the Penasco. South of the Penasco, in the bluff about 160 feet above the stream, on Mr. Williams' ranch in the SW¼ Sec. 11, there is a spring that was estimated to be flowing about one-half second-foot. This water issues from a cavernous limestone at the top of the red shale bed and is believed to come from the west, flowing up the dip and along the top contact of the red shale. The geologic structure that obtains here is shown in Figure 2. A sample of water (analysis No. 4) was collected here and is described later in this report.

Schoolhouse Spring.—In the bluff above the schoolhouse, in the NW¼ NW¼ Sec. 11, T. 16 S., R. 16 E., and 200 feet or more above the Rio Penasco there is a small stream of water, not exceeding a few gallons a minute, flowing from a cavernous limestone that rests on the red shale bed. The water from this spring is probably similar in quality to that from the Boyd Williams spring, in the SW¼ Sec. 11, and the geologic conditions controlling it are similar to those controlling the Cleve and Williams springs.

Trail's End Spring.—At the C. A. Bar ranch, in the SW¼ NW¼ Sec. 28, T. 16 S., R. 16 E., there is a spring flowing from the bank of the Penasco, 10 to 15 feet above the stream. Gravel and soil conceal the relation of the source of the water to the underlying bed rocks. Teeter (1) states that the yield of this spring was 2.8 second-feet when he examined it in the spring of 1923 (see table, p. 135). So far as is known there are no springs between this one and the eastern margin of the area shown on the map, Pl. I.

Considerable water could probably be obtained by drilling wells along the Lower Penasco in the vicinity of the head spring and the total supply of water could probably be increased by this method. However, if such wells delivered enough water to be valuable for irrigation they would almost certainly cause the flow of the nearby springs to decrease, and this would work as a detriment to the ranchers along the Lower Penasco. The drilling of wells along the Lower Penasco is therefore not rceommended unless the Hope community will first purchase the springs or give an adequate guarantee to protect the water rights of the inhabitants along the Lower Penasco.

CANYON SECTION

After leaving the C. A. Bar ranch the Penasco flows southeastward through a region of steep dissected barren limestone hills until it gradually emerges into a more or less open undulating plain. The lower limit of this stretch is in the vicinity of the Hope Diversion Dam. Teeter has referred to it as the Canyon section.

At the C A Bar ranch (Trail's End) there is a spring but downstream from there none was found. It was, however, reported by one person and denied by several that there was once a spring in the vicinity of the Cady Ranch. So far as could be learned no wells have been drilled in the Canyon stretch, but in the lower part of this stretch below the Cady ranch the main body of ground water is in all probability far below the surface because data obtained from wells to the north and south indicate that the water table is between 500 and 1,000 feet below the surface and that if perched bodies of ground water exist they are unimportant. It is therefore probable that somewhere within the stretch between the C A Bar ranch and the Cady ranch the near surface perched ground water sinks to greater depth. The cause for the sinking of a perched ground water is discussed on page 128.

Along the Penasco, one-half mile or more above Little Cuevo, might prove to be a satisfactory place for locating a test well. This location is in the center of a syncline between the Y-O overthrust and the Black Hills anticline and should water be encountered in this synclinal structure it might be expected to rise to a considerable height in the well, but a flowing well, though within the realm of possibility, is hardly to be expected.

---

(1). Teeter, E. E., op. cit., p. 74.

The log of the well that was drilled for oil on the so-called Dunken dome, in the SW¼ Sec. 29, T. 17 S., R. 18 E., to a depth of 1,012 feet and then abandoned, shows that the contact between the San Andreas and Yeso formations is somewhere between 674 and 712 feet (see p. 120). It is the general opinion of geologists that the heavy flow of water obtained in the Manning well between the depths of 275 and 300 feet came from near the top of the Yeso. It is believed that the top of the Yeso will probably be reached at a depth of less than 1,000 feet near the mouth of Little Cuevo, but if a well is undertaken here it is recommended that it be drilled to a depth of 1,000 feet unless a perched water supply that will rise to the surface or almost there is obtained at less depth.

Although this location has certain features in its favor, it is not regarded as good a prospect as the Middle Penasco.

THE VALLEY SECTION

At the lower end of the Canyon section, the Penasco gradually emerges upon a gently eastward sloping plain. This portion of the Penasco, which extends from about the Hope diversion dam to Pecos River, has been referred to by Teeter as the Valley section. The main body of ground water is far below the surface in the vicinity of Hope.

In this connection the deep well that was drilled to prospect for oil southeast of Hope, in NE¼ SE¼ Sec. 4, T. 18 S., R. 23 E., is instructive although the reports regarding the waterbearing rocks encountered in it are somewhat conflicting.

LOG OF HOPE COMMUNITY WELL (FITE WELL NO. 1) IN NE¼ SE¼ SEC. 4, T. 18 S., R. 23 E.

	Thickness Feet	Depth Feet	Remarks
Surface	5	5	
Gyp shale	5	10	
Hard lime	40	50	
Conglomerate	55	105	Probably a cemented breccia.
Red bed	105	210	
Lime shell	4	214	
Red gypsum	16	230	
Lime shell	10	240	One bailer of water per hour.
Sandy lime	10	250	
Soft lime	5	255	Two bailers of water per hour.
Hard white lime	202	457	Two-foot crevice at 351-353 ft.
Water sand	18	475	
Brown lime	25	500	
Sand	35	535	
Hard sand	5	540	
Black lime	45	585	Hole reduced at 582 feet.
Oil sand	180	765	
Lime	35	800	
Sand	34	834	
Red bed	1	835	
Black sandy lime	275	1,110	

The following data were obtained from the driller's log and seem to be fairly well established: Between 230 and 240 feet there was one bailer of water per hour; between 250 and 255 feet, there were two bailers of water per hour; a 2-foot crevice was encountered between 351 and 353 feet, and all of the water encountered above disappeared into it; another crevice was penetrated at 436 feet; at 452 feet another waterbearing bed was penetrated and this water is considered by the driller to have risen to the level of the 436-foot crevice where it, together with the drill cuttings flowed away underground. The driller reported that at 1,100 feet a large quantity of water was found and that because of the upward current drilling was slow and the bailer could not be lowered to the bottom of the hole. The water encountered at 1,100 feet is reported to rise to the level 436 feet below the surface and there to escape into the crevice which occurs at that level.

The above data show that in this locality there is a considerable body of water at a depth of 452 feet, and a large supply at a depth of 1,100 feet. If this well were cased below the 436-foot crevice the water would probably rise higher in the well but would probably not come near the surface.

