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Hydrologic Data Collection Program for New Mexico

Ralph L. Strother

HYDROLOGIC DATA COLLECTION PROGRAM

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By

Ralph L. Strother

A Thesis
In partial fulfillment of the
Requirements for the Degree of
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DATE

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INTRODUCTION

Hydrology provides the engineer with basic data and methods required to solve engineering problems relating to the regulation, control and utilization of water. In a broad and literal sense the science of hydrology encompasses the behavior of water as it occurs in the atmosphere, on the surface of the ground and underground. Although extensive research has been conducted and enormous amounts of literature have been published on the subject, it cannot as yet be called an exact science. Due to variations in its functioning because of the innumerable combinations of hydrologic phenomena and physical conditions which may occur in nature, the science of hydrology has not yet progressed to the stage where any one exact scientific disposition of water can be expressed to the exclusion of all other possibilities.

Stereotyped procedures and criteria for hydrologic studies have never been developed. The variety of problems involved from place to place and from time to time, the variability and wide range of available data and the lack of positive progress in definitive research have all served to deter their development. Until relatively recent times this field of science has been almost completely dependent upon empirical relationships between various hydrologic

factors. Research and progressive improvement of methods are continuously adding new concepts and opening new avenues of approach. That some of the newly developed concepts and methods may be at variance with others already in use is only to be expected. Until there has been opportunity to thoroughly establish or refute new concepts and methods on the basis of fact, conflict and lack of agreement on new concepts are certain to exist.

Federal and state agencies responsible for planning of water use and control projects have developed, over the years, practices and procedures and have adopted criteria for hydrologic studies peculiar to their own needs. These are usually referred to as established agency procedures and criteria. However, even within the same agency they are not stereotyped. Instead of hard and fast rules of procedures and criteria, the general rule is that for any project or program the particular procedures and criteria used in the hydrologic analysis are determined by the type and extent of basic data available, the objective of the study and the training and past experience of the individual or individuals conducting the study. Foremost in any hydrologic analysis is basic hydrologic data. Basin- or state-wide planning of this all-important item should be initiated and followed through.

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CHAPTER I

OBJECTIVE AND SCOPE

The objective of this thesis is to present a program for the collection of basic hydrologic data for the state of New Mexico. It is an expansion of the existing program which currently becomes more inadequate with the progressively extensive use of the water resources of the state. The need for hydrologic data for planning and operation of water use and control structures far exceeds that obtained by the existing program.

Types of data reported upon are climatological, stream flow, ground water, quality of water, suspended sediment, snow cover and reservoir, valley and channel sedimentation. For the purposes presented herein the individual programs are listed by the five larger drainage basins within the state. These are the Rio Grande, the Pecos, the Canadian, the Gila and the San Juan rivers. Brief descriptions of these drainage basins follow.

Rio Grande Basin. The Rio Grande rises in the Rocky Mountains on the Continental Divide in southern Colorado and flows 182 miles in a southeasterly direction through Colorado, then 465 miles southward across New Mexico to Texas and continues in a southeasterly direction to the

Gulf of Mexico, forming the international boundary between the United States and Mexico. Its major tributary, the Pecos River, rises in Mora County, north-central New Mexico, and flows also in a general southeasterly direction through the state and on through western Texas to its confluence with the Rio Grande near Langtry, Texas. The Rio Grande and the Pecos River watersheds together drain an area in New Mexico of almost 57,000 square miles or nearly half the area of the state. The terrain varies from rugged mountains to low-lying desert plains and mesa lands. Elevations range from more than 13,000 feet above sea level in the Sangre de Cristo Mountains north of Santa Fe to about 2,800 feet at the southern border.

The Rio Grande drainage area above the New Mexico-Texas state line is about 38,960 square miles, of which about 31,480 square miles lie in New Mexico. The principal tributaries of the Rio Grande, lying wholly within New Mexico, are the Rio Chama, Rio Galisteo, Jemez Creek, Rio Puerco and Rio Salado. The main stem and tributaries of the Rio Grande in New Mexico are entrenched in deep canyons or are confined to alluvial valleys that vary in width from one-fourth to four miles and in length from a few miles to more than 100 miles. There are three notable valleys along the main stem: Espanola (upper) Valley, about 30 miles long;

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The Rio Grande drainage area above the New Mexico-Texas state line is about 30,950 square miles, of which about 31,480 square miles lie in New Mexico. The principal tributaries of the Rio Grande, lying wholly within New Mexico, are the Rio Chama, Rio Galisteo, Jemez Creek, Rio Puerco and Rio Salado. The main stem and tributaries of the Rio Grande in New Mexico are entrenched in deep canyons or are confined to alluvial valleys that vary in width from one-fourth to four miles and in length from a few miles to more than 100 miles. There are three notable valleys along the main stem: Espanola (upper) Valley, about 30 miles long;

Middle Valley, about 165 miles long; and Lower Valley, some 110 miles in length. Within these valleys are some of the state's most densely populated areas, including Albuquerque, Belen, Socorro, Truth or Consequences and Las Cruces. Industries, transportation and communication facilities and highly developed agricultural areas are also concentrated along the Rio Grande.

Over the past years, deposition of large quantities of sediment brought down by floods has caused a gradual building-up of the Rio Grande channel through the valley reaches. At the present time in the Espanola and Middle Valleys the stream bed is as high as, and in many localities higher than, the adjacent valley floor. As a result, the developed areas in the valleys are subject to damage from major floods of the Rio Grande. In addition large areas of valuable agricultural land are becoming nonproductive as a result of the rising water table. Also the accumulation of sediment in the stream bed has encouraged and promoted the growth of native vegetation which pirates vast quantities of water.

Pecos River Basin. The Pecos River watershed in New Mexico drains an area of about 25,470 square miles. The principal tributaries of the Pecos River in New Mexico are Salt Creek, Rio Hondo, Rio Felix and Rio Penasco. The

larger towns in the watershed, Las Vegas, Santa Rosa, Fort Sumner, Roswell, Artesia and Carlsbad, are located in the valleys of either the main stem or its tributaries.

There are many diversion and storage dams on the Pecos River and its tributaries constructed for the purpose of regulating and utilizing stream flow to provide water for irrigation. However, the supply, generally insufficient except in time of floods, is a limiting factor in the development of the watershed. The use of water and water rights have been the subject of litigation for years, and until recently basin-wide development of the resource was hampered by the lack of agreement between the states on the division and use of waters of the Pecos River and its tributaries. In 1949 a compact which provides for apportionment of Pecos River waters and contains provisions to permit and facilitate full development of the river became effective.

Canadian Basin. In northeastern New Mexico an area of approximately 16,910 square miles drains to the Mississippi River as a part of the Arkansas River system. The Canadian River, the North Canadian River and the Cimarron River are the principal streams in the area. The latter two are locally known as Corrumpa Creek and the Dry Cimarron River, respectively. Each of these streams is

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San Juan Basin. The San Juan River, a tributary to the Colorado River, drains the northwest part of the state west of the Continental Divide. Major tributaries

which enter the San Juan River in New Mexico are Los Pinos, Animas and Chaco Rivers. The principal towns are Farmington and Shiprock.

Gila Basin. The Gila River, also a tributary to the Colorado River, drains the southwest part of the state. Major tributaries which enter the Gila River in New Mexico are the Diamond, Sapillo, Duck, Mangas and Blue Creeks. Principal towns are Lordsburg and Red Rock. Also included is the closed basin of the Mimbres River in south-central New Mexico, with the principal towns of Silver City and Deming.

PROCEDURES

Procedures followed in selecting the recommended program for each type of data were as follows:

A list of all existing and proposed water resource projects within the state was obtained from the Soil Conservation Service, Bureau of Reclamation, Corps of Engineers and the Office of the State Engineer. These projects are located on a map of the state designated as Plate 1, and are listed in Table 1 on pages 15 to 17. Existing collection points for each type of data were located on overlays of Plate 1. These overlays were placed over Plate 1 to determine the adequacy of the

existing programs to supply the required data. When an existing program appeared inadequate, recommended additions or modifications were made. No statistical criteria or techniques were used to develop the patterns or densities of the station programs required for the basic data hydrologic program herein recommended. All recommendations were based on individual judgement in determining the additional stations, instrumentations and modifications necessary to provide a rather uniform distribution capable of producing a fair sampling of the various types of data that are basic to general hydrologic studies and research over the state. It was intended that recommendations be limited to a program both technically plausible and economically feasible. In no area was it deemed desirable to provide for an instrumentation which was sufficiently dense to produce all the data needed for special studies or detailed investigations. In general, the recommended program is meant to be a reasonable compromise for meeting the general needs of federal and state agencies within New Mexico.

