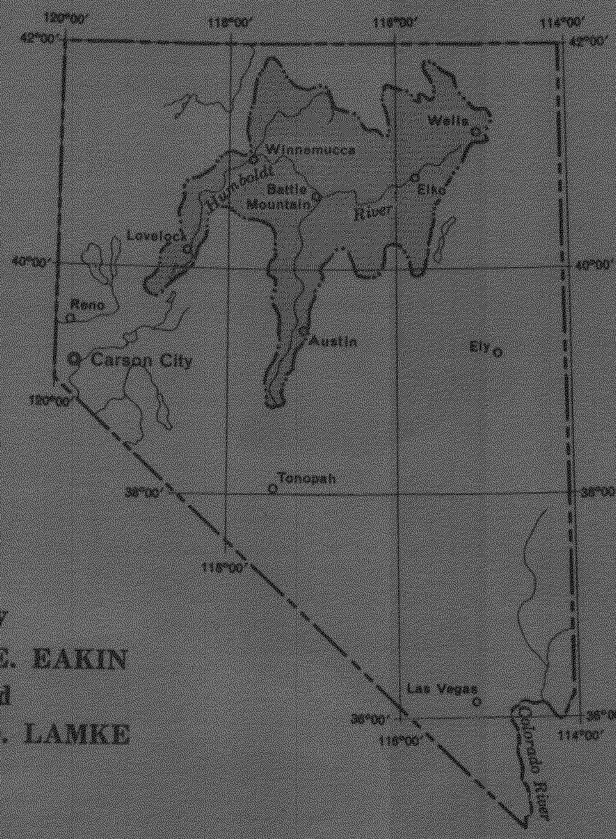
HYDROLOGIC RECONNAISSANCE OF THE HUMBOLDT RIVER BASIN, NEVADA



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UNITED STATES DEPARTMENT OF THE INTERIOR

GEOLOGICAL SURVEY

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By THOMAS E. EAKIN and ROBERT D. LAMKE

ABSTRACT

The Humboldt River basin is entirely within Nevada and includes an area of nearly 17,000 square miles in the Basin and Range physiographic province. This basin of interior drainage is comprised of a series of alternating north-trending mountains and intervening valleys, whose altitudes range between about 11,800 and 3,900 feet above mean sea level. Average annual precipitation ranges from about 40 inches in the Ruby Mountains to about 4 inches in the lowest part of the basin near the Humboldt Sink. If distributed evenly over all the area of the basin, the average annual rainfall would be slightly more than 10 inches.

The Humboldt River basin was divided into three general units, and estimated average annual hydrologic values, in thousands of acre-feet, rounded to two significant figures, are summarized below:

	Precipitation	Yield from mountains	Evapotranspiration	Outflow
Upper basin above Palisade	3,400	550	3,100	250
Middle basin between Palisade and Comus	4,200	290	4,200	180
Lower basin below Comus	1,800	150	2,000	74[1]
Humboldt River basin	9,400	990	9,300	74[1]

[1]Lost by evapotranspiration from Humboldt Sink and occasional outflow to Carson Sink.

Variations occur from year to year and from place to place within the hydrologic system. For example, it is estimated that the annual precipitation might range from 17 to 3.5 million acre-feet and annual runoff might range from 1.8 to 0.3 million acre-feet. Recharge occurs mainly during years of high precipitation. Ground-water storage in the upper 100 feet of saturated valley fill is estimated to be about 28 million acre-feet and is relatively constant through long periods of time. Locally however, seasonal or year to year changes may be significant. In the upper 10 feet of saturated deposits beneath the flood plain of Humboldt River and its tributaries, short-term natural variations may be as much as 500,000 acre-feet from extreme low levels to very high levels of ground-water storage.

The water in the Humboldt River basin commonly is a calcium bicarbonate type in the upper basin but tends to be modified toward sodium bicarbonate water downstream. Water in Humboldt River and its principal perennial tributaries commonly has a dissolved-solids content ranging from 300 to 600 ppm (parts per million). However, snowmelt runoff has a very low concentration, and water being concentrated by evaporation, such as in Humboldt Sink, may have a dissolved-solids content of several thousand parts per million. Ground water tends to have a somewhat higher concentration than the water in the perennial streams. However, it too is variable, generally having low concentration near the areas of recharge and high concentration near areas of discharge by evapotranspiration.

The hydrology of the Humboldt River basin has been analyzed using available data. These estimates reasonably represent the components of the hydrologic system. However, many of the estimates were obtainable largely or entirely by differences. Increased reliability of estimates requires additional data and more direct means of determining the quantities of water in the various components of the hydrologic system. Additional data are required concerning precipitation, temperature, evaporation, transpiration, surface water, ground water, and water quality, as well as geology and meteorology. The degree to which the various data are needed is dependent to a large extent on the degree to which optimum development of the system is contemplated.

CHAPTER I

INTRODUCTION

Man's use of water in the Humboldt River basin has been increasing during the past few decades. Increased demands for water tend to result in increasing modifications of the hydrologic system, in increasing diversity of use, and in competition for the water among the users.

Final emphasis of water development in the Humboldt River basin will be determined by a combination of social, political, economic, and physical considerations. However, any successful long-range water development must be based upon a sound knowledge and understanding of the hydrologic system.

The hydrologic system of the Humboldt River basin (fig. 1, pls. 1, 2) as herein used, refers to the total amount of water, considered as an entity, within the basin and its interrelations in time and space with the environment in which the water occurs. It includes the precipitation from the atmosphere, the water flowing or in storage on the ground surface and underground, the water returned to the atmosphere by evaporation and transpiration, and water entering or leaving the basin by underflow and upon the surface. Much of the water in the Humboldt River basin is removed from the basin more or less where it entered the basin as precipitation. Much of the runoff is lost by evapotranspiration without becoming a part of Humboldt River or its perennial tributaries. Thus, the hydrologic system of the Humboldt River basin involves a substantial number of subsystems which may function most of the time as almost separate hydrologic systems.

The emphasis in this report is on the existing hydrologic system in the basin which has been only slightly modified from the natural system by storage and diversion. For that reason the hydrologic effects of present development can be included in the analysis of the natural system with little adjustment.

PRESENT DEVELOPMENT

The early development of water in the Humboldt River basin largely was in support of the livestock industry—water was diverted to grow hay for winter feed and onto pasture land. Later, water was diverted for farming, mainly to supply the principal farming area near Lovelock. More recently ground water has been developed for irrigation in new farming areas in Grass, Paradise, and middle and upper Reese River Valleys. As towns developed, water was needed for public supply. Water was needed for the railroads, mining, and industry. Recreational use of water is increasing rapidly.

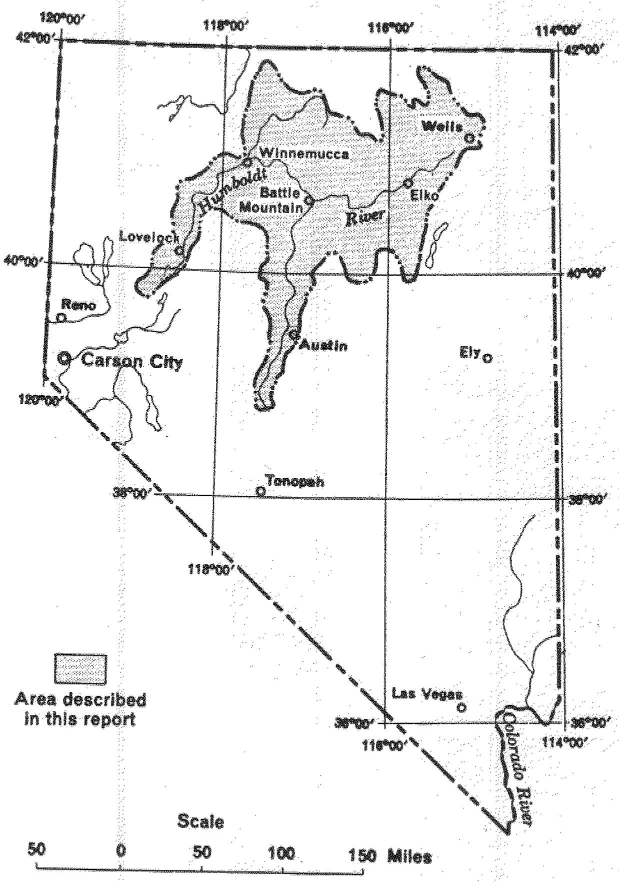

FIGURE 1. Map of Nevada showing the location of the area described in this report.

With the development of the water, more attention has been given to management and control of the water. Thus, Rye Patch Reservoir has provided regulation of the flow of Humboldt River in the lower part of the basin since 1936. Conservation measures have been applied on numerous ranches in the basin as well as on range and forest land.

Rights to water supplies were recognized very early. Court decisions and legislation concerning water rights preceded Nevada's admission to Statehood, October 31, 1864. The latest re-enactment of the present "water code" was in 1913

(Hutchins, 1955, p. 4). A statute relating to ground waters was enacted in 1939. The waters of the Humboldt River and its principal tributaries were adjudicated during the interval 1923–38 (Mashburn and Mathews, compilers, 1943). Hennen (1964, p. 6) notes that "the court has found that the water of the stream system is fully appropriated and that in an average year, as shown by the flow in the stream system, there is no surplus water for irrigation. This finding is contained in findings of Fact 44, Bartlett Decree, p. 28 of the compiled edition, Humboldt River Adjudication." Fact 44 concludes with the statement, "The Court makes no finding of the water available for storage of water in the nonirrigation season on the Humboldt River stream system."

Further development of Humboldt River and its tributaries thus must consider the present water rights. Most or all the streamflow in the other streams in the basin also has been appropriated. Ground water too, has been appropriated in many places. With these limitations, it will be more and more necessary to have adequate data concerning the hydrologic system to assist in the sound determination of possible additional development.

THE HUMBOLDT RIVER RESEARCH PROJECT

Recognizing the increasing need for hydrologic data and information, the Nevada State Legislature authorized the Humboldt River Research Project in 1959 (Chap. 97, Stats. 1959). That project provided a substantial stimulus toward acquiring technical information about water in the Humboldt River basin. Fourteen State, Federal, and other organizations (see Cohen, 1964a, p. 12) conducted studies in hydrology, geology, and meteorology. In these studies, particular emphasis was given to the section of the Humboldt River valley between Comus and Rose Creek near Winnemucca.

The results of the 5-year study of water in the Winnemucca area are summarized by Cohen (1964a). During the 1965 fiscal year, besides the continuing and areal studies within the basin such as the stream-gaging program, phreatophyte study, reconnaissance water-resources programs, and geological investigations, the Geological Survey has made a provisional evaluation of the hydrologic system of the Humboldt River basin. The results of that evaluation are contained in this report.

PURPOSE AND SCOPE OF THIS INVESTIGATION AND REPORT

The purpose of this investigation is: to identify hydrologic data and information available for the Humboldt River basin; to review and analyze this material; to quanitatively describe in preliminary fashion essentially all of the hydrologic processes in the basin and develop generalized hydrologic budgets; and on the basis of these, indicate additional needs for data and special studies. The investigation is of a reconnaissance level.

The results of the investigation are presented in the following ways:

(1) This report analyzes the available data and presents provisional hydrologic budgets for the basin. Budgets were developed for the 1912–63 reference period as representing about average conditions but it is recognized that variations from "average" conditions, in fact, are normal;

(2) Basic records and information relating to the hydrology of the Humboldt River basin are summarized in the appendix of this report; and

(3) Suggestions of additional needs for data and special studies are contained in a statement to the Director of the Nevada Department of Conservation and Natural Resources.

For some purposes, it may be desirable to develop estimates based on various frequencies of occurrence, such as have been used by the U.S. Department of Agriculture in its "Water and Related Land Resources" studies in the Humboldt River basin. Such estimates would be expected to diverge to some extent from those contained in this report. Additionally, some variations should be expected because insufficient data require varying degrees of subjective judgment.

Many of the estimates of the principal components of the hydrologic system had to be made with few direct data; a number of the estimates presently can be made only by differences between estimates of other components; and some can be made only by differences of estimates that in turn were obtained by difference. Although the resulting hydrologic budgets probably are reasonably valid general representations of actual conditions, they may be in considerable error in detail.

Present use of water is considered herein only in relation to the hydrologic system. For this report then, the analysis is directed toward the removal of water from the hydrologic system rather than whether or not it has been used. The merits, effectiveness, and relative efficiency of the various uses are beyond the scope of this report. The determination of possible changes in use or of the type, amount, and location of future development is not a function of this report.

REFERENCE PERIOD USED IN THIS REPORT

A common reference period should be used in analyzing hydrologic conditions. The data available do not allow this to be done for all elements of the hydrologic system of the Humboldt River basin. However, for most of the streamflow and runoff data the reference period 1912–63 is used for this study. The 1912–63 period represents the continuous-record interval of the flow of Humboldt River at Palisade to the time this study began. Averages for streamflow at other gaging stations were adjusted to this period. Estimates of runoff are based on the reference period.

Precipitation and temperature data are given for the reference period where available. However, shorter periods were used where necessary in lieu of estimating significant non-record intervals. Averages used in estimates of ground-water levels are based on shorter periods of record than the reference period. Averages used in estimates of ground-water quantities are based on general conditions rather than a specific period of reference. Ground-water conditions, however, change but slowly under natural conditions as is true for most of the Humboldt River basin. For this reason, the averages used are probably not significantly different from the reference-period average.

NUMBERING SYSTEMS

Gaging Stations

Gaging stations at which streamflow records have been collected are listed and numbered in a downstream direction along the main stem of the river with all stations on a tributary entering above a main-stem station listed before that station. The complete number for each station, such as 10–3315.00, includes the part number "10", assigned to the Great Basin, and a six digit station number. In this report, because of the limitation of space, only the essential digits of the station number are shown; for example, the complete number 10–3315.00 appears as 3315.

Wells, Springs, Sample Points

Numbering of all control points and samples, except streamflow measuring stations along the Humboldt River and water samples from the river, is based on the rectangular system for the subdivision of public lands. Accordingly, the numbers both identify and locate each control point and sample. The first unit of each number indicates the township north of the Mount Diablo base line. The second unit, separated from the first by a slant, indicates the range east of the Mount Diablo meridian. The third unit, separated from the first two units by a hyphen, lists the section number, followed in turn by a letter that designates the quarter section. The letter is followed by a number that indicates the chronological order in which the control point was recorded within the 160-acre subdivision. The letters a, b, c, and d designate, respectively, the northeast, northwest, southwest, and southeast quarters of each unit. For example, well number 33/52–27d1 designates the first well recorded in the SE¼ sec. 27, T. 33 N., R. 52 E., Mount Diablo base line and meridian. Because of the limitation of space, only that part of the number designating the subdivision of the section and the order in which the control point was recorded is shown on the maps accompanying this report.

ACKNOWLEDGMENTS

The Nevada Department of Conservation and Natural Resources made available personnel of the Humboldt River Water Distribution District to make a series of discharge measurements at several sites within the Humboldt River basin in 1964. Additionally, streamflow data in the District files were used in analyses of the runoff characteristics of the basin. The precipitation map (fig. 3) in this report is based upon a precipitation map of Nevada prepared by George Hardman of the Department. Credit is given in the report to various other agencies and people from whose reports the authors have abstracted data.

This report was prepared by the U.S. Geological Survey under the supervision of G. F. Worts, Jr., district chief. J. R. Harrill compiled many of the available data, made many of the computations, and helped to prepare the illustrations. P. L. Soule did most of the statistical streamflow computations presented in Chapter III.

CHAPTER II

WATER AND ITS ENVIRONMENT

THE HYDROLOGIC SYSTEM

Precipitation supplies virtually all of the inflow of water to the Humboldt River basin. Water occurs as streamflow and ground-water recharge principally because most of the precipitation is localized in cooler mountainous areas, because the cold winter is a period of low evapotranspiration rates, and because precipitation commonly accumulates as snow. Additionally, warm-weather precipitation may be sufficiently localized and of sufficient intensity to provide water in excess of immediate evapotranspiration requirements.

Evaporation and transpiration provide the means by which water is removed from the Humboldt River basin. Although the rates of loss vary with time and place, potential evapotranspiration loss at a given location tends to be relatively consistent from year to year. Potential evapotranspiration varies with temperature, cloud cover, precipitation, humidity, and wind movement. The concept of potential evapotranspiration assumes that water is readily available. In fact, the potential evapotranspiration is greater than the total precipitation in the Humboldt River basin, and actual evapotranspiration is smaller than potential evapotranspiration.

The movement or occurrence of water between the time it enters the basin and the time it leaves the basin makes up the hydrologic system of the Humboldt River basin.

Inflow to the hydrologic system equals outflow from that system under natural conditions over a long period of time. Inflow may not equal outflow for shorter periods but the difference must be accounted for by a change in storage within the system.

Storage changes within the basin may be seasonal or long-term. Seasonal storage may occur in the snow pack, streams, ponds, lakes, reservoirs, soil moisture, or ground water. Lakes and reservoirs generally reflect seasonal changes of storage but also may reflect long-term storage changes. Local fluctuations in the level or surface of the ground-water reservoir reflect diurnal, seasonal, and other short-term storage changes; but over a large area fluctuations of water levels tend to reflect long-term storage changes caused by deficiencies or excesses of recharge.

A simplified flow pattern is shown in figure 2 and represents the general character of the overall system and the major subsystems of the Humboldt River basin.

Several major factors have an important influence on the particular hydrologic system. For the Humboldt River basin, the meteorology, the land surface, and the geology all exert an influence on the various components of that hydrologic system. These together with some physical features are discussed subsequently in this chapter to provide a useful framework to the analysis and interpretations which are presented later in this report.

Landforms and the Hydrologic System

The Humboldt River basin is in the Great Basin section of the Basin and Range physiographic province. Plate 1 shows that the basin includes a number of valleys separated by mountains and drained in part by the Humboldt River. The basin includes an area of about 17,000 square miles mainly in Elko, Eureka, Humboldt, Lander, and Pershing Counties. The altitude ranges from about 3,900 to 11,800 feet above sea level. The vegetative cover generally is of brush or grassland types but is absent in some of the playa and saline areas. Greasewood, rabbitbrush, native grasses, willow, and irrigated crops occur in the valley lowlands. In the mountains piñon and juniper stands are common but pine and fir occurs in favorable areas and aspen generally are found along many of the mountain streams.

The simplified flow system for the Humboldt River basin shown in figure 2 groups the general hydrologic characteristics and interrelations of "subcycles" according to landforms. The three hydrologically significant landforms are mountains, valley uplands, and valley lowlands.

Mountains—The crests of the mountains ordinarily are 2,000 to 3,000 feet above the floor of the adjacent valley, but locally the difference is as much as 5,000 feet adjacent to parts of the Toiyabe Range and Ruby Mountains. Crest altitudes of the mountains vary to some extent but commonly exceed 8,000 feet in the western and central part of the basin, such as in the Santa Rosa, Sonoma, and Humboldt Ranges. However, the highest altitudes are in the Toiyabe Range, Ruby Mountains, and East Humboldt Range,

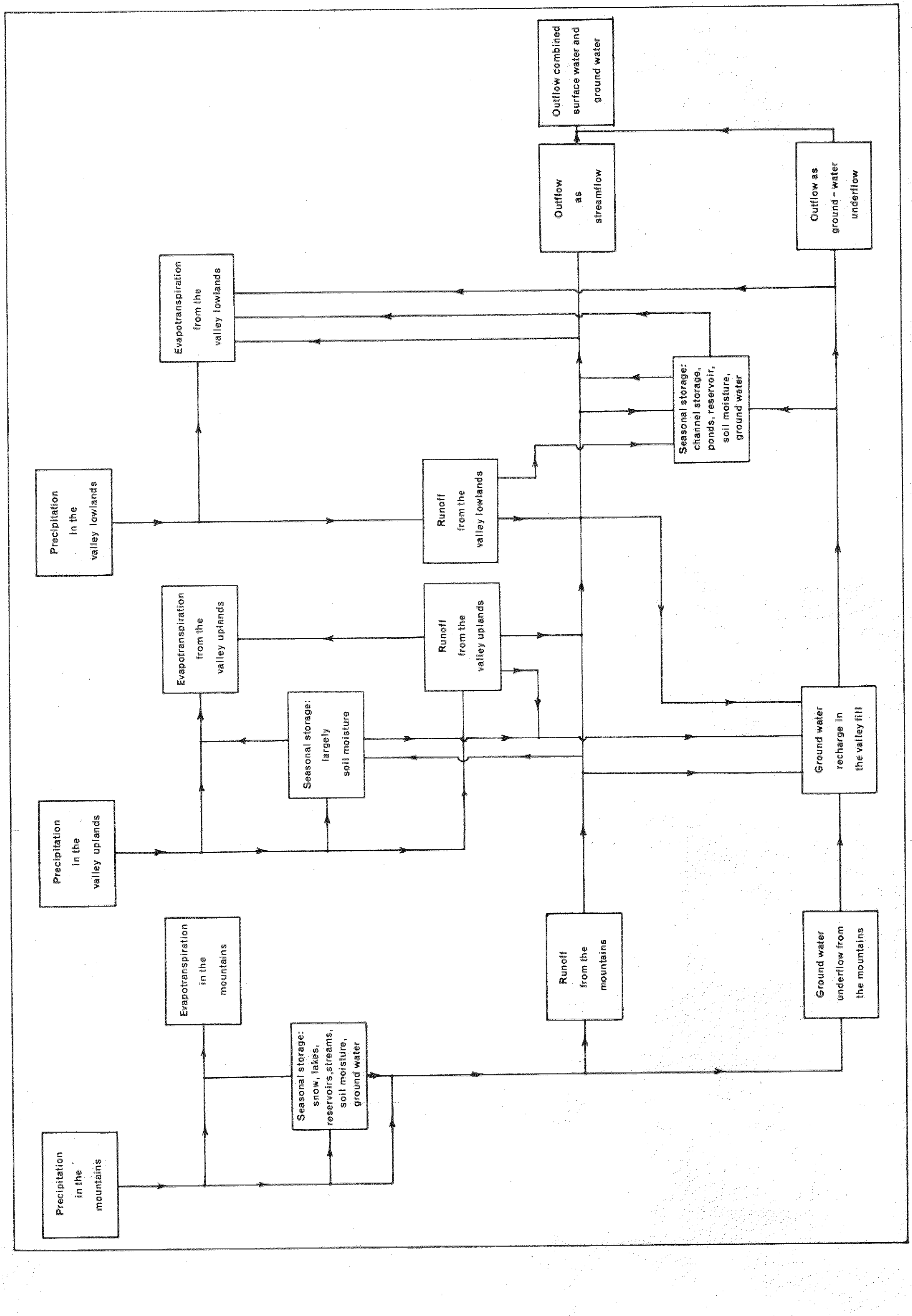

FIGURE 2. Simplified flow system for the basin and its principal subsystems.

where crest altitudes exceeding 11,000 feet occur; for example, Toiyabe Dome, altitude 11,788 feet and Ruby Dome, altitude 11,349 feet. The flanks of the mountains commonly are steep with slopes ranging from several hundred to more than 1,000 feet per mile.

The crests of the mountain ranges form surface-water drainage divides. Ground-water divides ordinarily occur in the ranges, because of the low permeability of the complexly faulted masses of consolidated dense rocks in the mountains. Seasonal storage of water plays an important role in the mountain hydrologic subcycle. Water stored as snow, or in lakes, ponds, or reservoirs supplies most of the streamflow to the valley uplands. Water stored as soil moisture supplies much of the summer requirements of vegetation. Water stored seasonally as ground water supplies much of the late season flow of the streams. Also, some of this ground water is transmitted along faults or fractures at relatively shallow depth in the general direction of the slope of the overlying land surface. However, more than 80 percent of the precipitation in the mountains is lost by evapotranspiration in the mountains.

Valley uplands—The valley uplands can be identified conveniently as an area of intermediate slope between the mountains and the valley lowlands. Valley uplands in the Humboldt River basin are classified in two general types. One type consists of a series of dissected terraces cut in partly consolidated Tertiary rocks. These surfaces commonly have a thin veneer of well-drained slope wash, alluvial fan, or stream deposits. Stream erosion has deeply dissected the valley fill. Locally the dissection is as much as several hundred feet. Downcutting of the valleys was interrupted several times, and these episodes were marked by the development of terraces or benches. Successively lower entrenchment partly removed the older terraces but locally several levels can be identified, particularly in Pine (Eakin, 1961, figs. 1, 2) and Huntington Valleys. This type of valley upland is common in the upper Humboldt River basin.

The other type consists of a single generally sloping surface which is referred to as an alluvial apron. Such areas also may be underlain by only a veneer of unconsolidated rocks, but in other localities they may be underlain by alluvial-fan deposits several hundred feet thick. The large alluvial fan at the mouth of Big Creek, near Austin, in upper Reese River valley is a good example of a well-formed alluvial fan. Alluvial fans also are well illustrated along the west flank of the Cortez Mountains in Crescent Valley (Zones, 1961, p. 9). Alluvial aprons are well developed in Grass and Paradise Valleys and elsewhere in the lower basin. Both valley upland and alluvial-apron areas occur in the middle basin.

Where the valley uplands principally are cut surfaces in partly consolidated to consolidated rocks, percolation to the ground-water reservoir proportionally is small and streamflow is large. In contrast, valley uplands underlain by thick sections of permeable unconsolidated alluvial-fan or stream deposits are favorable areas for recharge to the ground-water reservoir and relatively unfavorable for runoff. In either case, precipitation and runoff on the valley uplands provides substantial quantities of water to the soil zone. Most of the soil moisture subsequently supports vegetation which provides much of the range feed for livestock but some water percolates downward and becomes perched or semiperched ground water. Most of the evapotranspiration occurring in the valley uplands is supplied by local precipitation and to some extent runoff from the mountains. Ground water, with minor exceptions, is too deep to support vegetation on the surface.

Valley lowlands—The valley lowlands include the flood plains of the Humboldt River and its tributaries and also the playas or dry lake areas of the closed or semiclosed subbasins. The well-developed flood plains of the main stem of Humboldt River and its tributaries in the upper basin and Pine Valley are included in the valley lowlands. The less developed flood plains of Crescent, Carico Lake, Reese River, Boulder, Kelly-Evans Creek, Paradise, and Grass Valleys as well as the playas or dry lake areas in Crescent, Carico Lake, Buffalo, and Paradise Valleys are also included.

The flood plain of the Humboldt River commonly is about 1 mile wide, but Cohen (1963, p. 25) indicates that in the Winnemucca section it locally is as much as 5 miles and as little as 0.2 mile wide. The maximum width of the Humboldt River flood plain near Battle Mountain also is on the order of 5 miles. The flood plain is very narrow in the bedrock constrictions or narrows through which the river flows, such as those between Elko and Beowawe and in Emigrant Canyon. For the most part the width of the flood plains of tributary streams is less than that of the Humboldt River. The longitudinal gradient of the flood plain ranges from less than 3 feet per mile in the lower basin to more than 100 feet per mile at the head of some tributaries in the upper basin.

The valley lowlands are underlain by late

Quaternary deposits of unconsolidated stream-laid gravel, sand, silt, and clay, commonly to depths of several tens of feet. However, the thickness of these deposits ranges from a few feet in bedrock narrows, such as near Palisade, to several hundred feet, as in the central part of the Winnemucca section (Cohen, 1963, p. 25). The late Quaternary deposits underlying playas or areas having poor exterior drainage tend to be fine-grained, similar to the silty clay units of Lake Lahontan deposits referred to by Cohen (1963, table 3).

Seasonal storage of water in the valley lowlands, particularly in the flood plains of the principal perennial streams, occurs in the stream channels, ponds, surface reservoirs, soil moisture, and ground-water reservoirs. Movement of water into and out of, and temporary storage in the flood-plain deposits are dominant features in the hydrologic regimen of the basin and the Humboldt River. This transient storage acts to retard or delay streamflow in its route to the Humboldt Sink. Also, evapotranspiration rates are high in the lowlands, which results in significant water losses, even though the lowland area is only a small part of the basin.

The Meteorological Environment and the Hydrologic System

The meteorological environment provides the means by which water is brought into and removed from the Humboldt River basin. Moisture in the air masses moving into the region provides a supply from which precipitation over the basin occurs. Relatively dry air moving over the region acts like a blotter to remove water from the basin. Thus, the atmosphere functions as the beginning and the end of the hydrologic system of the Humboldt River basin.

Air-mass movement over the Humboldt River basin is a part of the general circulation pattern of the northern hemisphere. Its regional characteristics and relation to hydrology are discussed by Thomas (1962, p. A8–A14) in conjunction with studies of droughts in the southwest. The Humboldt River basin is along the northern side of the area considered by Thomas.

The Pacific Ocean provides most of the moisture that is brought into this part of the Great Basin. Winter precipitation is supplied mainly from the cool moist Pacific air mass that is generated in the northern Pacific area and which sweeps southeastward into the northwestern States and on eastward. The general path of these air masses shifts southward during the winter in response to an expansion of the high pressure system in Canada and shifts northward during the summer months as that system contracts or moves northward. During the winter, the path of storms also varies, both for individual storms and from year to year. Thus a series of storms that move over the Humboldt River basin in a given year may result in a relatively wet year. This may be contrasted with a dry year in which there are fewer storms or the seasonal storms may tend to pass north of the Humboldt River basin.

Infrequently warm, moist air masses developed in the tropical Pacific enter the continent in the latitude of southern California and move eastward. Occasionally the trajectory of the tropical Pacific air mass may shift northward far enough to pass through parts or all of the Humboldt River basin. The warm heavy winter rains that occur occasionally in the basin in part may be of this type.

During the summer months, moisture brought in from the south by the tropical Gulf air mass usually reaches the southern part of Nevada, but the Humboldt River basin normally is beyond the limits of that supply.

The inflow of moisture from the Pacific Ocean is interrupted by the Sierra Nevada in California and the Cascade Mountains of Oregon and Washington. These ranges exert a strong orographic influence, resulting in substantial precipitation from the air masses moving over them. Thus the Great Basin generally is arid to semiarid as the result of being more or less in the rain shadow of these prominent ranges. However, within the Great Basin and the Humboldt River basin specifically, the valley floors rise in altitude to the east. Further, the corrugated effect of alternating mountains and valleys and the fact that the crests of the higher ranges commonly exceed 10,000 feet and locally exceed 11,000 feet all combine to wring moisture out of the atmosphere. In doing so, however, the distribution of precipitation is localized so that the higher average precipitation occurs in the mountains. Even in the mountains precipitation is localized. The Ruby and East Humboldt Ranges and the Jarbidge and Santa Rosa Mountains normally receive more precipitation than other mountain ranges in the basin. The mountain and valley terrain also favors the development of differential thermal heating conducive to local convective thunderstorms—a feature that occurs most commonly during the summer.

The Geological Environment and the Hydrologic System

The geological environment is a major controlling factor in the hydrologic system within the Humboldt River basin. The stratigraphy and structure control the present-day topography, the gross form of the land surface. The resulting sequence of mountains and valleys forms the characteristic corrugated land surface which influences the air masses moving over the basin, and the amount and distribution of precipitation within the basin.

Geologic conditions also control the routing of water through the hydrologic system. Thus in mountainous areas where impermeable rock is at the surface, precipitation in excess of evapotranspiration requirements largely is disposed of as overland runoff. In contrast, excess precipitation on mountain areas with a deep soil mantle or more permeable rocks largely infiltrates to the ground-water reservoir. Water, whatever its source, rapidly infiltrates the unconsolidated sand and gravel deposits that underlie the younger alluvial fans and flood-plain areas.