STREAM DATA

Teeter (1) states that "meter measurements were made in 1924 before the irrigation season started to check the amount of loss between Lower Penasco and the Hope Diversion dam" and he furnishes the following data:

	Location	Mean discharge in second-feet
(1)	Elk	15.5
(2)	Lower Penasco, above Bonham's' diversion	40.5
(3)	Trail's End, above Spring-?	29.0
(4)	Trail's End Spring	2.8
(5)	Laramore Ranch	36.7
(6)	Y-O crossing	29.2
(7)	Hope Diversion Dam	24.0

BLUEWATER CREEK

For several miles along Bluewater Creek, in T. 17 S., R. 16 E., and T. 18 S., R. 16 E., the water table is close to the surface, as is shown by a number of shallow wells. The well of Ed. Watts, in Sec. 35, T. 17 S., R. 16 E., is 30 feet deep with the water level 17 feet below the surface, and the J. D. Jermgan well, in Sec. 33, T. 17 S., R. 16 E., is 35 feet deep with the water level 23 feet below the surface.

Along Bluewater Creek, in T. 17 S., R. 17 E., there are no shallow wells, and shallow ground water can apparently not be obtained. There are also no deep wells in this stretch, and the exact depth to the main body of ground water is therefore not definitely known. However, in the township next south there are two deep wells along Four Mile Creek that are instructive. Netherland Brothers' and Lee's well, in Sec. 34, T. 18 S., R. 17 E., is reported to be 832 feet deep with the water standing 500 feet below the surface; and Bates and Champions well, in Sec. 24, T. 18 S., R. 17 E., is 700 feet deep with the water level 600 feet below the surface.

(1). Teeter, E. E., op. cit., p. 73.

A considerable supply of ground water could probably be developed by sinking several shallow wells along Bluewater Creek in the southern part of T. 17 S., R. 16 E., where there is perched ground water. Even if a considerable supply could be developed in this stretch, however, there would be a serious problem in connection with delivering it into the Penasco and making it available for Hope. In this connection it must be remembered that where the main body of ground water is far below the surface a stream or ditch will soon lose its water by seepage unless it is made waterproof by concrete lining or other means. East of the middle of R. 17 E., Bluewater Creek is an ephemeral stream and the main water table is far below the surface. Most, if not all of the water that could be obtained from wells, would be lost before it reached the Penasco if the water were permitted to flow down the channel of the Bluewater. Another means of delivering water into the Penasco would be by constructing a ditch leading northward into Cherry Creek, but here again it seems almost certain that a large proportion of the water would be lost by underground seepage before it would reach the Penasco because a ditch from Bluewater Creek to Cherry Creek would cross a region of creviced limestone where the water table is far below the surface. Cherry Creek is a very gravelly dry wash that would doubtless allow the water to sink rapidly.

LONG CANYON

Mr. Emory Carper furnished the following data regarding his well located in Long Canyon, in the NW¼ NW¼ Sec. 22, T. 18 S., R. 16 E. The well is 1,000 feet deep, is cased from top to bottom, and the water stands at 950 feet below the surface. He reports that a small amount of water (1 gallon per minute) was encountered at a depth of 200 feet in a yellow sandy shale and that a second water was encountered at 995 feet in a shelly gray limestone. The above data indicate that the area of perched ground water along the Bluewater in T. 17 S., R. 16 E., does not exist in Long Canyon in T. 18 S., R. 16 E.

The Carper well is located along the prolongation of the axis of the Bluewater anticline and it is entirely probable that the water in a well located several miles from the axis, especially east of the axis where the ground is lower, would rise higher than in the Carper well.

QUALITY OF WATER

A sample of water was collected from the head spring of the Lower Penasco on the Cleve ranch, in the SW¼ Sec. 3, T. 16 S., R. 16 E., (see No. 3 table, p. 137) and from Boyd Williams Spring in the SE¼ SW¼ Sec. 11, T. 16 S., R. 16 E. (see No. 4 table, p. 137). The water from Boyd Williams Spring contains about 220 parts per million of total dissolved solids and that from the head spring about 620 parts per million. The water from both of these springs is hard, that from Boyd Williams Spring having a hardness of 203, and that from the Cleve Spring 484. For convenience of comparison two analyses

of waters by E. M. Skeats have been selected from Fisher's report. (1). Analysis No. 2, in the following table, shows that the water from the spring near the head of the Felix; located near the Middle of the west line of Sec. 13, T. 15 S., R. 17 E., is less mineralized than the water of the head spring of the Lower Penasco and more mineralized than the water from the Boyd Williams Spring. These four waters are probably representative of the surface and shallow ground waters of this region of limestone rocks. Inspection of the analyses shows that all of these waters are hard and that the constituents, calcium and magnesium, which account for the hardness, occur as carbonate and sulphate. The waters are entirely satisfactory for irrigation, drinking, and stock uses, but would be too hard for laundry use without softening, and if used in a steam boiler they would doubtless cause considerable scale.

ANALYSES OF WATERS FROM WESTERN CHAVES COUNTY, NEW MEXICO

(Parts per million)

	a1	a2	b3	b4
Silica (SiO2)	10	19	2.8	15
Iron (Fe)	..	..	.11	.26
Calcium (Ca)	137	108	138	55
Magnesium (Mg)	43	24	34	16
Sodium and Potassium (Na plus K)	15	15	15	9.4
Carbonate radicle (CO3)	..	..	0	0
Bicarbonate radicle (HCO3)	c219	c254	314	226
Sulphate radicle (SO4)	324	152	219	27
Chloride radicle (Cl)	23	23	18	8
Nitrate radicle (NO3)	..	..	Trace	.40
Total dissolved solids	650	467	620	220
Total hardness as CaCO3 (Calculated)	519	368	484	203

a Analyzed by Prof. E. M. Skeats, El Paso, Tex., from U. S. Geol. Survey Water Supply Paper 158, 1906.

b Analyzed by C. S. Howard, U. S. Geological Survey.

c Reported as equivalent carbonate (CO3).

1. Rio Penasco (near Gilbert's ranch).

2. Rio Felix (head spring) near center west line S 13, T 15, S, R 17 E.

3. Spring on lower Penasco on south side of creek, near Elk, N. M. SW¼ Sec. 3, T 16 S, R 16 E. (Head Spring of Lower Penasco).

4. Spring from a cavernous limestone bed at the top of a red shale, near Elk, N. M., SE¼SW¼ Sec. 11, T 16 S, R 16 E. (Boyd Williams Spring).

TYPE OF WELLS

In this region most of the drilling will be in limestone, which, on the whole, should be drilled with little trouble. It is believed that the first well should be put down with a relatively large diameter, probably 10 or 12 inches, because if it is successful it will yield much more than a well of only 4 to 6 inches in diameter. The difference in cost of a large and small diameter well is largely due to the difference

(1). Fisher, C. A., Preliminary report on the geology and underground waters of the Roswell Artesian Basin: U. S. Geol. Survey Water-Supply Paper 158, p. 23, 1906.

in the cost of casing. In drilling the well it will only be necessary to use a short string of casing to case off the alluvium and gravel near the surface. If the well proves to be capable of yielding a good supply of water it can then be cased deeper.

In order for a well to be successful, that is, capable of economical operation, it must be either a flowing artesian well or a pump well in which the water rises within about 50 feet of the surface. When the pump is operated there will be considerable drawdown. It will be unprofitable to pump from wells if the lift is very great.