TABLE 1

WATER RESOURCES DEVELOPMENTS IN NEW MEXICO

Basin	Development No.	Development	Status	Purpose
Canadian				
	1	Baker Reservoir	Proposed	Irrigation
	2	Honey Reservoir	"	"
	3	Bueyeros Reservoir	"	"
	4	Guadalupita Reservoir	"	"
	5	Conchas Reservoir	Existing	Flood Control and Irrigation
Rio Grande				
	6	El Vado Reservoir	Existing	Irrigation
	7	Abiquiu Reservoir	Proposed	Flood Control
	8	Chamita Reservoir	"	" "
	9	Jemez Reservoir	Existing	Flood and Sediment Control
	10	Bernalillo Arroyo Control	Proposed	Watershed Improvement
	11	Bluewater Reservoir	Existing	Irrigation

(Cont'd)

Basin	Development No.	Development	Status	Purpose
Rio Grande (Cont'd)	12	Rio Puerco Reservoir	Proposed	Irrigation, Flood and Sediment Control
	13	Elephant Butte Reservoir	Existing	Irrigation, Power
	14	Caballo Reservoir	Existing	Irrigation
	15	Hatch Valley Arroyos	Proposed	Watershed Improvement
	16	Dona Ana Arroyo	"	" " "
Pecos	17	Los Esteros Reservoir	Proposed	Irrigation and Flood Control
	18	Alamogordo Reservoir	Existing	Irrigation
	19	Upper Rio Hondo	Proposed	Watershed Improvement
	20	Two Rivers Reservoir	"	Flood Control
	21	Upper Penasco	"	Watershed Improvement
	22	McMillan Reservoir	Existing	Irrigation
	23	Auelon Reservoir	"	"
San Juan	24	Navajo Reservoir	Proposed	Irrigation

(Cont'd)

Basin	Development No.	Development	Status	Purpose
Gila				
	25	Hooker Reservoir	Proposed	Irrigation

NOTE: Diversion structures and irrigation projects are not listed.

Developments are located on Plate 1.

CHAPTER II

DESCRIPTION OF THE PROBLEM

Need for hydrologic data. Optimum development of the water resources of the state is an ultimate objective of comprehensive long-range planning in New Mexico. Knowledge of the quantity, quality and mode of occurrence of this important resource is essential if projects and programs for its control and utilization are to be well planned and efficiently operated. The foundation for this knowledge is basic hydrologic data.

To be most useful the collection of hydrologic data should precede project planning by a considerable number of years. Unfortunately, it is now too late to do anything about the deficiencies of past hydrologic collection programs. It must be appreciated, however, that full development of the water resources of the state can be accomplished only over a period of many years. Hydrologic data collection programs should be adjusted and expanded as soon as possible to anticipate needs for data for future planning, design and construction, for the refinement of development plans now in preliminary stages, and for the more efficient operation of current projects and programs.

During the last two decades good progress has been made in expanding data collection programs in New Mexico,

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During the last two decades good progress has been made in expanding data collection programs in New Mexico, but a great deal of additional information is needed. Frequent inadequacy and occasional complete absence of data regarding water supply in some places is a recognized barrier to solution of problems faced by individuals working with hydrologic data of New Mexico. Currently available hydrologic data are insufficient to answer all the problems encountered in a broad interrelated program for use and control of the state's water resources.

CHAPTER III

HYDROCLIMATIC DATA PROGRAM

Weather stations. Precipitation in all its various forms constitutes the gross water supply upon the land. Accurate knowledge of the precipitation regime of an area is important in the planning and operation of water utilization projects and programs. Information on other meteorological data such as pan evaporation, temperature, humidity, sunshine and wind velocity are also important to planning and operation.

Records of precipitation and other meteorological data in New Mexico are generally more extensive and of longer history than other types of hydrologic data. The earliest records of weather were collected by the Army Signal Corps at the forts and outposts which were located in the state over a hundred years ago. At a few of these original locations records have been collected continuously for approximately 100 years. Following creation of the Weather Bureau in 1870 a systematic collection of climatological data was established. Throughout the years, gradually and with the assistance of a large number of public-spirited voluntary observers, the network of climatic observations was expanded.

Currently, the hydroclimatic network for the state consists of 315 stations which is equivalent to an average density of one station for each 387 square miles. This average density, if uniformly distributed, with proper instrumentation would be more than adequate for the definition of general climate characteristics. However, there are many areas where a more uniformly distributed grid is desirable to provide adequate areal coverage over small areas. The Department of Agriculture, the Corps of Engineers and the Weather Bureau established in 1939 a hydroclimatic network to supplement the Weather Bureau network of meteorological and climatological stations. This program has been continued to date and has resulted in a greatly improved coverage for this essential type of data. The locations of the stations comprising the existing program are shown on the map of Precipitation Stations, Plate 2.

In hydrologic studies meteorological data, because of extensive coverage and long history, are most valuable as a basis for extrapolation of other types of hydrologic data, both for areal coverage and for historical time coverage. There are, however, many deficiencies in available information. Like all hydrologic phenomena, meteorological factors vary continually from time to time and place to place. The existing meteorological network of stations

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Evaporation and transpiration processes in nature are subjects which require much additional observational data before their probable effects can be accurately predetermined or extrapolated to unsampled areas. Additional information is therefore needed on pan evaporation, temperature, wind movement and solar radiation. As many of these meteorological factors are more uniform over large areas than rainfall, fewer observations are required to define averages and ranges in fluctuation. Table 2, Pages 26 to 34, lists the individual stations which comprise the existing hydroclimatic program. The areal distribution of the recommended program is shown on the map on Plate 2 with the existing program.

Distribution of the recommended program by river basins is shown in the following tabulation:

Distribution of Recommended Hydroclimatic
Program by River Basins

Status	Rio Grande	Pecos	Canadian	Gila	San Juan	Total
Existing	105	89	57	39	25	315
Additional	27	19	5	3	8	62
Modifications*	6	5	6	6	4	27

*Modifications to existing installations.

New techniques. The development of new techniques in the meteorological field may have considerable effect in the future on the collection of hydroclimatic data. Radar-meteorology promises much assistance to the hydrologist in overcoming rainfall data deficiencies. At the present time use of this facility is in its infancy, and the recommended data observations will assist in its development.

Improvements in long-range weather forecasting are being sought constantly, and experiments are being made currently on the latest ideas in numerical forecasting by means of electronic computers.

It cannot be stated positively at this time what may develop with regard to the controversial question of weather modification by artificial means. At present, so far as is known, most of the experimental work along this line has been concentrated on cloud-seeding with dry ice or silver iodide in an attempt to increase rainfall at times and places

where precipitation is likely to occur.

Snow surveys. Irrigation projects on streams draining the high mountain areas of New Mexico are largely dependent upon runoff from snow melt in the spring or early summer seasons. The efficient operation of such projects depends in large measure on advance knowledge of the water supply that will be available each year. Thus the forecasting of water supplies from stored snow is extremely important to the water users of New Mexico. Sudden melting of the snow pack can create local flood problems, and advance warning of a flood potential will be useful in planning remedial action.

The collection of data on distribution, amounts and water content of the snow received comparatively little attention until about the middle 1930's. In 1935 Congress designated the Division of Irrigation, Bureau of Agricultural Engineering, U. S. Department of Agriculture, to coordinate and expand the existing program of snow surveys for water supply forecasting in all of the western states. These responsibilities were later transferred to the Soil Conservation Service. This program has developed as a cooperative undertaking between the states, private concerns and federal agencies acting under the general leadership of the Soil Conservation Service.

Snow surveys in New Mexico are conducted through cooperative agreement between the Office of the State Engineer and the Department of Agriculture, Soil Conservation Service. These surveys, upon which water supply forecasts are based, were initiated in 1937. As of September, 1954, twenty-two snow courses were in operation in the various basins of New Mexico. These were distributed as follows: Rio Grande 14, Pecos 1, Canadian 1, Gila 6. Depth of snow and water content measurements are made on a regular schedule within four days of the first day of February, March and April of each year. Occasional measurements are made during the month of May. In addition to the New Mexico courses in the Rio Grande Basin there are 20 snow courses in Colorado which furnish pertinent data for that basin.

To serve adequately the immediate needs of the state it is recommended that nine additional courses be established. The present program of snow surveying is tabulated in Table III, page 35 and the present locations and recommended locations for additional snow courses are plotted on Plate 3.