Collectively the rocks provide a tremendous reservoir for natural water storage in the basin. Locally, even the consolidated rocks have fractures that contain water; of course the valley-fill deposits that underlie the valley uplands and lowlands form the largest reservoirs. This water in storage provides a balance to the wide year-to-year variations of total inflow to and outflow from the hydrologic system in the basin.

Drainage

The Humboldt River of today largely is the result of prior events in Quaternary time. During the more humid intervals of Pleistocene time runoff was sufficient to develop an integrated drainage system that supplied water to Lake Lahontan in late Pleistocene time. During at least one interval the drainage area was about 3,100 square miles greater than the area shown in plate 1. At that time runoff from Monitor, Antelope, Kobeh, and Diamond Valleys in central Nevada overflowed through Railroad Pass in northeastern Diamond Valley into Huntington Valley and thus was tributary to Huntington Creek.

During late Pleistocene time, Humboldt River and its tributaries, particularly upstream from Palisade and in Pine Valley, cut deeply into the valley fill and locally into consolidated rocks; and the present drainage system developed principally during this period. Several levels of dissection are recorded in those areas which attest to the fact that the downcutting varied in intensity and time. The detritus excavated from the upper basin was transported downstream and largely was deposited in Lake Lahontan and to a lesser extent along the river channel upstream from the lake. At the highest levels, Lake Lahontan covered the lower parts of the lower Humboldt River basin downstream from Emigrant Canyon, including the floors of Paradise and Grass Valleys. With desiccation of the lake, the Lahontan deposits were dissected by the Humboldt River as the river flowed over the lake deposits to reach the lake at successively lower levels (Cohen, 1963, p. 24).

The present-day Humboldt River follows a large looping westward course across north-central Nevada terminating in the Humboldt Sink, about 15 miles southwest of Lovelock. From the town of Wells the flood-plain distance is about 300 miles to the Humboldt Sink. Actual river-channel distance probably is twice the flood-plain distance, because of the meandering course of the channel.

For convenience in discussion, the Humboldt River basin is divided into three major units—upper, middle, and lower basins.

Upper basin—The upper basin is the drainage area of about 5,000 square miles upstream from Palisade. The principal tributaries draining the northern part of the upper Humboldt River basin are Marys River and North Fork Humboldt River with drainage areas of about 520 and 1,020 square miles, respectively. However, more than half of the streamflow in the Humboldt River at Palisade is contributed by streams draining the northwest flanks of the Ruby Mountain and East Humboldt Range. These streams include the comparatively small drainage areas extending southward from Ackler Creek, Lamoille Creek, and the headwaters of the South Fork Humboldt River. The Bishop, Tabor, Maggie, and Susie Creek drainages, and minor tributary drainages along the main stem between Deeth and Palisade also contribute streamflow. Mean annual flow of the Humboldt River increases to a maximum of about 260,000 acre-feet downstream from Palisade just below the confluence with Pine Creek. Downstream from that point, evapotranspiration losses exceed inflow and the flow decreases to the Humboldt Sink.

Middle basin—The middle basin has a drainage area of about 7,800 square miles between Palisade and Emigrant Canyon—a narrow gap downstream from Comus. South of the main stream, it includes Pine Valley, Crescent Valley, Carico Lake Valley, Reese River Valley, Antelope Valley, and Buffalo Valley, and the smaller Whirlwind and Pumpernickel Valleys. North of the main stream are the Rock Creek drainage area and the smaller Boulder Creek area and Evans-Kelly Creek area. Pine Creek has a perennial flow at the mouth. Rock Creek discharges a substantial quantity of water into Boulder Valley. Much of this water is lost by evapotranspiration before it reaches the Humboldt River. However, Rock Creek seasonally reaches the Humboldt River in most years. Kelly Creek similarly loses much of its flow prior to reaching the Humboldt River, but commonly extends to the Humboldt River during the spring runoff. Reese River Valley, with a drainage area of more than 2,000 square miles, contributes a significant quantity of water to the Humboldt River only during infrequent times of exceptional runoff.

Lower basin—The lower basin is the area downstream from Emigrant Canyon to and including Humboldt Sink, an area of about 4,100 square miles. It includes Paradise Valley, Grass Valley, and minor tributary drainages along the main stem, such as Pole and Little Rock Creek. Little Humboldt River, Martin Creek, and smaller streams provide a substantial streamflow into Paradise Valley. However, streamflow seldom reaches the Humboldt River from their combined drainage area of about 1,770 square miles. Gumboot Lake, near the mouth of Paradise Valley, was drained into the Humboldt River in 1953 and 1958 by artificially removing the sand dunes that blocked the channel. The Little Humboldt River has discharged naturally to the Humboldt River (Nevada Department of Conservation and Natural Resources and U.S. Department of Agriculture, 1962, table 18) about 8 times in the last 100 years of which three occurrences were in the last 50 years. The quantities of water are not known, but the average probably is not more than a few thousand acre-feet per year. Streamflow from Grass Valley and other minor tributary drainages into the Humboldt River is inconsequential. Runoff from the mountains occasionally extends across the alluvial apron and into the valley lowland.

The Humboldt River drains into Humboldt Sink. When water is available, Humboldt Drain, at the southwestern end of Humboldt Sink, drains water through the alkali flat to Humboldt Slough, which in turn drains to Carson Sink.

Valley of the Humboldt River—Later in this report the term valley of the Humboldt River as distinct from the Humboldt River basin is used. The valley of the Humboldt River refers to the flood plain and adjacent minor tributary drainages downstream from the gaging station known as Humboldt River near Elko (3185) which is in the narrows near Ryndon. The main stem of the Humboldt River is divided into upper, middle, and lower sections using the narrows at Palisade and below Comus as dividing points.

CHAPTER III

ANALYSIS AND INTERPRETATION OF DATA

This chapter presents analyses, interpretation, and estimates of the various components of the hydrologic system for the Humboldt River. Most of the data and estimates have not previously been analyzed, synthesized, or reported. However, this report incorporates some analytical and interpretative material presented in previous reports, especially the material concerning the Winnemucca area (Cohen, 1963 and 1964a).

The concept of average conditions generally is used to convey the characteristics of the occurrence and movement of water in a hydrologic system. However, this concept presents an incomplete picture, as it involves much simplification especially with respect to the variability that actually occurs. Divergence from average conditions brings about those natural crises, drought or flood, that bear heavily on man's utilization of water. Variability in time and space, however, is also a principal factor in the production in local areas of quantities of water that are susceptible to management and use. Thus, in the Humboldt River basin the usable precipitation, or that which produces significant streamflow or recharge, in large part accumulates as snow in the mountains during the winter. If the same amount of precipitation were uniformly distributed throughout the year and over the entire basin, little streamflow or ground-water recharge would occur. The only water available to man would be that obtained from ground water stored during former times of greater precipitation. The general hydrologic cycle visualized for the Humboldt River system is illustrated in figure 2.

CLIMATE

Precipitation

Most of the precipitation in the Humboldt River basin occurs between December and May, generally as snow in the mountains. Snowmelt combined with spring rains causes seasonal runoff that supplies most of the flow to Humboldt River and its tributaries. The amount of water accumulated varies from year to year at a given locality, and the amount of precipitation during a given year varies from place to place.

In a general way precipitation increases with altitude but this relation is modified by exposure, orientation, local relief, and relative rate of rise of land surface. Figure 3 shows the distribution of precipitation in the Humboldt River basin by generalized lines of equal precipitation (isohyets) as adapted from Hardman (1964, written commun.). The average annual precipitation in the Humboldt River basin ranges from about 4 inches in the Humboldt Sink to about 40 inches in parts of the Ruby Mountains and Jarbidge Mountains. The average annual precipitation in the Humboldt River basin calculated from data shown on figure 3 is about 9.4 million acre-feet or 10.4 inches. Of this amount about 60 percent occurs in the mountains and about 40 percent occurs on the valley uplands and lowlands. Table 1 shows the estimated distribution of precipitation, based on figure 3.

TABLE 1. DISTRIBUTION OF AVERAGE ANNUAL PRECIPITATION

(Values, in thousands of acre-feet, to two significant figures)

			Valleys	
Basin segment	Total	Mountains	Uplands	Lowlands
Upper basin	3,400	2,100	1,100	240
Middle basin	4,200	2,600	1,300	260
Lower basin	1,800	1,100	620	120
Humboldt River basin, total	9,400	5,800	3,000	620

Variations in precipitation from year to year at given points are illustrated in figure 4 by the graphs of cumulative departure from average annual precipitation for five stations in the Humboldt River basin. The rising trends indicate successive years of above average precipitation and the declining trends reflect several years of below average precipitation. Although the trends are not the same for all stations for the entire period, most stations show above average precipitation in the late 1930's and early 1940's. All stations show below average precipitation during the 1950's; the Lovelock graph most nearly approaches average precipitation during the period illustrated. In gross aspect these graphs suggest that the wet and dry periods range in length from 10 to 20 years and are reasonably similar at all stations.

The distribution of precipitation within the year is summarized for five stations in figure 5. Maximum and minimum precipitation by months is shown for the period 1912–63. Additionally the bars indicate values for which monthly precipitation is equaled or exceeded 25, 50, and 75 percent of the time. The maximum recorded water-year

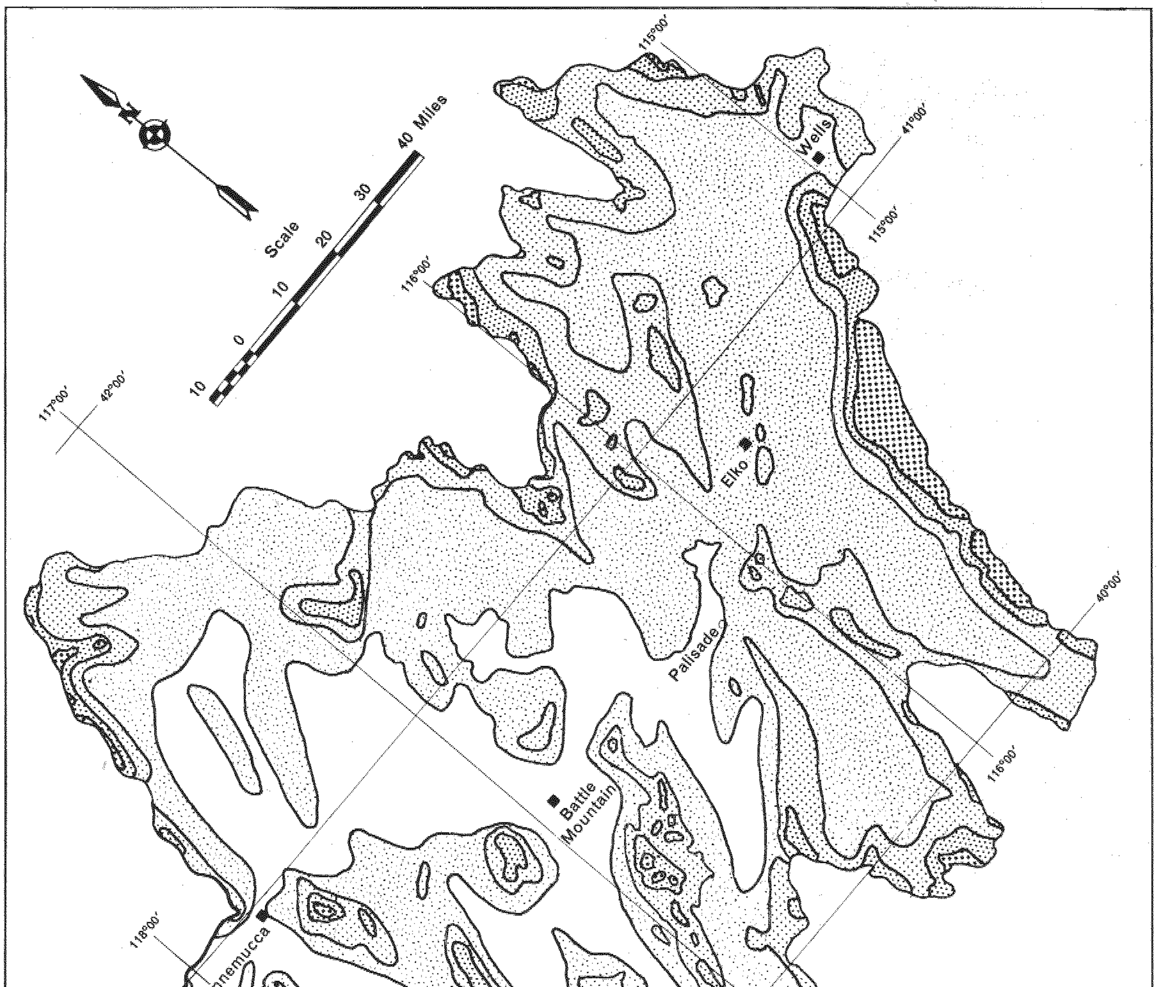

FIGURE 3. Map of the basin showing distribution of precipitation.

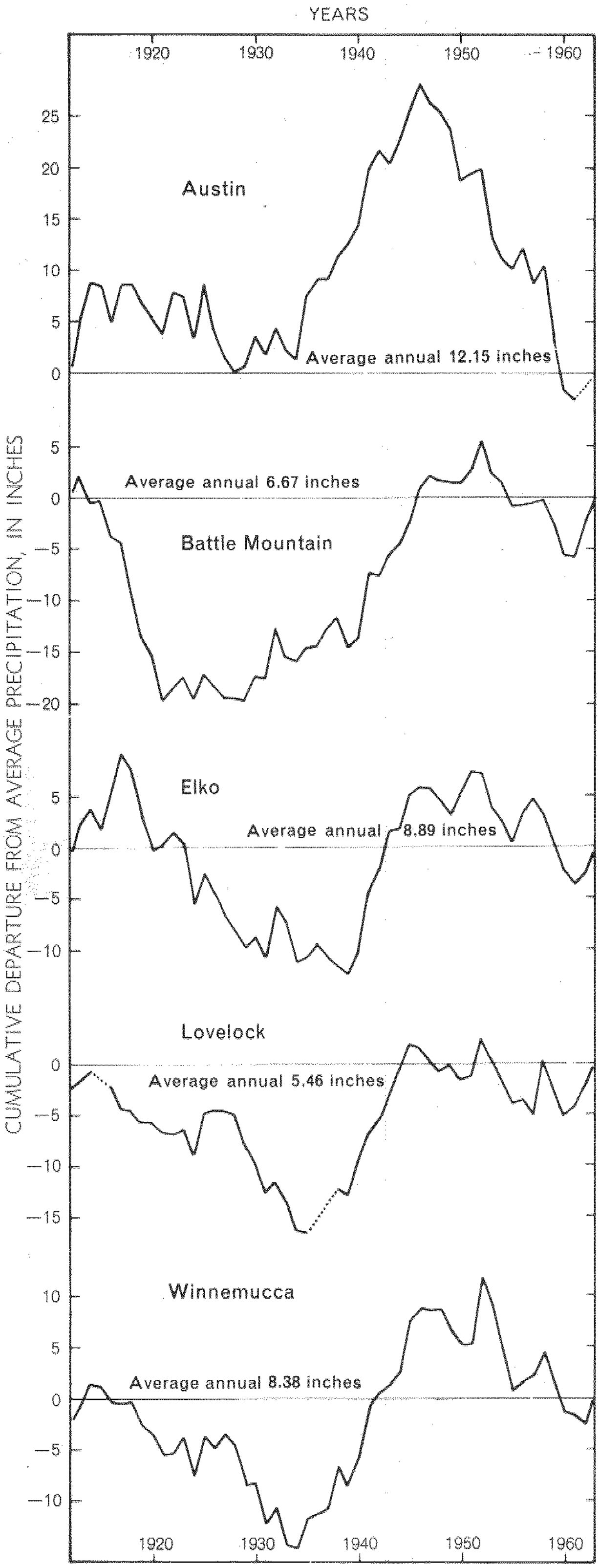

FIGURE 4. Cumulative departure from average annual precipitation at five stations, for the period 1912–63.

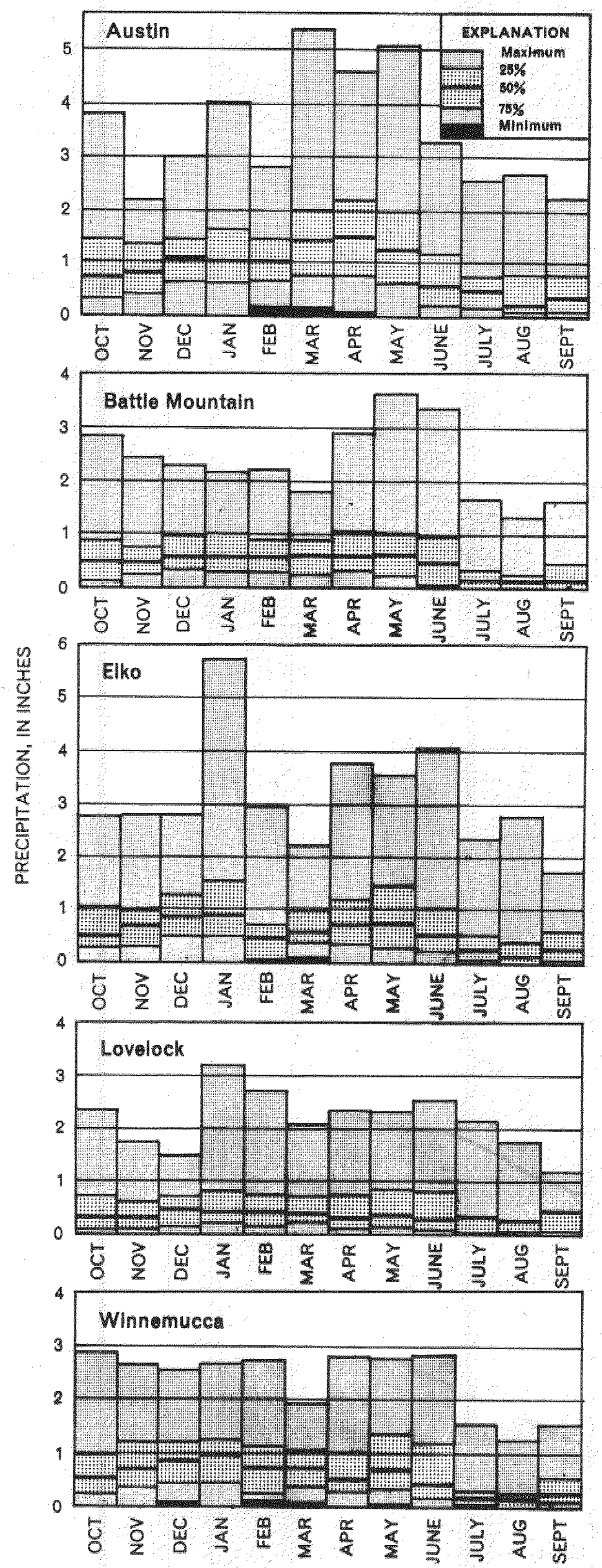

FIGURE 5. Distribution of monthly precipitation, in inches, at five stations for the period 1912–63. Variations given as maximum, minimum, and percent of time that monthly value has equaled or exceeded the indicated value.

precipitation is nearly equal to the sum of the upper quartile values for the 12 months. Similarly the minimum recorded water-year precipitation is approximately equal to the sum of the lower quartile values for the 12 months.

Temperature

Records of temperature are not as complete as those of precipitation in the Humboldt River basin. Generally however, temperature fluctuates through a wide daily and seasonal range. The daily range of temperature commonly is 30° to 40° F and occasionally more than 50° F. The wide range tends to obscure some of the geographic differences of temperature, but average temperature commonly decreases 1° to 3° F per thousand feet increase in altitude. Variations also are to be expected resulting from orientation and exposure of the land surface as well as in response to weather systems moving over the basin.

Variations in annual mean temperatures are illustrated by the cumulative departure graphs for Elko and Winnemucca in figure 6. Thomas (1962, p. A29) noted that at seven stations in the southwest maximum average temperatures were recorded in the early 1940's. A similar tendency also is indicated in the records for Elko and Winnemucca.

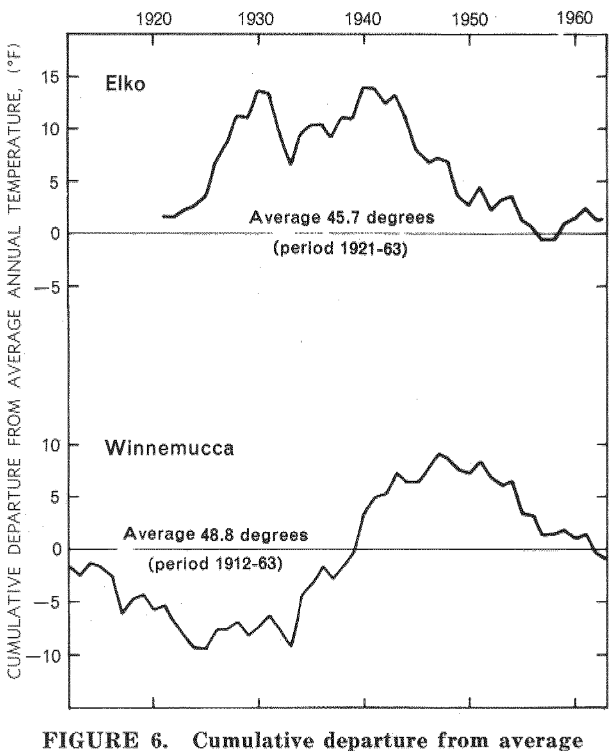

FIGURE 6. Cumulative departure from average annual temperature at Elko and Winnemucca.

Variations in temperature from month to month are shown in figure 7. Maximum and minimum monthly average temperatures are shown in the bar graph. Additionally the bars indicate values for which monthly average temperature was equaled or exceeded 25, 50, and 75 percent of the time.

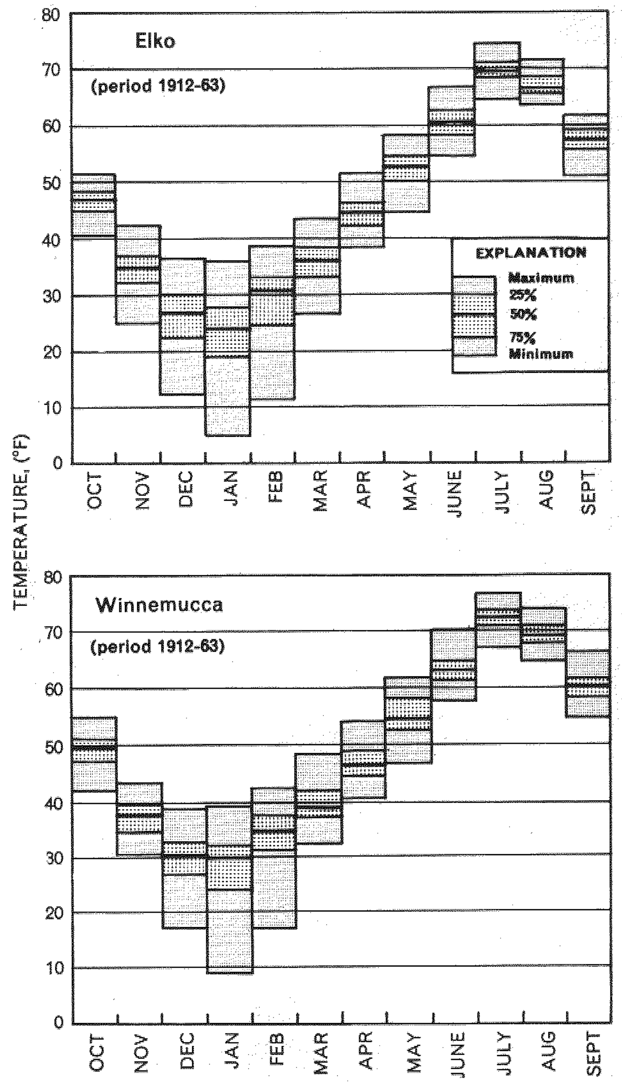

FIGURE 7. Distribution of monthly temperature at Elko and Winnemucca.

Evapotranspiration

Evaporation and transpiration are the natural processes by which nearly all the water is removed from the Humboldt River basin. Kohler, Nordenson, and Baker (1959, pl. 2) indicate that annual lake evaporation averages from about 42 inches in the northeastern part of Humboldt River basin to about 52 inches in the Humboldt Sink area. Thornthwaite (1948, fig. 3) indicates potential evapotranspiration for most of the middle and upper parts of the Humboldt River basin to range from 18 to 24 inches a year and somewhat more than 24 inches a year in the lower basin and the lowland section downstream from about Battle Mountain. The ranges for lake evaporation and potential evapotranspiration are substantially greater than the estimated average annual precipitation of 10.4 inches for the basin.

Evaporation varies seasonally and ordinarily is greatest in July and least in January as is indicated in figure 8 which shows average monthly pan evaporation records at three stations. The record for Fallon although outside of the Humboldt River basin, is shown to indicate the low evaporation rates prevailing during the winter months.

Evapotranspiration by vegetation also follows seasonal trends. After a dormant period during the winter months in most of the basin, evapotranspiration ordinarily begins in early spring, reaches peak rates during optimum plant activity and declines to minor amounts in the fall.

Evapotranspiration rates vary with vegetation physiology, density, and type. They also vary to some degree in response to available water, cloud cover, wind velocity, air temperature, humidity, and topographic parameters. As these show substantial variations locally within the Humboldt River basin, it is to be expected that actual evapotranspiration also should show variations within the basin.

Data on these factors are not available to estimate precisely actual evapotranspiration throughout the basin. However, rough estimates illustrate the general distribution of evapotranspiration in the basin. Table 2 summarizes those estimates.

TABLE 2. ESTIMATED AVERAGE ANNUAL EVAPOTRANSPIRATION

(Values, in thousands of acre-feet, to two significant figures)

Unit	Total	Mountains	Valleys: Uplands	Valleys: Lowlands
Upper basin	3,100	1,500	1,100	530
Middle basin	4,200	2,300	1,300	610
Lower basin	2,000	960	620	380
Humboldt River basin, total	9,300	4,800	3,000	1,500

The estimated total evapotranspiration in the Humboldt River basin of 9.3 million acre-feet very nearly equals the estimated total precipitation of 9.4 million acre-feet (table 1). About 90 percent of the total precipitation in the basin is lost by evapotranspiration about where it falls, either immediately or after a seasonal period of storage as snow or soil moisture. Further, of the approximately 10 percent of the total precipitation that becomes runoff or ground water, nearly all of it

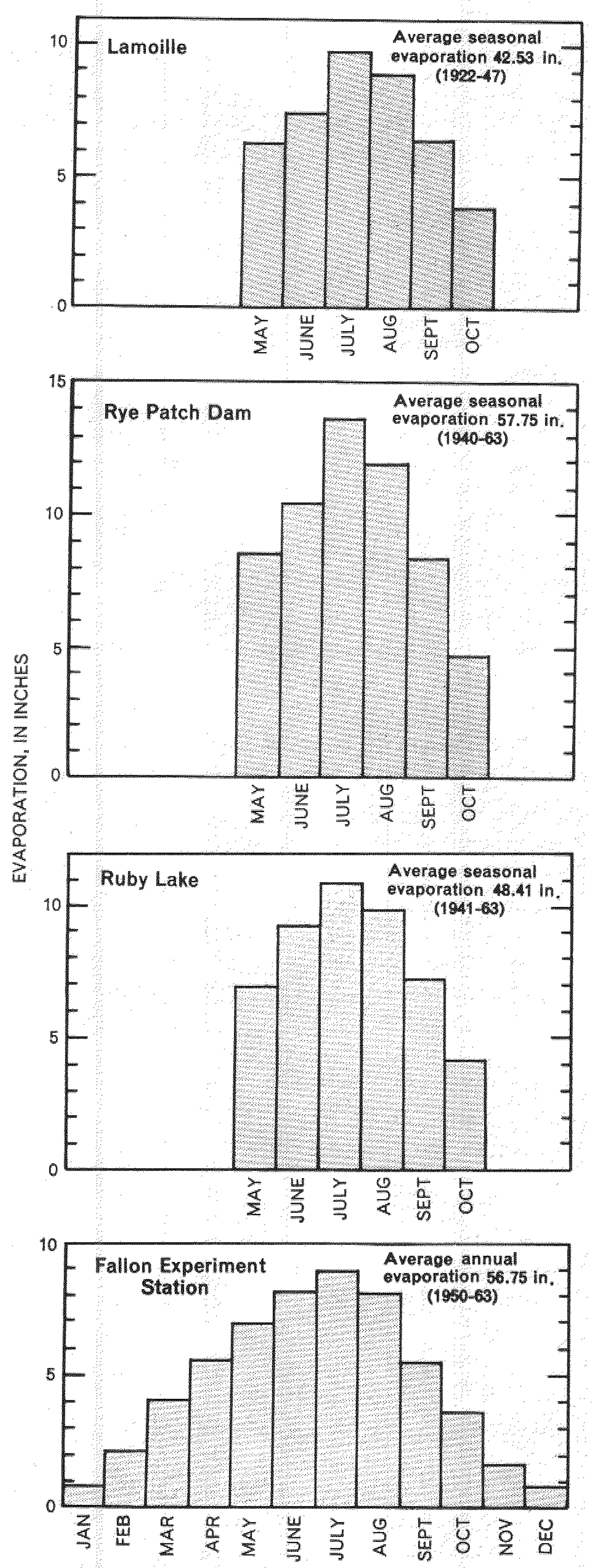

FIGURE 8. Average monthly pan evaporation at four stations.

ultimately is lost by evapotranspiration within the basin.

Thus, evapotranspiration begins to remove water from the Humboldt River basin almost from the instant precipitation begins. This is a continuing though variable demand for water in the Humboldt River basin, and water for other uses is available only as the supply locally is greater than that required by evapotranspiration, or as the supply can be utilized prior to evapotranspiration. Thus, water in excess of that demanded by evapotranspiration becomes available as runoff or ground-water underflow from the mountains.

Most of the water for evapotranspiration from the valley uplands probably is derived from precipitation on the valley uplands, although some undoubtedly is supplied by runoff from the mountains. Also, ground water supplies some water to phreatophytes where the water table is shallow in the valley uplands (commonly 50 feet or less). For example, phreatophytes on the bench land adjacent to the flood plain of the Humboldt River near Winnemucca derive part of their supply from the principal ground-water reservoir in the valley fill (Cohen, 1963, pl. 5, p. 73).

Table 3 summarizes the estimated losses by evapotranspiration in the flood plain and lowland areas in the upper, middle, and lower parts of the Humboldt River basin. Two areas—the "wet, semiwet, or irrigated areas" and the "other shallow ground-water areas" make up the shallow-water areas shown on plate 1. The third area "residual lowlands" includes normally dry tributary channels and other relatively dry lowland areas, especially where the depth to ground water may be greater than 10 feet but where evapotranspiration of ground water occurs. This area is partly identified on plate 1 by the 25-foot depth-to-water supplemental contours in the middle and lower basin.

The rates of evapotranspiration used for the several conditions are given in the footnotes of table 3. The appropriate rate is then applied to the indicated area. In a few places, values from previous reports were used in lieu of the computation method of this report. Presently, nearly all of the water used is removed subsequently by evapotranspiration at or near the points of use. In this report estimates of evapotranspiration losses from valley lowlands include water used beneficially.