Financial Statement

Hope Community Investigation

Appropriation by 1925 Legislature			$10,000.00
Expenditures 14th fiscal year:			
Salaries	$474.42		
Subsistence	163.60		
Transportation	341.70		
Supplies	5.00		
Miscellaneous Expense	11.35	$ 996.07	
Balance June 30, 1926		9,003.93	
		$10,000.00	$10,000.00

FORT SUMNER-CARLSBAD INVESTIGATION

Under the second division of work to be done under Chapter 49 an engineering study of methods to furnish a water supply to the vicinity of Fort Sumner and Carlsbad is necessary. In compliance therewith an agreement was entered into with the Bureau of Reclamation whereby they were to assign to the work an engineer from their department and would pay for the expense thereof at the ratio of $2.00 from the Government to $1.00 from the State.

They assigned to this work Mr. C. C. Elder, one of the engineers of the Reclamation Service, and he spent practically the entire season of 1925 in field investigations and submitted his report under date of March 6th, 1926.

Mr. Elder's work consisted very largely in the taking of detailed records and the study of the same to determine whether or not there were any losses in the Pecos River between Fort Sumner and the Acme bridge above Roswell which could not be accounted for by the reasonable evaporation losses attendant upon a stream of this character. His handling of this matter and its presentation in his report, which is now on file in the State Engineer's' Office, appears to demonstrate quite conclusively that there are no enormous losses into porous sections on the stream bed which are entirely lost to the stream.

The government funds expended in this co-operative work amounted to $1,953.81.

Financial Statement

Fort Sumner-Carlsbad Investigation

Appropriation by 1925 Legislature			$4,000.00
Expenditures for 13th fiscal year:			
Subsistence	$ 53.44		
Transportation	76.69		
Supplies	2.50	$ 132.63	
Balance June 30, 1925		3,867.37	
		$4,000.00	$4,000.00

Balance July 1, 1925			$3,867.37
Expenditures 14th fiscal year:			
Subsistence	$449.05		
Transportation	735.04		
Supplies	45.59		
Miscellaneous Expense	25.80	$1,255.48	
Balance June 30, 1926		2,611.89	
		$3,867.37	$3,867.37

ESTANCIA VALLEY INVESTIGATION

The Estancia Valley Investigation was authorized by Chapter 40 of the Session Laws of 1923, and the Sixth Biennial Report of the State Engineer recorded the progress that had been made up to that time and set forth how an elaborate and detailed investigation was planned in co-operation with the Bureau of Reclamation and the Geological Survey. It is regrettable that the Bureau of Reclamation was forced to withdraw from this work because it felt that the expenditure of so large an amount of money was not justified by the showing which was made in a preliminary report by Chas. H. Lee, a specialist on ground water conditions.

Upon the failure to work out this co-operative investigation with the Government agencies and upon insistant requests from the citizens of the Estancia Valley, it was decided to drill a limited number of test wells for the determination of the amount of water which could be relied upon in that area. Such a program, naturally, must include sustained tests on the wells drilled by the state and on all others where tests are practicable. In order to intelligently determine the supply in these wells an air-lift outfit was assembled. This consisted of an 8"x6" Gardner-Rix air compressor mounted on a Packard truck (leased from the State Highway Departmen), from which power was taken to compress the air as well as for locomotion. While this arrangement was not essentially an efficient one from the standpoint of the ratio of power to the water lifted, it was exceptionally suitable for the purposes to which it was put, being easily moved from place to place and having no pump or heavy equipment to insert or remove from the casings.

This pumping and testing of wells was begun May 17th, 1925 and completed October 15, 1925, during which time some 40 wells were tested. Owing to the neglected condition of a great many wells it was found necssary to do considerable preliminary work, such as dis-

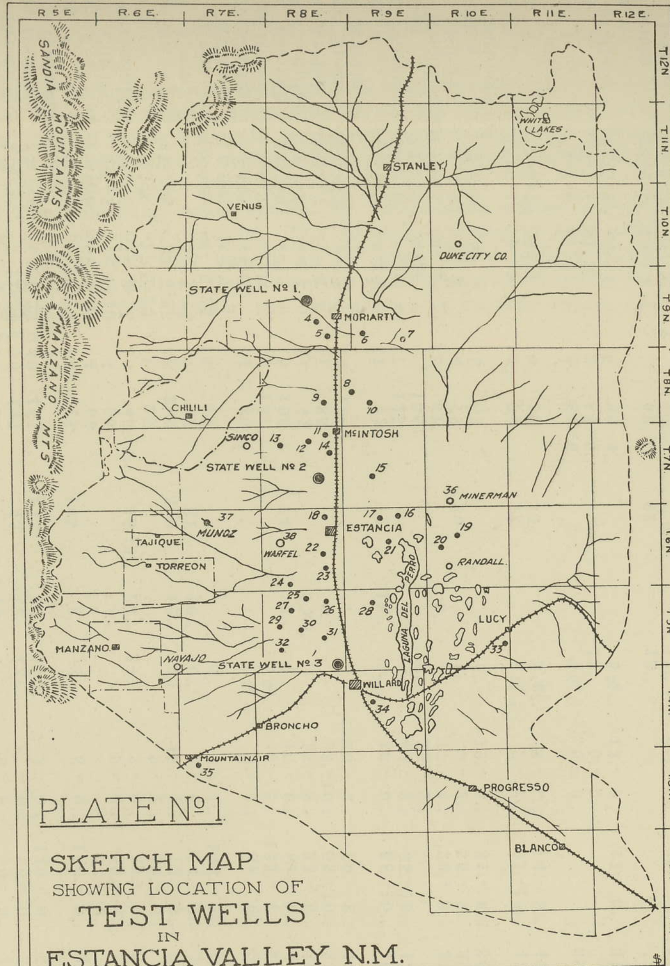
mantling and replacing existing pump installations, removing obstructions lodged in casing, preparing discharge channel and setting up weir. In all cases the wells appeared to develop under pumping although no appreciable increase in flow was noticeable in cases where the shooting of some wells was resorted to.

The following table shows the tabulations of tests following a four year period of draught. The discharge measurements were taken over a Cippoletti weir having an 18" crest and represent the average flow in minute gallons for the period run. The drawdown is the actual difference in feet between the original water surface before and after pumping.

TABLE I.