TABLE II

HYDROCLIMATIC STATIONS IN NEW MEXICO

CANADIAN BASIN

Station Number	Station	Instrumentation				
		Precipitation	NC	C	Temperature	Evaporation
1	Rutledge Ranch	x	x			
2	Long Canyon	x	x			
3	Lake Maloya	x	x		x	
4	Raton Filter Plant	x	x	x	x	
5	Dawson	x	x			
6	Philmont Ranch	x	x	x	x	
7	Eagle Nest	x	x	x	x	x
8	Cimarron	x	x		x	
9	Cimarron	x	x			
10	Maxwell	x	x		x	
11	Cunico Ranch	x	x			
12	Capulin 6 SSE	x	x		x	
13	Des Moines	x	x		x	
14	Grenville	x	x		x	
15	Clayton WB AP	Complete Meteorological NC & C				
16	Clayton 9 SE	x	x		x	
17	Sedan 7 NW	x	x	x		
18	Hayden 6 NE	x	x			
19	Pennington	x	x			
20	Pasamonte	x	x	x	x	
21	Gladstone	x	x			
22	Yates 6 S	x	x			
23	Ojo Rico Ranch	x	x			
24	Levy	x	x		x	
25	Abbott	x	x			
26	Springer	x	x	x	x	
27	Miami	x	x		x	
28	Aurora	x	x	x		
29	Black Lake	x		Storage		
30	Chacon	x		Storage		
35	Gascon	x	x		x	

(Cont'd)

CANADIAN BASIN (Cont'd)

Station Number	Station	Instrumentation				
		Precipitation	NC	C	Temperature	Evaporation
41	Valmora	x	x		x	
42	Optimo	x	x			
43	Roy	x	x	x	x	
44	Solano	x	x			
45	Mosquero	x	x		x	
46	Bueyeros	x	x			
47	Amistad	x	x		x	
48	Ione	x	x	x		
50	Naravisa	x	x			
51	Obar	x	x		x	
52	Logan	x	x		x	
53	Tucumcari	x	x	x	x	x
54	Tucumcari CAA AP	Complete Meteorological NC				
55	Tucumcari	x	x			
56	Montoya	x	x			
57	San Jon	x	x		x	
58	Porter	x	x			
59	Endee 5 SSE	x	x			
60	Cameron	x	x		x	
63	Quay 2 S	x	x			
70	Newkirk	x	x			
71	Variadero	x	x			
72	Conchas Dam	x	x	x	x	x
73	Bell Ranch	x	x		x	
74	Sanchez	x	x			
75	Trujillo	x	x			

PECOS BASIN

Station Number	Station	Precipitation	NC	C	Temperature	Evaporation
31	Cowles	x	x		x	
32	Cowles 1 SE	x			Storage	
33	Holy Ghost Canyon	x	x			
34	Tererro	x	x	x	x	
36	Harveys Upper Ranch	x			Storage	
37	Elk Cabin	x			Storage	
38	Pecos RS	x	x		x	
39	Las Vegas	x	x		x	

(Cont'd)

PECOS BASIN (Cont'd)

Station Number	Station	Instrumentation: Precipitation	NC	C	Temperature	Evaporation
40	Las Vegas CAA AP	Complete Meteorological NC & C				
61	Forrest	x	x			
62	Ragland	x	x			
64	House	x	x			
65	Hassell	x	x			
66	Alamogordo Dam	x	x	x	x	x
67	Powell Ranch	x	x			
68	Pastura	x	x		x	
69	Santa Rosa	x	x		x	
76	Dilia	x	x	x	x	
77	Villanueva	x	x			
78	Ribera	x	x			
79	Rencona	x	x		x	
80	Palma	x	x			
81	Pedernal	x	x			
82	Duran	x		x		
83	Vaughn	x	x		x	
84	Corona	x	x		x	
85	Ancho	x	x			
86	Carrizozo	x	x	x	x	
87	Bonita Dam	x		x		
88	Monjeau Lookout	x			Storage	
89	Cedar Creek Ski Club	x			Storage	
90	Ruidoso	x	x	x	x	
91	Nogal Lake	x		x		
92	Capitan	x	x			
93	Ft. Stanton	x	x		x	
94	White Tail	x	x			
95	Picacho	x	x		x	
96	Hondo	x	x			
97	Capitan Crest	x			Storage	
98	Farnsworth Ranch	x	x	x		
99	Dunlap	x	x	x	x	
100	Yeso Overton Ranch	x	x		x	
101	Yeso 2 S	x	x			
102	Canton	x	x			
103	Ft. Sumner 5 S	x	x			
104	Ft. Sumner	x	x		x	
105	Taiban	x	x			
106	Melrose	x	x		x	

(Cont'd)

PECOS BASIN (Cont'd)

Station Number	Station	Instrumentation				
		Precipitation	NC	C	Temperature	Evaporation
107	Clovis 13 N	x	x	x	x	x
108	Frio Draw	x	x			
109	Clovis	x	x	x	x	
110	Portales 7 WNW	x	x		x	x
111	Floyd	x	x			
112	Portales	x	x		x	
113	Elida	x	x		x	
114	Union Valley	x	x			
115	Milnesand	x	x			
116	Crossroads 1 NNE	x	x			
117	Bitter Lakes Wild Life Refuge	x	x		x	x
118	Roswell WB AP	Complete Meteorological NC & C				
119	Hagerman	x	x		x	
120	Caprock 4 SE	x		x		
121	Tatum	x	x		x	
122	Lovington 1 NW	x	x		x	
123	Maljamar	x	x	x	x	
124	Artesia	x	x	x	x	
125	Pearl	x	x	x	x	
126	Hobbs CAA AP	Complete Meteorological NC & C				
127	Hobbs	x	x		x	
128	Jal	x	x		x	
129	Ochoa	x	x			
129A	Carlsbad Caverns	x	x		x	
130	Carlsbad CAA AP	Complete Meteorological NC				
131	Carlsbad	x	x	x	x	
132	Lake Avalon	x	x		x	x
133	Felix	x	x			
134	Elk	x	x		x	
135	Mayhill RS	x	x		x	
136	Sacramento	x		x		
137	Carissa Lookout	x			Storage	
138	Lulu	x	x			
139	Alamogordo	x	x		x	
140	Mountain Park	x	x		x	
141	Cloudcroft 2	x			Storage	
142	Cloudcroft 1	x	x		x	
143	Mescalero	x	x		x	
144	Tularosa	x	x		x	

(Cont'd)

PECOS BASIN (Cont'd)

Station Number	Station	Instrumentation: Precipitation	NC	C	Temperature	Evaporation
145	White Sands Nat.M.	x	x	x	x	
146	Orogrande	x	x	x	x	

RIO GRANDE BASIN

Station Number	Station	Precipitation	NC	C	Temperature	Evaporation
147	Afton 5 ESE	x	x			
148	Agric College	x	x	x	x	x
149	Las Cruces	x	x		x	
150	Florida	x	x	x	x	x
151	Jornada Exp. RS	x	x	x	x	x
152	Hatch	x	x		x	
153	Parks Ranch	x	x			
154	Wedgewood Place	x	x			
155	Hillsboro 1 SSE	x	x	x	x	
156	Caballo Dam	x	x	x	x	x
157	Aleman Ranch	x	x			
158	Engle	x	x			
159	Elephant Butte Dam	x	x		x	x
160	Truth or Consequences 2 NE	x	x	x	x	
161	Truth or C. CAA AP	Complete Meteorological NC				
162	Narrows	x		x		x
163	Pankey Ranch	x	x			
164	Winston	x	x		x	
165	Rienhardt Ranch	x	x	x		
166	Bosque de Apache	x	x	x	x	x
167	Bingham	x	x		x	
168	Socorro	Complete Meteorological NC & C				
169	Kelly Ranch	x	x			
170	Magdalena	x	x		x	
171	Boys Ranch	x	x		x	
172	Gran Quivira Nat. M.	x	x		x	
173	Progresso	x	x	x		
174	Mountainair	x	x		x	
175	Bfeister Ranch	x	x			
176	Capillo Peak	x			Storage	
177	Estancia	x	x		x	
178	Tajique	x	x		x	
179	McIntosh	x	x		x	

(Cont'd)

RIO GRANDE BASIN (Cont'd)

Station Number	Station	Instrumentation				
		Precipitation	NC	C	Temperature	Evaporation
180	Los Lunas	x	x		x	
181	Belen	x	x		x	
182	Harrington Ranch	x	x			
183	Laguna	x	x	x	x	
184	Marquez	x	x			
185	Montano Grant	x		x		
186	Experiment Farm	x	x		x	
187	Albuquerque WBAP	Complete Meteorological NC & C				
188	Netherwood Park	x	x		x	
189	Sandia Crest	x	x	x	x	
190	Sandia Ski Course	x		Storage		
191	Sandia Park	x	x		x	
192	Tijeras RS	x	x		x	
193	Edgewood	x	x			
194	Otto CAA AP	Complete Meteorological NC & C				
195	Golden	x	x			
196	Hagan	x	x			
197	Bernalillo INNE	x	x	x	x	
198	Jemez Dam	x	x	x	x	x
199	Cabezon 5 SW	x		x		
200	Espiritu Santo Grant	x	x			
201	Jemez Springs	x	x		x	
202	Vallecitos	x	x			
203	Turquoise	x	x			
204	Santa Fe CAA AP	Complete Meteorological NC & C				
205	Glorieta	x	x			
206	Santa Fe	x	x	x	x	x
207	Elk Cabin	x		Storage		
208	Big Tesuque Ski Club	x		Storage		
209	Santa Fe Lake	x		Storage		
210	Bandelier Nat. M.	x	x		x	
211	Los Alamos	x	x		x	
212	Star Lake	x	x		x	
213	Penistaja	x	x		x	
214	Johnson Ranch	x	x			
215	Cuba	x	x		x	
216	Wolf Canyon	x		Storage		
217	Espanola	x	x		x	
218	Nambe 1	x	x			
219	Truchas	x		Storage		