Table 4 summarizes the evapotranspiration losses from the valley lowlands by grouping the estimates in table 3 in terms of sources of water. Of the water estimated to be removed from the valley lowlands by evapotranspiration, roughly 40 percent is supplied from direct precipitation, 30 percent is from streamflow, and 30 percent is ground water. However, much of the ground water discharged from the valley lowlands, in turn, is derived from infiltration of surface water as it crosses the flood plains.

GROUND WATER

Hydrogeology

The rocks that crop out in the Humboldt River basin range in age from Precambrian to Recent and represent a time span of more than 600 million years. The oldest rocks are metamorphosed and crop out in the Ruby Mountains. A wide variety of sedimentary, volcanic, and locally intrusive rocks are exposed in the basin. The wide variety of rock types reflect wide variations in the capacity of the rocks to store and transmit water. These variations can be significant either vertically or laterally in short distances. However, for the purpose of illustrating the common general hydrologic relations in the basin, the geologic units can be divided into two main groups: the consolidated rocks and the valley fill. The general surficial distribution of the two groups is shown on plate 1. A more detailed breakdown of the geology is shown on the geologic map (pl. A1) in the appendix of this report.

The metamorphic and intrusive rocks commonly are the least permeable of the consolidated rocks, but in fractures and weathered parts they may contain and transmit small quantities of water. Ordinarily this characteristic is limited to a depth of a few hundred feet, and the water moves in the direction of the general gradient of the overlying land surface.

The Paleozoic and Mesozoic sedimentary and volcanic rocks generally have low permeability. Cohen (1963, table 2) summarizes the hydrologic properties of the Paleozoic and Mesozoic rocks in the Winnemucca area. Fractures store and transmit some water mostly within a few hundred feet of land surface. Where extensive areas of these fractured rocks are in the zone of saturation, the quantity of water in storage is substantial. In the mountains many small springs are supplied by water moving in these rocks.

The carbonate rocks, limestone and dolomite, principally of Paleozoic age but including some of Mesozoic age in the western part of the basin, in part are exceptions to the above statement. Locally the carbonate rocks may transmit substantial

TABLE 3. ESTIMATED AVERAGE ANNUAL LOSSES BY EVAPOTRANSPIRATION FROM VALLEY LOWLANDS IN HUMBOLDT RIVER BASIN
(Values, in thousands of acre-feet, significant to no more than two figures)

Unit	Wet, Semi-wet, or Irrigated Areas					Other Shallow Ground-Water Areas					Residual Lowlands					Total	
	Area (acres)	Precip-itation[1]	Surface water[2]	Ground water[3]	Sum	Area (acres)	Precip-itation[1]	Surface water[4]	Ground water[5]	Sum	Area (acres)	Precip-itation[1]	Surface water[6]	Ground water[6]	Sum	Area (acres)	Loss
Upper basin	124.9	94.6	158.6	62.4	315.6	138.7	104.1	8.7	55.6	168.4	56.5	42.4	5.6	5.6	53.6	320	538
Middle basin	[7]62.7	[8]61.4	[8]114.5	[8/9]74.9	250.8	331	184.2	[9]20.7	[9]132.8	337.7	15	11.2	1.5	1.5	14.2	408	603
Lower basin	93.8	47.9	[9/10]153.8	[9]44.6	246.3	135	68.5	[9]8.4	[9]54	130.9	13	7.8	1.3	1.3	10.4	242	387
Humboldt River basin	281	204	427	182	813	605	357	38	242	637	84	61.4	8.4	8.4	78	[11]970	1,528

[1]Evapotranspiration from direct precipitation about equal to annual precipitation. Values used are as follows: 0.75 ft. for upper basin, Pine, and Rock Creek Valleys, 0.7 ft. for Paradise and Grass Valleys and Winnemucca section; 0.6 ft. for Imlay area and 0.5 ft. for other areas.

[2]Evapotranspiration from surface-water sources estimated to average about 1.25 ft. evapotranspiration plus 0.25 ft. evaporation from excess water for wet, semi-wet or irrigated areas in flood plain; all lowlands subject to inundation.

[3]Evapotranspiration from ground-water sources estimated to average about 0.5 ft. due to shallow water table commonly associated with these areas; ground water used as surface supplies diminish.

[4]Evapotranspiration from surface-water sources assumed to average about 0.25 ft. or a quarter of the indicated acreage, recognizing occasional natural flooding of parts of these areas.

[5]Evapotranspiration from ground-water sources estimated to average about 0.4 ft. in these areas where depth to water commonly averages about 10 feet or less.

[6]Evapotranspiration rates estimated to average 0.1 foot each from surface-water and ground-water sources in additional tributary flood plain or lowland areas not shown on plate 2, particularly in upper basin and Pine Valley.

[7]Excludes areas for Upper Reese River, Middle Reese River, and Antelope Valleys.

[8]Includes values for Middle and Upper Reese River and Antelope Valleys for which evapotranspiration estimates are taken from previous reports.

[9]Includes estimates contained in prior reports for one or more valleys within unit indicated.

[10]Includes 20,000 acre-feet, average seasonal evaporation from Rye Patch Reservoir estimated by Eakin (1961).

[11]Areas in this table in 1000's of acres.

quantities of water in fractures and solution openings. The Paleozoic carbonate rocks largely are included in the Cambrian to Devonian sedimentary and the undifferentiated Paleozoic rock units shown on the geologic map (pl. A1) in the appendix. The Paleozoic carbonate rocks occur largely in the eastern part of the middle basin and in the upper basin of the Humboldt River.

TABLE 4. ESTIMATED AVERAGE ANNUAL EVAPOTRANSPIRATION LOSSES FROM VALLEY LOWLANDS BY SOURCE OF WATER

(Values, in thousands of acre-feet, to two significant figures)

Unit	Precipitation	Surface water	Ground water	Sum
Upper basin	240	170	120	530
Middle basin	260	140	210	610
Lower basin	120	160	100	380
Humboldt River basin	620	470	430	1,500

Cenozoic volcanic and sedimentary deposits are extensively exposed in the Humboldt River basin and were deposited during the last 65 million years. Commonly the volcanic rocks crop out in the mountains. Regnier (1960) described a section of about 10,000 feet of Tertiary rocks in the Pine Valley area. These are exposed in the mountains but by projection extend beneath the valley floor.

In the Winnemucca area the Quaternary geology has been described by Hawley and Wilson (1965). Cohen (1963, table 3) described the hydrologic properties of 12 lithologic units of Cenozoic age for the Winnemucca area. These deposits, or their equivalents, are present elsewhere in the lower basin. The lacustrine deposits of Lake Lahontan are limited to the lower parts of the lower basin. Deposits similar in type and age, other than the Lake Lahontan deposits listed by Cohen (1963, table 3), occur locally elsewhere in the upper and middle basins.

Tertiary and early Pleistocene(?) deposits extensively underlie the valleys in the upper and middle basins. However, the upper basin was an area of erosion during late Pleistocene time when Lake Lahontan received large volumes of sediments. Thus, when the deposits of Lake Lahontan were being laid down in the lower basin, erosion of the valley fill in the upper basin was active, and the detritus removed from the upper basin was carried downstream toward Lake Lahontan. Pine Valley, upper and middle Reese River valley, and Rock Creek Valley were similarly eroded but some deposition occurred in the lower parts of the middle basin. Thus, late Pleistocene and Recent deposits tend to be relatively thin in the upper basin and the higher parts of the middle basin.

Locally deposits reached a substantial thickness in late Pleistocene time. For example, the large alluvial fan at the mouth of Big Creek in upper Reese River valley and the fans along the west flank of the Cortez Range in Crescent Valley contain several hundred feet of deposits. Although broad generalizations can be made of the Cenozoic geology in the basin, much more study is needed to assist in further defining its effect on the hydrologic regimen. Generally the more permeable deposits are the unconsolidated stream-laid sand and gravel of Quaternary age. The Tertiary sedimentary and volcanic deposits are more consolidated and typically have rather low permeability but do contain a very large amount of water in storage beneath the floors of the valleys.

The complicated structural history of the region affects the hydrologic regimen, but the full effect is not yet entirely known. Locally faulting impedes ground-water movement, but elsewhere faulting may result in fracturing the adjacent rocks, particularly some of the carbonate rocks, which in turn aids in transmitting water. The late Cenozoic structural events largely established the present-day configuration of the mountains and valleys, which in turn have a dominant influence on the occurrence and movement of water in the Humboldt River basin.

Thus in general, the valley fill shown on plate 1 includes the Quaternary deposits in most valleys together with Tertiary sedimentary and volcanic rocks beneath the Quaternary deposits, and these collectively function as ground-water storage units. Locally in the upper basin and in the higher valleys in the middle basin the Quaternary deposits may be absent or above the zone of saturation; there ground water occurs principally in the Tertiary valley-fill deposits.

The consolidated-rock units shown on plate 1 for the most part, includes rocks exposed in the mountains. These consolidated rocks include all of the rocks of Mesozoic age and older. Where the Tertiary volcanic and associated sedimentary rocks occur in the mountains and are unsaturated or contain only perched or semiperched ground water, they are included in the consolidated-rock unit on plate 1. As a group the consolidated rocks have a much smaller capacity to transmit ground water than does the valley fill. Locally, however, segments of the consolidated rocks, such as the previously mentioned carbonate rocks, may transmit water freely through fractures or solution openings. Conversely the fine-grained valley fill may transmit water only slowly.

The generally low permeability of the consolidated rocks, the commonly steep slopes in the mountains where they occur, and the greater average precipitation in the mountains favor the development of runoff in the mountain areas. This combination of physical features is most pronounced in the Ruby Mountains and East Humboldt Range, an area where perhaps the maximum rate of runoff (about 60 percent of the precipitation) is generated in the Humboldt River basin.

Occurrence

For purposes of discussion subsurface water was divided into three zones by Meinzer (1923, p. 23), as is illustrated in figure 9. Water in the zones of aeration and saturation are of principal importance in the hydrologic system. The zone of aeration includes soil water, intermediate vadose water, and water in the capillary fringe. Below this is the zone of saturation in which ground water occurs. The two zones are separated by the water table or upper surface of the zone of saturation.

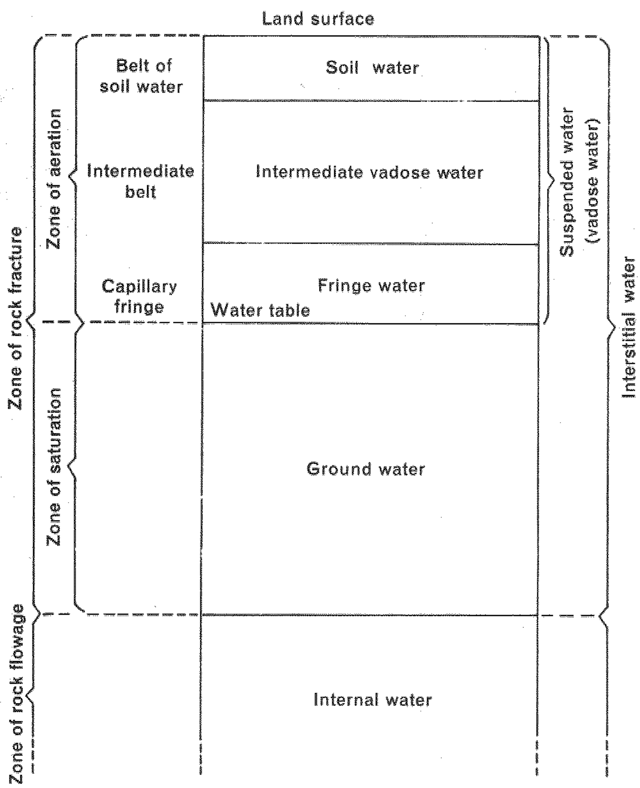

FIGURE 9. Diagram showing the divisions of subsurface water. (After Meinzer, 1923, p. 23.)

Ground water occurs extensively in the valley fill in the Humboldt River basin. Commonly the water table is close to land surface along the valley axis or flood plain of valleys with exterior drainage or beneath the playa in closed valleys. The water table slopes upward from these areas toward the mountains but at a gradient less than that of the overlying land surface. Ground water occurs in the interstitial openings of the porous valley-fill deposits forming an area of continuous saturation.

Ground water also occurs in the consolidated rocks that are exposed principally in the mountains and hills and underlie the valley fill. In those rocks, ground water occurs in fractures or weathered zones and locally in solution openings of carbonate rocks especially in the eastern part of the basin. Although a large amount of ground water is stored in the consolidated rocks, the ground water commonly is not a continuous body through an entire mountain range. Rather, local barriers formed by faults or rocks of low permeability produce a complex pattern of perched and semiperched ground-water bodies. Ground-water bodies of this type ordinarily provide the principal supply of water for the numerous small springs in the mountains and much of the late season flow of the mountain streams.

Movement

Ground water moves from areas of recharge to areas of discharge. The actual flow lines however, follow paths that may have a considerable vertical component, particularly near the areas of recharge and discharge. Figure 10 shows that the flow lines most distant from the river are nearly parallel and the slope diverges only slightly from the hydraulic gradient indicated by the water table. Near the stream into which ground water is discharging, the flow lines converge and some are nearly vertical. In this sense water-level contour lines on maps show the general hydraulic gradient, and flow lines normal to the contours refer only to the lateral component of flow. Plate 1 shows partial water-level contours of equal altitude to illustrate the general direction of lateral ground-water flow in the Humboldt River basin. They show movement away from the mountains, which represent general areas of recharge, to areas of discharge. In and for some distance downgradient from the recharge areas the vertical component of the flow line is steeply downward and the lateral component of flow is at right angles to the contour.

Although the general movement of ground water is from the mountains toward the lowlands, local conditions may cause variations from the general pattern. Along the flood plain, the interrelation of surface water and ground water is such that, depending on the river stage, the flood plain functions both as an area of recharge and discharge. At low flow of the stream, the ground-water movement is toward the river, as is shown by the contours of plate 1 and by flow lines in figure 10. However, at high flow, the river surface is higher than that of the adjacent ground water and water moves from the stream to the ground-water reservoir, as is illustrated in figure 11. Under the extreme conditions of flooding, most of the flood plain is inundated and water percolates downward to the water table. Subsequently, as the surface water flows off and is evaporated, evapotranspiration begins to remove soil moisture and to draw upon ground water. Within a few months the general pattern of flow toward the river is reestablished. Variations in the configuration of water-level contours adjacent to the river under different conditions are illustrated in figure 12. However, in the gross sense, the water-level contours in the flood plain and lowland areas are concave downstream, as is shown on plate 1.

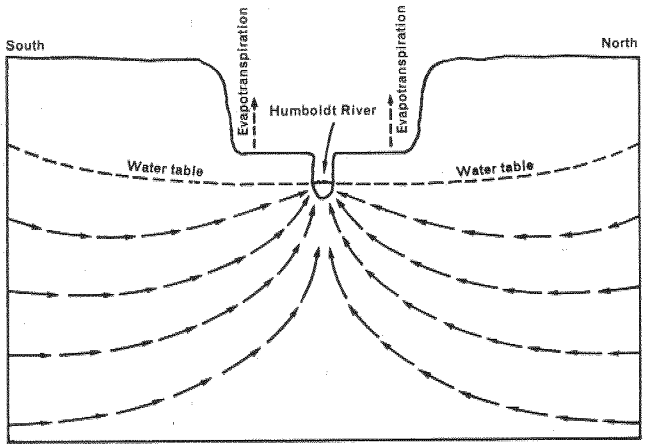

FIGURE 10. Schematic cross section showing the direction of ground-water movement in the Humboldt River valley near Winnemucca, when the stage and flow of the river are low. (After Cohen, 1964a, p. 37.)

The principal flood plains, especially those in the upper basin and Pine Valley, then, generally function as ground-water drains to carry off ground water that otherwise is not lost by evapotranspiration. Thus the ground-water component of streamflow from Pine Valley, estimated by Eakin (1961, p. 23, 24) to provide more than one-half the streamflow, is ground water that is in excess of the amount discharged by evapotranspiration from the valley under existing conditions.

The spacing between contours along the flood plain of the Humboldt River in the middle and lower basins is controlled by the gradient of the flood plain which commonly is less than 5 feet per mile. In Pine Valley the indicated water-level gradient is steeper, about 12 feet per mile, and even steeper than that in the upper parts of the

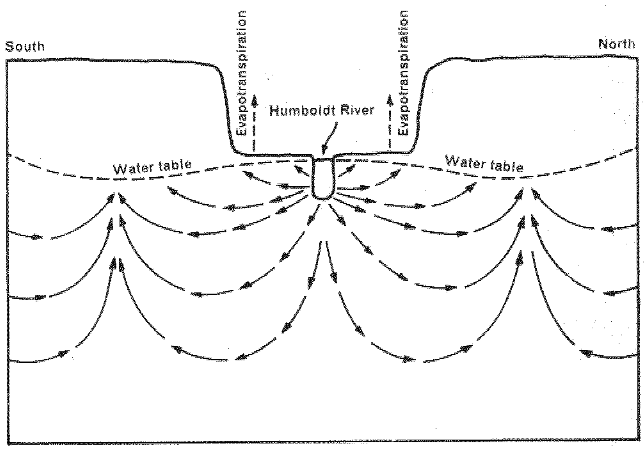

FIGURE 11. Schematic cross section showing the direction of ground-water movement in the Humboldt River valley near Winnemucca, when the stage and flow of the river are high. (After Cohen, 1964a, p. 37.)

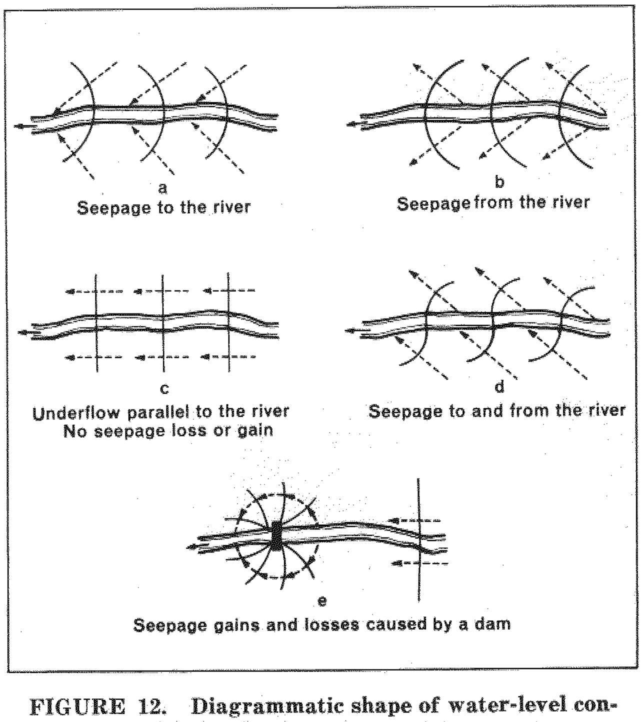

FIGURE 12. Diagrammatic shape of water-level contours as they cross the Humboldt River for various conditions along the river. Solid arrows indicate the direction of streamflow; dashed arrows indicate the horizontal component of the direction of ground-water movement. (After Cohen, 1963, p. 62.)

principal tributaries in the upper basin. For example, the gradients near the flanks of the Ruby Mountains approach 100 feet per mile (pl. 1). These steep gradients occur in the Tertiary valley fill in the interstream areas and suggest that the capacity of the deposits to transmit water is low. Similar areas occur extensively in the upper basin.

Water-level fluctuations—The amount of ground water in storage varies in response to seasonal and year-to-year variations of recharge and discharge. The largest range of natural fluctuations probably occurs in the areas of recharge, although no records are available to demonstrate the extremes. Significant fluctuations also occur in the areas of ground-water discharge. The natural range of fluctuations of water levels in discharge areas probably is less than fluctuations in recharge areas. As water levels rise toward the land surface, evapotranspiration increases to offset continued rise. As water levels decline, decreased evapotranspiration reduces the rate and amount of decline. In effect the natural system tends to dampen the range of fluctuations.

Water-level fluctuations are demonstrated by the hydrographs of four wells in Lamoille Valley (fig. 13). Plate 1 shows the location of the wells. The hydrograph for the upstream well 33/58–30acd, which is nearest the mountains, commonly has an annual water-level fluctuation about five times that of the downstream well 34/58–31ddb, about 6 miles downstream. The large annual rise of water level in the upstream well is in response to recharge during the spring runoff of Lamoille Creek. The subsequent decline reflects the depletion of the recharge mound as water moves away from the mountain front in an expanding cross section. As the ground water moves outward from the mountains, the fluctuations are dampened as is illustrated in the hydrographs. The 2- to 4-foot range commonly shown in the hydrograph for well 34/58–31ddb is not greatly different from water-level fluctuations in some of the flood-plain areas. Long-term extreme ranges of water level in the flood plain may be as much as 5 feet above and 5 feet below average water levels.

Storage

The very large area of the Humboldt River basin together with the characteristics of ground-water occurrence discussed above, indicate that the quantity of ground water in storage is large. Although the absolute amount of ground water in storage cannot be determined, the following calculation partly illustrates the magnitude of storage.

The area of valley fill shown on plate 1 occupies about 2.8 million acres. This represents the approximate areal extent of the principal ground-water reservoirs. Assume that the upper 100 feet of saturated deposits underlying this area have an average specific yield of 10 percent. Thus, the volume of ground water stored in this volume of deposits is about 28 million acre-feet. Although this is about three times the estimated average annual precipitation over the entire Humboldt River basin, it still represents only a small fraction of the total amount of ground water in storage. Ground water also is stored in fractures in the consolidated rocks, and the valley fill in many of the valleys may be saturated to a depth of several thousand feet. The assumed specific yield (10 percent) of the deposits is conservative. The quantity of ground water in storage, therefore, far exceeds the quantity of water moving yearly into and out of the hydrologic system of the Humboldt River basin.

Of the estimated 28 million acre-feet of water stored in the upper 100 feet of saturated valley fill for the basin as a whole, about 9 million, 13 million, and 6 million acre-feet are stored in the upper, middle, and lower basins, respectively.

Much of the ground water stored in the valley fill is far from Humboldt River and its principal tributaries and has little natural effect on the river and the river has little effect on it. Therefore, we may use a more restricted example of ground water in storage. Along the main stem of the Humboldt River downstream from the narrows near Ryndon (fig. 32), excluding the principal tributaries, the estimated storage in the upper 100 feet of saturated deposits of valley fill is about 0.6, 3.7, and 3.6 million acre-feet for the upper, middle, and lower basins, respectively. This volume is nearly 8 million acre-feet, which is more than 30 times the average annual flow of the Humboldt River at Palisade.

Within this storage area in the valley of the Humboldt River only a small fraction of the volume is involved in natural short-term changes. Most of the short-term storage changes occur in the upper few feet of deposits beneath the flood plain. In the Winnemucca area, Cohen (1964a, table 6) showed a seasonal gain in storage of 26,000 acre-feet during the period December–June 1962; but about 80 percent of this was depleted by the end of the water year. The flood plains of perennial streams thus form a dynamic though localized environment for changes of ground water in storage.

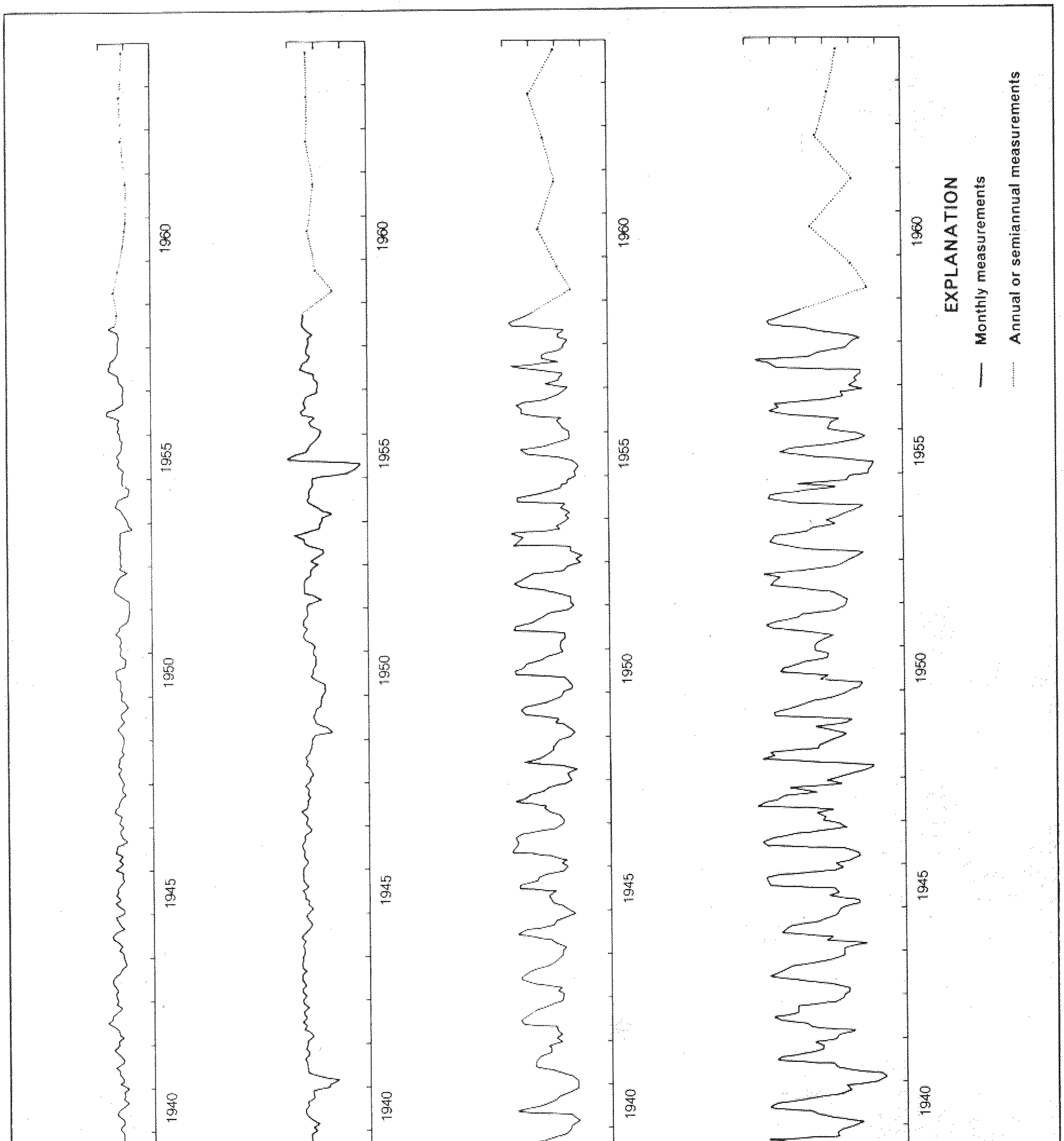

FIGURE 13. Hydrographs of four selected wells in Lamoille Valley.

Changes in water stored beneath the flood plains of the river system may be an important factor in controlling the magnitude of the flow in the Humboldt River. The changes in the volume of water stored beneath the surface area of the flood plain of the Humboldt River and its principal perennial tributaries may be illustrated by the following calculation. This area, which is not equivalent to the irrigated area, is about 260,000 acres. During wet years substantial recharge raises water levels virtually to land surface. Water levels may average about 5 feet above the mean water level in the flood plain. If the average specific yield of the upper part of the flood-plain deposits is 20 percent (Cohen, 1963, table 22), then 260,000 acre-feet of water may be stored temporarily in the zone above mean water level in the flood plain. On the other hand, through an extended dry period, the water level may decline as much as 5 feet below average. The range of natural fluctuation is then on the order of 10 feet. This would indicate a possible range of temporary storage of somewhat more than 500,000 acre-feet beneath the flood plain under the present general climatic conditions. Inasmuch as surface water and ground water in the flood plain are closely interrelated (figs. 10, 11), recharge of the flood-plain deposits by surface water is quite variable from year to year. Further, this recharge may have a marked effect on downstream streamflow.

Recharge

Precipitation within the Humboldt River basin provides virtually all of the water that enters the ground-water system. Precipitation may infiltrate directly to the ground-water reservoir, may accumulate as snow, which after melting infiltrates to the ground-water reservoir, or becomes runoff and then in part infiltrates.

As precipitation provides the supply for ground water, its distribution is significant in determining where ground-water recharge may occur. Thus, areas of greatest average precipitation are areas of the greatest potential recharge. Whether or not recharge does occur also depends upon the infiltration characteristics of the rocks in those areas. If the rocks are permeable, recharge occurs, but if they are impermeable excess water will collect in streams. The streams then may flow over permeable areas and recharge the ground-water reservoir in the valley fill. The effectiveness of this manner of recharge is increased by overbank flooding and diversions for irrigation.

Estimates of average annual recharge presented in published reports for nine areas in the Humboldt River basin are:

Area	Estimated average annual recharge (acre-feet)	Remarks
Huntington Valley (drainage area of South Fork Humboldt River)	28,000	Rush and Everett (1965); potential recharge much greater but is rejected
Pine Valley	45,000–50,000	Eakin (1961); value about 2 times the estimated discharge
Crescent Valley	13,000	Zones (1961)
Upper Reese River valley	37,000	Eakin and others (1965)
Middle Reese–Antelope Valleys	18,000	Crosthwaite (1963)
Paradise Valley	24,000±	Loeltz and others (1949)
Grass Valley	12,000	Cohen (1964b)
Imlay area	7,000	Eakin (1962)
Lovelock Valley	25,200+	Everett and Rush (1965)

For six of the valleys in the above tabulation the estimates of ground-water recharge and discharge are in reasonable agreement. But in Pine and Huntington Valleys, the two upstream valleys, the estimates of recharge are substantially larger than the estimates of discharge. In Huntington Valley, stream gradients are steep, ground water occurs at shallow depth beneath the flood plains of the more prominent streams, and the valley fill is substantially dissected. The direct estimate of recharge in that valley may represent a potential recharge that is not realized. Actually much of the potential recharge probably is rejected, and leaves the valley as streamflow. This characteristic seems to be representative of most or all the tributary areas in the upper basin and perhaps occurs locally in the middle and lower basins. For this reason a direct estimate for the basin as a whole is not included in the hydrologic budget. However, under long-time natural conditions, recharge equals discharge.

Discharge

Ground water is discharged from the Humboldt River basin almost entirely by evapotranspiration. For the most part, the discharge occurs within the shallow water area shown on plate 1. Some ground water is discharged by evapotranspiration adjacent to the areas shown on plate 1, where depths to water may be 25 feet or more, as is indicated for Paradise Valley (Loeltz, Phoenix, and Robinson, 1949, p. 40), Crescent Valley (Zones, 1961, p. 21), Pine Valley (Eakin, 1961, p. 22), middle Reese River Valley (Crosthwaite, 1963, p. 14), Winnemucca area (Cohen, 1963, p. 73), Grass Valley (Cohen, 1964b, p. 21), and upper Reese River Valley (Eakin, Moore, and Everett, 1965, table 5).

A minor amount of ground water may discharge across the drainage divides of the basin by subsurface outflow. Such outflow may occur in areas such as in the southern part of the Ruby Mountains and in the Sulphur Spring Range.

The estimated average annual discharge of ground water by evapotranspiration for the valley lowlands of the basin is about 430,000 acre-feet per year (table 4). Of the estimated total, about 120,000 acre-feet is discharged from the upper basin, 210,000 acre-feet from the middle basin, and 100,000 acre-feet from the lower basin. The losses from ground water by evapotranspiration for the upper basin are about 60 percent of those from the middle basin. However, as the upper basin supplies most of the streamflow to the middle and lower basins, the losses in the upper basin are not as obvious. Additionally, most of the ground-water loss by evapotranspiration in the upper basin is very closely associated with Humboldt River and its principal tributaries. One-third of the ground-water losses in the middle basin occurs in tributary areas, most of which contribute little actual flow to the Humboldt River. In the lower basin, most of the ground-water losses occur in or adjacent to the Humboldt River flood plain.