ESTANCIA VALLEY WELL TESTS

Name—	Location	Date	Hours Tested	Depth Hole	Depth Casing	Size Hole	Size Casing	Static Level	Air Submergence	Air Pressure	Draw-down	Discharge mi. gals.	Remarks
J. Whitlow	26-5-8	5-16-25	14	110'		10"		9'- 0"	50'- 0"	31	12'-10"	116	Well caved in, test discont'd.
Ray Brown	17-5-8	7-11-25	16	127	43'	12"	12"	27'- 0"	96'- 0"	36	9'- 7"	326	Good quality of water.
H. L. Ramsey	23-7-8	6-17-25	140	161	132	12"	12"	3'- 0"	140'- 0"	54	47'- 0"	203	Good quality of water.
H. C. Williams—													
No. 1	26-6-8	6-26-25	14	318	165	8"	8"	8'- 0"	106'- 9"	46	50'- 8"	97	Good quality of water.
No. 2	23-6-8	6-27-25	4	60					58'- 0"				Pumped dry in 2 hours.
D. H. Cowley	2-5-8	7- 1-25	4	55		8"		9'- 0"	39'- 0"	34	19'- 2"	55	Good quality of water.
W. Waggoners	3-5-8	7- 3-25	10	45'-9"	45'-9"	24"	24"	8'- 0"	39'- 0"	35	9'-10"	151	Good quality of water.
E. Berry	9-5-8	7- 9-25	1	25				9'- 2"	19'- 6"				Pumped dry in 15 minutes.
State No. 3	36-5-8	8- 5-25	18	300	300	12"	12"	48'- 1"	73'- 7"	54	7'-11"	286	Water contains pack sand.
E. H. Ayers		7-29-25	7	81	81	10"	10"	9'- 6"	64'- 3"	39	34'- 6"	48	
A. J. Green	10-6-9	8- 7-25	16	769			8"	6'- 1"	148'- 2"	65	14'- 5"	354	Water good quality, muddy.
N. C. Williams	11-6-9	8-10											Not tested, well caved in.
Jessie Shirley	4-6-9	8-10	4	60			5⅝"	8'- 1"	48'- 0"	35	15'- 3"	63	
Ernest Green	3-6-9	8-10	6	137			5⅝"	3'- 2"	133'- 7"	56		248	Dr'wd'n 1 min. after shutd'wn
J. W. Koopen	28-7-9	8-12	8	100	74	6"	6"	10'- 0"	88'- 0"	44		178	Water slightly saline.
W. S. Compton	8-7-8	8-14	11	42		5'x5'		18'- 8"	23'- 6"	35	6'- 0"	151	Good quality of water.
Ross Archer	19-8-9	8-19	17	85		6"		22'-10"	55'-10"	35	37'- 0"	106	Good quality of water.
Harry Bigger	29-8-9	8-22	14	100		7"		23'- 8"	70'- 2"	47	9'- 8"	286	Good quality of water.
D. S. Martin—													
No. 2	31-9-9	8-25	11	72	72	18"	9"	13'- 0"	58'-10"	40	26'- 6"	126	Good quality of water.
C. H. Skinner	35-9-8	8-26	17	135			6"	44'- 2"	65'-10"	45	23'- 5"	126	
Seaman	33-9-9	8-26		105			6"	15'- 2"				60	Well caved in.
Geo. Woodmars	26-9-8	9- 2	12	67'		6"		17'- 4"	24'- 9"	31	11'- 3"	20	
J. N. Shirley	2-6-8	9- 4	6	72	20		8"	9'- 3"	56'- 7"	39	9'- 4"	140	Water slightly saline.
Pete Moe	9-5-9	9- 7	8	55			6"	19'- 6"	31'- 6"	36	18'-10"	106	Good quality water.
J. M. Milburn—													
No. 1	18-6-10	9- 9	13	98	98		5⅝"	7'- 2"	91'-10"	43	34'-10"	110	Good quality water.
No. 2	8-6-10	9-11	10	80	80		5⅝"	8'- 6"	74'- 5"	40	21'- 4"	172	
R. C. Farley—													
No. 1	3-7-8	11-27	2	84'-6"			5⅝"	0'- 0"		39		616	Combined test on both wells
No. 2	3-7-8	11-25	2	84'-0"			12"	0'- 0'			15'- 0"	534	gave 1060 gals. per minute.
Bud Hollebe	22-5-8	10-14	5	66'-4"			5⅝"	13'- 0"	47'- 0"	31	16'- 0"	145	Good quality water.
Town of Estancia	11-6-8	10-15		62'	62		12"						Good quality water.
J. W. Begley	20-5-8	10- 9	7	140"			12"	25'- 9"	67'- 3"	34	12'- 1"	248	6'x6'x20' pit. water good qual.
Haney	30-6-8	10- 8											Well filled up.
Henry Cox	32-6-8	10- 3	11	140'		7"		16'- 8"	46'- 4"	33	11'- 3"	313	Good quality water.
McIntosh Ranch	2-7-8	9-28						2'-11"					Rep't'd pumped dry in 15 mi.
John Britton	35-8-8	9-28		20'		42"		18'- 0"					Well caved in.
W. W. Wagoner	26-8-8	9-29	7	26'-6"		8"		7'- 2"	16'- 0"	30	8'-10"	20	Good quality water.
J. E. Homan	12-7-8	9-30	8	61'-8"		5'x5'		30'- 3"	31'- 0"	34	12'- 9"	145	Good quality water.



Nº	STATIC LEVEL	DEPTH OF WATER STRATUM	DISCHARGE G. P. M.	Nº	STATIC LEVEL	DEPTH OF WATER STRATUM	DISCHARGE G. P. M.
1		60		20	7-2	99	110
2	3-0	3.-25.-132.	203	21	6-1		354
3	48-1	59	286	22	8-0		
4	17-4		20	23	8-0		97
5	44-2		126	24	16-8	22-74-124-144.	313
6	13-0	35-65	126	25	8-0		151
7	15-2		60	26	9-0		55
8	22-10		106	27	9-2		
9	7-2		20	28	19-6		106
10	23-8	24-62	286	29	27-0	26-60	326
11	0-0		FLOWING WELL.	30	13-0		145
12	0-0	13-31-84	534	31	9-0		116
13	18-8		151	32	25-9		248
14	30-3		145	33		260 - 320	
15	10-0		178	34		57 - 209	
16	3-2		248	35		295	
17	8-1		63	36	(MINERMAN)	50, 62. 95. 238. 325, 572, 1770.	
18	9-3		140	37	(MUNOZ)	325.	
19	8-6		172	38	80-0	80 (WARFEL)	

Plate 1.—General map of Estanc'a Valley showing location of wells tested.

Plate No. 1 shows the location of all wells tested, each being designated by a number opposite which in the table may be found the static level, depths of water bearing strata, and discharge in minute gallons. In addition, there are shown several deep well locations, information upon which is not complete as some are still drilling.

Plate No. 2 represents graphically the drawdown and return flow in State Well No. 2, the curves being drawn in terms of the drawdown in feet and the hours from the beginning of pumping.

Plate No. 3 shows graphically the effect that pumping on State Well No. 2 has on adjacent wells located each side of test well and at right angles to direction of flow of underground water. The curves are drawn separately for different periods of pumping and show the drawdown in feet at different distances away from the test well.