(Cont'd)

RIO GRANDE BASIN (Cont'd)

Station Number	Station	Instrumentation: Precipitation	NC	C	Temperature	Evaporation
220	Alcalde	x	x		x	
221	Penasco RS	x	x			
222	Agua Piedra Lodge	x			Storage	
223	Taos Canyon	x			Storage	
224	Taos	x	x		x	
225	Ojo Caliente	x	x			
226	El Rito	x	x			
227	Ghost Ranch	x	x			
228	Regina	x	x	x	x	
229	Gavilan	x	x		x	
230	Canjilon RS	x	x			
231	El Vado Dam	x	x		x	
232	Bateman Ranch	x			Storage	
233	Aspen Grove Ranch	x			Storage	
234	Tres Piedras	x			Storage	
235	San Cristobal	x	x		x	
236	Lobo Peak	x			Storage	
237	Red River	x			Storage	
238	Cerro	x	x		x	
239	Skarda	x	x			
240	Chama	x			Storage	
241	El Vado Dam	x	x	x	x	
242	Stinking Lake	x	x			
243	Wirt	x			Storage	
267	Thoreau 6 ENE	x	x			
268	Bluewater	x	x		x	
269	Grants	x	x		x	
270	San Mateo	x		x		
271	La Mosca Peak	x			Storage	
272	San Fidel 3 E	x	x	x	x	
273	Grants CAA AP	Complete Meteorological NC				
278	Hickman	x	x			

SAN JUAN BASIN

Station Number	Station	Precipitation	NC	C	Temperature	Evaporation
244	Dulce	x	x		x	
245	Vaqueros	x			Storage	
246	Gobernador	x	x		x	

(Cont'd)

SAN JUAN BASIN (Cont'd)

Station Number	Station	Instrumentation: Precipitation	NC	C	Temperature	Evaporation
247	Bloomfield	x	x		x	
248	Aztec Ruins Nat. M.	x	x		x	
249	Farmington 3 NE	x	x	x	x	x
250	Farmington CAA AP	Complete Meteorological NC				
251	Fruitland	x	x		x	
252	Shiprock 2 NW	x	x		x	x
253	Newcomb	x	x		x	
254	Cottonwood Pass	x			Storage	
255	Chaco Canyon Nat. M.	x	x		x	
256	Lybrook	x	x		x	
257	Otero	x	x			
258	Pitt Ranch	x	x			
259	Crownpoint	x	x	x	x	
260	Tohatchi Peak	x			Storage	
261	Tohatchi	x	x		x	
262	Mexican Springs	x	x			
263	Gallup KGAK	x	x		x	
264	Sheep Lab.	x	x			
265	Fort Wingate	x	x		x	
266	McGaffey	x	x		x	
274	El Morro Nat. M.	x	x		x	
275	Zuni CAA AP	Complete Meteorological NC & C				

GILA BASIN

Station Number	Station	Precipitation	NC	C	Temperature	Evaporation
276	Salt Lake 4 NE	x	x			
277	Quemado	x	x		x	
279	Augustine 7 SW	x	x	x	x	
280	Horse Mountain	x	x		x	
281	Jewett RS	x	x		x	
282	Luna RS	x	x	x	x	
283	Reserve RS	x	x		x	
284	Birmingham Ranch	x	x		x	
285	Adobe Ranch	x			Storage	
286	Inman Ranch	x			Storage	
287	Beaverhead RS	x	x	x	x	
288	Hedrick Ranch	x	x			
289	Willow Creek RS	x			Storage	

(Cont'd)

GILA BASIN (Cont'd)

Station Number	Station	Instrumentation				
		Precipitation	NC	C	Temperature	Evaporation
290	Fanny Ranch	x	Storage			
291	Mogollon	x			x	
292	Glenwood	Complete Meteorological NC				
293	Buckhorn	x	x			
294	Cliff 10 SE	x	x		x	
295	Bear Creek Ranch	x	x			
296	Mimbres RS	x	x	x		
297	Pinos Altos	x	x			
298	Ft. Bayard	x	x		x	
299	Silver City	x	x		x	
300	Redrock	x	x			
301	Virden	x	x			
302	Cureton Ranch	x	x			
303	White Signal	x	x			
304	Whitewater	x	x			
305	Faywood	x	x			
306	Deming	x	x			
307	Gage	x	x		x	
308	Lordsburg	x	x		x	
309	Road Forks	x	x			
310	Rodeo	x	x	x	x	
311	Animas	x	x		x	
312	Hatchita	x	x		x	
313	Hermanas	x	x			
314	Columbus CAA AP	Complete Meteorological NC & C				
315	Eicks Ranch	x	x	x	x	

NOTE: NC represents Non-recording Precipitation Gauge. C represents Recording Precipitation Gauge.

Stations are located on Plate 2.

TABLE III

SNOW COURSES IN NEW MEXICO

Basin	Course Number	Course
Canadian		
	1	Hematite Park
Pecos	2	Panchuela
Rio Grande	3	Red River
	4	Taos Canyon
	5	Aspen Grove
	6	Tres Ritos
	7	Pay Roll
	8	Chama Divide
	9	Chamita
	10	Cordova
	11	Big Tesuque
	12	Elk Cabin
	13	Rio En Medio
	14	Quemazon
	15	Bateman
	16	Fenton Hill
Gila	17	Frisco Divide
	18	State Line
	19	Taylor Creek
	20	Inman
	21	Black Canyon
	22	Mogollon

NOTE: Courses are located on Plate 3.

CHAPTER IV

STREAM FLOW DATA

History of investigations. The first sytematic measurements of stream flow in New Mexico were initiated in the Rio Grande Basin in the late 1880's and early 1890's. The records for one of these stations, Rio Grande at San Marcial, have been continued from 1895 to date and constitute the longest continuous discharge record in the state. The primary interest in stream flow in these earlier years was in connection with irrigation developments in the arid and semi-arid regions. Quite substantial stream-gauging programs were initiated throughout the state late in the nineteenth and early in the twentieth centuries. Unfortunately, most of the gauging stations were generally operated for only short periods and these earlier records were fragmentary and incomplete.

As interest in the flow of streams broadened in connection with problems other than irrigation, such as flood control, navigation and hydroelectric power, the need for records of stream flow became increasingly apparent and various states began to supplement the federal stream-gauging program. In 1929 Congress adopted the policy of dollar-for-dollar cooperation with the

CHAPTER IX

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The widespread droughts of the '30's, interspersed with damaging floods, gave impetus to public demands for better utilization and control of our streams. All of these factors contributed to the realization of the need for more information on the flow of streams, and systematic programs for the gauging of the most important streams began to take shape throughout the nation. Marked expansion in these programs in New Mexico began about 1938. During the period of 1938 to 1945 the number of gauging stations was about trebled, but only moderate expansion has taken place since then.

Current program. The existing program, as of September, 1954, for the collection of stream flow data states in connection with the stream-gaging program of the U.S. Geological Survey. At about the same time the Corps of Engineers was engaged in nation-wide investigations of water resource development as directed by the Rivers and Harbors Act of 1927 which resulted in the series of "308 Reports." The lack of adequate stream flow data greatly handicapped the Corps of Engineers in the prosecution of these studies, and one of their first steps in carrying out this broad directive was to expand the network of stream-gaging stations, largely in cooperation with the U.S. Geological Survey.

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<u>Current program</u>. The existing program, as of September, 1954, for the collection of stream flow data

consists of 165 stations for the determination of daily discharge or reservoir contents and various other stations where discharge and/or stage records are collected intermittently for periods of less than a month to several months. A listing of the existing gauging stations for which daily discharges and reservoir contents are being collected is shown on Table IV, Pages 60 to 71. Locations of these stations are shown on Plate 4.

The existing network of gauging stations furnishes fairly adequate information on the flows of major streams, although the length of many of the records is too short to delineate long-term trends in runoff. The smaller streams, in general, have less adequate coverage both in respect to areal extent and length of record.

Basic considerations in developing a comprehensive program for stream flow records. A comprehensive program for stream flow measurements in New Mexico should consider stations of the following general classifications: (1) a hydrologic network of primary or base gauging stations; (2) a supplementary network of secondary or short-term hydrologic stations; and (3) project or special purpose stations. The objective of primary and secondary hydrologic stations is to furnish the background of basic data for the development of surface water resources, consists of 165 stations for the determination of daily discharge or reservoir contents and various other stations where discharge and/or stage records are collected intermittently for periods of less than a month to several months. A listing of the existing gauging stations for which daily discharges and reservoir contents are being collected is shown on Table IV, Pages 60 to 71. Locations of these stations are shown on Plate 4.

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while the project or special project station serves the present; the hydrologic network, although of value for present needs, looks primarily to the future. Together they provide the facts needed for sound water management.