SURFACE WATER

Runoff

Runoff characteristics—Runoff is defined as that part of precipitation that appears in surface streams. Most of the runoff is produced by melting snow in the mountainous regions of the Humboldt River basin, because greater precipitation and snow accumulations generally occur at higher elevations. Also, the soil mantle overlying the bedrock commonly is thin in the mountains, the consolidated rocks in the mountains ordinarily have low permeability, and the mountain slopes are steep; all these factors favor the production of runoff. The mountain tributaries are gaining streams until they near the mouths of the canyons or the base of the mountain front. The mountain front thus commonly represents the point of maximum flow of the mountain streams. Some runoff originates below this point of maximum surface flow, but typically the streams heading in the lower-lying areas flow only during a short snowmelt period or after high-intensity precipitation.

Runoff values—The method used to estimate runoff at the mountain front is described in detail by Riggs and Moore (1965, D199–D202). Briefly, altitude-runoff relations for general areas were based on long-term records of streamflow and precipitation. For this report all available streamflow data were adjusted on the basis of the longer gaging stations records to a common reference period, 1912–63, and expressed as average annual streamflow. Some of these average streamflow values were then used to adjust the previously derived runoff-altitude relations for general areas to account for local variations in the runoff-altitude relation.

Streamflow near the base of the mountain front and upstream from irrigation diversions or with minor upstream diversions is the best indicator of local variations in the runoff-altitude relation. The streamflow data used to adjust the relation ranged from single streamflow measurements at several sites, to long-term discharge records, and included series of measurements at some sites and short-term discharge records at other sites.

A runoff map (pl. 2) was developed from the runoff-altitude relations for the various areas. The isopleth lines connect points of inferred equal mean annual runoff, expressed as depth in inches. Plate 1 shows areas where runoff of more than 5 inches originates.

Table 5 shows the estimated average annual runoff for the upper, middle, and lower basins. For each, the estimated runoff originating in the mountains and valley uplands is separately shown. Runoff from the mountains accounts for more than 90 percent of the total. The runoff originating within the valley lowlands is negligible and is not shown. The estimated average runoff originating in the whole Humboldt River basin is 854,000 acre-feet per year.

TABLE 5. ESTIMATED AVERAGE ANNUAL RUNOFF

(Values, in thousands of acre-feet, to two significant figures)

Unit	Total	Mountains	Valley uplands
Upper basin	530	466	64
Middle basin	194	180	14
Lower basin	130	129	1
Humboldt River basin, total	854	775	79

Streamflow

Streamflow is the flow that occurs in a natural channel. The term, streamflow, is more general than runoff as streamflow may be applied to flow whether or not it is affected by diversion or regulation. Some of the characteristics of streamflow in the Humboldt River basin are presented by describing the variations in streamflow with time and geographic location.

Time variations—An example of expressing the minute-to-minute variations in streamflow is presented later in this report under flood magnitude and frequency. Another example is in the day-to-day variations as presented in figure 14. The probability that the indicated mean daily streamflow of the Humboldt River at Palisade (3225) will be equaled or exceeded on a particular date is indicated in this graph. The graph was prepared by listing the daily flow at 5-day intervals for water years 1945 through 1963 and ranking those flows in order of magnitude. Next, the lower quartile, median, and upper quartile values of streamflow were determined and plotted for every fifth day. The curve was drawn mainly through the plotted points, although a minor amount of curve smoothing was necessary.

The average seasonal pattern of streamflow at selected gaging stations is shown in figure 15. Because the pattern varies from year to year, the average seasonal pattern provides only a rough indication of the amount of flow to be expected in any given year.

Figure 16 shows the variations in streamflow as cumulative departures from average annual streamflow for the period 1912–63, for three selected streams that have long-term discharge records. Figure 16 also shows the variations in precipitation for representative precipitation records. The composite precipitation records represent the combined records collected at several stations and were weighted according to amounts of runoff occurring in their respective areas. The flow typically is above or below average in any given year and may remain above or below normal for several successive years. Man-made changes in the environment may obscure long-term trends in streamflow. However, figure 16 shows certain definite trends in past years as cumulative departures from average streamflow. An upward slope of the line over a period of years indicates a period of greater than average streamflow; conversely, a downward slope indicates a dry period. Normally a period of greater than average precipitation produces streamflow proportionately greater than average. The effect of antecedent precipitation, however, is seen where periods of greater than average precipitation have resulted in less than average streamflow because of a prolonged antecedent dry spell. Differences in distribution of precipitation within the year also result in differences in streamflow even though the total precipitation may be about the same.

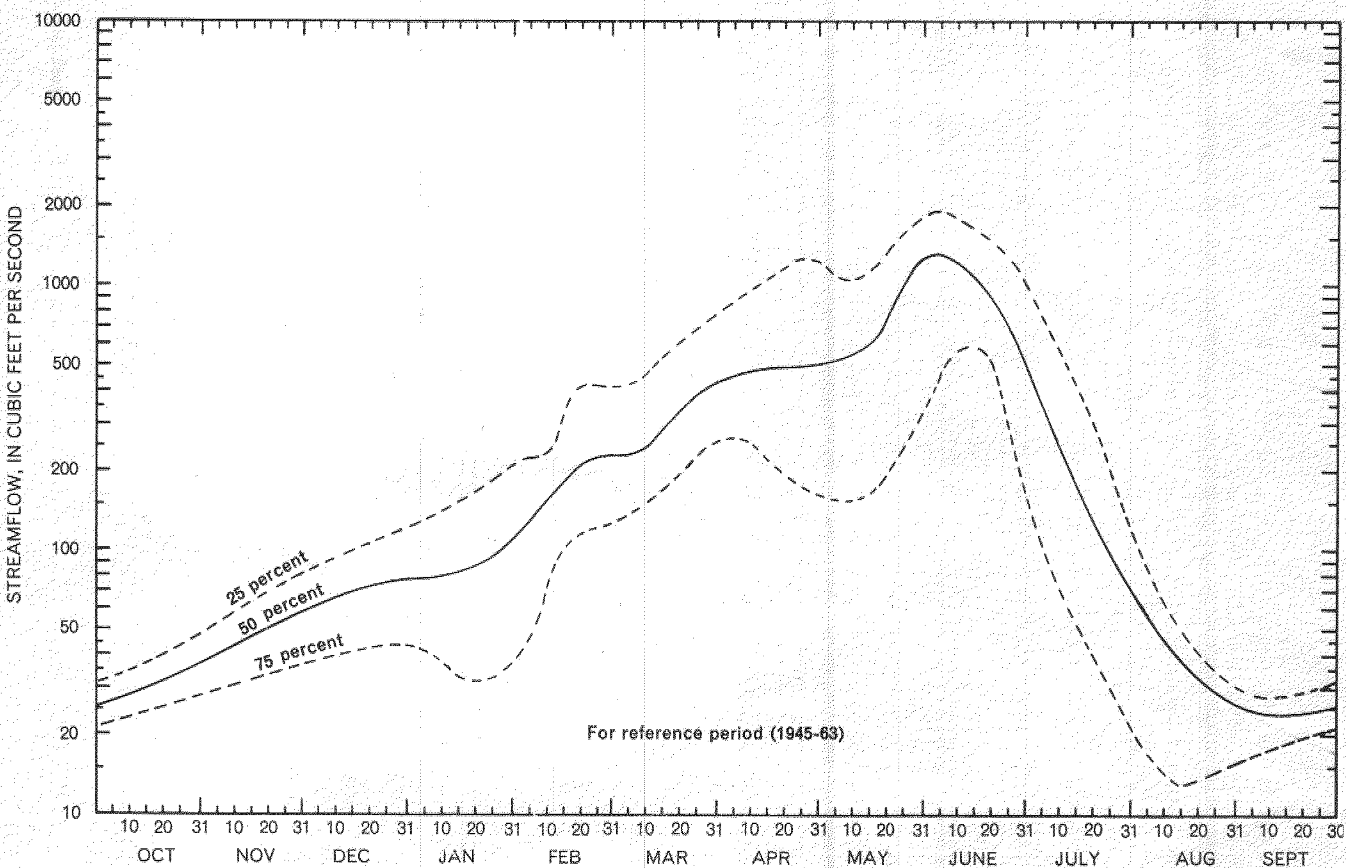

FIGURE 14. Probability that indicated mean daily streamflow of Humboldt River at Palisade (3225) will be equaled or exceeded. Based on 1945–63 period of record.

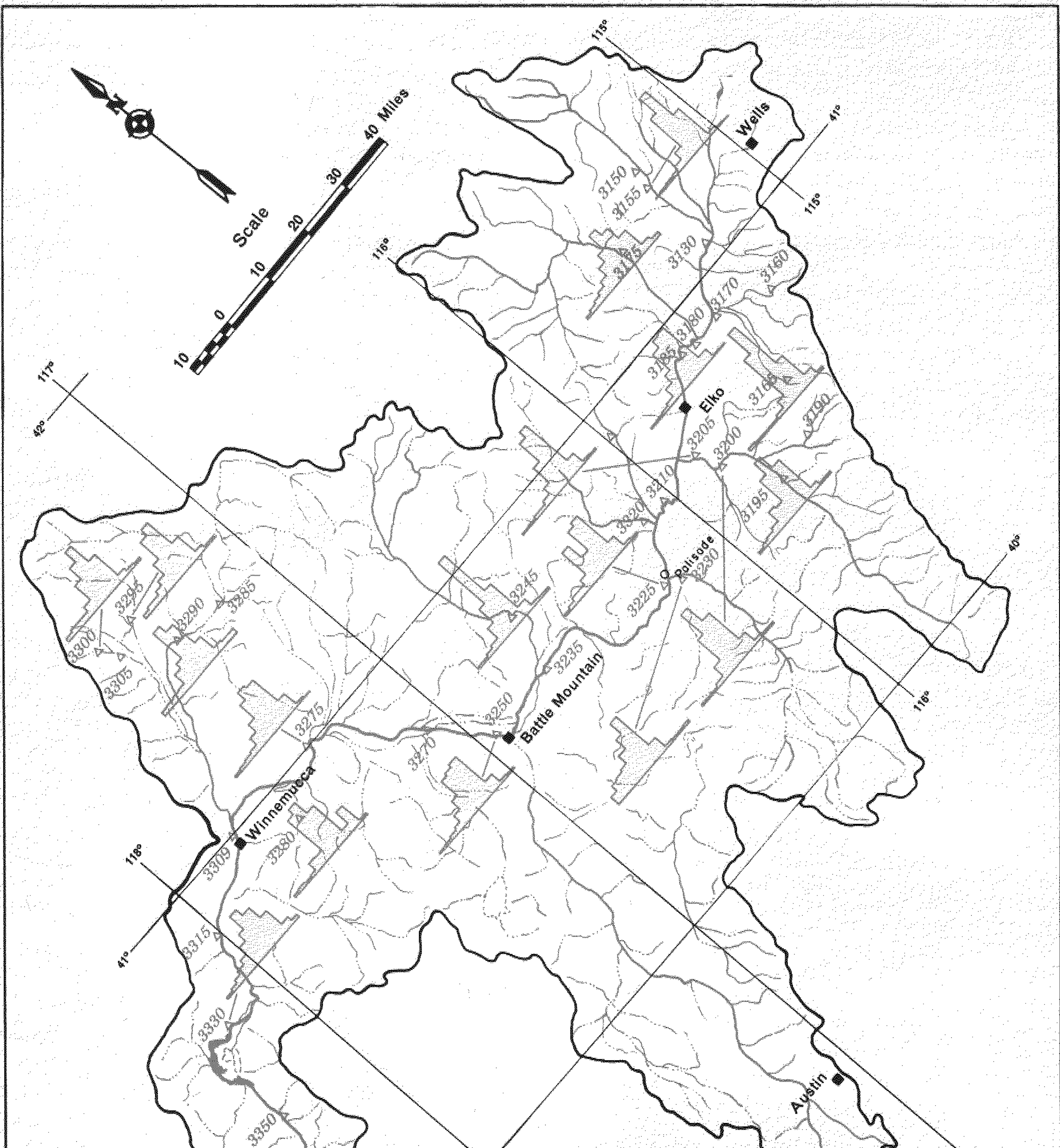

FIGURE 15. Map showing average seasonal pattern of streamflow at selected gaging stations.

The theory that streamflow in the upper basin has decreased in the last few years because of changing irrigation practices was tested by double-mass curve techniques (Searcy and Hardison, 1960). Double-mass curves (fig. 17) of measured streamflow versus computed streamflow were prepared for the gaging stations, Humboldt River at Palisade (3225), where the streamflow leaving the upper basin is measured and for South Fork Humboldt River near Elko (3205). The computed streamflow was based on composite effective long-term precipitation records adjusted (Searcy and Hardison, 1960, p. 34–42, 44–50) to the reference period, 1912–63. If the flow at these stations had decreased, perhaps 20 percent or more, in the last few years because of changing irrigation practices, the plotted points on the graphs in figure 17 would rise at an angle greater than the dotted 45-degree line. However, the plotted points roughly follow the 45-degree line. This may be due to compensating factors or that decreased flow due to changing irrigation practices is not sufficient to be reflected in this relatively coarse plot. A more refined analysis would be required to test the theory in detail.

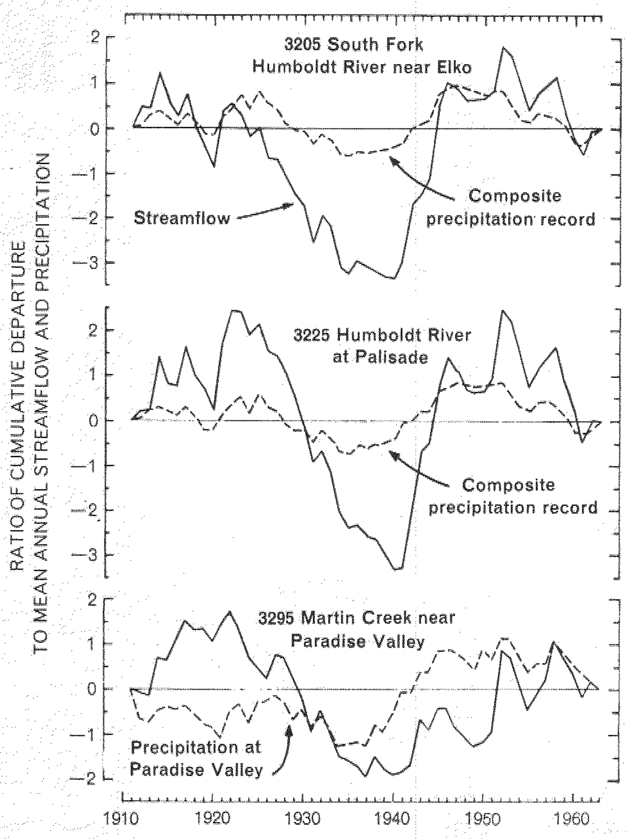

FIGURE 16. Cumulative departure from average annual streamflow at three stations, 1912–63.

Geographic variations—Plate 2 shows that the runoff originating at similar altitudes varies at different locations. Streamflow at the base of the mountains is effectively an accumulation of the runoff originating in that drainage area; therefore, the amount of streamflow is dependent upon the gross size of the drainage area as well as the relative size of the areas of high and low runoff within that drainage area. As the stream progresses down the alluvial apron, the streamflow generally decreases because of increased infiltration, evapotranspiration, and irrigation diversions.

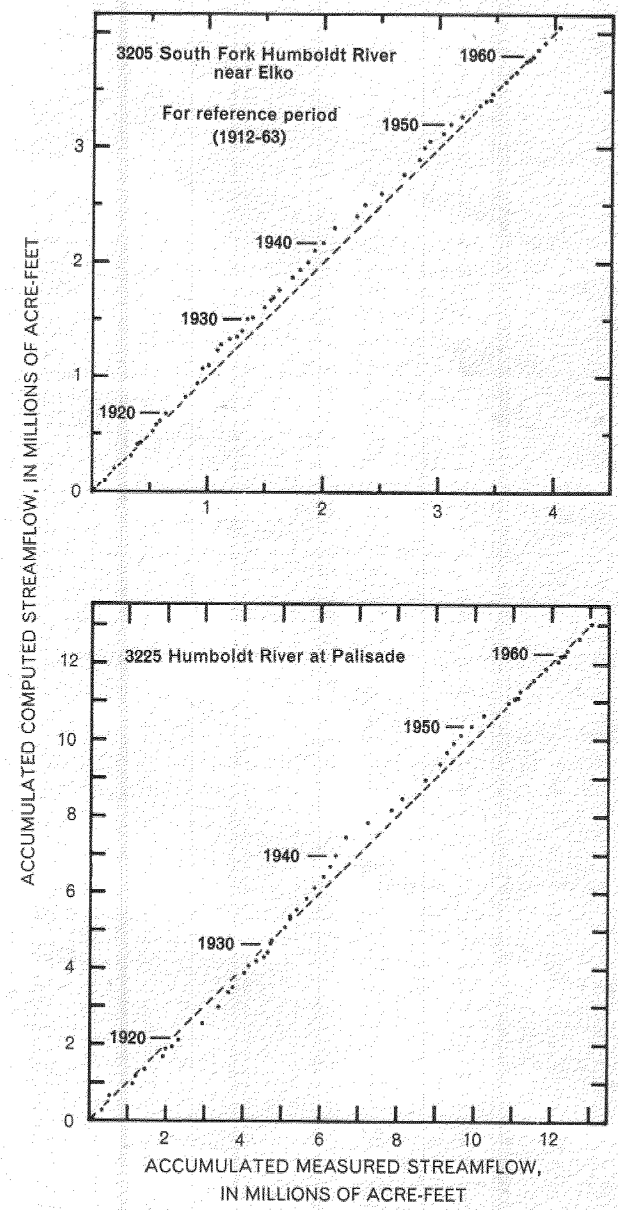

FIGURE 17. Double-mass curves of measured streamflow versus computed streamflow for two gaging stations.

Site-to-site variability in streamflow is shown on plates 1 and 2 by the values of average annual streamflow at selected gaging stations for the reference period. Figure 18 shows how streamflow varies geographically by a graphic representation of the stream system of the Humboldt River basin. The streamflow data are listed in table A3 in the appendix.

Locally, streamflow increases on the larger streams because of ground-water inflow to the stream. For example, there was a net increase in flow of about 7 to 10 cfs (cubic feet per second) in September and November 1964 between low flow measurements made at the gaging station, South Fork Humboldt River near Elko (3205), and at the mouth of South Fork. Another example is the increase in flow between the gaging stations on the Humboldt River at Comus (3275) and near Rose Creek (3315) during periods of low flow (Cohen, 1964a, p. 35).

The Humboldt River gains in streamflow in the upper basin until an average annual flow of 260,-000 acre-feet (fig. 18, pl. 1, 2) is reached just below Pine Creek. Average annual streamflow decreases downstream from this point to 175,000 acre-feet at the gaging station, Humboldt River at Comus (3275). These points are approximately the boundaries of the middle basin. In the lower basin average annual streamflow decreases from Comus to relatively minor infrequent outflow from Humboldt Sink into Carson Sink.

Streamflow values—The average annual streamflow for the reference period is listed (table A3) for 46 gaging stations. Table 6 lists the estimated average annual streamflow for the reference period at the mouths of streams or valleys tributary to the main stem of the Humboldt River.

The range from 3 to 59 complete water years of record for the 35 gaging stations listed in part 1 of table A3 indicates the need for adjusting the record to a common reference period. Short-term records may be obtained during a series of wet or dry years (fig. 16) but can hardly include a representative distribution of the variations in flow typical of a longer period.

Average values thus may differ substantially depending upon the particular periods used. For example, based on streamflow data collected at the gaging station, Humboldt River at Palisade (3225), the following periods and their corresponding average annual streamflow were computed:

Period	Length (years)	Average annual streamflow (acre-feet)	Remarks
1903–6 1912–63	56	256,000	Period of complete years of record
1912–63	52	251,000	Reference period
1923–40	18	170,000	Drought period
1931–60	30	253,000	Standard 30-year period
1931–63	33	251,000	Shorter reference period
1941–46	6	449,000	Wet period
1951–60	10	240,000	Last decade

In the above tabulation the average streamflow based on the dry period 1923–40 is only 38 percent of the average streamflow based on the wet period 1941–46.

TABLE 6. ESTIMATED AVERAGE ANNUAL STREAMFLOW, IN ACRE-FEET, FOR HUMBOLDT RIVER TRIBUTARIES AT MOUTH

Stream or valley	Average annual streamflow	Base
Bishop Creek	4,000	Discharge measurements in 1964
Tabor Creek	2,000	Discharge measurements in 1950, 1951, 1953, 1962, and 1964
Marys River	32,000	Upstream gaging station discharge and tributary streamflow minus evapotranspiration losses
Starr Valley	17,000	See table 3 for period of gaging station discharge record
Lamoille Valley	46,000	Do.
North Fork Humboldt River	33,000	Do.
South Fork Humboldt River	a87,000	Do.
Susie Creek	5,000	See table 3 for period of seasonal gaging station discharge records
Maggie Creek	15,000	See table 3 for period of gaging station discharge record
Pine Creek	9,400	Do.
Crescent Valley	1,000	Observation
Boulder Creek	(b)	Do.
Rock Creek	(b)	Do.
Reese River	c5,000	Observation and discharge measurements
Pumpernickel Valley	(b)	Observation
Kelly-Evans Creek	(d)	Observation and discharge measurements
Rock-Pole Creek	(d)	Do.
Paradise Valley	e2,000	Rare flood-water overflow or drainage from Gumboot Lake
Grass Valley	(d)	Observation

a—Included an estimated 9,000 acre-feet of springflow downstream from gaging station near Elko (3205).
b—Unknown; flow is largely dissipated on flood plain before reaching main channel.
c—High flows occur about once every 15 years, on the average.
d—Minor, flow is largely dissipated on flood plain before reaching main channel (Cohen, 1964a, p. 30).
e—Water from Gumboot Lake overflowed into Humboldt River in 1914 and 58,000 acre-feet of flood water drained from Gumboot Lake in 1953 and 1958 (Cohen, 1964a, p. 30).

Adjusting the streamflow records to a common reference period produces values that probably reflect the differences in basin characteristics more than variations in climate. The longest continuous streamflow record in the Humboldt River basin is for the Humboldt River at Palisade (3225), which spans the water years 1912–63. Generally missing streamflow records were estimated by graphical

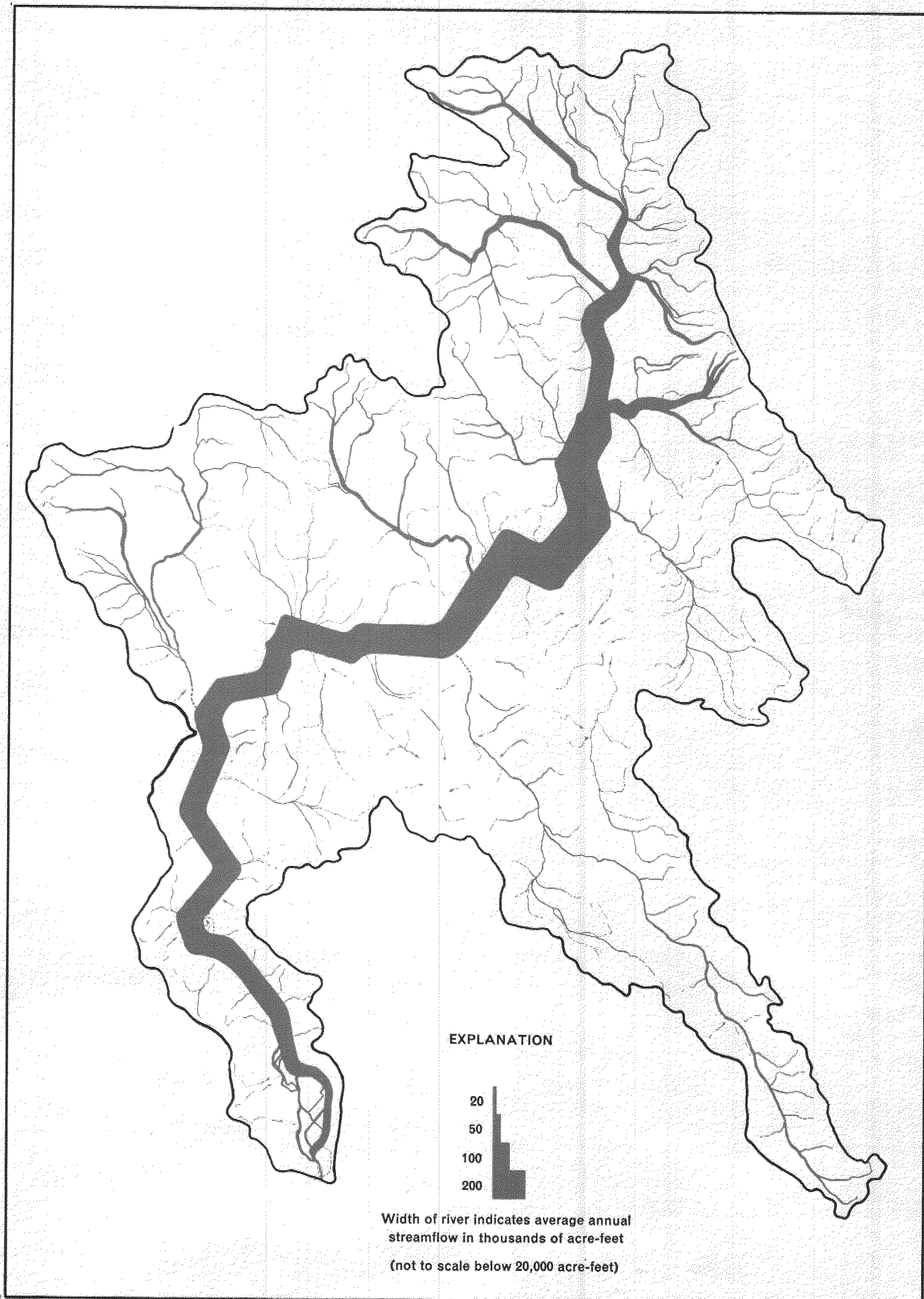

FIGURE 18. Map showing geographic variation in average annual streamflow.

correlation with other streamflow records as described by Searcy (1960) to obtain values for the 1912–63 reference period at other locations. The cumulative departure graphs of figure 16 were used in a few cases to determine shorter representative periods, mainly 1931–63 for the two upper Humboldt River stations near Elko (3185) and Carlin (3210) and Little Humboldt River station near Paradise Valley (3290). The period 1945–63 was used for South Fork Humboldt River and Huntington Creek near Lee (3190 and 3195). These shorter periods were used to avoid estimating an excessive amount of discharge record and because of possible changes through the years in the correlation between the comparative station records.

Flood-plain gradient and cross section—Flood plains develop from the interaction of streamflow and the rocks over which the stream flows; the gradient and width of the flood plain thus, in part, influences the flow of the stream along its course. The gradient and width of the flood plain may influence gains or losses, the time of travel, channel storage, and high or low flow. The gradient of the Humboldt River flood plain is less than 5 feet per mile through the middle basin and is even less in the lower basin. Figure 19 shows the longitudinal profiles of the flood plain of the main stem of the Humboldt River and those of the principal tributaries. Cohen (1963, p. 27) noted in the Winnemucca area that the gradient of the Humboldt River, which meanders down the flood plain, is about 1.7 feet per mile, or about one-half the gradient of the flood plain. This ratio of river gradient to flood-plain gradient probably holds throughout most of the course of the Humboldt River in the middle and lower basins. The stream and flood-plain gradients increase in the upper basin, although a meander pattern still is a prominent channel characteristic. The gradient of the flood plain generally decreases downstream, but the profile is not everywhere a smooth curve. Local changes in slope occur in or upstream from bedrock gaps where the gradient may be slightly flattened. This is consistent with the fact that the bedrock in the narrows is resistant to erosion and therefore restricts vertical erosion.

The principal tributaries that regularly contribute streamflow to the Humboldt River have relatively high gradients, 15 feet per mile or greater at their mouth, and relatively narrow flood plains. Lamoille Creek is an example where the gradient and also the precipitation are fairly high. Maggie and Susie Creeks, which have even steeper gradients but appreciably less precipitation in their basins than in the Lamoille Creek drainage basin, contribute considerable streamflow to the Humboldt River. Tributary drainage areas with low gradient surfaces near their confluence with the Humboldt River contribute little surface flow. Thus, the relatively low gradients at the downstream end of Reese River and Paradise Valleys are compatible with the fact that they contribute little streamflow to the Humboldt River.

The cross section of the present-day Humboldt River flood plain has been developed by lateral migration of the river, as is indicated by the meander scroll pattern which is particularly well developed in the wider segments of the flood plain. Abandoned channels may be nearly as deep as the main channel, as is shown in figure 20 by the several cross sections in the vicinity of Winnemucca (Hanson, 1963, fig. 21). Such wide, low-gradient flood plains provide favorable sites for overbank flooding and temporary storage of streamflow in and on the flood-plain deposits. Much of the water in temporary storage is removed later by evapotranspiration.

Losses—Annual flow in the main stem of the Humboldt River is affected by evapotranspiration losses in the flood plain as well as by tributary inflow. The losses are estimated to average 17,000, 88,000, and 94,000 acre-feet per year, respectively, for the upper, middle, and lower sections of the valley of the Humboldt River, or nearly 200,000 acre-feet per year for the entire main stem. The estimated average annual evapotranspiration losses from streamflow in all the lowlands (main stem, tributary flood plains and valley floors, and playas) is about 170,000, 140,000, and 160,000 acre-feet per year (table 4) for the upper, middle, and lower basins, respectively, or a total of 470,000 acre-feet for the entire basin.

Different evapotranspiration rates (table 3) were used for the three different classifications of flood-plain water-loss areas, which was explained earlier in the section on evapotranspiration. Also, the evapotranspiration losses were separated into those from a surface-water or ground-water supply. However, this separation is based on an arbitrary definition of whether the water source is primarily surface or ground water. Much of the lowland ground water was derived from surface water infiltrating the flood plain. Much of the surface water considered lost by evapotranspiration temporarily becomes soil moisture before evaporation and transpiration.