It was the purpose to attempt the pumping of any and all wells which might tend to give the desired information irrespective of location, no effort being made to confine the test to any particular section of the valley. However, as the work progressed, it was found that the scarcity of suitable wells would necessarily restrict the investigation to the shallow-water belt. Considerable difficulty was experienced in obtaining reliable data with reference to the logs of the various wells, particularly as regards the depth and thickness of the water bearing strata, without which information it is impossible to accurately determine the extent and storage capacity of the water sands.

In the shallow water belt there appears to exist four distinct and continuous water bearing sands at depths of 25, 60, 84 and 136 feet respectively, all of which contain considerable water of good quality. The water table throughout this stretch varies but little, having a static level of about seventeen feet at Moriarty, three feet at McIntosh, and eight feet at Estancia and south for a distance of nine miles, beyond which it falls off rapidly until it reaches a depth of fifty-seven feet at Willard.

Artesian possibilities in the valley are not to be expected, especially in view of the failure to obtain flowing water in any of the deep wells recently drilled for oil. In the Munoz well, located in the SE 1-4, Sec. 5, T. 6 N., R. 7 E., the total depth reached was 1235 feet and the only water of any importance was found in a limestone formation at 345 feet, rising to within 200 feet of the surface. The Minerman well, SE 1-4, T. 7 N., R. 10 E., was abandoned at a depth of 2330 feet after encountering ten successive water bearing sands, the most prolific being at a depth of 325 feet from which point the water, of good quality, rose to within 50 feet of the surface and remained stationary during times of bailing. The first three waters between 60 and 238 feet contained small quantities of sulphur and between 572 and 1770 feet six sands were encountered which carried heavy salt water. The Randall and Warfel wells, located in Section 20, T. 6 N., R. 10 E., and Section 7, T. 6 N., R. 8 E., respectively, are still drilling, the first of which has reached a depth of about 300 feet and is having some difficulty casing off water of a decidedly poor quality, whereas, in the latter well drilling has been temporarily suspended at a depth of 265 feet but a small quantity of water of good quality was obtained at 80 feet, remaining at this level.

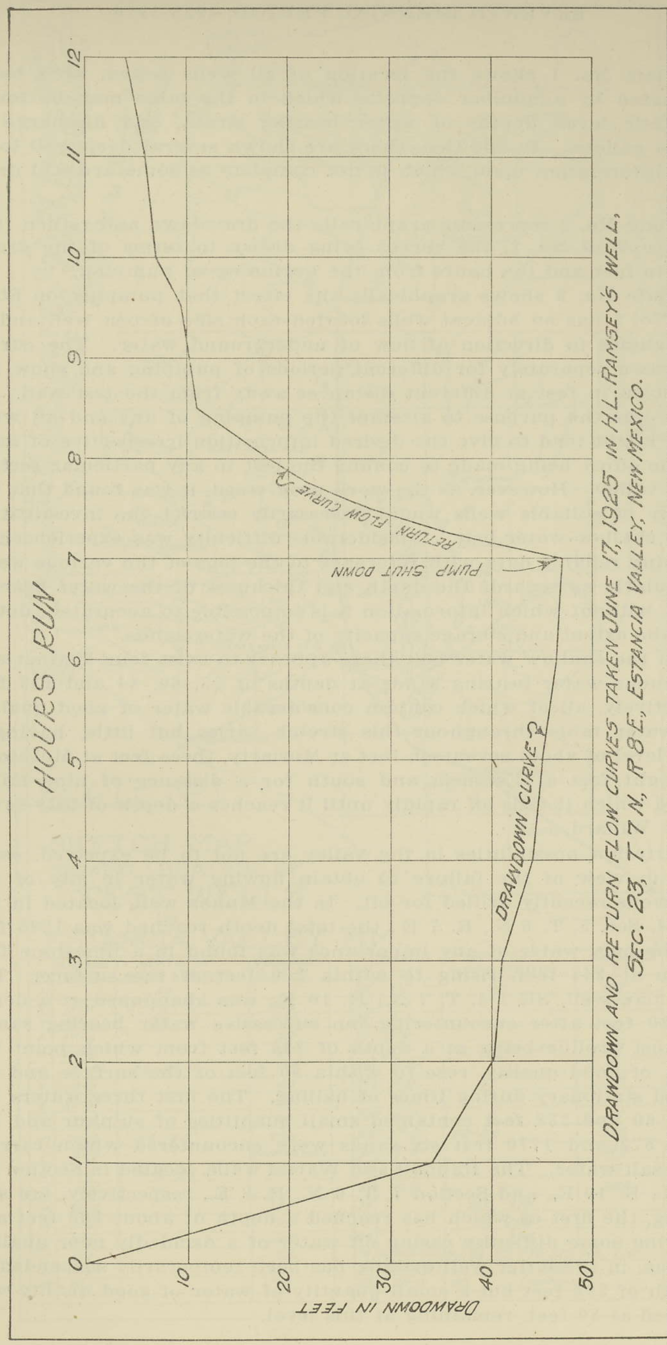


Plate 2.—Showing the drawdown and return flow during a period of tests on State Well No. 2.

Under an agreement entered into the 23rd day of August, 1924, between H. L. Ramsey of Estancia Valley and the State Engineer, whereby the surplus water from State Well No. 2 was used in an experimental test to study crop and soil conditions and the most economical duty of water, a plat of ground containing 9 acres was laid out and planted to pinto beans. Careful records were kept of the date each acre was planted; date and number of times irrigated either before or after planting; periods of rains; times cultivated; dates harvested; and yield per acre.

Acre No. 1 planted dry was a total failure, likewise acre No. 6 put to lima beans proved a loss, due to the destructive activity of rabbits, whose ravages were also responsible for only a half stand in four more acres. Of the five acres planted to pinto beans the yield averaged 425 pounds per acre, or a total of 2125 pounds.

There were four additional plats devoted to cane, corn, highgear and sudan grass, each of which received one irrigation before planting and three cultivations. These plats produced the following per acre yields: cane 3781 pounds, corn 2800 pounds, highgear 1400 pounds and the sudan grass 1600 pounds. The beans sold for $5.75 per sack and the forage crops were valued at $15.00 per ton. In addition to these, one-half acre of water melons brought $117.00.

From a total of 20.3 acres the gross return was $500.00 and after deducting for pumping-fuel and labor the net return was found to be $305.63. The average lift of the water was approximately 50 feet. It must be borne in mind that the season of 1925 was an exceptionally dry one and was preceded by four dry years. During this period also th s whole section was infected with rabbits which hindered the experiment and cut down the yields.

For the purpose of securing a more elaborate and detailed experiment on crop production and water requirements a co-operative agreement was entered into in January, 1926, between the Irrigation Department of the New Mexico Agricultural Experiment Station, the State Engineer's Office, the Continental Oil Company, and H. L. Ramsey of Estancia, New Mexico. The Irrigation Department of the State College was to furnish the seed, water-stage register, weir boards supervise the experiment, and furnish all parties with a copy of the yearly report upon its completion. The State Engineer was to furnish and install pumping equipment with suitable housing, purchase cement for foundations, headgates and weirs, and supply funds for the salary of the field co-operator. The Continental Oil Company agreed to donate 400 gallons of coal oil and additional fuel when necessary. H. L. Ramsey was to furnish 30 acres of land and all labor and farming equipment, prepare the field, plant, irrigate, cultivate and harvest the crops, as well as record all data relative to the same.