Primary hydrologic stations are stations which should be operated on a long-term continuing basis. The network coverage of these stations should be sufficiently intensive to represent in a general way the widely variable runoff characteristics of all parts of the region, to serve as base "correlation" stations and to be the basis for the definition of long-term trends in runoff. To be included in this group of stations are key stations at strategic points on major streams, stations at or near state boundaries on important streams, and stations in each major geologic and climatological province for small, medium and large streams. All such stations together serve to determine the net effects of development on long-term water supply.

It is not considered economically justifiable or practicable to operate long-term gauging stations on every minor stream or at every major stream site that may be subject to development or use at some time in the future. Instead, secondary or short-term stations may be established on these streams and correlated with the base

"correlation" stations in the primary network. Secondary stations are to be operated only for periods sufficient to develop adequate correlation with longer-term record stations. The short-term records may then be extended satisfactorily to cover known periods of critical flows.

Project stations are those gauging stations required for some specific purpose. Examples of needs for the records of such stations include the operation of various types of control works, administrative and legal problems related to stream discharge, the planning of water utilization or control works and information for research in hydrology and hydraulics. Project stations for operational, administrative and legal purposes will need to be operated for an indefinite period, but those for design of specific projects or research ordinarily would be established for a definite term.

Development of primary hydrologic network. In classifying stations for the primary hydrologic network the following criteria were generally observed: (1) The area gauged should be relatively homogeneous from a hydrologic standpoint and, where possible, be representative of a fairly large area; (2) the flow at the site should not be affected generally by regulation or diversion, but when so affected, adequate adjustments

for flow modification should be introduced; (3) records of an acceptable degree of accuracy should be obtainable at reasonable cost.

Observing these general criteria, the selection of primary stations was based on the estimated degree of correlation to be expected and the density of streams in each area on which water use or control developments might reasonably be expected in the future. Thus, primary stations are more closely spaced in areas of many perennial streams than in areas where streams are dry most of the time.

For the perennial streams throughout the state it was found that the need for primary network stations was quite well satisfied under the current program. Almost all of the stations listed in Table IV and located on Plate 4 were considered to be within the primary network. The major exceptions are reservoir stations and the canal stations which are considered as project stations.

Recommendations. With the perennial streams throughout the state being adequately gauged, it is not economically justified to recommend additional network stations for the intermittent streams even though some need for stream flow data would prove invaluable in the future. The probability of usage would not warrant investment even for secondary network stations.

Modifications to several existing stations are recommended, however, and will be discussed in Chapters V and VI.

The systematic collection of certain supplemental information in addition to that collected at regular gauging stations is recommended for inclusion in the program. Items suggested for inclusion are as follows: (1) a network of crest-stage gauges for use in developing flood-frequency curves for all portions of the state; (2) the determination of peak discharges for unusual floods at points other than at regular gauging stations; (3) the recording and preservation of high-water marks for outstanding floods along all important streams; (4) occasional or periodic measurement of ungauged streams, particularly those draining areas of large ground water discharge, for correlation with ground water investigations, and those in areas of existing or potential pollution problems for correlation with chemical and biological analysis of the waters. Needs for other supplemental information, not presently urgent, will no doubt develop as the economy of the state expands. For example, as optimum utilization of the water resources approaches, a comprehensive and continuing inventory of water use from all sources will be desirable.

CHAPTER V

QUALITY OF WATER DATA

Chemical quality. Water undergoes continuing alteration in chemical content as it progresses through the hydrologic cycle. The type of material with which water has been in contact as well as the length of contact period governs the degree of mineralization and ultimately the utility of the water. The quality of stream waters fluctuates quite widely both with time and location, primarily because of differences in climate and in solubility of rock materials. Evaporation from free water surfaces and transpiration by plants tend to increase quantities of dissolved minerals in stream water. Irrigation return waters, mine drainage, oil field waste waters, municipal sewage and industrial process wastes alter the chemical quality of water in streams.

In the New Mexico basins surface water of excellent quality is generally available in the high mountains. Quality of the stream water in the valley sections deteriorates generally from north to south, but there are so many special conditions that it is not feasible to predict what quality of water can be developed from a particular stream without systematic sampling.

The chemical quality of ground water also varies noticeably from place to place and with depth. Ordinarily the quality of water produced from a particular well is fairly consistent, but heavy pumping may result in introduction of water from adjacent areas and cause change in quality. Polluted waters from other sources may also enter the aquifer and impair the quality.

The chemical composition of available water determines in many ways the use to which the water may be put. In such uses as development of hydro-power and navigation, chemical quality is unimportant. But for other uses such as irrigation or municipal and industrial water supply there are definite limitations on the concentrations of minerals that can be tolerated. The demand of many industrial processes for water of high purity is increasing, and these more exacting needs are causing a continual search for water of better quality. Most uses of water cause some deterioration in quality, and the continual use and reuse of water can render it unfit for many purposes.

The collection of data on chemical quality of surface waters for the most part has lagged behind the collection programs for the other types of hydrologic data. Scattered samples have been collected over a

period of many years, but no continuous or systematic program of sampling has been carried on until comparatively recent years. Current programs vary widely from basin to basin and for many areas are seriously deficient.

Considerable data on the chemical quality of ground water in the state has been collected as part of ground water investigations, but in many areas where ground water investigations have not been made chemical quality data on the ground water resource are very deficient. However, much miscellaneous information is available from analyses of many municipal and some industrial supplies from ground water sources.

In the formulation of a program for the collection of data on the chemical quality of surface waters to supplement the existing program two types of network stations were considered: primary, those to be maintained on a permanent or continuing basis; and secondary, those to be maintained for a relatively short period of one to three years. Primary stations are useful in evaluating normal fluctuations, long-term trends or changes due to changing water or land uses. Secondary stations are generally designed to meet the planning requirements of a specific project or to extend general coverage. The frequency of sampling for all stations in the recommended program is to be adequate for the

determination of daily values. The concentration of dissolved minerals usually varies widely with rates of stream discharge, therefore, in order to obtain weighted average concentration, it is desirable that sampling stations be established at sites where stream flow records are being obtained or can be closely estimated. Programs for obtaining discharge and quality-of-water data are thus mutually interrelated.

Chemical quality determinations to be made under the proposed program should include: total hardness, non-carbonate hardness, specific conductance, silica, calcium, magnesium, chloride, sodium, potassium, carbonate, bicarbonate, sulfate, nitrate, boron, dissolved solids and pH. In addition iron, fluoride, and manganese will be determined where local conditions indicate they will be problems in the use of water.

The collection of chemical quality data on ground water is included in most detailed ground water investigations. It is recommended that this practice be continued in all future ground water investigations on a systematic basis. Therefore, no specific program is being presented herein.

Temperature of water in both surface and sub-surface locations has become an item of increasing interest in recent years. This is particularly so in connection with

industrial uses, air conditioning and fish and wildlife problems. It is recommended that the collection of water temperatures be integrated into quality of both surface-water and ground water programs.

The program for chemical quality stations as developed indicates ten sites at which stations should be established for the collection of chemical quality data adequate for the determination of daily values. These are in addition to the 16 stations in operation as of September, 1954, where data adequate for determination of daily values were being collected. Of the 26 indicated chemical quality stations all would be considered primary stations. The list of existing chemical quality stations is shown in Table IV, Pages 60 to 71, and their locations along with the recommended stations are shown on Plate 4. A comparison between existing and recommended programs by major drainage basins is as follows:

Chemical Quality

Status	Rio Grande	Pecos	Canadian	Gila	San Juan	Total
Existing	4	10	0	0	2	16
Recommended	3	1	2	3	1	10

Biological quality. The chemical and physical properties of natural waters exert a great influence on the plant and animal life therein. Numerous kinds of industrial uses, air conditioning and fish and wildlife problems. It is recommended that the collection of water temperatures be integrated into quality of both surface-water and ground water programs.

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Chemical Quality

Status	Rio Grande	Pecos	Canadian	Gila	San Juan	Total
Existing	4	10	0	0	2	16
Recommended	3	1	2	3	1	10

Biological quality. The chemical and physical properties of natural waters exert a great influence on the plant and animal life therein. Numerous kinds of aquatic animals and plants live in natural waters and are affected by its chemical and physical characteristics. Pollution of water with accompanying changes in chemical or physical water quality characteristics usually reduces the number of kinds of organisms in a stream, although the total number of organisms may increase. Living organisms may alter the quality of water. For example, nitrogen, phosphorous, carbon, potassium, sulfur, iron and other elements are taken up by aquatic plants and used in building plant cells. During photosynthesis the amount of dissolved oxygen, carbon dioxide, bicarbonate and other constituents in the water may be greatly altered. Certain types of algae may create problems of taste and odor or produce toxic substances. Rapid die-off of algae may result in oxygen-depleted water. Bacteria improve water quality by converting organic materials into stable inorganic compounds.