Evaporation losses from the water surface of

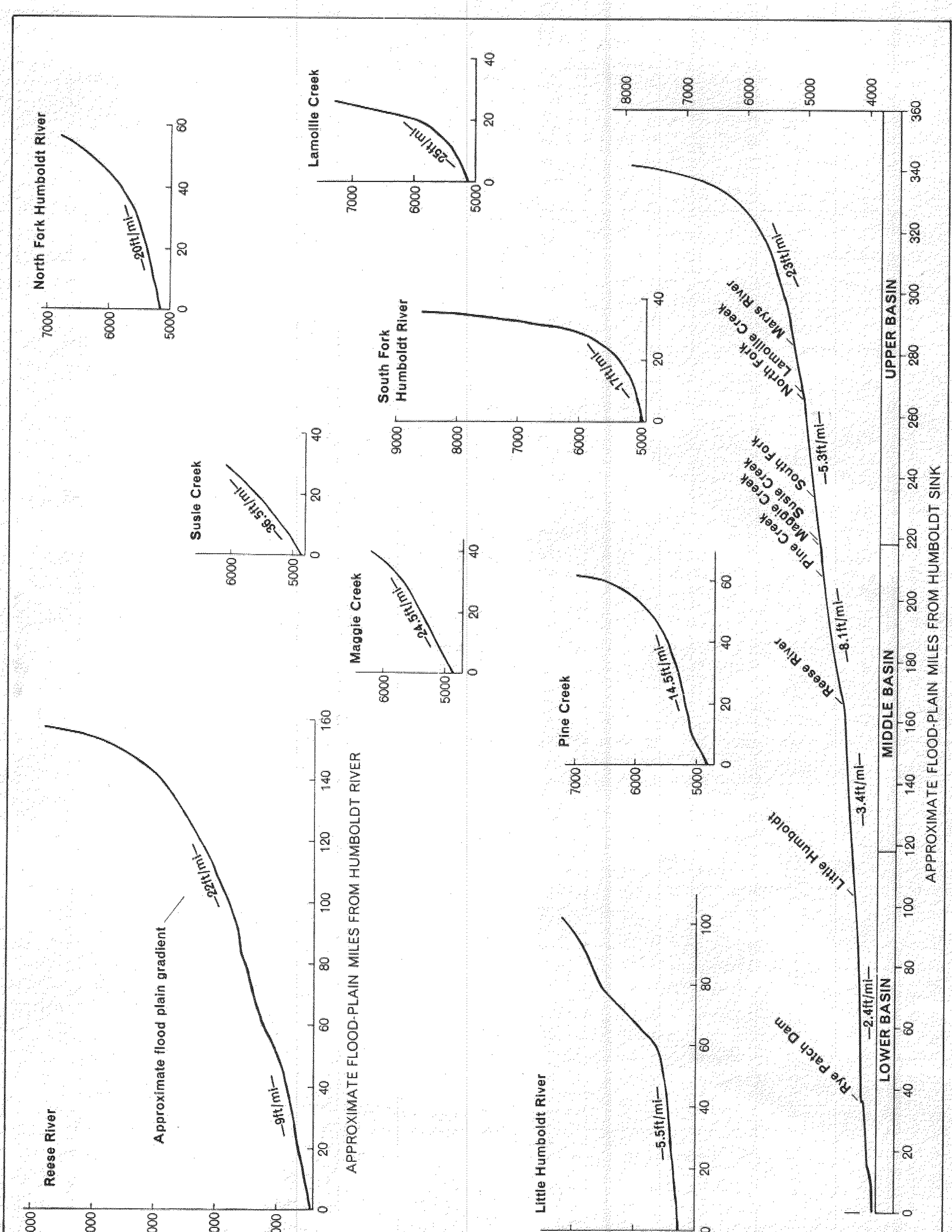

FIGURE 19. Flood-plain profiles of Humboldt River and lower segments of selected tributaries.

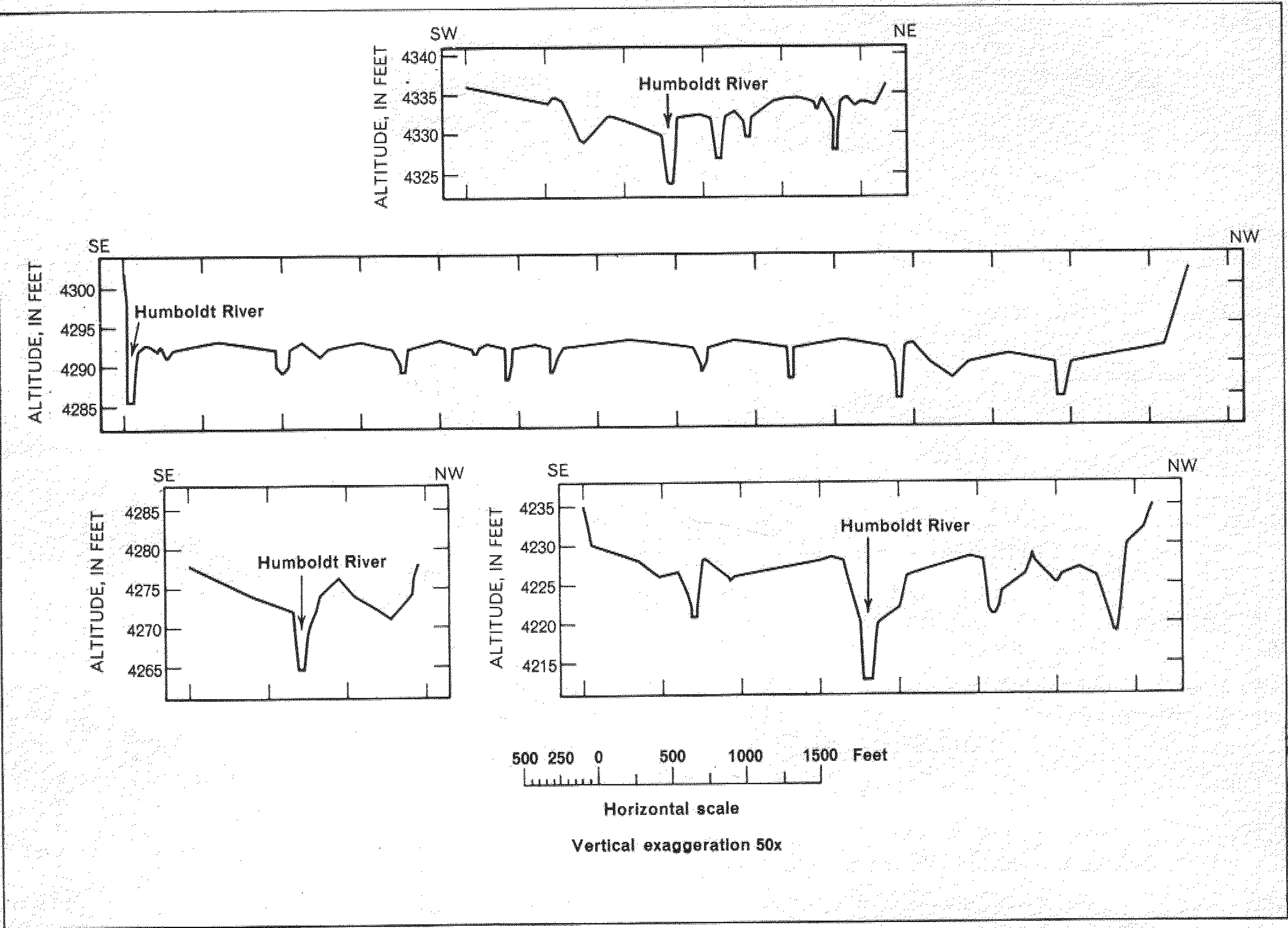

FIGURE 20. Flood-plain profiles across the Humboldt River near Winnemucca. View is downstream. (After Hanson, 1963, p. 53.)

the channel are included in the evapotranspiration totals listed in table 3. Hanson (1963, fig. 23) shows a relation between the annual streamflow at the Comus gaging station (3275) to annual water-surface evaporation losses between the Comus and Rose Creek gaging stations (3315); this relation is shown in figure 21. Average annual evaporation loss from the main-stem water surface is estimated to be about 50,000 to 80,000 acre-feet. This estimate is based on an average annual streamflow at Comus of 175,000 acre-feet, the relation shown in figure 21, and an approximation that the main-stem water-surface area is 3 to 5 times greater than the main-stem water-surface area in the Comus to Rose Creek section used for figure 21.

Evapotranspiration in the valley uplands and the mountains occurs from precipitation, runoff, soil moisture, and ground water. However, it is difficult to distinguish among them. Therefore, in the valley upland and mountains a single evapotranspiration loss value was determined. The estimated values are listed in table 2 for the upper, middle, and lower basins.

Time of travel—Time of travel on the main stem of the Humboldt River depends upon a complex interrelation between the amount of streamflow, amount of available channel storage, amount of water retained behind diversion dams, roughness, slope and shape of channel, and rate of increase or decrease in streamflow. For these reasons specific travel time between points on the main stem varies at different times. However, the Humboldt River Water Distribution District presently uses the general times of travel between gaging stations shown in table 7 in distributing water along the main stem (D. L. Danner, oral commun., 1965).

The times of travel are considered to apply mainly to a range of discharge from 50 to 200 cfs and are reasonably applicable for discharges up to 1,000 cfs. Hanson (1963, table 14) states that the time of travel, based on a study of 1962 peak flows between Comus (3275) and Rose Creek

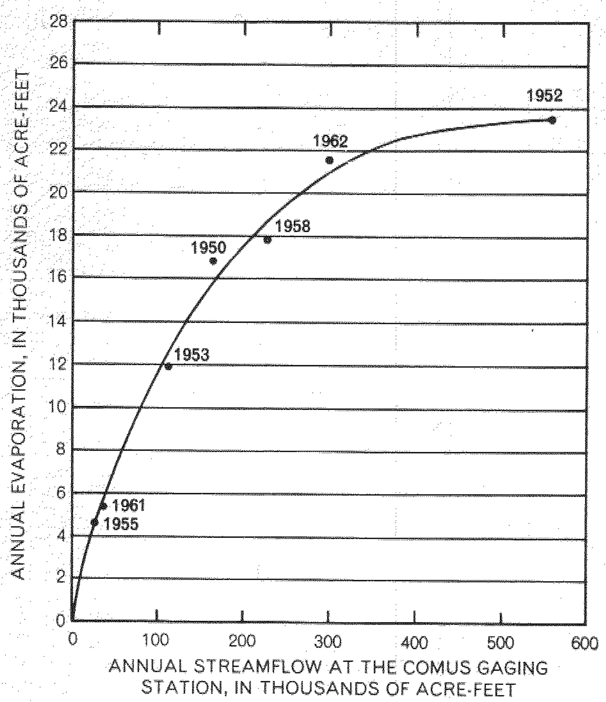

FIGURE 21. **Relation of annual streamflow at the Comus gaging station to annual water-surface evaporation losses between the Comus and Rose Creek gaging stations, water years 1950, 1952–53, 1955, 1958, 1961–62. (After Hanson, 1963, p. 54.)**

(3315), ranges from 8 to 12 days for flows of about 1,000 cfs.

Along the South Fork Humboldt River the time of travel between the gaging station, South Fork Humboldt River near Elko (3205) and the gage near Carlin (3210) is three-fourths of a day.

TABLE 7. TIME OF TRAVEL BETWEEN SELECTED HUMBOLDT RIVER GAGING STATIONS

(Approximate values from Humboldt River Water Distribution District)

Gaging Stations — From		Gaging Stations — To		Time of Travel (Days) — Between gages	Time of Travel (Days) — Cumulative	Approximate flood-plain miles between gages
(3185)	Elko	(3210)	Carlin	3		39
(3210)	Carlin	(3225)	Palisade	¾	3¾	18
(3225)	Palisade	(3235)	Argenta	3	6¾	31
(3235)	Argenta	(3250)	Battle Mountain	2	8¾	20
(3250)	Battle Mountain	(3275)	Comus	6	14¾	43
(3275)	Comus	(3315)	Rose Creek	9	23¾	45
(3315)	Rose Creek	(3330)	Imlay	1	24¾	15

Channel storage—Hanson (1963, fig. 24) shows a relation of channel storage between Comus (3275) and Rose Creek (3315) and the average of streamflow at the two gaging stations. This relation is shown as figure 22. The channel storage for the entire main stem of the Humboldt River would probably be 3 to 5 times greater than that shown in figure 22. For example, if the average flow was about 1,000 cfs throughout the Humboldt River main stem, channel storage would be approximately 70,000 to 110,000 acre-feet. The relation between channel storage and flow for the main stem was not developed further because of the lack of adequate maps showing the channel dimensions.

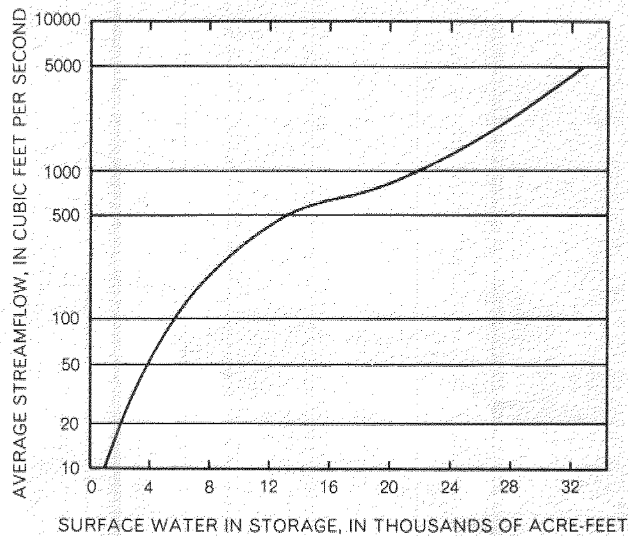

FIGURE 22. **Relation of total surface water in storage between the Comus and Rose Creek gaging stations to the average streamflow at the two gaging stations. (After Hanson, 1963, p. 55.)**

Flood characteristics—Floods in the Humboldt River basin generally can be divided into three main types as to when they occur and how they are caused. Winter floods are caused primarily by large-area rainstorms falling on low altitude snow or on frozen ground. Spring floods occur as a result of rising temperatures that melt the snowpacks accumulated in the winter. Heavy rains during the spring can accelerate or augment the snow-melt runoff. Summer floods occur as the result of localized high-intensity rainfall and are capable of producing peaks of extreme magnitude and short duration on small drainage basins.

Most of the annual maximum instantaneous discharges at gaging stations occur during the spring as a result of snowmelt. For example, at the gaging station, Humboldt River at Palisade (3225), of the 57 annual maximum discharges for which dates and discharges are known, 52 occurred in the spring. Hydrographs of spring floods are of long duration and of slow rise and fall.

The maximum instantaneous discharge that has occurred at most gaging stations occurred during the winter and was caused by regional rains or snow. Winter-flood hydrographs are characterized by a rapid rise and fall, and are of short duration.

Examples of the larger winter floods are those that occurred in 1910, 1943, and 1962. The 1910 flood occurred throughout the Humboldt River basin, whereas the other two floods occurred mainly in the upstream portion of the basin. The spring flood of 1952 resulted from the rapid melting of the large amount of snow accumulated during the winter. Pertinent facts about these floods at the Palisade gaging station are presented below:

Data	Gage height (ft)	Peak flow (cfs)
About Feb. 28, 1910	about 17	about 17,000
Feb. 26, 1943	9.92	6,250
May 2, 1952	9.53	6,050
Feb. 12, 1962	10.00	6,610

Because of the localized nature of the summer storms, only a very few of the annual maximum instantaneous discharges recorded at gaging stations occurred as a result of thunderstorms. Flood flows from this type of flood usually originate in the mountains and usually carry considerable mud and debris. The flood waters spread out and are dissipated on the alluvial aprons and the debris is deposited.

The flash floods of July and August 1961 are examples of summer floods caused by thunderstorms. Peak flow was determined by indirect methods at four sites. A summary of these peak flows is listed in table 8.

TABLE 8. SUMMARY OF PEAK FLOWS CAUSED BY THUNDERSTORMS DURING 1961 AT FOUR LOCATIONS

Stream	Location	Drainage area (sq. miles)	Date	Peak flow (cfs)
Pole Creek	At Pole Creek gaging station near Golconda	10.7	Aug. 6	about 4,000
Clear Creek	SW¼ sec. 13, T. 33 N., R. 38 E., 0.9 mile above Clear Creek Ranch, 17 miles south of Winnemucca	32.4	Aug. 5	11,400
Thomas Creek	SE¼ sec. 17, T. 35 N., R. 38 E., 2½ miles above Grass Valley Road, 5 miles south of Winnemucca	8.38	July 3 or 4	1,370
Eldorado Canyon	N½ sec. 27, T. 31 N., R. 33 E., 1.4 miles east of U.S. Highway 40, 6 miles northeast of Rye Patch	3.63	Aug. 21	1,880

Frequency analysis

Discharge data collected at long-term gaging stations were analyzed statistically to determine the frequency characteristics of the streamflow in the Humboldt River basin.

Flow-duration—The flow-duration curve is a cumulative frequency curve that shows the percent of time specified discharges were equaled or exceeded during a given period (Searcy, 1959, p. 1). Curves were prepared for 23 gaging stations. Flow-duration curves for four representative gaging stations are shown in figure 23. The ordinate used in figure 23 is expressed as a ratio of daily mean streamflow to average annual streamflow to permit comparison of streams with different magnitudes of streamflow on a single graph. The figure shows that the average annual streamflow has been equaled or exceeded about 25 percent of the time in the 52-year period analyzed. Table 9 contains data from which flow-duration curves can be plotted for the 23 gaging station discharge records analyzed.

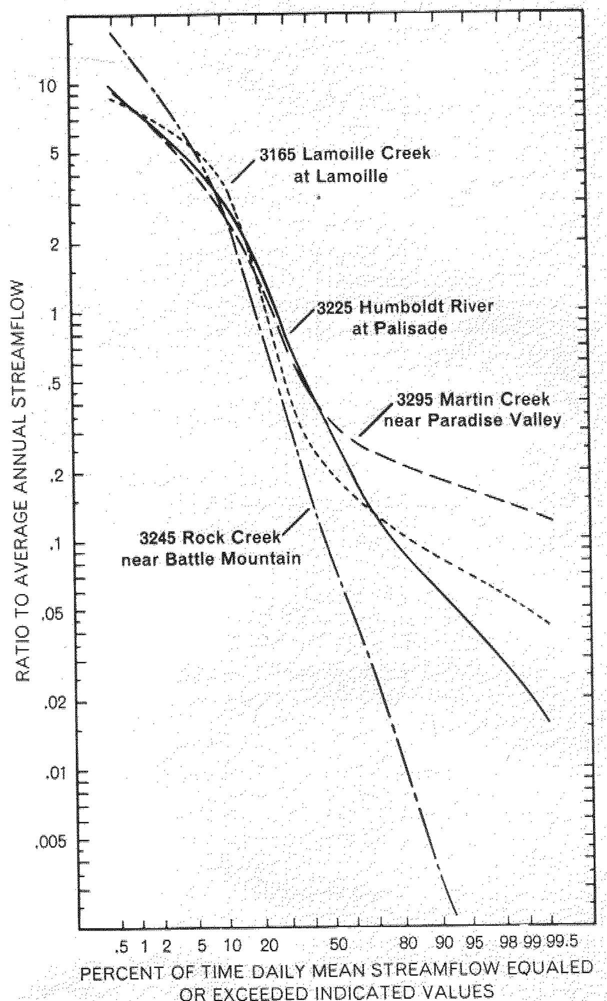

FIGURE 23. **Flow-duration curves for four gaging stations, 1912–63.**

Searcy (1959) discussed the hydrologic significance and the uses of the flow-duration curve. A curve with a steep slope indicates a "flashy" stream, such as Rock Creek (fig. 23) with flow mainly from storm or snowmelt runoff. A curve with a flat slope at the lower end indicates a high

TABLE 9. FLOW–DURATION SUMMARY FOR SELECTED STREAM–GAGING STATIONS

PART I. Adjusted to reference period 1912–63.

Station number	Station name	Mean discharge in cfs	Percent of Time That Discharge, in cfs, is Equaled or Exceeded: 99.5	99	98	95	90	80	70	60	50	40	30	20	10	5	2	1	0.5
3155	Marys River above Hot Springs Creek, near Deeth	55.1	0.1	0.2	0.3	0.5	1.0	2.3	4.2	7.7	12	20	36	80	200	280	370	440	500
3165	Lamoille Creek near Lamoille	40.4	1.7	2.0	2.3	2.8	3.4	4.2	5.1	6.3	7.8	10	19	54	155	220	273	310	347
3175	North Fork Humboldt River at Devils Gate, near Halleck	66.0	1.4	1.8	2.5	3.7	5.3	8.2	11.5	15	20	26	40	85	210	320	460	580	830
3185	Humboldt River near Elko	195	0.3	0.4	0.6	0.9	1.3	2.4	12	24	45	80	153	300	675	1,000	1,380	1,630	1,950
3190	South Fork Humboldt River near Lee	67.9	3.0	3.4	3.9	4.7	5.7	7.1	8.0	9.4	11	15	33	103	255	345	440	520	610
3195	Huntington Creek near Lee	35.2	0.7	0.9	1.1	1.6	2.2	3.7	6.0	8.0	10	14	22	42	89	145	235	325	430
3205	South Fork Humboldt River near Elko	108	---	---	---	---	1.4	7.1	13.3	20	27	42	74	150	350	520	730	920	1,120
3220	Maggie Creek at Carlin	20.7	0.01	0.02	0.03	0.08	0.2	0.7	1.2	2.0	3.3	5.4	10	25	72	120	180	220	260
3225	Humboldt River at Palisade	346	5.7	7.4	10	14	20	31	43	66	97	150	260	525	1,100	1,580	2,200	2,700	3,250
3230	Pine Creek near Palisade	13.0	---	---	---	0.04	0.1	0.3	0.9	2.5	6.0	8.4	11	12	24	40	76	120	185
3245	Rock Creek near Battle Mountain	29.1	---	---	---	0.04	0.1	0.3	0.7	1.3	2.3	4.5	10	25	87	160	265	365	490
3250	Humboldt River at Battle Mountain	288	0.05	0.1	0.1	0.2	0.3	10	24	44	76	147	230	430	850	1,200	1,600	1,900	2,250
3275	Humboldt River at Comus	242	0.06	0.1	0.1	0.2	0.2	0.8	13	31	58	103	197	380	830	1,170	1,570	1,900	2,300
3290	Little Humboldt River near Paradise Valley	23.3	5.0	5.2	5.5	6.0	6.4	7.0	7.5	8.1	9.2	11	16	23	58	97	153	205	265
3295	Martin Creek near Paradise Valley	31.4	3.9	4.3	4.7	5.1	5.6	6.7	7.6	8.7	10	13	22	43	90	131	187	245	305
3315	Humboldt River near Rose Creek	214	5.6	7.4	9.6	11	14	24	39	55	79	117	190	345	640	820	1,100	1,400	1,900

PART II. Not adjusted to reference period.

Station number	Station name	Years used in analysis	Percent of Time That Discharge, in cfs, is Equaled or Exceeded: 99.5	99	98	95	90	80	70	60	50	40	30	20	10	5	2	1	0.5
3150	Marys River near Deeth[1]	1913–27	---	1.0	1.1	1.4	2.1	4.4	6.8	9.5	13	17	29	70	170	280	380	425	460
3200	South Fork Humboldt above Dixie Creek, near Elko[1]	1949–63	0.7	1.0	1.5	3.2	5.5	10	16	21	29	46	73	135	308	510	750	910	1,110
3210	Humboldt River near Carlin[1]	1944–63	0.7	1.0	2.3	6.2	10	18	30	54	88	140	240	470	950	1,440	2,100	2,540	3,000
3235	Humboldt River near Argenta[1]	1947–63	0.3	0.3	0.4	0.5	0.9	6.0	22	44	82	133	220	400	800	1,160	1,810	2,550	3,600
3255	Reese River near Ione[2]	1952–63	0.1	0.2	0.4	0.8	1.1	1.5	2.0	2.5	3.1	4.0	5.2	9.0	19	54	103	145	200
3300	Cottonwood Creek near Paradise Valley[2]	1926–34	---	---	---	---	0.2	0.4	0.7	1.2	2.0	3.0	5.0	9.0	16	25	36	45	54
3330	Humboldt River near Imlay[3]	1936–42, 1946–63	---	---	---	---	5.5	13	24	40	65	105	175	300	530	740	1,100	1,550	2,000

Reasons for not adjusting to reference period:
[1]Near other gaging stations on same stream.
[2]Short period of record.
[3]Streamflow bypassing gage and not included in discharge record.

base flow from ground-water storage; two examples are Martin Creek (fig. 23) and Little Humboldt River.

The flow-duration curves do not show the sequence of streamflow. However, the graphs of figure 15, presented earlier, show the monthly distribution of streamflow for selected gaging stations and can generally be used to determine when the high- and low-flow periods occur.

Flood magnitude and frequency—Using widely accepted procedures for analyzing flood data (Dalrymple, 1960), Butler, Reid, and Berwick (1966) have made a study of the relation between flood magnitude and frequency in the Great Basin, of which the Humboldt River basin is a part. The following text, illustrations, and procedures for the Humboldt River basin are briefly summarized from Butler, Reid, and Berwick (1966).

1. Flood-frequency curves were computed to show the relation between annual peak flows and the recurrence interval at long-term gaging stations. Four examples of a flood-frequency curve for selected gaging stations in the Humboldt River basin are presented in figure 24. The abscissa (fig. 24) is recurrence interval, which may be defined as the average interval of time within which a peak flow of a given magnitude will be equaled or exceeded once. In a sense, recurrence interval is the reciprocal of the percent chance of a peak flow of a given magnitude being equaled or exceeded; that is, a flood with a 50-year recurrence interval has a 2 percent chance of being equaled or exceeded in any given year. A flood with a recurrence interval of 2.33 years commonly is referred to as the mean annual flood.

2. Two homogeneous flood regions (fig. 25) in the Humboldt River basin were selected by comparing the shapes and slopes of the individual flood-frequency curves. Flood region A covers the area upstream from the gaging station, Humboldt River near Carlin (3210), and flood region B covers the area downstream from the Carlin gaging station. Average or composite flood-frequency curves (fig. 26) for flood regions A and B were developed. Each composite curve provides the most likely shape and slope of the flood-frequency curve for any site, gaged or ungaged, on any stream in the homogeneous region to which it applies. However, the main stem of the Humboldt River is treated differently, as discussed later in this report.

3. The Humboldt River basin was divided into two hydrologic areas (fig. 27) by correlating the mean annual flood with drainage area and, where significant, with mean basin altitude. Most of the basin is in hydrologic area 8. Hydrologic area 7 includes the major runoff-producing areas, as shown in figure 27. A graphical method of estimating the mean annual flood for hydrologic areas 7 and 8 is presented in figure 28.

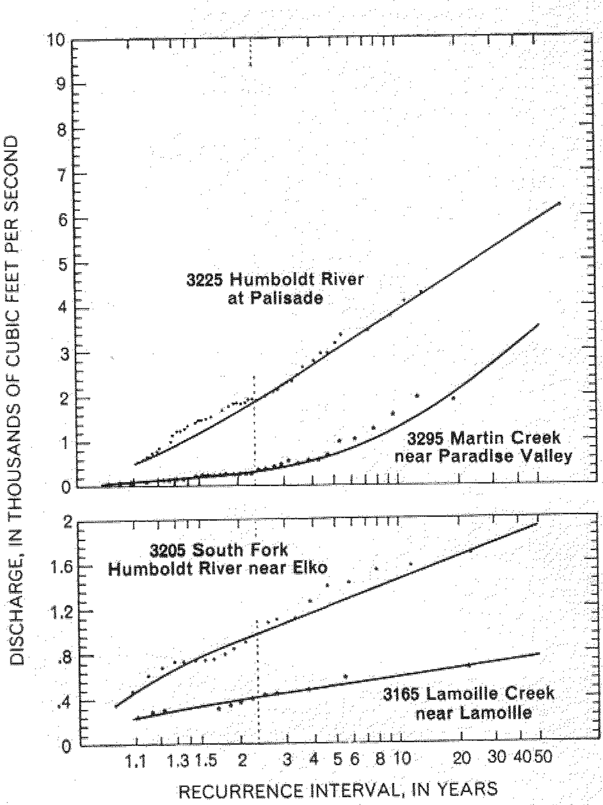

FIGURE 24. Flood-frequency curves for four gaging stations, based on 1938–59 period. (After Butler, Reid, and Berwick, 1966.)

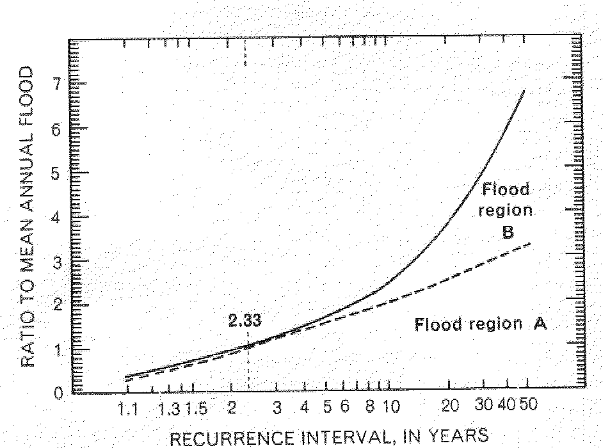

FIGURE 26. Composite flood-frequency curves. (After Butler, Reid, and Berwick, 1966.)

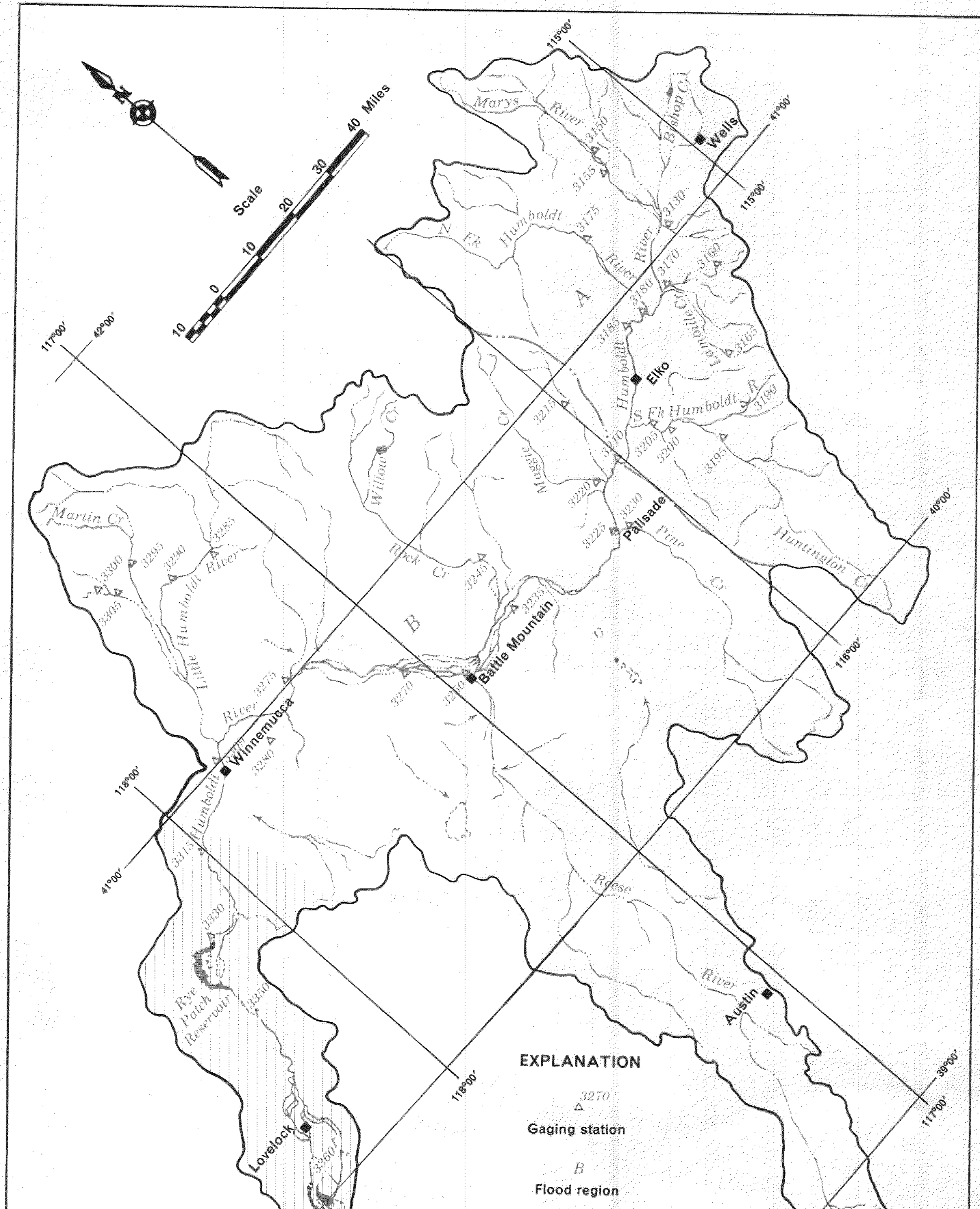

FIGURE 25. Flood regions. (After Butler, Reid, and Berwick, 1966.)