The equipment was purchased, installed and properly housed when the State Engineer's Office was compelled to withdraw from participation because it was held that expenditures from the "Water Reservoirs for Irrigation Purposes Income Fund" could not be made for investigation on irrigation projects. Notwithstanding this reversal, the Continental Oil Company adhered to its agreement and the State College attempted to carry out its original program and undoubtedly

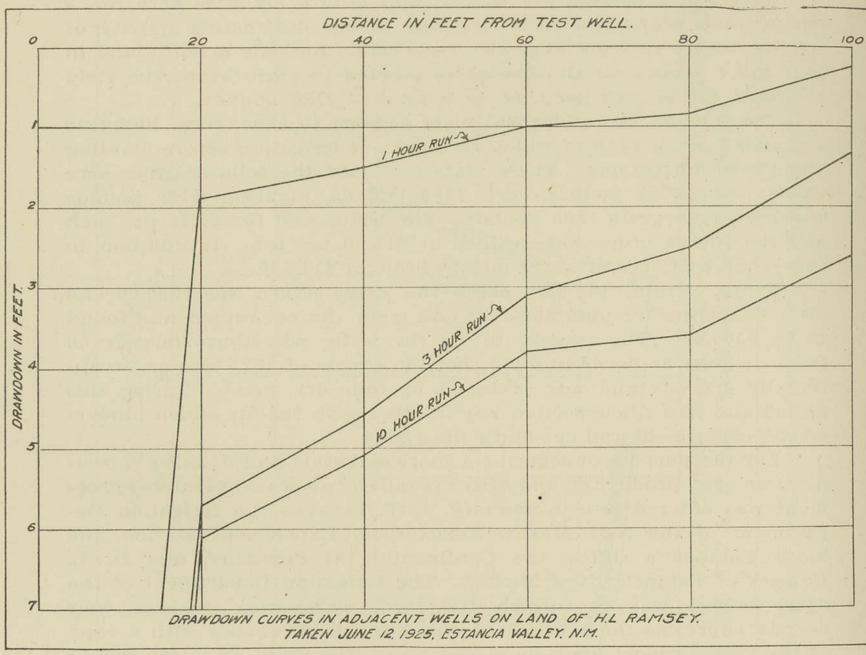


Plate 3.—Showing drawdown at different intervals of time during test on State Well No. 2.

would have been successful had it not been for three severe hail storms, the first and second occurring May 26th and June 17th, both of which completely ruined the crops. The third occurred August 23rd and destroyed one-half the replanted crops. This experiment has been designated as Purnell Project No. 7 by the New Mexico Agricultural Experiment Station and it is to be hoped that the work can be continued because of its inestimable value to the people of the Estancia Valley.

In addition to the investigations to encourage the utilization of the underground waters, a comprehensive study of the feasibility of storing surface flood waters and their economical application to the soil is under way.

Through the utilization of the flood waters by storage and the careful development of the underground waters by the installation of economical pumping equipment to supplement the rainfall, agriculture in this valley may be placed on a sound basis and attractive homes and employment provided for a large number of people.

The early portion of this investigation was conducted under the supervision of C. E. Perkins and the later portion under that of Fred G. Healy, both of the State Engineer's Office.

Financial Statement

Estancia Valley Investigation

Balance December 1, 1924			$16,031.80
Expenditures for 13th fiscal years:			
Salaries	$3,379.03		
Subsistence	263.58		
Transportation	909.39		
Miscellaneous Supplies	89.38		
Testing and Drilling	5,055.06		
Office Expense	50.50	$ 9,746.94	
Balance June 30, 1925		6,284.86	
		$16,031.80	$16,031.80
Balance July 1, 1925			$6,284.86
Expenditures for 14th fiscal year:			
Salaries	$2,631.85		
Subsistence	231.35		
Transportation	593.69		
Miscellaneous Expense	46.40		
Testing and Drilling	1,297.29	$4,800.58	
Sale of Equipment			693.61
Balance June 30, 1926		2,177.89	
		$6,978.47	$6,978.47

TAOS - RIO ARRIBA INVESTIGATION

Chapter 52 of the 1925 Session Laws makes an appropriation of $11,000 and directs the investigation of the feasibility of storage, reservoirs and canals for the purpose of flood control and for the reclamation of unproductive lands located west of the Rio Grande in western Taos and eastern Rio Arriba Counties from Rio de los Pinos and Rio de San Antone and other streams of the Rio Grande watershed.

An irrigation project under this Act means the diversion of water from the streams mentioned, which naturally flow from New Mexico into Colorado, from their channels across the divide into the drainage of the Agua de la Petaca, lying wholly within the State of New Mexico. In taking water from these streams we are confronted with prior direct diversion rights on them and also with possible objections from the State of Colorado. The endeavor is being made to find a simple plan by which the surplus waters can be diverted without excessive cost and stored in a reservoir, possibly in what is known as the No Agua reservoir site.

Numerous lines have been run from the streams in question to obtain preliminary costs of their construction and the point at which the water can be intercepted and delivered.

The field season in this locality is comparatively short, because of its high altitude and the severe snows which fall there, and the entire working season of 1925 was employed in the preliminary work necessary. The winter season following, up to the time of the tying up of funds, was spent by the engineer in charge, Mr. Earl M. Smith, in computing capacities, making estimates of cost of construction, and working up the data on the No Agua storage site.

Further preliminary lines are to be run from the water supply and crossing the ridge on the south side of San Antone Mountain to determine the estimates of construction and the amount of water which can be intercepted by such a plan, all of which is to be used in the selection and formulation of final plans for a feasible project. There are still other reservoir sites on the Agua de la Pataca to be considered and the final examination and classification of the best available lands to be irrigated are yet to be made. The work of this investigation has been pushed with all possible speed but must await the release of funds.

Financial Statement

Taos-Rio Arriba Investigation

Appropriated by 1925 Legislature			$11,000.00
Expenditures 14th fiscal year:			
Salaries	$2,294.48		
Subsistence	51.35		
Transportation	301.68		
Equipment and Supplies	1,028.76		
Miscellaneous Expense	25.71	$ 3,701.98	
Balance June 30, 1926		7,298.02	
		$11,000.00	$11,000.00

GUADALUPE - SAN MIGUEL INVESTIGATION

Chapter 109 of the 1925 Session Laws appropriates $7,500 and directs the making of investigations as to the feasibility of ditches and storage reservoirs for the purpose of flood control and for irrigation of lands in the Pecos River Valley within Guadalupe and San Miguel Counties, and the determination of the amount of flood waters of the Pecos River in these counties which is available for storage and irrigation.