A healthy stream from a biological viewpoint is one which contains physical, chemical and environmental characteristics that will allow the development of a varied number of kinds of aquatic organisms, each of which competes for the available food. The distribution of aquatic life in a stream contributes a good index for determining the degree of past pollution. It may be used as a supplement to the usual chemical and physical

analyses. In addition, analyses for dissolved oxygen and bio-chemical oxygen demand and bacteria determinations are frequently employed as indices of biological quality. This information may be collected on a short-term or long-term basis.

Biological studies are sometimes performed as brief survey studies to show existing biological conditions. Other studies are conducted over a long period in order to show minor variations or to detect sudden and drastic changes in stream conditions. These studies may be undertaken by federal or state agencies, by municipalities or by industry. A particularly useful and frequently applied use of biological studies is practiced by many industries which initiate studies prior to and following the establishment of an industrial plant to determine the changes brought about by the discharge of the industrial effluent. Ordinarily these studies are the property of the sponsoring industry and are not generally available. Biological studies conducted by state or federal agencies are generally available as special reports or as a part of specific project reports.

Biological studies are vitally important for an understanding of many pollution problems. Although sampling procedures and methods of evaluating data are not well defined, and biological habitats and factors are

which affect them are complex, careful interpretations of biological studies are required. A study of the living organisms in the bottom of a stream, for instance, can yield useful information on the condition of a stream. A healthy stream will contain a variety of different kinds of aquatic life which will readily consume moderate quantities of organic pollution and maintain or restore good water quality. Toxic materials, even though occurring in relatively small quantities, may not alter the appearance of water but may render it useless as a habitat for aquatic life and seriously interfere with the recovery capacity of a stream.

No specific program of data collection or studies is proposed herein. It is anticipated, however, that special studies will be needed from time to time to provide data defining biological quality.

CHAPTER VI

SEDIMENT DATA

General. As movement and deposition of sediment is detrimental in almost all instances to the economic development of water resources, all agencies responsible for the conservation and development of land and water resources are concerned with the availability of sediment records. Adequate planning for prevention and relief from sediment damages requires definite knowledge of sediment production, movement and deposition in all its phases.

The sediment loads carried by streams are the result of either erosion of the soil mantle from farm, forest and range lands or of modification of stream channels due to movement of bank and bed materials. To supply data on sediment loads carried by streams sampling stations to measure suspended sediment concentrations and bed load are required.

A part of the sediment in transport in a stream may be temporarily or semi-permanently deposited in a downstream reach of the stream channel. A part of the sediment in transport also may have been derived by scour of the stream bed and bank at some upstream place. This process of aggradation and degradation of stream channels presents a continuing problem to those interested in the

utilization of the channels. Accumulation of sediment in water courses reduces their carrying capacity, causing increase in overbank flooding. Sediment carried by floods may damage crops, and its deposition on the flood plain may ruin productive bottom land. Data for this phase of sedimentation may be obtained by periodic surveys of selected reaches of stream channels and valleys.

A part or all of the sediment transported by streams entering a lake or reservoir, depending on the trap efficiency of the impoundment, will be deposited in the lake or reservoir. In the case of reservoirs, the reduction in capacity by deposition of fluvial sediments may create additional maintenance expense and result in a lowering of income or degree of protection derived from the project. Unless adequate provision has been made in the reservoir design for this reduction in storage space the ability of the structure to fulfill its purpose will be impaired. Up-to-date information on the extent of reduction due to sediment deposition in the water-storing capacity of constructed reservoirs is necessary in connection with reservoir operations. It is therefore imperative that designing and operating engineers have adequate knowledge of reservoir sedimentation rates and extent of sedimentation. Data for this phase of sedimentation may be obtained by periodic reservoir surveys.

As the various phases of sedimentation are related, so are the several programs for collection of sedimentation data closely related. The programs for measurement of accumulated deposits in stream channels on flood plains and in impoundments and the measurement of suspended sediment and bed load sampling programs are complementary or, in some cases, alternate methods for supplying data on sediment yields, transport rates and other sediment characteristics. Each program has its limitations and area of usefulness, but all are essential to supply data needed in resolving the many problems in water resource planning and utilization, including the evaluation of improvements having sediment reduction effects.

Suspended sediment and bedload. Sediment is the insoluble material transported by streams either in suspension or bed load. The sediment particles which move with only occasional contact with the channel bed or banks are termed suspended sediment and consist chiefly of fine sands, silts and clays. Sediment which rolls or bounces along the bottom is termed bed load and consists primarily of gravel and coarse sand. Until very recently, because of difficulty in measuring the movement of bed load, the sediment transport data program was almost entirely limited to suspended sediment sampling.

Only meager data are available on the magnitude and distribution of suspended sediment loads carried by the streams in the state. Random and intermittent measurements of the suspended loads carried by the streams have been made in the past 50 years. During the past 15 years, however, progress has been made toward more adequate programs for the collection of this type of hydrologic data.

Suspended sediment concentrations usually vary widely from time to time, especially during periods of flood flows, and in order to make reliable computations of loads transported frequency of sampling should be sufficient for determination of daily values. This may require daily or more frequent sampling in some cases, particularly during flood flows. In developing the program for additional suspended sediment sampling, first consideration was given to stations requiring frequency of sampling adequate for determination of daily loads. Stream discharges are necessary in conjunction with sediment concentration determinations to compute the sediment loads. All such sediment sampling stations, therefore, must be confined to sites of existing or proposed stream flow stations.

The suspended sediment measuring stations may be placed in two classifications, depending upon the

objective for which the data are to be used. The first deals with the collection of data over a long period of years in order to determine annual variations and long-term trends or to serve as a basis for evaluating the effectiveness of control works and programs for the reduction of sediment yields. These form a primary network and should be continued for an indefinite period.

The second type of station is to be operated for a shorter period, generally three to four years, depending upon the range in flows experienced. This type is intended to furnish data in connection with specific projects or problems and forms a secondary network of stations needed to give areal coverage to the recommended program. If long-term discharge records are available at the sites of secondary sediment stations it will be possible, by the use of correlation techniques, to estimate the sediment record for the longer period.

The program as developed proposes the collection of suspended sediment data at 17 sites in addition to the 26 sediment sampling stations now in operation. The following table summarizes the existing and additional program as developed for such stations by river basins:

Suspended Sediment

Status	Rio Grande	Pecos	Canadian	San Juan	Gila	Total
Existing	19	4	0	3	0	26
Recommended	4	4	6	0	3	17

The specific sites of the existing sediment sampling stations are shown in Table IV, Pages 60 to 71. The locations of these sites are shown on Plate 4. Of the 17 additional stations all are classed in the primary network, as are those of the 26 existing stations.

Recent developments in total sediment load (suspended sediment and bed load) studies have provided feasible methods of computing total sediment discharge in alluvial streams. Additional data for determination of bed loads consist of the collection of bed samples, vertical velocity distribution at the same points and particle size analysis of suspended load and bed load materials. As the additional data and analysis of data are not a large item, it should be combined with the suspended sediment sampling program at least at a number of locations where bed-load movement is of importance. Since this method of determination of bed load is relatively new, details for a definite program have not been worked out. However, there probably will be many specific locations within the state where the determination of bed load movement is of primary importance, and it is estimated that bed load determinations will be needed at approximately one-fourth of the existing and recommended suspended sediment sample stations.

The overall program should also include the systematic collection over the state of periodic sediment discharge measurements. Such a program will assist in locating the more important areas of sediment contribution and in selecting locations for more intensive study. In streams where suspended sediment is not a serious problem adequate information may be obtained from sediment measurements obtained at periodic intervals.

Reservoir sedimentation surveys. The measurement of trapped sediment in reservoirs may be used as a basis for estimating the probable sedimentation rates in proposed reservoirs, for evaluation of the net effect of changes in land use practices upon sediment yield rates, and for estimation of the effect of channel stabilization and other upstream sediment control measures. It should be kept in mind that such data should be used with caution and properly evaluated. Such factors as stream channel above the reservoir and the "trap efficiency" of the reservoir should be considered in the analysis of reservoir data.

To obtain the maximum amount of information concerning sedimentation it is essential that reservoir sedimentation surveys be coordinated with other basic data programs and that the reservoir sedimentation survey program be of a continuing nature with a definite

program of surveys scheduled at periodic intervals.

In the past 15 years a number of sedimentation surveys of reservoirs, stock water tanks and farm ponds have been made. For the most part the program has been random, and much of the data are incomplete, especially with respect to correlation with suspended sediment sampling and reservoir inflow and outflow. Also, many of these surveys were made according to reconnaissance standards, and most of the results obtained can be considered only as indicative. Most of the surveys, in addition, have been made without any study of the watershed conditions which are one of the primary casual factors in determining the rate of sedimentation.

Present programs of the Bureau of Reclamation and Corps of Engineers provide for periodic sedimentation surveys of constructed reservoirs in connection with normal maintenance and operations. No program for additional reservoir sedimentation surveys is presented herein. However, it can be assumed that the present programs will be continued.