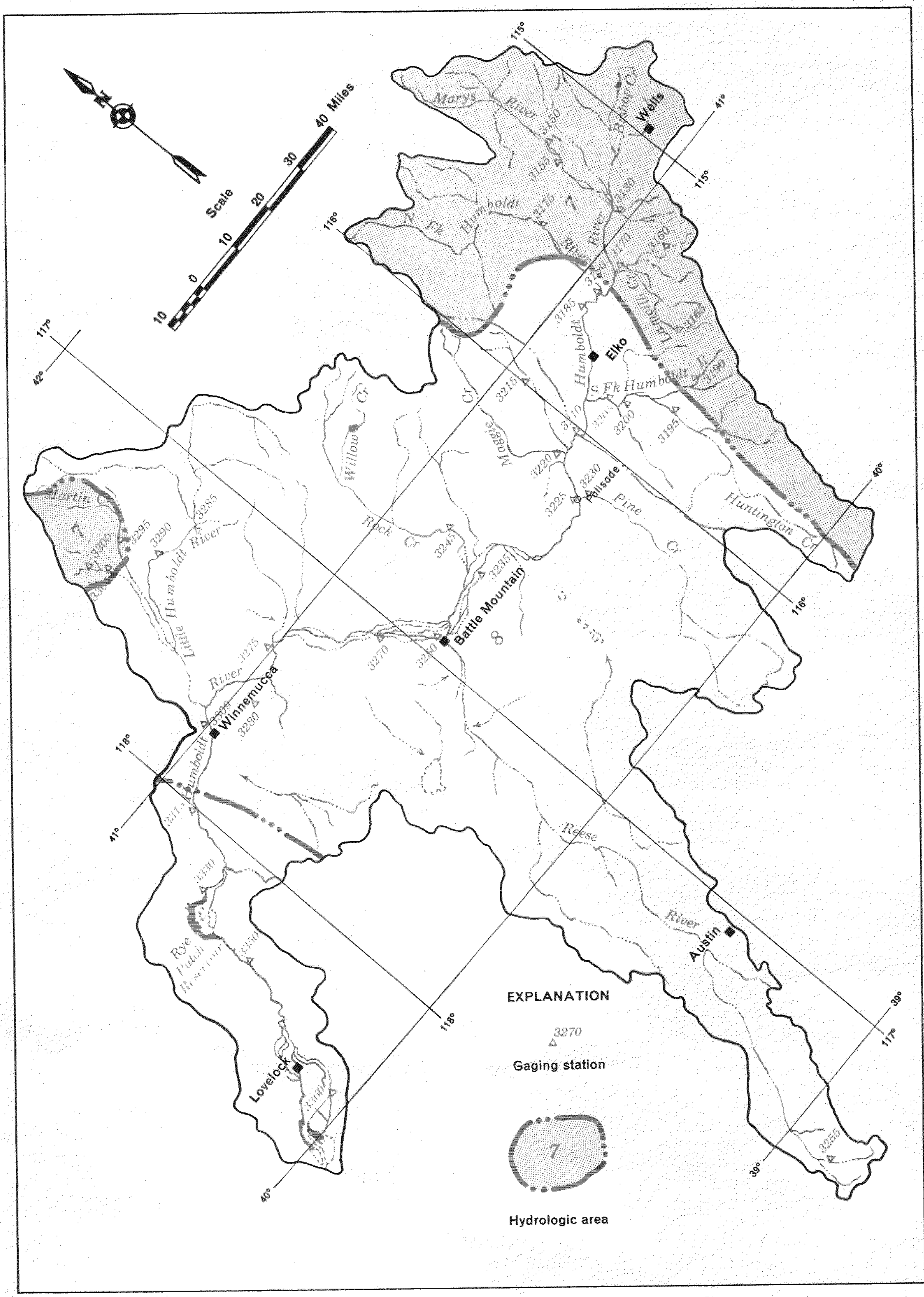

FIGURE 27. Map showing hydrologic areas. (After Butler, Reid, and Berwick, 1966.)

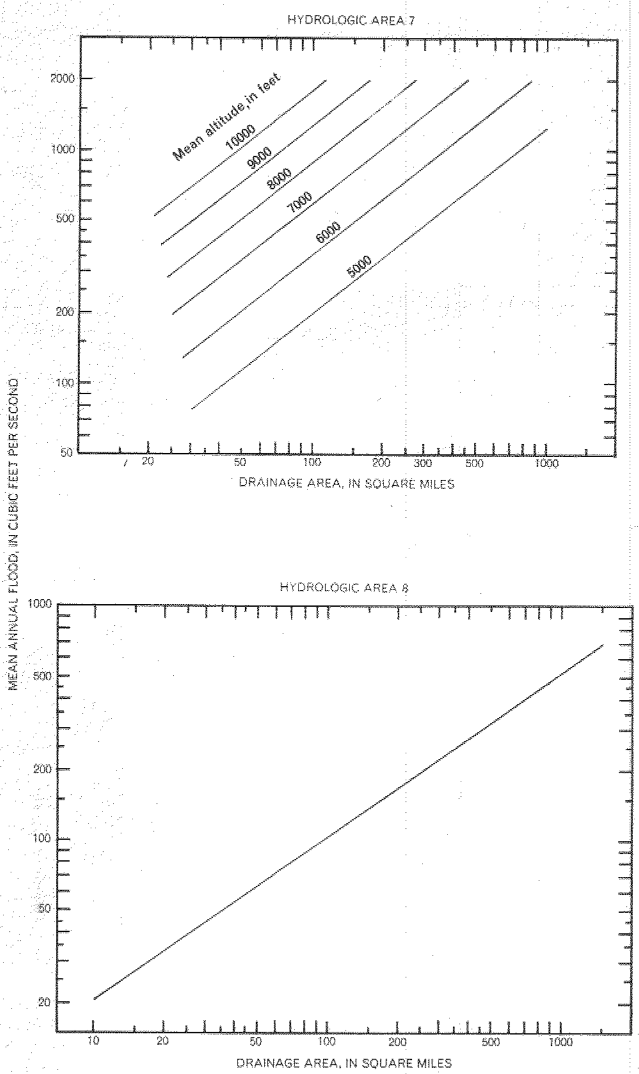

FIGURE 28. Variation of mean annual flood with basin characteristics. (After Butler, Reid, and Berwick, 1966.)

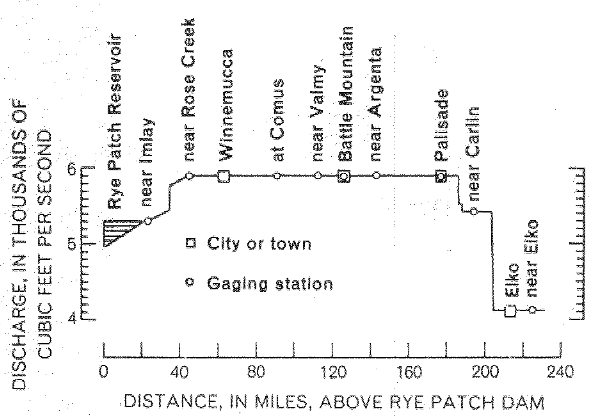

FIGURE 29. Discharge of 50-year flood, Humboldt River above Rye Patch Reservoir. (After Butler, Reid, and Berwick, 1966.)

The magnitude and frequency of floods for recurrence intervals ranging between 1.1 and 50 years can be estimated for any site in the Humboldt River basin, gaged or ungaged, within the limits of the base data. The flood-frequency relations are defined from the records of streams with natural flow. Curves should not be extrapolated beyond the limits shown. Magnitude and frequency of floods on regulated streams will require corrections for manmade development. Frequency estimates presented are in terms of averages for very long periods of time, and no prediction is made for regularity of recurrence. For example, several 50-year floods may occur in a given 50-year period, or no 50-year flood may occur in a period much longer than 50 years.

An example of the determination of the peak discharge for a selected recurrence interval at a hypothetical site is presented:

1. Drainage area=225 square miles.
2. Flood region B and hydrologic area 7 (from figs. 25 and 27).
3. Mean altitude=6,000 feet.
4. Mean annual flood=680 cfs (from fig. 28).
5. For a recurrence interval of 20 years, the flood ratio=3.6. (Use curve for flood region B in fig. 26.)
6. Magnitude of 20-year flood=680 x 3.6= 2,400 cfs.

To estimate the value of the 50-year flood at a point on the main stem of the Humboldt River:

1. Scale the mileage of the main stem from Rye Patch Reservoir, as indicated in figure 29.
2. Select magnitude of 50-year flood from figure 29.

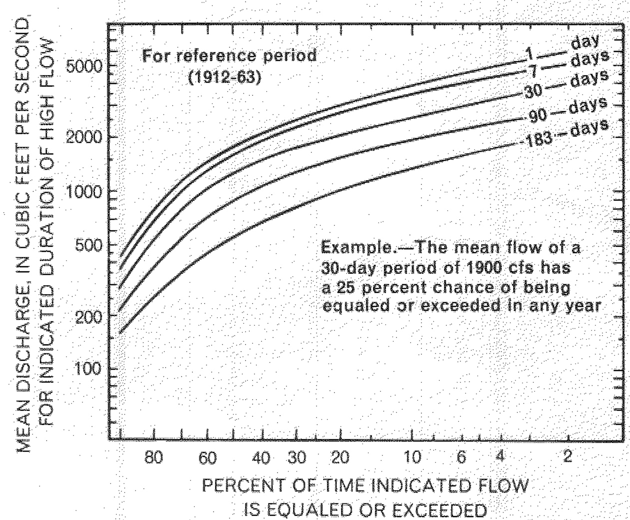

FIGURE 30. High-flow frequency curves of Humboldt River at Palisade (3225).

High-flow frequency—High-flow volume and frequency relations can be developed by methods similar to those used in developing flood magnitude and frequency relations. The method used is appropriate for streams having one major high-water period in any given year.

Frequency curves of annual highest average discharge for gaging station, Humboldt River at Palisade (3225), for 1-, 7-, 30-, 90-, and 183-day periods are shown in figure 30. Similar curves can be plotted for 12 other selected gaging stations from data presented in table 10.

High-flow frequency curves can be used to define the flood-control storage needed to schedule reservoir releases to a certain limit.

TABLE 10. HIGH-FLOW FREQUENCY TABLE, ADJUSTED TO REFERENCE PERIOD 1912–63, FOR SELECTED STREAM-GAGING STATIONS

Station number	Station name	Mean discharge in cfs	Period in days	Percent chance that average discharge, in cfs, for indicated period of days will be equaled or exceeded in any water year: 75	50	25	10	4	2
3155	Marys River above Hot Springs Creek, near Deeth	55.1	183	56	91	130	170	220	270
			90	98	170	230	290	360	420
			30	140	250	340	400	490	570
			7	180	320	420	530	650	760
			1	200	350	460	600	770	930
3165	Lamoille Creek near Lamoille	40.4	183	62	79	93	100	110	120
			90	120	150	170	190	210	220
			30	190	240	270	300	320	340
			7	250	300	340	380	430	490
			1	280	340	390	440	520	580
3175	North Fork Humboldt River at Devils Gate, near Halleck	66.0	183	51	100	170	230	290	350
			90	86	180	280	380	500	620
			30	110	250	380	520	680	840
			7	160	350	530	750	1,000	1,300
			1	220	450	720	1,000	1,300	1,700
3185	Humboldt River near Elko	195	183	170	340	520	760	1,100	1,400
			90	270	550	790	1,100	1,400	1,700
			30	390	770	1,200	1,500	2,000	2,500
			7	520	1,000	1,600	2,100	2,700	3,300
			1	620	1,200	1,800	2,700	4,100	5,600
3195	Huntington Creek near Lee	35.2	183	32	51	75	110	160	220
			90	43	76	110	160	230	300
			30	68	130	200	320	500	700
			7	100	190	300	470	730	1,000
			1	130	260	400	670	1,100	1,600
3205	South Fork Humboldt River near Elko	108	183	110	180	270	360	480	580
			90	200	320	450	600	770	930
			30	330	500	680	880	1,100	1,400
			7	450	670	900	1,200	1,600	2,000
			1	520	810	1,100	1,600	2,100	2,600
3225	Humboldt River at Palisade	346	183	300	550	880	1,300	1,800	2,100
			90	450	880	1,400	1,900	2,400	2,800
			30	660	1,300	1,900	2,500	3,300	4,000
			7	830	1,600	2,500	3,400	4,400	5,000
			1	960	1,800	2,700	3,800	5,000	6,000
3245	Rock Creek near Battle Mountain	29.1	183	16	43	89	150	210	270
			90	26	73	150	250	380	530
			30	38	120	230	380	600	850
			7	71	180	360	650	1,100	1,700
			1	110	300	620	1,100	2,000	3,000
3250	Humboldt River at Battle Mountain	288	183	220	430	720	1,000	1,300	1,500
			90	330	660	1,000	1,500	2,100	2,700
			30	490	940	1,400	2,000	2,900	3,800
			7	570	1,100	1,600	2,300	3,300	4,400
			1	650	1,200	1,700	2,600	3,900	5,300
3275	Humboldt River at Comus	242	183	180	370	610	980	1,500	2,100
			90	260	580	930	1,500	2,200	3,000
			30	380	780	1,200	1,800	2,800	3,700
			7	450	920	1,400	2,200	3,300	4,500
			1	500	1,000	1,600	2,700	4,200	5,900
3290	Little Humboldt River near Paradise Valley	23.3	183	17	27	48	90	140	170
			90	25	47	87	150	220	280
			30	28	56	110	200	320	420
			7	30	62	130	250	400	550
			1	40	83	170	330	580	850
3295	Martin Creek near Paradise Valley	31.4	183	31	47	71	100	130	160
			90	48	80	120	170	230	290
			30	65	110	160	230	310	400
			7	85	150	220	330	460	600
			1	110	190	340	620	1,100	1,600
3330	Humboldt River near Imlay	----	183	110	230	480	880	1,300	1,700
			90	150	320	670	1,200	1,800	2,400
			30	220	450	850	1,500	2,300	3,400
			7	260	510	900	1,600	2,600	3,800
			1	290	560	990	1,700	2,800	4,000

CHEMICAL QUALITY

By D. E. Everett

Daily samples have been collected by the U.S. Geological Survey at three locations on the Humboldt River: Humboldt River near Rye Patch for extended periods during the interval December 1951 to the present time (1966) ; Humboldt River at Palisade for the period May 1962 to August 1964; and Humboldt River near Carlin for the period September 1964 to the present time. In addition, miscellaneous water samples were collected from other locations on the Humboldt River and from most of its tributaries. Analyses of the samples taken for this investigation are given in table 11, and their locations are shown on figure 31.

Major tributaries sampled in the upper basin include Marys River, North Fork Humboldt River, Lamoille Creek, South Fork Humboldt River, Susie Creek, and Maggie Creek. Water from all these streams is a calcium bicarbonate type and usually is low in dissolved-solids content. In the Marys River, North Fork Humboldt River, and South Fork Humboldt River the concentration of dissolved solids varies inversely with streamflow and increases as the water moves downstream. Base flow, or low sustained flow, of a stream generally is water that has entered the stream from the ground-water reservoir. This water has been in contact with rock and soil particles and has leached some of the soluble minerals. At high stages the more mineralized ground water entering the stream is diluted by large volumes of surface runoff. For example, the specific conductance of water from Marys River near Deeth increased from 208 micromhos per centimeter during the high-flow period (158 cfs) in May 1964 to 406 micromhos during the low-flow period (3.65 cfs) in August 1964.

Chemical analyses of daily water samples from the Humboldt River at Palisade, however, show very little variation in chemical concentration between high and low flow (U.S. Geological Survey, 1964, p. 229). During high-flow periods in May and June, the South Fork Humboldt River contributes about 25 to 35 percent of the dissolved solids and about 20 to 25 percent of the flow of the Humboldt River which passes the daily sampling station at Palisade. However, during low-flow periods, the South Fork Humboldt River contributes about 70 to 80 percent of the dissolved solids and about 90 percent of the flow. The quality of Humboldt River water which flows past Palisade does not vary greatly, because the quality of South Fork Humboldt River water at low flow, which controls the quality of water at low flow in the main stem at Palisade, is similar to the quality of Humboldt River water at high flow.

The major tributaries sampled between Palisade and the Humboldt Sink are Rock Creek and Pine Creek. Water from Rock Creek is a sodium bicarbonate type in which the specific conductance values ranged from 241 to 488 micromhos in samples analyzed. Water from Pine Creek also is a sodium bicarbonate type but is more mineralized than that of Rock Creek. Specific conductance values ranged from 830 to 981 micromhos in samples analyzed.

Chemical analyses of Humboldt River water from five locations, designated in downstream order A, B, C, D, and E on figure 31, show that the water becomes more mineralized as it moves downstream. The water also changes from a calcium bicarbonate to a sodium bicarbonate type. Shown below are the water types and dissolved-solids contents of water from these five locations; and the tons per day of dissolved solids which passed each location during September 1964.

Station	Location	Water type	Dissolved Solids—September 1964— (ppm)	(tons per day)
A	Near Carlin	Calcium bicarbonate	312	12.3
B	At Beowawe	Sodium calcium bicarbonate	371	7.0
C	At Battle Mountain	Sodium bicarbonate	435	14.9
D	Near Winnemucca	Sodium bicarbonate	555	48.2
E	Near Imlay	Sodium bicarbonate	541	95.7

The accumulation of dissolved solids as the water moves downstream is usually an additive process. Streamflow from each tributary contributes its own load to the stream. Where water is being diverted or lost to the ground-water reservoir, however, there is a loss in dissolved-solids load. In the absence of inflow or outflow the chemical quality is relatively constant between points on the same stream. The loss in tons per day of dissolved solids between Carlin and Beowawe was due to diversions for irrigation, which at that time amounted to about 65 percent of the flow. The large increase between Battle Mountain and Imlay was due mainly to ground-water seepage to the river. Ground water, of nearly the same concentration as Humboldt River water, discharges to the Humboldt River from Grass Valley. This inflow

TABLE 11. CHEMICAL ANALYSES, IN PARTS PER MILLION, OF WATER FROM SELECTED POINTS ON THE HUMBOLDT RIVER AND TRIBUTARIES

(Analyses by the U.S. Geological Survey)

Date of collection	Mean discharge (cfs)	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)		Potassium (K)	Bicarbonate (HCO_3)	Carbonate (CO_3)
Humboldt River at Battle Mountain (site C)										
6– 4–64[1]	----	----	--	50	11		65		244	16
9– 2–64	12.7	34	0.03	43	21	68		8.4	263	0
11– 5–64	29.7	32	.08	48	17	68		8.4	281	0
Humboldt River at Beowawe (site B)										
5–27–64[1]	----	----	----	37	8.1		32		164	12
9– 2–64	7.0	33	.00	50	13	58		8.5	256	0
11– 4–64	----	31	.01	54	20	58		8.4	280	0
Humboldt River near Carlin (site A)										
9/1–30/64	14.6	----	----	45	15	40		7.7	264	0
10/1–31/64	----	----	----	50	14	43		6.0	276	0
11/1–30/64	----	----	----	56	15	54		7.5	298	0
Humboldt River near Elko										
6–12–64[1]	----	----	----	48	11		44		241	11
8–31–64	1.93	49	.00	50	14	43		8.0	246	0
11– 3–64	16.2	30	.02	52	15	54		5.8	302	0
Humboldt River near Imlay (site E)										
9– 3–64	65.5	39	.00	57	18	96		8.4	334	0
11– 5–64	47.2	35	.01	58	25	123		8.4	342	10
Humboldt River above Lovelock (site F)										
10– 6–64	----	38	.07	42	18	98		13	288	13
Humboldt River below Lovelock (site G)										
10– 8–64	----	38	.02	45	25	1,190		29	329	27
Humboldt River at Palisade (annual weighted average)										
1963	346	36	.01	51	13	44		8.4	265	2
1964	430	----	----	49	12	42		7.4	258	0
Humboldt River near Rye Patch (annual weighted average)										
1960	172	37	----	51	21	199		21	325	0
1961	128	38	----	92	30	303		26	345	0
1962	300	39	.02	49	13	95		13	277	4
1963	138	39	.01	51	17	113		14	339	3
1964	197	----	----	45	17	115		----	314	6
Humboldt River near Winnemucca (site D)										
9– 3–64	----	41	.02	50	21	108		4.6	353	0
11– 4–64	----	35	.02	58	23	135		9.2	368	6
Lamoille Creek near Lamoille										
6– 3–64[1]	----	----	----	22	0.7		3.7		72	0
9– 3–64[1]	9.58	----	----	34	2.2		4.4		114	0
Maggie Creek near Carlin										
6–15–64[1]	----	----	----	46	17		31		198	11
8–24–64[1]	----	----	----	41	18		39		200	8
Marys River near Charleston										
5–16–64[1]	218	----	----	5.1	1.1		3.7		22	0
9–16–64[1]	1.90	----	----	11	4.0		6.7		57	0
Marys River near Deeth										
5–16–64[1]	----	----	----	20	4.6		14		100	0
8–31–64	1.83	52	0.00	38	16	23		9.5	240	0
11– 2–64	7.29	50	.02	40	13	22		8.1	220	0
North Fork Humboldt River, at Devils Gate, near Halleck										
5–15–64[1]	----	----	----	33	9.1		32		175	0
8–31–64	8.10	49	.02	21	11	34		8.7	160	0
11– 2–64	13.5	43	.02	28	8.0	30		7.8	149	6
North Fork Humboldt River, below Haystack Ranch, near North Fork										
5–14–64[1]	----	----	----	34	9.2		14		163	0
8–27–64[1]	----	----	----	35	9.8		16		180	0
North Fork Humboldt River, at Doheny Ranch, near North Fork										
5–14–64[1]	----	----	----	11	3.0		3.9		47	0
8–27–64[1]	----	----	----	35	10		7.6		156	0
Pine Creek near Palisade										
8–24–64[1]	----	----	----	66	23		104		304	0
9–14–64[1]	----	----	----	33	29		113		229	0
Rock Creek near Battle Mountain										
5–12–64[1]	----	----	----	19	4.7		26		104	0
8–31–64	----	13	.07	20	6.6	68		8.9	144	0
11– 5–64	3.81	25	.00	31	7.4	42		5.8	153	0
South Fork Humboldt River near Elko										
6– 4–64[1]	----	----	----	28	4.4		17		132	0
8–31–64	1.64	33	.01	29	9.4	42		8.0	202	4
11– 4–64	12.4	27	.00	57	12	40		6.9	286	0
South Fork Humboldt River, at mouth, near Elko										
9– 3–64[1]	22.7	----	----	41	12		45		240	0
Susie Creek near Carlin										
6–15–64[1]	----	----	----	51	14		43		196	16

See footnotes on page 53.

TABLE 11—(Continued)

Date of collection	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Boron (B)	Dissolved Solids —(Residue at 180°C)— Parts per million	Tons per acre-foot	Hardness as $CaCO_3$ Calcium magnesium	Noncarbonate	Specific conductance (micromhos at 25°C)	pH
Humboldt River at Battle Mountain (site C)											
6- 4-64[1]	53	23	----	----	----	----	----	172	0	608	8.5
9- 2-64	74	40	0.9	3.0	0.3	435	0.59	193	0	680	8.0
11- 5-64	63	38	.8	.7	.3	[2]414	.56	191	0	684	8.2
Humboldt River at Beowawe (site B)											
5-27-64[1]	24	11	----	----	----	----	----	126	0	373	8.6
9- 2-64	56	30	.7	2.5	.3	371	.51	180	0	597	7.8
11- 4-64	59	36	.7	.6	.2	[2]406	.55	216	0	640	8.2
Humboldt River near Carlin (site A)											
9/1-30/64	33	17	----	1.5	.2	312	.42	175	0	508	8.1
10/1-31/64	33	16	----	.8	.2	329	.45	184	0	537	8.2
11/1-30/64	41	20	----	1.2	.4	382	.52	200	0	587	8.2
Humboldt River near Elko											
6-12-64[1]	28	9.8	----	----	----	----	----	164	0	476	8.4
8-31-64	49	22	1.2	1.5	.2	358	.49	182	0	539	7.9
11- 3-64	38	18	.8	.3	.3	[2]363	.49	190	0	588	8.2
Humboldt River near Imlay (site E)											
9- 3-64	51	62	1.0	2.5	.6	541	.74	215	0	862	8.1
11- 5-64	98	79	.9	.9	.6	[2]606	.82	248	0	1,010	8.4
Humboldt River above Lovelock (site F)											
10- 6-64	63	61	.7	1.3	.5	492	----	178	0	784	8.6
Humboldt River below Lovelock (site G)											
10- 8-64	177	1,590	.9	8.7	5.0	3,330	----	214	0	6,070	8.6
Humboldt River at Palisade (annual weighted average)											
1963	39	19	.6	1.0	.2	345	.47	181	0	533	----
1964	36	16	----	2.6	.2	327	.45	177	0	512	----
Humboldt River near Rye Patch (annual weighted average)											
1960	115	201	----	.3	.9	807	1.10	214	0	1,330	----
1961	139	447	----	1.4	1.3	1,280	1.74	353	71	2,150	----
1962	65	54	.7	1.3	.4	480	.65	178	0	737	----
1963	73	75	.8	.9	.5	560	.75	200	0	881	----
1964	----	----	----	----	----	551	.75	183	0	866	----
Humboldt River near Winnemucca (site D)											
9- 3-64	76	59	1.1	3.1	.5	556	.76	213	0	878	8.2
11- 4-64	108	80	1.1	.4	.6	[2]637	.87	240	0	1,110	8.3
Lamoille Creek near Lamoille											
6- 3-64[1]	4.8	1.3	----	----	----	----	----	58	0	127	7.6
9- 3-64[1]	4.4	3.9	----	----	----	----	----	94	1	181	7.9
Maggie Creek near Carlin											
6-15-64[1]	51	12	----	----	----	----	----	184	3	466	8.4
8-24-64[1]	60	15	----	----	----	----	----	176	0	502	8.4
Marys River near Charleston											
5-16-64[1]	4.0	2.1	----	----	----	----	----	17	0	51	7.4
9-16-64[1]	8.0	2.6	----	----	----	----	----	44	0	103	7.5
Marys River near Deeth											
5-16-64[1]	9.2	4.9	----	----	----	----	----	69	0	208	7.8
8-31-64	12	5.8	0.7	2.7	0.2	289	0.39	160	0	406	7.8
11- 2-64	15	5.8	.5	.1	.0	[2]263	.36	152	0	390	7.8
North Fork Humboldt River, at Devils Gate, near Halleck											
5-15-64[1]	27	12	----	----	----	----	----	120	0	354	8.2
8-31-64	27	14	.7	.0	.2	255	.35	98	0	351	8.1
11- 2-64	27	14	.8	.5	.0	[2]239	.32	103	0	343	8.4
North Fork Humboldt River, below Haystack Ranch, near North Fork											
5-14-64[1]	12	6.1	----	----	----	----	----	123	0	303	8.0
8-27-64[1]	7.2	5.0	----	----	----	----	----	128	0	300	8.0
North Fork Humboldt River, at Doheny Ranch, near North Fork											
5-14-64[1]	6.8	2.0	----	----	----	----	----	40	2	94	7.5
8-27-64[1]	13	2.8	----	----	----	----	----	129	1	263	7.5
Pine Creek near Palisade											
8-24-64[1]	105	91	----	----	----	----	----	261	12	981	8.2
9-14-64[1]	104	106	----	----	----	----	----	200	13	830	8.2
Rock Creek near Battle Mountain											
5-12-64[1]	22	11	----	----	----	----	----	67	0	241	7.3
8-31-64	50	38	1.4	3.5	.3	298	.41	77	0	488	7.5
11- 5-64	34	26	1.5	.6	.1	248	.34	108	0	409	7.9
South Fork Humboldt River near Elko											
6- 4-64[1]	8.8	6.0	----	----	----	----	----	88	0	240	7.8
8-31-64	23	12	.8	2.1	.2	263	.36	111	0	400	8.4
11- 4-64	34	16	.6	.7	.1	[2]335	.46	190	0	532	7.9
South Fork Humboldt River, at mouth, near Elko											
9- 3-64[1]	29	15	----	----	----	----	----	150	0	478	8.2
Susie Creek near Carlin											
6-15-64[1]	60	20	----	----	----	----	----	184	0	520	8.6

[1]Field analyses by the U.S. Geological Survey.
[2]Dissolved-solids calculated.

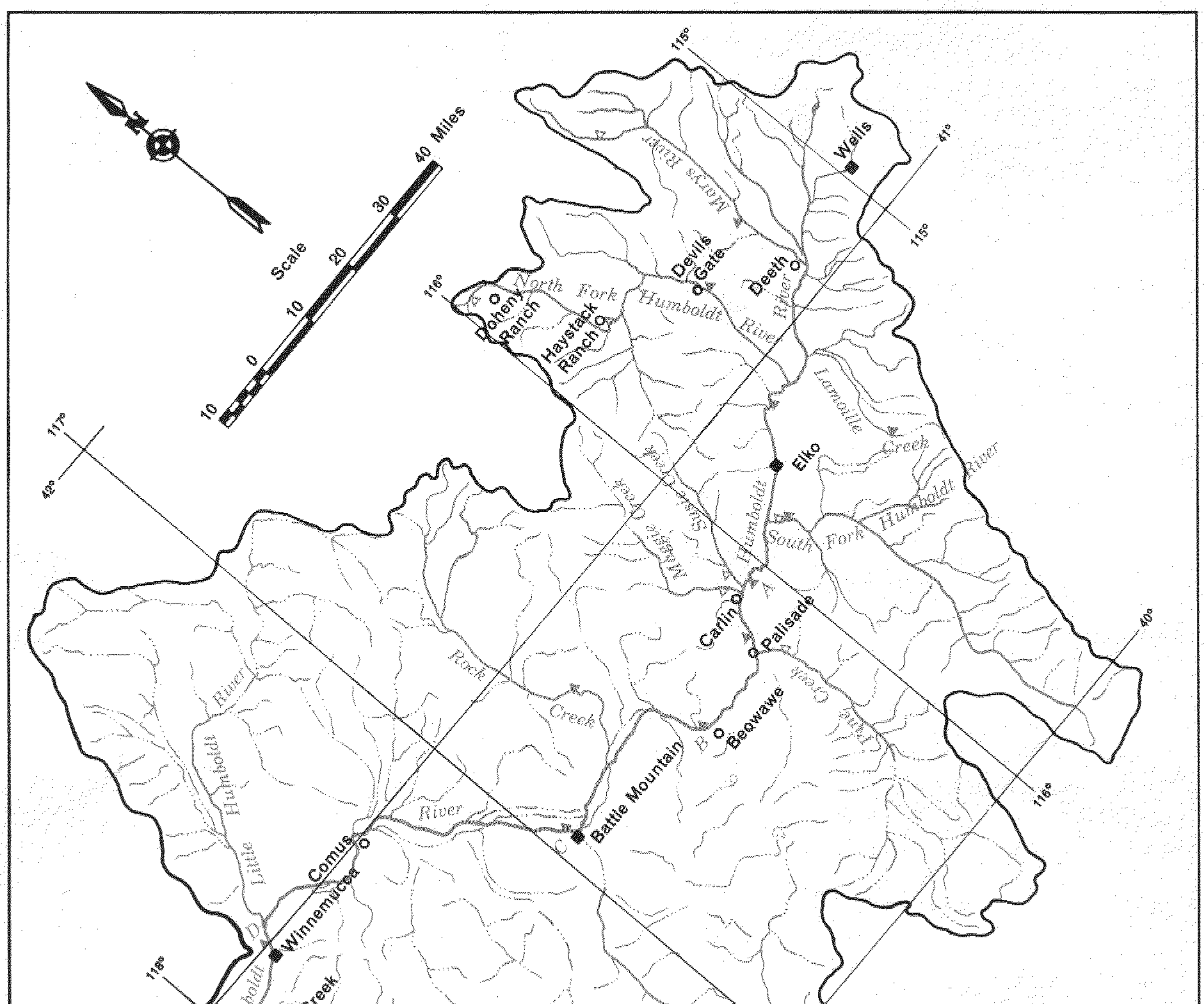

FIGURE 31. Sampling points for selected chemical analyses listed in table 11.

accounts for most of the increase in the amount of dissolved solids (tons per day) between the two stations.