A large part of the provisions of this Act have been covered by private surveys and reports and this department has taken up with private parties the matter of securing results of such surveys, in order that unnceessary field work might be avoided. A request to the Bureau of Reclamation for co-operation in this work was declined. The assembling of existing data was in process when the abandonment of the work was made necessary.

Financial Statement

Guadalupe-San Miguel Investigation

Appropriation by 1925 Legislature			$7,500.00
Expenditures 14th fiscal year:			
Salaries	$574.68		
Subsistence	52.65		
Transportation	77.15	$ 704.48	
Balance June 30, 1926		6,795.52	
		$7,500.00	$7,500.00

CAPITOL GROUNDS WELL

Because of the extreme shortage in the city water supply of Santa Fe during the season of 1925, the State Finance Board deemed it advisable to attempt to secure a dependable water supply from wells for irrigation of the lawns and trees on the Capitol and Mansion grounds and allotted for that purpose $2,000.00.

This work was placed under the direction of the State Engineer and it was decided to drill a well at the south end of the new addition to the State Capitol building in the bottom of and about three feet in a southwesterly direction from the center of the old dug well which existed there.

A well rig was found which could be purchased with all equipment for the sum of $600.00, and an arrangement was entered into with the State Penitentiary whereby the rig was purchased and paid for equally by the two departments.

Drilling commenced September 14th, 1925, and the rig was moved off November 20th, 1925. Considerable difficulty was encountered with quick sand and continued caving occurred during the early stages of the work, which conditions necessitated the frequent setting of casing accompanied by some loss of time. After reaching a depth of 90 feet the hole stood up and good progress was made.

The old dug well is 7 1-2 feet in diameter at bottom and 30 feet deep. The side walls are laid up in rock masonry for a distance of 21 feet, the lower 6 feet being dry masonry. The hole was drilled 18 inches in diameter for a depth of 32 feet and then carried 12 inches for 118 feet additional, making the total depth of well 180 feet from the surface of the ground. Single stove pipe casing, 18 inches in diameter, was temporarily set for the 32 foot section and later withdrawn, after being first replaced by double 12 inch, 10 and 16 gauge, casing and

the space between filled in with gravel to prevent the accumulation of quicksand in the well. The 12 inch double casing protrudes two feet above the bottom of dug well and extends for a depth of 96 feet. This casing is equipped with driving shoe, perforated and solidly riveted and "picked" together so that it may be more easily withdrawn. The hole is finished with 63 feet of 10 inch wrought iron pipe which overlaps the 12 inch casing seven feet. This pipe is jointed and in one continuous length, as is also the 12 inch casing, and thoroughly perforated.

The static level of water in dug well is 24 feet, 3 inches below surface of ground. First water was encountered at a depth of 47 feet, 6 inches, in a 12 inch thickness of fine gravel; second water at 67 feet in 12 inches of coarse gravel; third water at 72 feet in 2 1-2 feet of fine gravel; fourth water at 95 feet in 8 feet of fine sandy gravel; and fifth water at 146 feet in 6 feet of fine gravel. This stratum produced the greatest amount of water.

Originally the capacity of the dug well was very limited and usually required less than one hour's pumping to go dry. A test on the new well with air lift, using 3¼ inch discharge pipe and submergence of air nozzle of 126 feet from surface, was made on December 7th and developed an average discharge of 50 gallons per minute with an actual drawdown of 48 feet, the air pressure being 56 pounds. The present pump developed 35 gallons per minute for a period of one hour and ten minutes, or until the drawdown reached the level of the suction valve, after which the flow was reduced to and remained constant at 9 gallons per minute.

The total expenditures amounted to $1,767.71, itemized as follows:

Fuel	$163.95	
Well Rig and Equipment	391.94	
Automobile and Rig: Supplies and Repairs	160.83	
Casing and Fittings	262.28	
Freight on Well Rig	68.00	
Salary and Expense	391.30	$1,438.30
Testing Well North of Executive Mansion		329.41
		$1,767.71

The item for well rig and equipment includes an expenditure of $300.00 which covers one-half the purchase price of rig and represents the interest of the Capitol Custodian Commission in same. The Well Rig and complete set of drilling tools, costing $600.00, was purchased and is owned jointly by the State Penitentiary and the Capitol Custodian Committee. The inventory value and resale price of rig, equipment and casing included in the above items amounts to $452.25, which leaves a revised cost of $1,315.46.

The discharge from the new well is ample to irrigate the Capitol and Executive grounds but the present equipment is of too small capacity for this purpose and it will be necessary to install a type of deep well pump, having a capacity of at least 100 gallons per minute. However, it is believed that the capacity of the present equipment can be increased to approximately 30 gallons per minute with some slight changes, consisting of an increase in speed of engine and lengthening of suction and pressure pipes.

Careful computations disclosed that, at the rates for electrical current and water which prevail in Santa Fe, and based on a monthly consumption of 720,000 gallons, it would cost 17.3 cents per thousand to pump water from this well with electrical current purchased from the utility company, while the average cost for this amount of water purchased from the water company would be slightly over ten cents per thousand.

However, with current from a state owned plant at the penitentiary or with a suitable engine installation, the cost would be materially reduced. The well has a definite value as a standby in case there should come another water shortage that threatens lawns and trees on the Capitol and Mansion grounds.

HORMIGOSO AND JUAN DE PAIS COMMUNITY DITCHES

The Hormigoso and Juan de Pais Community Ditches, both diverting through the same intake during recent years, are located near the San Miguel-Guadalupe County line on the Pecos River, and are among the oldest ditches in the State so far as known. The dam, built of rock-filled cribs, was entirely destroyed by flood and there was no water available during the seasons of 1924 and 1925. Some families under these ditches were forced to move to other localities and others to undertake other employmnt for their subsistence.

In October, 1925, these communities, through a committee, sought assistance from the State Engineer to build an entire new dam and intake canal. There were no funds available to the State Engineer for such assistance, but, after going over the situation and pointing out the most feasible and logical course to be followed, Mr. C. E. Perkins was assigned to the task of making surveys and designs for a new dam and canal, connecting with their canal system. Estimates were furnished them, showing what proportion of cost of this work would be necessary in cash for the purchase of supplies and materials, the remaining portion to be furnished by the water users in labor. By this method, works representing a total value of approximately $20,000 were constructed with a cash outlay not to exceed $2,400. The dam itself is built of rubble masonry upon solid rock and it is believed will serve these communities for an indefinite period.

As the new diversion is about ¾ of a mile upstream from the old it was necessary to build that length of canal, the last 800 feet of which is along the face of a red sandstone cliff and is not yet entirely completed. The work had advanced, however, to such a stage as to serve for the season of 1926.

EL RITO SPANISH - AMERICAN NORMAL SCHOOL

Late in 1925, the attention of the State Engineer was invited to the condition of the water supply of this institution and an inspection was made by him. In January, 1926, Mr. C. E. Perkins was assigned to make a detailed examination and the following report was submitted:

REPORT
EL RITO SPANISH - AMERICAN NORMAL SCHOOL
Water Supply Investigation

This school has been operating continuously since 1909. The enrollment has gradually increased to 138 students. The water supply is obtained from a well sixty feet deep in the campus and an intermittent irrigation supply from a small ditch supplied by a flow through private ditches from El Rito Creek.