Valley and channel sedimentation surveys. Present programs of the Corps of Engineers and Bureau of Reclamation in connection with operation and maintenance of constructed projects provide for channel sedimentation

surveys in streams where problems of channel aggradation or degradation are related to their projects. Channel sedimentation surveys are also occasionally made in connection with authorized or proposed projects.

Data collected in connection with these programs are principally limited to downstream reaches along major streams. Only a limited amount of sedimentation data are available on upper reaches of stream channels and in small valleys along tributary streams.

No program for additional valley and channel sedimentation surveys is outlined. The existing programs of the Corps of Engineers and Bureau of Reclamation appear to be adequate to meet the needs for such surveys on main stem streams, and will no doubt be continued. A program for additional sedimentation surveys for small valleys along tributary streams is not believed justifiable.

TABLE IV

RIVER AND RESERVOIR STATIONS IN NEW MEXICO

CANADIAN BASIN

Station No.	Station	Instrumentation				
		Stage & Q.	Chem. Qual.	Temp.	Sed.	Res. St. & Cont.
1	Cimarron River nr Guy, N.M.	x				
2	Canadian River nr Hebron, N.M.	x				
3	Vermejo River nr Dawson, N.M.	x				
4	Eagle Nest Reservoir					x
5	Cimarron River below Eagle Nest Dam	x				
6	Cimarron River nr Cimarron, N.M.	x				
7	Ponil Creek nr Cimarron, N.M.	x				
8	Rayado River at Sauble Ranch nr Cimarron, N.M.	x				
9	Rayado River nr Miami, N.M.	x				
10	Cimarron River at Springer, N.M.	x				
11	Canadian River nr Taylor Springs, N.M.	x				
12	Canadian River nr Roy, N.M.	x				
13	Mora River nr Holman, N.M.	x				

(Cont'd)

CANADIAN BASIN (Cont'd)

Sta-tion No.	Station	Instrumentation: Stage & Q.	Chem.	Temp.	Sed.	Res. St.
14	Mora River at La Cueva, N.M.	x				
15	Mora River nr Golondrinas, N.M.	x				
16	Coyote Creek nr Holman, N.M.	x				
17	Coyote Creek nr Golondrinas, N.M.	x				
18	Mora River nr Shoemaker, N.M.	x				
19	Canadian River nr Sanchez, N.M.	x				
20	Conchas River at Variadero, N.M.	x				
21	Conchas Reservoir at Conchas Dam, N.M.					x
22	Bell Ranch Canal nr Conchas Dam, N.M.	x				
23	Conchas Canal below Conchas Dam, N.M.	x				
24	Canadian River below Conchas Dam, N.M.	x				
25	Ute Creek nr Bueyeros, N.M.	x				
26	Ute Creek nr Logan, N.M.	x				
27	Canadian River at Logan, N.M.	x				

(Cont'd)

RIO GRANDE BASIN

Station No.	Station	Instrumentation				
		Stage & Q.	Chem. Qual.	Temp.	Sed.	Res.St. & Cont.
28	Costilla Creek below Costilla Dam, N.M.	x				
29	Costilla Creek nr Costilla, N.M.	x				
30	Costilla Creek nr Garcia, Colo.	x				
31	Costilla Creek nr Jaroso, Colo.	x				
32	Latir Creek nr Cerro, N.M.	x				
33	Rio Grande nr Cerro, N.M.	x				
34	Red River nr Red River, N.M.	x				
35	Red River nr Questa, N.M.	x				
36	Cabresto Creek nr Questa, N.M.	x				
37	Red River nr mouth nr Questa, N.M.	x				
38	Rio Hondo nr Valdez, N.M.	x				
39	Rio Hondo at Arroyo Hondo, N.M.	x				
40	Rio Taos nr Ranchos de Taos, N.M.	x				
41	Rio Taos at Los Cordovas, N.M.	x				
42	Rio Grande below Taos Junction Br.	x				

(Cont'd)

RIO GRANDE BASIN (Cont'd)

Station No.	Station	Instrumentation				
		Stage & Q.	Chem. Qual.	Temp.	Sed.	Res.St. & Cont.
43	Carson Reservoir nr Carson, N.M.					x
44	Embudo Creek nr LLano, N.M.	x				
45	Embudo Creek at Dixon, N.M.	x				
46	Rio Grande at Embudo, N.M.	x		x	x	
47	Rio Chama at Park View, N.M.	x				
48	El Vado Reservoir					x
49	Rio Chama below El Vado Dam, N.M.	x				
50	Rio Chama nr Abiquiu, N.M.	x			x	
51	Rio Ojo Caliente at La Madera, N.M.	x				
52	Rio Chama nr Chamita	x		x	x	
53	Rio Santa Cruz at Cundiyo, N.M.	x				
54	Rio Grande at Otowi Bridge, N.M.	x	x	x	x	
55	Sili Main Canal Heading	x				
56	Cochiti East Side Main Canal Heading	x				
57	Rio Grande at Cochiti, N.M.	x				
58	McClure Reservoir					x
59	Santa Fe Creek nr Santa Fe, N.M.	x				

(Cont'd)

RIO GRANDE BASIN (Cont'd)

Station No.	Station	Instrumentation: Stage & Q.	Chem.	Temp.	Sed.	Res.St. & Cont.
60	Nichols Reservoir					x
61	Galisteo Creek at Domingo, N.M.	x		x	x	
62	Rio Grande at San Felipe, N.M.	x				
63	Albuquerque Main Canal at Algondones, N.M.	x				
64	Jemez River nr Bernalillo, N.M.	x				
65	Jemez Reservoir					x
66	Jemez River below Jemez Reservoir	x		x	x	
67	Rio Grande nr Bernalillo, N.M.	x		x	x	
68	Arenal Main Canal at Albuquerque, N.M.	x				
69	Rio Grande at Albuquerque, N.M.	x				
70	Barr Canal at Albuquerque, N.M.	x				
71	Barr Canal at End, nr Isleta, N.M.	x				
72	Chical Lateral at Head at Isleta, N.M.	x				
73	Peralta Main Canal nr Isleta, N.M.	x				

(Cont'd)

RIO GRANDE BASIN (Cont'd)

Sta-tion No.	Station	Instrumentation: Stage & Q.	Chem.	Temp.	Sed.	Res.St. & Cont.
74	Chical Acequia at Head at Isleta, N.M.	x				
75	Cacique Acequia at Head at Isleta, N.M.	x				
76	Belen High-line Canal nr Isleta, N.M.	x				
77	Rio Grande nr Belen, N.M.	x				
78	San Juan Canal nr Bosque, N.M.	x				
79	Rio Grande nr Bernardo, N.M.	x			x	
80	San Juan Canal nr Bernardo, N.M.	x				
81	Rio Puerco above Chico Arroyo nr Guadalupe, N.M.	x		x	x	
82	Chico Arroyo nr Guadalupe, N.M.	x		x	x	
83	Bluewater Creek below Bluewater Dam, N.M.	x				
84	Bluewater Creek nr Bluewater, N.M.	x				
85	Bluewater Creek at Grants, N.M.	x				
86	San Jose River nr Grants, N.M.	x				
87	San Jose River at Correo, N.M.	x		x	x	

(Cont'd)

RIO GRANDE BASIN (Cont'd)

Sta-tion No.	Station	Instrumentation				
		Stage & Q.	Chem.	Temp.	Sed.	Res.St. & Cont.
88	Rio Puerco at Rio Puerco, N.M.	x		x	x	
89	Rio Puerco nr Bernardo, N.M.	x		x	x	
90	Rio Salado nr San Acacia, N.M.	x		x	x	
91	Socorro Main Canal at San Acacia, N.M.	x				
92	Rio Grande at San Acacia, N.M.	x	x	x	x	
93	Rio Grande at San Antonio, N.M.	x		x	x	
94	Socorro Main Canal nr San Antonio, N.M.	x				
95	San Antonio Riverside drain nr San Antonio, N.M.	x				
96	Elmendorff Interior Drain nr San Antonio, N.M.	x				
97	San Antonio Riverside drain nr San Marcial, N.M.	x				
98	Rio Grande above San Marcial, N.M.	x	x	x	x	
99	Rio Grande (Tiffany Channel) San Marcial, N.M.	x		x	x	
100	Rio Grande Headwaters Elephant Butte Res.	x				

(Cont'd)

RIO GRANDE BASIN (Cont'd)

Station No.	Station	Instrumentation: Stage & Q.	Chem.	Temp.	Sed.	Res.St. & Cont.
101	Rio Grande (Main Channel) San Marcial, N.M.	x	x	x	x	
102	Rio Grande at the Narrows, Elephant Butte Res.	x				
103	Elephant Butte Reservoir					x
104	Rio Grande below Elephant Butte Dam, N.M.	x				
105	Caballo Reservoir					x
106	Rio Grande below Caballo Dam, N.M.	x				