Chemical analyses of water samples collected daily from the Humboldt River at Palisade and from Rye Patch release also show that the water becomes more mineralized as it moves downstream. The tons per acre-foot of dissolved solids at Palisade for the water years 1963 and 1964 were 0.47 and 0.45, respectively, whereas at Rye Patch release, the tons per acre-foot were 0.75 for both years. The total dissolved-solids load was not compared between these two stations because of the effects of controlled release of water from Rye Patch Reservoir; during some years there is a net loss in water storage, whereas for other years there is a net gain.

The quality of both surface water and ground water in the Winnemucca section of the Humboldt River valley between Comus and Rose Creek is presented in a report by Cohen (1963, p. 85–92). More than 225 chemical analyses were made of samples of surface water and ground water collected in three periods, July and August 1961, November and December 1961, and April and May 1962. Cohen discusses variations of quality along the Humboldt River and quality variation in ground water both vertically and laterally. The dissolved-solids content of most of the ground water is less than 600 ppm, although locally it is more than 5,000 ppm. Sodium and bicarbonate commonly are the most abundant ions. Eakin (1962, p. 39–42) describes the water quality between Rose Creek and Rye Patch Dam. The quality of both surface water and ground water in Lovelock Valley between Rye Patch Dam and Humboldt Sink is presented in a report by Everett and Rush (1965). Ground water in the upper part of Lovelock Valley has a dissolved-solids content generally less than 500 ppm, whereas below Lovelock it is more mineralized with dissolved solids greater than 1,000 ppm. Humboldt River water also becomes more mineralized as it moves southward. During October 1964 the dissolved solids increased from 492 ppm at site F to 3,330 ppm at site G (fig. 31). This increase was due largely to irrigation return flow.

Data on the chemical quality of ground water throughout the Humboldt River basin are adequate to provide only a general description of the distribution of chemical constituents. For example, in Paradise Valley (Loeltz, Phoenix, and Robinson, 1949, p. 48) six samples of ground water ranged from 339 to 1,250 ppm in dissolved-solids content; in the upper Reese River valley (Eakin, Moore, and Everett, 1965, table 6) 12 samples of ground water ranged from 280 to 1,440 micromhos in specific conductance, equivalent to a range of about 200 to 1,000 ppm of dissolved-solids content; in middle Reese River and Crescent Valleys (Crosthwaite, 1963, p. 20 and Zones, 1961, p. 28, 29) 10 samples of ground water ranged from 265 to 1,140 ppm in dissolved-solids content; and in the Elko area (Fredericks and Loeltz, 1947, p. 61) five samples of ground water ranged from 269 to 451 ppm of dissolved-solids content.

These analyses indicate a common range of dissolved-solids content of 250 to 500 ppm with a few areas having concentrations of 1,000 ppm or more throughout the Humboldt River basin.

Ground water near an area of recharge is generally similar to that available for recharge. Thus recharge supplied directly from nearby precipitation or from snowmelt streamflow generally has a low concentration. The concentration tends to increase as the water moves through the ground-water system. Near areas of discharge by evapotranspiration the concentration tends to be high as the dissolved solids are left behind by evaporation and largely rejected by plant roots during transpiration. If the discharge is by inflow to a stream, such as the discharge from Grass Valley to the Humboldt River in the Winnemucca section, the concentration of dissolved solids may be only moderate. If the circulation through the ground-water system is relatively free, concentration tends to be low. If restricted, the concentration tends to be high. If the rocks through which the ground-water system functions are relatively insoluble, the concentration of the water tends to remain low. If the rocks are highly soluble, the concentration of the ground water will be high.

From these generalizations it may be inferred that:

1. The dissolved-solids content of ground water might be relatively high in much of the older valley fill away from the flood-plain areas in the upper basin and in Pine Valley, because low transmissibility is inferred from the close spacing of water-level contours (pl. 1) in that area.

2. In the middle and lower basins, excluding Pine Valley, ground water in the Quaternary valley fill, beneath the alluvial apron, and other areas where ground-water circulation is relatively rapid, will tend to be of moderate concentration.

High concentration may be expected in and adjacent to principal areas of discharge by evapotranspiration. This may be modified if local recharge may be significant, such as in the flood plain of the Humboldt River.

These generalizations in no way replace the need for specific data. They do indicate that the variations in the chemical quality of ground water, sometimes in very short distances, may have a significant bearing on ground-water development.

HYDROLOGIC BUDGETS OF SUBAREAS

Although the hydrologic budgets for the upper, middle, lower basins, and the entire basin are reasonably balanced, budgets for some of the subareas illustrate that significant imbalances may occur. Further, compensating errors may occur in subareas for which there is an apparent balance.

Hydrologic budgets to show the dynamic interrelationship between the various components of the hydrologic cycle within main subareas of the basin are given in table 12. The table lists values for the principal components of the simplified flow system shown in figure 2. The subareas (table 12) are shown in figure 32. Some of the components were obtained by direct determinations; however, other components were obtained by differences, as shown in the footnotes of table 12. For this reason, the hydrologic budgets of the subareas (table 12) should be considered as tentative or generalized. However, the values listed are considered to be a reasonable representation of average conditions. A simplified graphic version of table 12 is presented in figure 33.

In the Elko section of the Humboldt River valley the direct estimate of locally derived ground-water recharge is 13,000 acre-feet per year. The value of 28,000 acre-feet for water yield from the mountains to ground water (table 12, column 6), which is obtained by difference, suggests that 15,000 acre-feet is derived from outside of this section. The following information suggests that the higher value may be reasonable, although the actual quantity was not directly determined. Springs occur in and along the flood plain in the Elko section. Elko Hot Spring, the springs along the South Fork Humboldt River between the gaging station and the Humboldt River, the spring area in the flood plain southwest of Carlin, the springs at the mouth of Marys Creek near Carlin, and others suggest this part of the flood plain may be characterized as one of rising ground water. Also, records of the Carlin and Palisade gaging stations indicate a gain of nearly 16 cfs between the two stations during October. Typically, October is a period of minor evapotranspiration losses, minor runoff from current precipitation, and minor return flow from seasonal storage in the flood plain.

Another example of imbalance occurs in the Rock Creek Valley subarea where the estimated yield (50,000 acre-feet) exceeds the estimated streamflow and ground-water losses by evapotranspiration (9,000 acre-feet) plus outflow (21,000 acre-feet at the gaging station) by 20,000 acre-feet. The estimated surface-water yield from the mountains seems reasonable in that the area appears to be in a relatively high runoff environment. Additional data might produce values for the several estimates that would be more compatible. However, if all three estimates are reasonably correct and an imbalance does exist, then a ground-water outflow of 20,000 acre-feet is indicated. Significant underflow in the alluvium at the gaging site is unlikely; but underflow through the underlying consolidated rocks may occur.

A potential hydraulic gradient exists to the southwest between the upper Rock Creek Valley and the Valmy section of the Humboldt River valley. The Valmy section is losing more surface water and ground water by evapotranspiration and outflow than can be accounted for by inflow. This fact is compatible with the inference of ground-water underflow from Rock Creek Valley. Additional support for this theory is suggested by the significant and nearly uniform discharge, about 2 cfs, of the Izzenhood Ranch Springs (fig. A3). These springs come to the surface not far from outcrops of carbonate rocks. The surficial drainage immediately upgradient from the springs is inadequate to support this flow. A large part of their supply probably originates outside the local drainage area. Upper Rock Creek Valley lies beyond the area to the east and northeast and at higher altitude. Thus the location and uniformity of discharge of the Izzenhood Ranch Springs strongly support the possibility of ground-water underflow from upper Rock Creek Valley toward the Valmy section.

The Valmy section of the Humboldt River valley offers another example of hydrologic imbalance, but one in which the estimated evapotranspiration losses from surface water and ground water plus outflow were substantially greater than the estimated inflow and locally generated surface water and ground water. Balance is obtained by difference, resulting in a value of 40,000 acre-feet being assigned to water yield from the mountains to

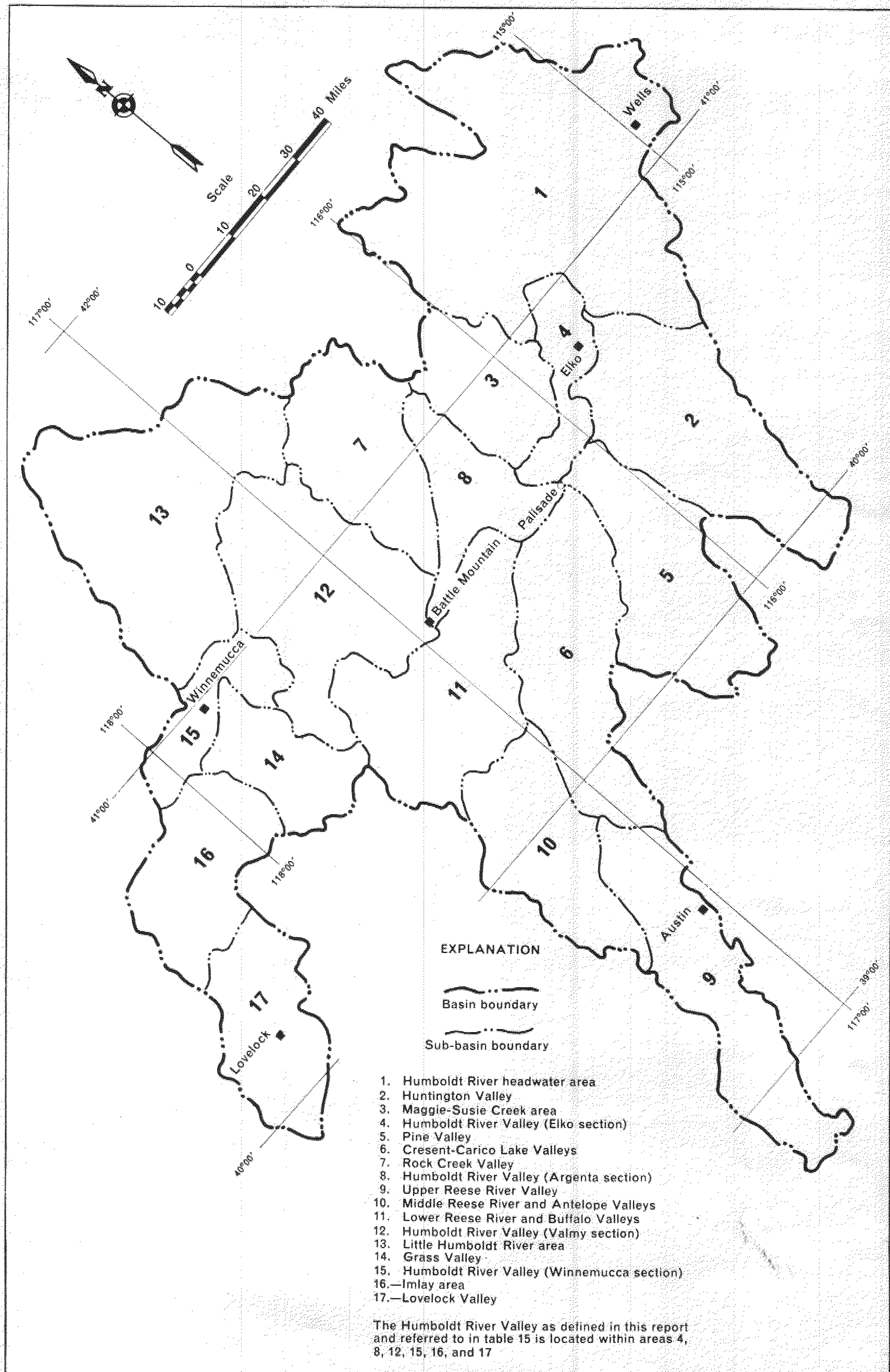

FIGURE 32. Subareas used in table 12 and figure 33.

TABLE 12. HYDROLOGIC BUDGETS OF MAIN SUBAREAS

(Values, in thousands of acre-feet a year, are significant to not more than two figures)

Map number (fig. 32)	Basin and subarea	Precipitation Total (1)	Precipitation Mountain (2)	Precipitation Valley (3)	Inflow from upstream unit (4)	Water Yield from Mountains Surface water (5)	Water Yield from Mountains Ground water (6)
	UPPER BASIN						
1	Humboldt River headwater area (above gage nr. Elko)	1,828	1,203	625	—	304	31
2	Huntington Valley (Drainage area of S. Fork of the Humboldt River)	903	550	353	—	134	12
3	Maggie-Susie Creeks area	396	225	171	—	23	10
4	Humboldt R. Valley (Elko section)	245	85	160	248	5	[2]28
	MIDDLE BASIN						
5	Pine Valley	654	399	255	—	24	14
6	Crescent and Carico Lake Valleys	602	335	267	—	12	14
7	Rock Creek Valley	489	474	15	—	[3]50	
8	Humboldt River Valley (Argenta section)	223	140	83	283	11	2
9	Reese River Valley (Upper)	702	374	328	—	36	23
10	Middle Reese and Antelope Valley	432	223	209	3.5	13	2
11	Lower Reese and Buffalo Valley	519	346	173	10	12	16
12	Humboldt River Valley (Valmy section)	557	290	267	218	22	[5]40
	LOWER BASIN						
13	Little Humboldt River area	910	711	199	—	102	1
14	Grass Valley	250	179	71	—	12.5	11
15	Humboldt River Valley (Winnemucca section)	137	40	97	186	8.5	9
16	Humboldt River Valley (Imlay area)	302	110	192	158	3.2	1
17	Humboldt River Valley (Lovelock Valley)	262	72	190	[7]125	3	Tr.
	Humboldt River Basin	9,411	5,756	3,655	—	774	214

COLUMN NOTES:

(1) Direct calculation—sum of area of ppt. zone times average ppt. for each zone within designated drainage area.

(2) Direct calculation as in (1) for mountain part of drainage area.

(3) Direct calculation as in (1) for valley part of drainage area.

(4) Measured, estimated, or combination thereof of surface water and ground water from upstream areas beyond designated drainage area.

(5) Direct computation (see description of method in this chapter).

(6) Obtained by difference: sum of (10), (11), (15), minus (5) and (4) where appropriate. This includes errors of estimates of those cols. Represents ground water derived in addition to the part of surface water runoff that later becomes ground water.

(7) Obtained by difference: col. (2) minus sum of (5), (6).

(8) Obtained by difference: col. (8) minus (9). Value (a) is evapotranspiration from direct precipitation on valley upland: value (b), evapotranspiration of runoff originating on valley upland.

(9) Direct calculation: area of defined lowland times assumed average precipitation.

(10) Direct calculation: sum of wet, intermediate, and residual lowland areas by rates of 1.5 ft., 0.25 x 0.25 of acreage, 0.1 ft., respectively.

(11) Direct, calculation: sum of wet, intermediate, and residual lowland areas by rates of 0.5, 0.4, 0.1 foot, respectively.

(12) Summation of cols. (9), (10), and (11).

(13) Streamflow from unit under consideration; measured for most larger units, estimated or measured at others.

(14) Ground-water underflow from unit under consideration; estimated values.

(15) Summation of cols. (13) and (14).

TABLE 12—(Continued)

Map number (fig. 32)	Basin and subarea	Evapotranspiration Losses: From mountains (7)	From valley uplands (8) (a)	(b)	From Valley Lowlands — Supplied From: Precipitation (9)	Surface water (10)		Ground water (11)	Sum (12)	Outflow: Surface water (13)	Ground water (14)	Sum (15)
	UPPER BASIN											
1	Humboldt River headwater area (above gage nr. Elko)	868	439	36	149.7	110.8	194	83.4	344	141	Tr.	141
2	Huntington Valley (Drainage area of S. Fork of the Humboldt River)	404	290	14	48.9	38.3	59	20.9	108	78.5	[1]9	87
3	Maggie-Susie Creeks area	192	144	8.3	18.8	6.9	13	6.1	32	20	Tr.(?)	20
4	Humboldt R. Valley (Elko section)	67	131	6.2	22.7	17	30	13	53	251	Tr.	251
	MIDDLE BASIN											
5	Pine Valley	361	217	7	31.3	12.7	28	15	59	9.4	.3	10
6	Crescent and Carico Lake Valleys	309	225	2	39.6	5.5	25	19.6	65	Tr.	Tr.	1
7	Rock Creek Valley	424	10	Tr.	5.2	5.5	9	2.8	14	21	Tr.	[4]21
8	Humboldt River Valley (Argenta section)	127	49	Tr.	33.5	56	86	30.4	120	208	2	210
9	Reese River Valley (Upper)	315	314	Tr.	14	19	56	37	70	3	<.5	<3.5
10	Middle Reese and Antelope Valley	208	194	2	13	1.6	8	6.5	21	1	9	10
11	Lower Reese and Buffalo Valley	318	139	3	31	4	30	26	61	5	3	8
12	Humboldt River Valley (Valmy section)	228	179	Tr.	88	32.5	104	71.9	192	175	1	176
	LOWER BASIN											
13	Little Humboldt River area	608	164	Tr.	35.4	64.8	97	32.5	132	2	3.5	6
14	Grass Valley	156	55	Tr.	15.7	5.5	19	12.8	35	—	4	4
15	Humboldt River Valley (Winnemucca section)	23	79	Tr.	17.6	29.1	45	15.9	63	155	3	158
16	Humboldt River Valley (Imlay area)	106	172	.8	19	[6]30	37	7.4	56	124	1	125
17	Humboldt River Valley (Lovelock Valley)	69	154	Tr.	36.5	34.7	[8]66	31.1	103	[8]51	[8]23	[9]74
	Humboldt River Basin	4,786	2,955	79	621	474	[10]907	433	1,528	—	—	[9]74

[1]Estimated outflow to downstream part of Humboldt River basin; excludes several thousand acre-feet of underflow from southern Ruby Mountains to Ruby Valley.
[2]Computed local recharge by direct estimate of 13,000 acre-feet suggests at least 15,000 acre-feet is derived from outside of boundary of Elko section, which is not included in col. 4.
[3]Computed surface-water runoff exceeds estimated evapotranspiration from surface water and ground water plus outflow by 20,000 acre-feet.
[4]Value is outflow at gaging station Rock Creek near Battle Mountain (3245).
[5]Computed local recharge by direct estimate of 18,000 acre-feet suggests at least 22,000 acre-feet may be derived from outside of boundary of Valmy section.
[6]Includes 20,000 acre-feet estimated average annual evaporation loss from Rye Patch reservoir.
[7]Computed value differs from 140,000 acre-feet used by Everett and Rush (1965) largely because of different reference period.
[8]Estimated evapotranspiration losses from surface water and ground water plus outflow are 12,000 acre-feet greater than inflow plus locally derived surface water and ground water. Probably due primarily to the effect in "average" outflow of a few years of very high flow to Humboldt Sink since 1940 being extended to 1912–63 reference period.
[9]Lost by evapotranspiration in the Humboldt Sink and occasional outflow to Carson Sink.
[10]Numbers in this column are the sum of columns 10 and 11.

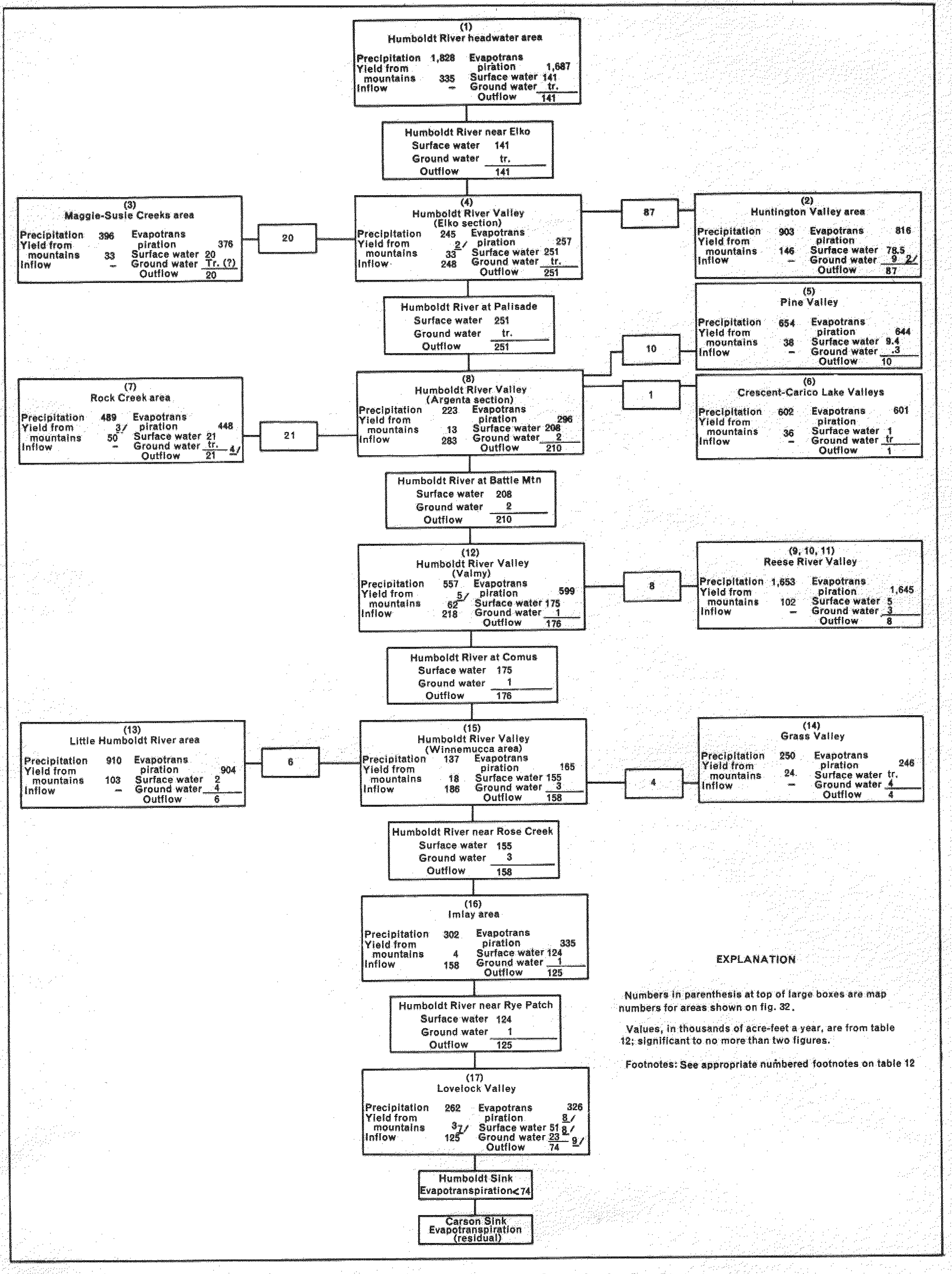

FIGURE 33. Hydrologic budgets of the principal subareas.

ground water (table 12, column 6). However, local ground-water recharge is estimated directly as about 18,000 acre-feet, which suggests that about 22,000 acre-feet is derived from outside of the section. The difference could be accounted for by using higher underflow values entering the section from the Reese River valley and Argenta sections of the Humboldt River valley, as these values also are estimated. However, present information suggests that underflow from Rock Creek Valley may be more likely. The principal problem again is that assumptions in the absence of adequate data must be used to make the estimates.

A final illustration of how imbalances may come about occurs in the hydrologic budget for the Lovelock Valley subarea. The estimated evapotranspiration losses from surface water and ground water plus outflow to the Humboldt Sink are 140,000 acre-feet per year. This is 12,000 acre-feet more than the inflow plus local water yield from the mountains. Again because some of the elements are obtained by difference, the summation of possible errors in estimates used are included in the residual value. However, the surface-water outflow value (5,100 acre-feet) shown in table 12, is for conditions since construction of Rye Patch Reservoir. The reservoir caused a considerable local change in the hydrology of Lovelock Valley. Because of this change no effort was made to extend the surface-water outflow value to the 1912–63 reference period. Nearly 95 percent of the actual outflow to the Humboldt Sink during the 26-year period (1936–61) occurred in 5 years (1942, 1943, 1945, 1946, and 1952), which had a combined outflow of about 1¼ million acre-feet. Possible errors in determining the amount of water discharged to the Humboldt Sink in three high runoff years might make a significant difference between the estimated and actual average outflow to the Humboldt Sink.

Even though some of the estimates are subject to error, as described above, the overall values are believed to represent reasonably the proportional distribution and quantities of the water comprising the dynamic phases of the hydrologic system of the Humboldt River basin.

CHAPTER IV

SUMMARY OF THE HYDROLOGIC SYSTEM

GENERALIZED HYDROLOGIC BUDGETS

The hydrologic budget shown in table 13 indicates the distribution of the components of the hydrologic cycle for the Humboldt River basin as a whole, and for the upper, middle, and lower basins. The generalized budgets presented in this report are considered to represent average conditions for the 1912–63 reference period.

The following generalizations for the Humboldt River basin can be deduced from table 13. About 60 percent of the total precipitation occurs in the mountains which in turn supplies most of the streamflow and ground water. Evapotranspiration losses in the mountains are estimated to be about one-half of the total precipitation. Evapotranspiration losses in the valley uplands are about one-third of the total precipitation. Thus, about 85 percent of the total precipitation is lost by evapotranspiration in the mountains and valley uplands. Five percent of the total precipitation falls directly in the valley lowlands and is lost by evapotranspiration.

Other inferences are that about one-quarter of the runoff from the mountains becomes ground-water recharge, and that total runoff is about twice the ground-water recharge (see table 12).

The water that becomes streamflow and ground water is roughly 10 percent of the total precipitation. This water is of particular importance as it represents the amount of water generally considered to be available for development by man. The general quantity and distribution of this water within the basin is summarized in table 14.

The estimates of evapotranspiration losses from surface water and ground water in the valley lowlands includes most of the water presently used for irrigation and municipal supply. The magnitude of these losses in the upper basin is significant but ordinarily tends to be obscured by the fact that the upper basin is the principal source of water for downstream use.

The hydrologic budget (table 13) does not readily distinguish lowland losses along the main stem of the Humboldt River from those in tributary areas, some of which contributes little if any water to the main stem of the Humboldt River. Therefore, a hydrologic budget for the main stem of the Humboldt River also is of interest. A general hydrologic budget primarily for the main stem of the Humboldt River—referred to as the valley of the Humboldt River to distinguish it from the entire Humboldt River basin—is given by including the flood plain of the Humboldt River downstream from the main stem gaging station, Humboldt River near Elko (3185). The valley also includes local tributary areas draining to the Humboldt River flood plain comprising areas 4, 8, 12, 15, 16, and 17 shown on the map in figure 32 and listed in table 12 and figure 33.

The hydrologic budget for the valley of the Humboldt River, so defined, is given in table 15. The elements in table 15 are the same as those used in table 13. However, inflow to the Humboldt River valley is proportionally of much greater importance.

From table 15 the surface-water and ground-water inflow to and outflow from the flood plain of the main stem of the Humboldt River is summarized in table 16. The indicated evapotranspiration losses from the flood plain in the middle section, which is 44 percent of the indicated total inflow, is particularly striking. The evapotranspiration losses for the upper section in this table are small relative to those estimated for the entire upper basin because of the restricted area defined for table 16.

VARIATIONS FROM AVERAGE CONDITIONS

The hydrologic budgets discussed in this chapter identify quantities of the several components in terms of average conditions. However, the "average" year may never occur. The components most susceptible to wide variations are precipitation, runoff, and streamflow in order of occurrence but in inverse order of variation range. Variations in these components, in turn, may result in year-to-year variations in the amount of evapotranspiration, in soil-moisture storage, in ground-water recharge, and of ground water in storage. The variations in year-to-year gains or losses of ground water in storage, however, are insignificant compared to the total quantity of ground water in storage.

The range in annual precipitation in the Humboldt River basin varies widely from the estimated average annual 9.4 million acre-feet. This may be illustrated by the following calculation. The

TABLE 13. HYDROLOGIC BUDGET OF THE HUMBOLDT RIVER BASIN

(Values, in thousands of acre-feet a year, are significant to no more than two figures)

Basin	Precipitation: Total (1)	Precipitation: Mountain (2)	Precipitation: Valley (3)	Inflow from upstream unit (4)	Yield from Mountains: Surface water (5)	Yield from Mountains: Ground water (6)	Evapotranspiration Losses: From mountains (7)	Evapotranspiration Losses: From valley uplands (8)	Evapotranspiration Losses: From Valley Lowlands: Precipitation (9)	Evapotranspiration Losses: From Valley Lowlands: Supplied from: Surface water (10)	Evapotranspiration Losses: From Valley Lowlands: Supplied from: Ground water (11)	Evapotranspiration Losses: From Valley Lowlands: Sum (12)	Outflow: Surface water (13)	Outflow: Ground water (14)	Outflow: Sum (15)
Upper basin above Palisade	3,372	2,063	1,309	----	466	81	1,531	1,069	240	173	124	537	251	[1]Tr.	251
										297					
Middle basin, between Palisade and Comus	4,178	2,581	1,597	[2]251	180	111	2,290	1,340	257	137	209	603	175	1	176
										346					
Lower basin below Comus	1,861	1,112	749	[2]176	128	22	962	625	124	164	100	388	51	23	[3]74
										264					
Humboldt River basin	9,411	5,756	3,655	----	774	214	4,786	3,034	621	474	433	1,528	51	23	[3]74
										[4]907					

[1]Estimated outflow to middle basin; excludes possibly several thousand acre-feet of underflow from southern Ruby Mountains to Ruby Valley.
[2]Streamflow and ground-water underflow into unit from upstream.
[3]Lost by evapotranspiration from Humboldt Sink and occasional outflow to Carson Sink.
[4]Sum of evapotranspiration losses from surface water (col. 10) and ground water (col. 11).