On account of the growth of the institution the domestic water supply is inadequate and the strictest economy is entailed. No baths are available and the latrines are necessarily closed during a large part of the day. In fact, the want of sufficient water is deplorable and intolerable for a State institution.

The well heretofore mentioned was dug about fifteen feet in diameter to three feet below the ground water table elevation, which has a seasonable variation of fifteen feet, the lowest occurring twice in the year, in early spring and late fall.

Electric power from the school lighting plant is used for pumping by means of a Fairbanks-Morse cylinder pump (an auxilliary Myers pump is available) which delivers all the water and inflow in the well in an average of six hours' time which is the daily supply. For some periods (which occur semi-annually) there is but 530 daily gallons' supply or less than four gallons per individual, and at such times the fire protection is nil.

It is possible and probable that other water can be developed by drilling or sinking this well to a greater depth, however, it is desired by the management to procure irrigating water in amount to cultivate from 20 to 50 acres and the seeming economical solution is to reservoir or store water from the River (El Rito). A reconnaissance of a zone west and north from the school building was made. A location was selected and surveys and estimates made.

The intake for a supply canal or ditch can best be made at a point some four miles distant from the reservoir but it will be possible to take advantage of some of the community ditches already constructed which run within a mile distant, this however, should be a temporary expedient.

The head from the proposed reservoir outlet is such that water can be conducted in pipes to the elevation of the upper story of the school building.

It is evident that seepage and evaporation losses in a reservoir and canal in this locality will be large, probably exceeding 50 per cent the first season, but with all evident drawbacks the situation is such that the necessity for more water offsets these. The reservoir site selected is about one-half mile westerly from the main school building.

The dam should be an earth fill to an average height of 7.4 feet and some 1,300 feet in length. The capacity with an allowance of two feet free-board will be 20 acre-feet, and 3,500 feet of pipe line should be laid from a point in the supply ditch to a stand pipe reservoir on the school tract of sufficient altitude to furnish pressure for fire protection purposes. The above and many details have been worked out in this office.

Estimate of Cost

Earthwork Dam:	
Embankment:	
6,000 cu. yds. at 40c	$2,400.00
Headgate and outlet	60.00
Ditches:	
Inlet 22,592 feet at 4c	903.68
Outlet 3,000 feet at 5c	150.00
Pipe Line:	
4,000 feet 2 inch pipe at 42c	1,680.00
Tank and Tower:	
10,000 gal. est.	1,000.00
Gates, etc.	20.00
	$6,213.68
Additional 10 per cent for incidentals	621.37
	$6,835.05

Water impounded at 5.4' contour will be twenty acre-feet.

The above estimate is such that freedom of action in construction can be used. In case such an amount is not available all costs may be pared down and eliminations made to conform to the sum at hand, but resort to such a method does not seem advisable.

It is recommended that action be at once taken to consummate a water filing with attendant rights-of-way from El Rito. This is imperative before any other action is taken.

(Signed) C. E. PERKINS.

Subsequent to this examination a detailed survey was made, a formal water application filed, steps taken to procure rights-of-way for canals and reservoir from the owners of the Lobato Grant.

These matters are now in abeyance, with the expectation of favorable results. Should there be an appropriation for this reservoir, which could evidently be made from the "Water Reservoirs for Irrigation Purposes Income Fund," economic height and detailed plans and specifications of dam and other features should be worked up. A domestic supply for the institution is imperative and an irrigation supply should return to the State its cost many fold in products raised.

RECOMMENDATIONS

In submitting a report upon the work of the State Engineer's Office for a period of two years, it would be a mistake to omit therefrom a record of the conclusions, bearing on legislative policies of the State, which have been reached, through work with the laws and a close observation of conditions as they exist. There is submitted hereinafter, with the recommendation that they be carefully considered by the legislature, a brief discussion of the following points: (a) A municipal or industrial concern should be granted a right to the use

of water to the extent to which it is prepared to utilize it; (b) a water user with a licensed or decreed right should be permitted to expand the acreage served by that right without taking a greater amount of water; and (c) the State Engineer should be permitted, when he deems it proper, to require **all** ditches to install suitable headgates and measuring devices and to furnish to his office a daily record of water drawn through that device and a seasonal report of the extent and class of crops grown under such ditch for the year.

(a) Under the present laws of the State an applicant can procure a final license only for that water which he has actually put to beneficial use. This is as it should be for irrigation but there are and will continue to be quite a number of applications for municipal and industrial uses of water. A city or a railroad does not build a water system for its immediate needs only but must provide for ten, fifteen, or twenty years in the future. Our present laws can not protect them in such construction because a license can be issued only for the amount of water which the applicant has put to beneficial use at the time the license is issued.

In cases which demand an ever increasing use of water, such as municipal, railroad and certain other industrial developments, our laws should grant the applicants such rights as their projects are prepared to utilize, subject of course to restrictions which will prevent unreasonable control of water supplies.

(b) Under the laws of our state water is appurtenant to the land, that is, a water right consists in the right to divert or store, as the case may be, a certain amount of water and apply it to a certain specified piece of land. In acquiring such a water right the applicant properly endeavors to secure for his land the largest possible supply, and even the State Engineer, in determining the amount to be granted, must take into consideration possible future changes in crops, methods of use, and low periods of precipitation. All this encourages a low duty of water.

After the amount of water to which an applicant is entitled is finally and definitely determined if he could be given the privilege, through a certain procedure before the State Engineer's Office, of applying that same amount of water to a greater area, a higher duty of water would be encouraged. Each individual could then work out the most economic rate of application and his area would expand or contract with the kind of crop grown or with his conviction as to how he can best use the water to which he is entitled. This should result in a higher duty of water, a greater area irrigated, and greater wealth to the State.

(c) Section 5707 of the New Mexico Statutes, Annotated, Codification of 1915, provides, among other things, that, whenever requested to do so by the State Engineer, any ditch owner shall construct and maintain a substantial headgate at the point where the water is diverted, and that he shall install a measuring device at the place and in the manner prescribed by the engineer.

It has been held by our courts that this law does not apply to community ditches and consequently is inoperative in such cases. If possible to do so this law or a similar one should be made effective

in all cases, in order to have control over the diversions and minimized flood damages on certain rivers.

The State Engineer should have the power to require the installation of measuring devices on **all** ditches when it is deemed necessary and the ditch owners should furnish him with a daily record of water passing such devices. They should also, along with such records of flow through ditches, submit each season an estimate of the acreage in different crops under said ditch, the number of water users, and the approximate acreage irrigated by each. Such records would be very valuable in making hydrographic surveys or in furnishing to the courts data on which to base decrees of water rights and would place in the files records showing whether or not ditches are increasing their use in violation of the laws.