PECOS BASIN

Station No.	Station	Stage & Q.	Chem.	Temp.	Sed.	Res.St. & Cont.
107	Pecos River nr Pecos, N.M.	x				
108	Pecos River nr Anton Chico, N.M.	x				
109	Gallinas River nr Montezuma, N.M.	x				
110	Gallinas River at Montezuma, N.M.	x				
111	Gallinas River nr Lourdes, N.M.	x				
112	Gallinas River nr Colonias, N.M.	x				
113	Pecos River at Santa Rosa, N.M.	x				
114	Pecos River nr Puerto de Luna, N.M.	x	x	x	x	

(Cont'd)

PECOS BASIN (Cont'd)

Station No.	Station	Instrumentation: Stage & Q.	Chem.	Temp.	Sed.	Res.St. & Cont.
115	Alamogordo Reservoir					x
116	Pecos River below Alamogordo Dam, N.M.	x	x			
117	Pecos River nr Fort Sumner, N.M.	x				
118	Pecos River nr Acme, N.M.	x	x	x		
119	Rio Ruidoso at Hollywood, N.M.	x				
120	Rio Ruidoso at Hondo, N.M.	x				
121	Rio Bonita at Hondo, N.M.	x				
122	Rio Hondo at Diamond A Ranch nr Roswell, N.M.	x		x	x	
123	Rio Felix nr Hagerman, N.M.	x				
124	Pecos River nr Lake Arthur, N.M.	x				
125	Cottonwood Creek nr Lake Arthur, N.M.	x				
126	Pecos River nr Artesia, N.M.	x	x	x	x	
127	Rio Penasco nr Daton, N.M.	x		x	x	
128	Kaiser Lake-McMillan Channel nr Lakewood, N.M.	x				
129	Pecos River at Lake McMillan, N.M.	x				
130	McMillan Reservoir					x

(Cont'd)

PECOS BASIN (Cont'd)

Sta-tion No.	Station	Instrumentation				
		Stage & Q.	Chem.	Temp.	Sed.	Res.St. & Cont.
131	Pecos River below McMillan Dam, N.M.	x				
132	Pecos River at Dam Site 3 NR Carlsbad, N.M.	x	x			
133	Avalon Reservoir					x
134	Pecos River below Avalon Dam, N.M.	x	x			
135	East Canal at Head	x				
136	East Canal at Carlsbad, N.M.	x				
137	Carlsbad Main Canal at Head	x				
138	Pecos River at Carlsbad, N.M.	x	x	x		
139	Black River above Malaga, N.M.	x				
140	Pecos River nr Malaga, N.M.	x	x			
141	Pecos River at Pierce Canyon Crossing nr Malaga, N.M.	x	x	x		
142	Pecos River at Red Bluff, N.M.	x	x	x		
143	Delaware River nr Red Bluff, N.M.	x				
148	Rio Tularosa nr Bent, N.M.	x				

(Cont'd)

SAN JUAN BASIN

Station No.	Station	Stage & Q.	Chem.	Temp.	Sed.	Res.St.
149	San Juan River at Rosa, N.M.	x				
150	Los Pinos at La Boca, Colo.	x				
151	Spring Creek at La Boca, Colo.	x				
152	Citizens Ditch nr Turley, N.M.	x				
153	San Juan River nr Blanco, N.M.	x	x	x	x	
154	Animas River nr Cedar Hill, N.M.	x				
155	Animas River at Farmington, N.M.	x	x	x	x	
156	San Juan River at Farmington, N.M.	x				
157	La Plata River at Colo.-N.M. State Line	x				
158	La Plata River nr Farming ton, N.M.	x				
159	San Juan River at Shiprock, N.M.	x		x	x	

GILA BASIN

Station No.	Station	Stage & Q.	Chem.	Temp.	Sed.	Res.St.
144	Bear Canyon nr Mimbres, N.M.	x				
145	Mimbres River nr Mimbres, N.M.	x				
146	Mimbres River nr Faywood, N.M.	x				

(Cont'd)

GILA BASIN

Station No.	Station	Instrumentation: Stage & Q.	Chem.	Temp.	Sed.	Res. St. & Cont.
147	Mimbres Draw nr Silver City, N.M.	x				
160	Gila River nr Gila, N.M.	x				
161	Gila River nr Red Rock, N.M.	x				
162	Gila River below Blue Creek nr Virden, N.M.	x				
163	Sunset Canal nr Virden, N.M.	x				
164	New Model Canal nr Virden, N.M.	x				
165	San Francisco River nr Glenwood, N.M.	x				

CHAPTER VII

GROUND WATER INVESTIGATIONS

In water-resource development planning if the available water resource is to be utilized to the optimum extent it is necessary to have factual knowledge of ground water, its availability and quality, and to know its relation to surface supplies. Ground water investigations have been made for a relatively large part of the state. Most of these investigations have been made systematically by counties or other convenient units, but some have been confined to trouble areas in which difficulties from failing ground water resources already may have developed.

In large sections of the state ground water is the only practicable source of supply for essential needs. In other areas there will be alternatives between the development of either surface or ground water supplies to serve specific needs. The best plan of development can be determined only from detailed studies of both sources of supply. These studies would require detailed information on the occurrence, availability, quantity and quality of the ground waters as well as surface waters. In view of certain general advantages of ground water, particularly with regard to uniformity of quality and

temperature, it is probable that in areas of intensive development good ground water reservoirs eventually will be developed to their optimum capacities.

The program of underground water investigations in New Mexico is conducted in cooperation with the Geological Survey, Water Resources Division, Ground Water Branch. The studies are generally of two principal types: (1) quantitative studies covering the areas of underground water irrigation; and, (2) studies which are generally reconnaissance in nature, covering broader areas. The quantitative studies provide the basic data needed by the State Engineer in administering underground water laws and by the public for information concerning underground water resources. The studies covering the broader areas give general information regarding the occurrence of underground water and provide the basis for determining areas of potential water supplies for stock, domestic and municipal use in addition to irrigation.

The investigations are basically aimed toward determining the quantity and chemical quality of the underground water available, its source and movement, the character, thickness, areal extent and depth below the surface of the water-bearing formations and the relation of underground water to stream flow. The scope and needs of the investigations are such that appreciable temperature, it is probable that in areas of intensive development good ground water reservoirs eventually will be developed to their optimum capacities.

The program of underground water investigations in New Mexico is conducted in cooperation with the Geological Survey, Water Resources Division, Ground Water Branch. The studies are generally of two principal types: (1) quantitative studies covering the areas of underground water irrigation; and (2) studies which are generally reconnaissance in nature, covering broader areas. The quantitative studies provide the basic data needed by the State Engineer in administering underground water laws and by the public for information concerning underground water resources. The studies covering the broader areas give general information regarding the occurrence of underground water and provide the basis for determining areas of potential water supplies for stock, domestic and municipal use in addition to irrigation.

The investigations are basically aimed toward determining the quantity and chemical quality of the underground water available, its source and movement, the character, thickness, areal extent and depth below the surface of the water-bearing formations and the relation of underground water to stream flow. The scope and needs of the investigations are such that appreciable time is required for the collection and analysis of data and compilation of reports.

One important phase of the program is that involving the annual measurement of water levels in approximately 1,500 wells and bi-monthly measurements in a smaller number of wells, primarily in areas of heavy withdrawal. These data, together with information on pumpage and a knowledge of the characteristics of each basin, indicate the part played by pumpage and recharge in the general year-to-year change in water level, and assist in pointing out areas of over-development or areas where additional development might be permitted.

Plate 5, showing the areas within the state covered by ground water investigations, indicates that a large portion of New Mexico has been investigated for the type of hydrologic data covered in this chapter. Additional programs will be initiated by the Office of the State Engineer in cooperation with the U.S. Geological Survey as needs are anticipated or as finances warrant. Continuing evaluation of ground water supplies and records of water levels and pumpage will expand with the economic development of the state.

CHAPTER VIII

CONCLUSIONS

It is generally recognized that the level of economic development of New Mexico will depend directly on the availability of adequate water. Furthermore, a static level of development may soon be attained unless additional conservation facilities are provided. The solution to this problem will involve the understanding and support by the general public along with those specific agencies dedicated to that prupose. Direct contact with this problem by most of the citizens of the state tends to inspire an individual alertness which is warranted in view of the possibility of water limitation. The continued threatened shortage of water for municipal and domestic use could drastically affect the economic condition of the state by a curtailment of industrial expansion and severe limitation of farming and ranching. The first step toward guarding against this crisis would be to know the water resources and potentialities which can only be derived from hydrologic data.

The basic data program as developed herein could be used to initiate a coordinated hydrologic collection program for New Mexico. This program could be circulated to all interested federal and state agencies for the

addition of stations which they felt were needed, indication of purpose that each proposed record would serve, and indication of urgency of need. The follow-up should include numerical values, based on relative agency interest and urgency of need for each item. After each agency has had an opportunity to review the program thoroughly the final program to be recommended would probably be decided at the conference table with representatives from all agencies present.

Data compiled herein were taken from Geological Survey Water Supply Papers, Weather Bureau Publications and data furnished by the Office of the State Engineer.