TABLE 15. HYDROLOGIC BUDGET FOR THE VALLEY OF THE HUMBOLDT RIVER

(Values, in thousands of acre-feet a year, are significant to no more than two figures)

Subarea and map number on fig. 32	Precipitation			Inflow		Water Yield from Mountains		Evapotranspiration Losses						Outflow		
										From Valley Lowlands						
										Supplied From						
	Total (1)	Mountain (2)	Valley (3)	Surface water (4[1])	Ground water (4[2])	Surface water (5)	Ground water (6)	From mountains (7)	From valley upland (8)	Precipitation (9)	Surface water (10)	Ground water (11)	Sum (12)	Surface water (13)	Ground water (14)	Sum (15)
Upper (Elko section) (4)	245	85	160	239	9	5	[1]28	67	137	23	17	13	53	251	Tr.	251
											30					
Middle (Argenta and Valmy section) (8 and 12)	780	430	350	288	3	33	[2]42	355	228	122	88	102	312	175	1	176
											[3]190					
Lower (Winnemucca, Imlay, and Lovelock sections) (15, 16, and 17)	701	222	479	177	9	15	10	198	406	73	94	55	222	51	23	[4/5]74
											149					
Humboldt River Valley (4, 8, 12, 15, 16, and 17)	1,726	737	989	277	21	53	80	620	771	218	199	170	587	51	23	[4/5]74
											369					

[1]Computed local recharge, by direct estimate, of 13,000 acre-feet suggests at least 15,000 acre-feet derived from outside this section of Humboldt River Valley in addition to the 9,000 indicated as ground-water inflow.

[2]Computed local recharge, by direct estimate, of 18,000 acre-feet for Valmy section, suggests at least 22,000 acre-feet may be derived from outside boundary of Valmy section.

[3]Includes 104,000 acre-feet estimated to be lost by evapotranspiration between Battle Mountain and Comus. This value is about 64,000 acre-feet greater than the loss indicated by difference between gaged inflow and outflow and estimated local runoff contribution.

[4]Lost by evapotranspiration from Humboldt Sink and occasional outflow to Carson Sink.

[5]Estimated evapotranspiration losses from surface and ground water plus outflow are 12,000 acre-feet greater than inflow plus locally derived surface water and ground water; probably due primarily to the effect on "average" outflow of a few years of very high flow to Humboldt Sink since 1940 being extended to 1912–63 reference period.

TABLE 14. SUMMARY OF SURFACE-WATER AND GROUND-WATER INFLOW AND OUTFLOW, HUMBOLDT RIVER BASIN

(Values, in thousands of acre-feet per year, to two significant figures)

	Upper basin	Middle basin	Lower basin	Total
INFLOW:				
Water yield from mountains				
Surface water	466	180	128	774
Ground water	81	111	22	214
Inflow from upstream basin				
Streamflow	0	251	175	----
Ground water	0	Trace	1	----
Total (1)	547	542	326	988
OUTFLOW:				
Evapotranspiration losses from valley lowlands				
Surface water	173	137	164	474
Ground water	124	209	100	433
Outflow to downstream basin				
Streamflow	251	175	51	[1]51
Ground water	Trace	1	23	[1]23
Total (2)	548	522	338	981
IMBALANCE: (1)-(2)	—1	20	—12	7

[1]Lost by evapotranspiration from Humboldt and Carson Sinks.

TABLE 16. SUMMARY OF SURFACE-WATER AND GROUND-WATER INFLOW AND OUTFLOW ALONG THE MAIN STEM OF THE HUMBOLDT RIVER

(Values, in thousands of acre-feet per year, to two significant figures)

	Upper section	Middle section	Lower section	Total
INFLOW:				
Water yield from the mountains within valley				
Surface water	5	33	15	53
Ground water	[1]28	[2]42	10	80
Inflow from upstream section and other tributary areas				
Surface water	239	288	177	277
Ground water	9	3	9	21
Total (1)	281	366	211	431
OUTFLOW:				
Evapotranspiration losses from valley lowlands				
Surface water	17	88	94	199
Ground water	13	102	55	170
Outflow to downstream section				
Streamflow	251	175	51	[3]51
Ground water	Trace	1	23	[3]23
Total (2)	281	366	223	443
IMBALANCE: (1)-(2)	0	0	[4]—12	[4]—12

[1]Computed local recharge, by direct estimate, of 13,000 acre-feet suggests at least 15,000 acre-feet derived from outside the section of Humboldt River valley.
[2]Computed local recharge, by direct estimate, of 18,000 acre-feet for Valmy section suggests at least 22,000 acre-feet may be derived from outside the boundary of this section.
[3]Lost by evapotranspiration from Humboldt and Carson Sinks.
[4]Estimated evapotranspiration losses from surface and ground water plus outflow are 12,000 acre-feet greater than inflow plus locally derived surface water and ground water; probably due primarily to the effect on "average" outflow of a few years of very high flow to Humboldt Sink since 1940 being extended to 1912–63 reference period.

average annual precipitation at Elko for the period 1912–63 was 8.89 inches. During that period, precipitation ranged from a high of 16.24 inches (1941) to a low of 3.30 inches (1930). The maximum year was about 1.8 times the average and the minimum year was about 0.37 of the average year. If these proportions are applicable to the basin-wide precipitation, total basin-wide precipitation might range from about 17 million to 3.5 million acre-feet in a particular year.

Runoff also varies widely from year to year but not necessarily in the same degree as does precipitation. Within a given year, temperature variations may accelerate or retard the timing of runoff and increase or decrease the amount of runoff for a given amount of precipitation. However, variations in runoff are illustrated by the streamflow records for Lamoille Creek and Martin Creek, the gaging stations that are at points where runoff from the mountains ordinarily is measured. The streamflow at long-term gaging stations near the base of the mountains and above diversions can be used to represent the variations in basin-wide runoff. The following tabulation was prepared for these two stations from data in part 1 of table A3:

	Complete years of record	Annual Streamflow, in Acre-Feet, for Complete Years of Record: Average	Max.	Min.	Ratio of max. to av.	Ratio of min. to av.
3165 Lamoille Creek at Lamoille	1915–23, 1944–63	30,840	46,200 (1921)	14,800 (1959)	1.5	0.47
3295 Martin Creek near Paradise Valley	1922–63	21,940	63,940 (1952)	5,910 (1931)	2.7	0.27
			Mean ratio		2.1	0.37

The range between the maximum and minimum annual streamflow has been from about 2.1 to 0.37 times the average. If these proportions are applicable basin-wide, surface-water runoff (average 854,000 acre-feet a year) might range from about 1.8 million to 0.3 million acre-feet in a given year.

Streamflow variations are well illustrated by records at Palisade, the point of outflow from the upper basin. Here the annual flow of the Humboldt River averaged 251,000 acre-feet for the period 1912–63. However, the recorded maximum annual flow (636,400 acre-feet in 1952) is more than 2.5 times the average and the recorded minimum annual flow (25,170 in 1934) is about 0.1 the average.

The variation of ground water in storage is proportionally small compared to the total volume in storage throughout the basin. In the Winnemucca area, Cohen (1964a, table 6) showed a seasonal gain in storage in the flood-plain deposits of 26,000 acre-feet during the period December–June 1962, of which 80 percent was dissipated by the end of that water year (September 30). Thus, in the flood-plain deposits ground water in storage locally may vary considerably through relatively short intervals. Similar information was not available for the entire flood plain of the Humboldt River and its principal tributaries. However, in the preceding chapter it was estimated that these flood-plain deposits may be capable of temporarily storing about 500,000 acre-feet of water. This value approximately represents a limiting value for the range in natural fluctuations of ground water in storage in the flood-plain deposits. The ordinary seasonal storage variations probably are less than half this value.

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APPENDIX 1

SUMMARY OF BASIC RECORDS AND INFORMATION

INTRODUCTION

Basic records and information, as used in this report, refers not only to data concerning water in its various environments but also to data concerning the environment in which the water exists.

Water records can be grouped conveniently on the basis of types of publications and the agencies which collect the data. Thus, most of the climatological data on precipitation, temperature, and wind movement are published by the U.S. Weather Bureau. Similarly, most snow-survey data are published by the U.S. Soil Conservation Service, and data on streamflow, ground water, and water quality are published by the U.S. Geological Survey. However, a substantial degree of cooperation is generally involved in the collection of nearly all kinds of water data and commonly involves funds and personnel from many State and Federal agencies and other groups and individuals.

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ILLUSTRATIONS

TABLES

CLIMATE

Table A–1 summarizes records of precipitation, snow surveys, temperature, and evaporation. The locations of the stations are shown in figure A–1. Sixteen of the storage-gage locations shown in the general vicinity of Winnemucca are operated by the Nevada Department of Conservation and Natural Resources, and although the records have not been published, the data are available for reference in the offices of the Department.

In addition to stations shown on figure A–1, precipitation and temperature records are obtained at other locations in conjunction with special studies. For example, precipitation and temperature records have been obtained at the test plots in conjunction with evapotranspiration studies in the Winnemucca area. Additionally, observations are made for local reference by many people in the basin.

Published records of evaporation are available at only two locations in the basin and one nearby station at Ruby Lake. Evaporation records (unpublished) also have been obtained at the test plots near Winnemucca in conjunction with evapotranspiration studies under the Humboldt River Research Project.

TABLE A–1. SUMMARY OF AVAILABLE CLIMATIC DATA IN AND ADJACENT TO THE HUMBOLDT RIVER BASIN, NEVADA

(From published records of the U.S. Weather Bureau, published summaries of snow survey records of U.S. Dept. of Agriculture, and measurements made by Nevada Department of Conservation and Natural Resources.)

PART I. Stations measuring precipitation, temperature, evaporation, and wind movement.

Station name	Location: Lat.	Location: Long.	Location: Elevation	Records available: Type	Records available: Total no. years complete record[2]	Summary of data[1]: Average annual	Summary of data[1]: Maximum annual	Summary of data[1]: Minimum annual	Remarks
Arthur 5 NW	40°47'	115°11'	6,280	precip.	56	14.87	23.63	6.42	
Austin	39°30'	117°05'	6,600	precip. temp.	73 44	12.03 47.6	21.07 51.8	6.34 43.6	
Battle Mountain	40°38'	116°56'	4,515	precip. temp.	92 44	6.70 48.8	14.03 53.0	2.40 45.3	Station moved from town of Battle Mountain to airport in 1945.
Beowawe	40°36'	116°29'	4,695	precip. temp.	86 44	6.65 48.0	14.92 52.4	2.17 45.3	
Buckskin Mountain	41°47'	117°33'	7,800	precip	13	25.79	28.39	18.58	Storage gage station
Cabin Creek	41°42'	117°32'	6,500	precip.	4	12.30	15.66	9.53	Storage gage station; †
Clear Cr. Canyon	40°43'	117°34'	6,000	precip.	4	10.27	12.67	8.40	Storage gage station, †
Deeth	41°04'	115°17'	5,343	precip. temp.	12 13	10.20 43.4	19.00 45.3	5.97 41.2	
Doby Summit	40°54'	115°52'	6,600	precip.	10	9.38	13.20	6.35	Storage gage station
Dun Glenn Peak	40°47'	117°27'	7,000	precip.	4	9.40	10.99	6.82	Storage gage station, †
Dutch Flat Mine	41°09'	117°31'	5,500	precip.	5	8.37	9.75	6.58	Storage gage station;
Elko	40°50'	115°47'	5,075	precip. temp.	94 44	8.74 45.6	18.94 49.1	.94 43.0	Station moved from town of Elko to airport in 1948
Emigrant Pass Hwy. St.	40°39'	116°18'	5,760	precip.	17	11.17	16.71	5.59	
Getchell Mine	41°12'	117°16'	6,000	precip.	5	13.43	15.14	9.10	Storage gage station; †
Golconda	40°58'	117°29'	4,392	precip. temp.	86 44	5.96 49.2	12.03 51.8	1.94 45.5	
Gance Creek	41°18'	115°55'	6,360	precip.	9	11.18	14.36	6.24	Storage gage station
Hanks Creek	41°27'	115°23'	6,700	precip.	15	9.59	13.22	6.77	Storage gage station
Hard-scrabble	41°38'	117°16'	6,000	precip.	4	7.21	10.35	.35	Storage gage station; †
Harrison Pass	40°20'	115°31'	7,300	precip.	17	16.37	19.60	11.64	Storage gage station
Hinkey Summit	41°41'	117°33'	8,250	precip.	6	12.06	16.67	10.65	Storage gage station
Imlay	40°40'	118°09'	4,209	precip. temp.	87 44	5.76 51.0	11.68 53.6	1.68 48.0	
Indian Creek	41°05'	117°32'	6,800	precip.	5	24.05	26.74	20.52	Storage gage station; †
Jacks Cr. Pass	41°33'	116°00'	7,725	precip.	15	32.00	41.46	22.48	Storage gage station
Jiggs	40°21'	115°40'	5,450	precip. temp.	51 5	12.07 44.8	17.73 45.8	6.74 44.7	
Kelly Cr. Ranch	41°20'	117°07'	5,000	precip.	5	9.73	11.63	7.30	Storage gage station; †
Lamoille P. H.	40°41'	115°28'	6,290	precip. temp. evap. wind	58 44 25 25	17.14 44.9 42.53 9,390	29.16 50.4 * *	8.60 42.7 * *	 Seasonal values (May - Oct) Seasonal values (May - Oct)
Lovelock	40°11'	118°28'	3,977	precip. temp.	70 44	4.88 51.6	11.93 54.6	.85 48.1	
Lovelock FAA A.P.	40°04'	118°33'	3,900	precip. temp.	16 16	4.40 50.8	8.57 52.3	1.66 48.0	

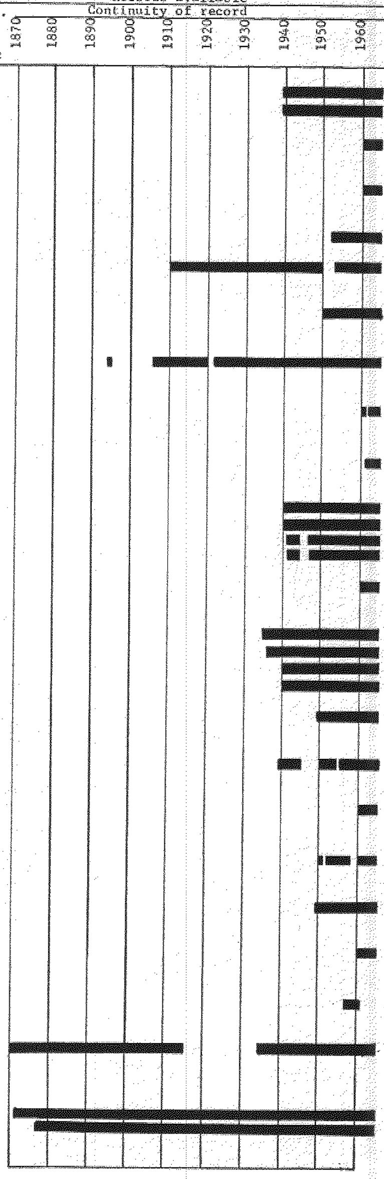
See footnotes on page 79.

TABLE A-1—(Continued)

PART I—(Continued)

Station name	Location: Lat.	Long.	Elevation	Type	Records available: Total no. years complete record[2]	Summary of data[1]: Average annual	Maximum annual	Minimum annual	Remarks
Mala Vista Ranch	41°19'	115°15'	5,585	precip.	22	9.64	15.83	6.57	
				temp.	25	43.2	45.4	41.0	
Martin Creek	41°38'	117°17'	7,200	precip.	5	23.54	26.89	19.83	Storage gage station; †
McCleary L.H. Ranch	41°28'	116°59'	4,800	precip.	5	10.20	12.21	7.11	Storage gage station, †
Midas 4 SE	41°12'	116°44'	5,200	precip.	11	9.26	15.02	6.17	
North Fork Mntc	41°29'	115°49'	6,200	precip.	53	10.01	17.82	5.40	
Overland Pass	40°01'	115°35'	6,789	precip.	14	9.78	14.91	5.05	Storage gage station
Paradise Valley 1NW	41°30'	117°32'	4,675	precip.	47	8.86	17.46	3.18	
				temp.	13	48.0	50.5	46.3	
Pole Creek	40°54'	117°34'	6,040	precip.	4	20.98	28.16	13.84	Storage gage station; †
Reed Ranch	41°22'	117°27'	4,600	precip.	4	8.12	8.94	7.39	Storage gage station, †
Ruby Lake	40°12'	115°30'	6,012	precip.	21	12.56	18.84	8.20	
				temp.	25	45.9	48.0	43.2	
				evap.	17	48.41	*	*	Seasonal average (May - Oct)
				wind	17	8,176	*	*	Seasonal average (May - Oct)
Ruck's Cabin	41°39'	117°32'	8,000	precip.	4	24.44	26.55	21.61	Storage gage station
Rye Patch Dam	40°28'	118°18'	4,135	precip.	28	7.15	12.48	3.28	
				temp.	28	50.6	53.4	47.7	
				evap.		57.75	*	*	Seasonal value (May - Oct)
				wind		12,571	*	*	Seasonal value (May - Oct)
Sadler Ranch	40°12'	115°44'	5,690	precip.	14	7.59	12.75	4.34	Storage gage station
Seventy One Ranch	40°54'	115°19'	5,550	precip.	16	12.37	20.21	9.36	
Sheep Cr. Canyon	40°36'	117°34'	5,500	precip.	5	10.29	12.12	6.36	Storage gage station, †
Smokey Valley	38°47'	117°10'	5,625	precip.	11	6.36	11.74	2.51	
Soldier Creek	40°46'	115°18'	7,200	precip.	11	15.52	22.06	9.67	
Spaulding Canyon	40°39'	117°17'	6,200	precip.	5	9.36	14.86	.45	Storage gage station; †
Twin Rivers	38°54'	117°15'	6,500	precip.	5	6.65	8.90	4.55	Storage gage station
Wells	41°07'	114°58'	5,633	precip.	58	9.76	18.51	3.40	Years 1902-1908 contain monthly values from Clover Valley so are not included
				temp.	25	44.7	46.5	41.8	
Winnemucca	40°54'	117°48'	4,299	precip.	93	8.38	18.38	3.13	Station moved from town of Winnemucca to airport in 1949
				temp.	87	48.7	53.2	46.0	

Records available — Continuity of record:



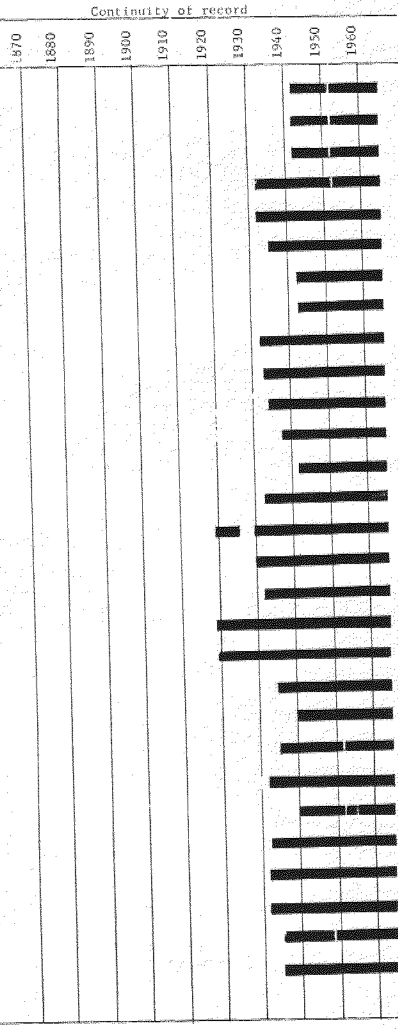
[1]Values given are precipitation and evaporation in inches, temperature in degrees Fahrenheit, and wind in total movement in miles per season. Asterisk (*) indicates insufficient data.
[2]Years of record for temperature commonly includes partial-record years.
[3]Dagger (†) indicates gage installed and maintained by Nevada Department of Conservation and Natural Resources.

TABLE A-1—(Continued)

PART II. Snow courses in the Humboldt River drainage basin.

Course: Name	Course: Number	Location: Lat.	Location: Long.	Location: Elev.	Records Available: total no. years	Average April 1 water content[1]	Remarks
Big Creek Campground	17K1	39°22'	117°08'	6,600	23	1.2	
Big Creek Mine	17K2	39°20'	117°07'	7,600	23	3.5	
Big Creek Upper	17K3	39°18'	117°07'	8,000	23	7.6	
Buckskin, Lower	17H2	41°43'	117°32'	6,700	33	7.9	
Buckskin, Upper	17H1	41°46'	117°34'	7,200	33	10.1	
Corral Canyon	15J12	40°18'	115°30'	8,500	30	18.8	
Corral, Lower	17L1	38°48'	117°26'	7,500	23	1.1	
Corral, Upper	17L2	38°50'	117°24'	8,500	23	3.7	
Dorsey Basin	15J1	40°53'	115°12'	8,100	33	14.4	
Dry Creek	15J3	40°57'	115°13'	6,500	32	3.7	
Fry Canyon	15H7	41°36'	115°54'	6,700	31	8.3	
Golconda #2	17J2	40°53'	117°34'	6,000	25	1.9	
Granite Peak	17H4	41°39'	117°35'	7,800	33	11.5	
Green Mountain	15J9	40°22'	115°15'	8,000	30	13.5	
Harrison Pass #1	15J10	40°19'	115°32'	6,600	46	3.7	
Harrison Pass #2	15J11	40°18'	115°32'	7,400	35	4.7	
Lamance Creek	17H5	40°19'	115°33'	6,000	33	7.1	
Lamoille #1	15J4	40°39'	115°25'	7,100	43	9.6	
Lamoille #2	15J5	40°39'	115°24'	7,300	43	9.9	
Lamoille #3	15J6	40°38'	115°23'	7,700	30	13.2	
Lamoille #4	15J7	40°37'	115°22'	8,000	25	18.8	
Lamoille #5	15J8	40°36'	115°22'	8,700	30	27.7	
Martin Creek	17H3	41°41'	117°31'	6,700	33	8.0	
Midas	16H3	41°15'	116°49'	7,200	25	2.0	
Rodeo Flat	15H6	41°34'	115°54'	6,800	31	8.0	
Ryan Ranch	15J2	40°54'	115°16'	5,800	33	0.9	
Tremewan Ranch	15H8	41°17'	115°47'	5,700	33	0.5	
Trout Creek, Lower	15H10	41°03'	115°06'	6,900	30	2.8	
Trout Creek, Upper	15H11	41°02'	115°06'	8,500	30	24.2	

Continuity of record (1870 1880 1890 1900 1910 1920 1930 1940 1950 1960):



[1]Average from total number of April 1 measurements, in inches.

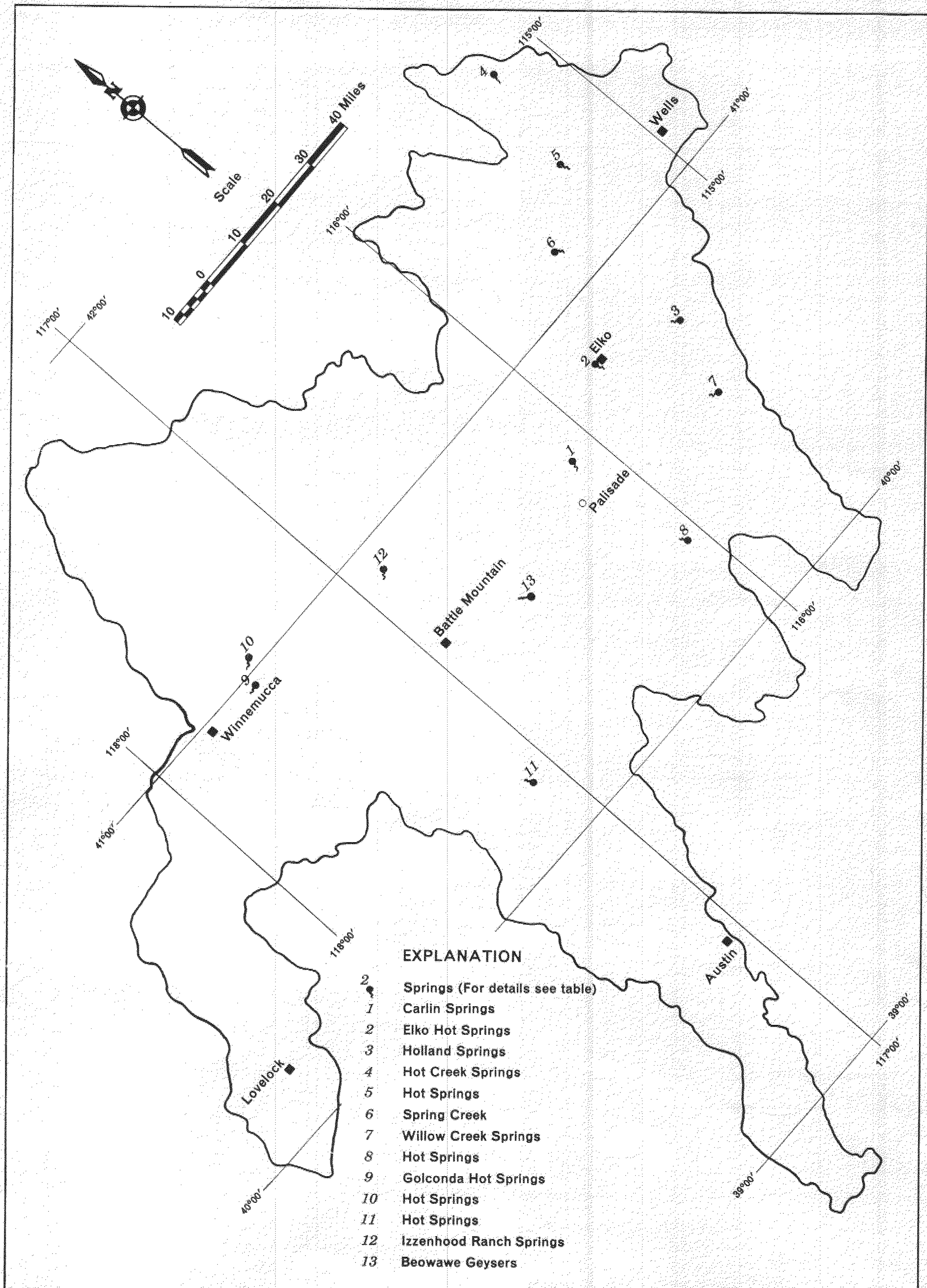


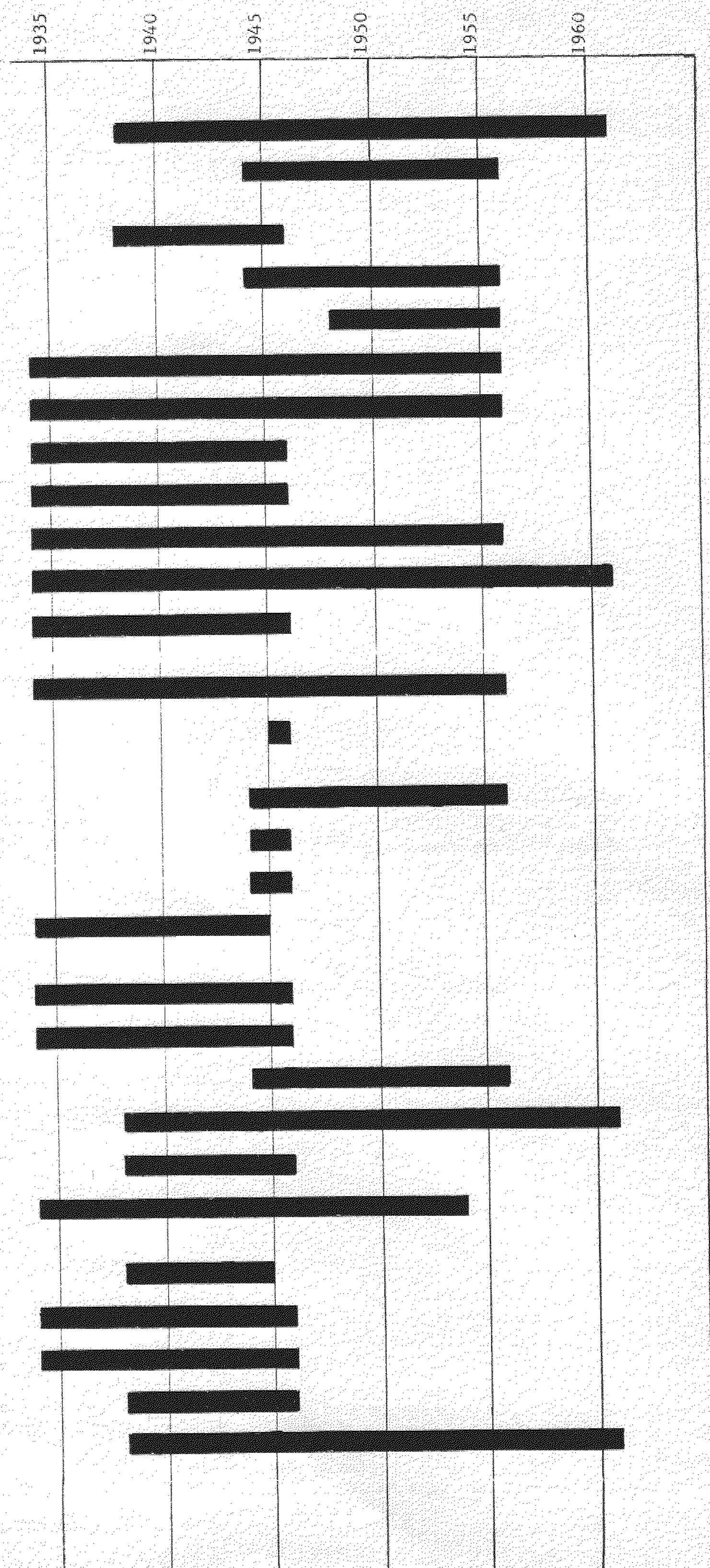
FIGURE A–3. Map showing location of selected springs.

TABLE A-5. PUBLISHED DATA ON GROUND-WATER LEVELS

PART I. Published measurements at observation wells.

Location	Owner and common name of well as described in publication
	Elko County
33/52-27d1	Carlin Town Government
33/53-20d1	C. E. Lee. Known as Box K Ranch
33/54-8a1	Charles S. Howard, known as Hunter and Banks Well
33/56-8d1	Moffat, known as Ten Mile well
33/57-22d1	Sutacha, formerly Ryan
33/58-5a1	George Ogilvie
33/58-7a1	No. 2 Lytton Lane
33/58-8a1	No. 1 Lytton Lane
33/58-17b1	McKinney Gate
33/58-18c1	John Patterson
33/58-19ad1	H. Conrad, Lamoille Church
33/58-19b1	H. L. Case
33/58-30a1	Joe Sustacha, known as Charles Well
34/55-11c5	City of Elko
34/57-18a1	U.S. Bureau of Land Management Known as Dry Lake Well
34/57-25b1	Balboa, Balboa No. 1
34/57-25b2	Balboa, Balboa No. 2
34/58-15c1	Panama well
34/58-28c1	C. Laucesica, known as Reinken Well
34/58-31d1	E. Martin
35/56-1b1	Moffat
35/56-30c1	Fernald
35/57-4d1	Tower Service Station
35/58-3cb1	Randolph
35/58-4b1	Clarence Gosh, known as Glazier Well
35/58-14b1	McIntyre
35/58-35b1	Unknown, known as John Day Well
36/58-1c1	Unknown, known as O'Boy Well
37/59-26a1	Deeth

Period of published record[1]



See footnote on page 94.

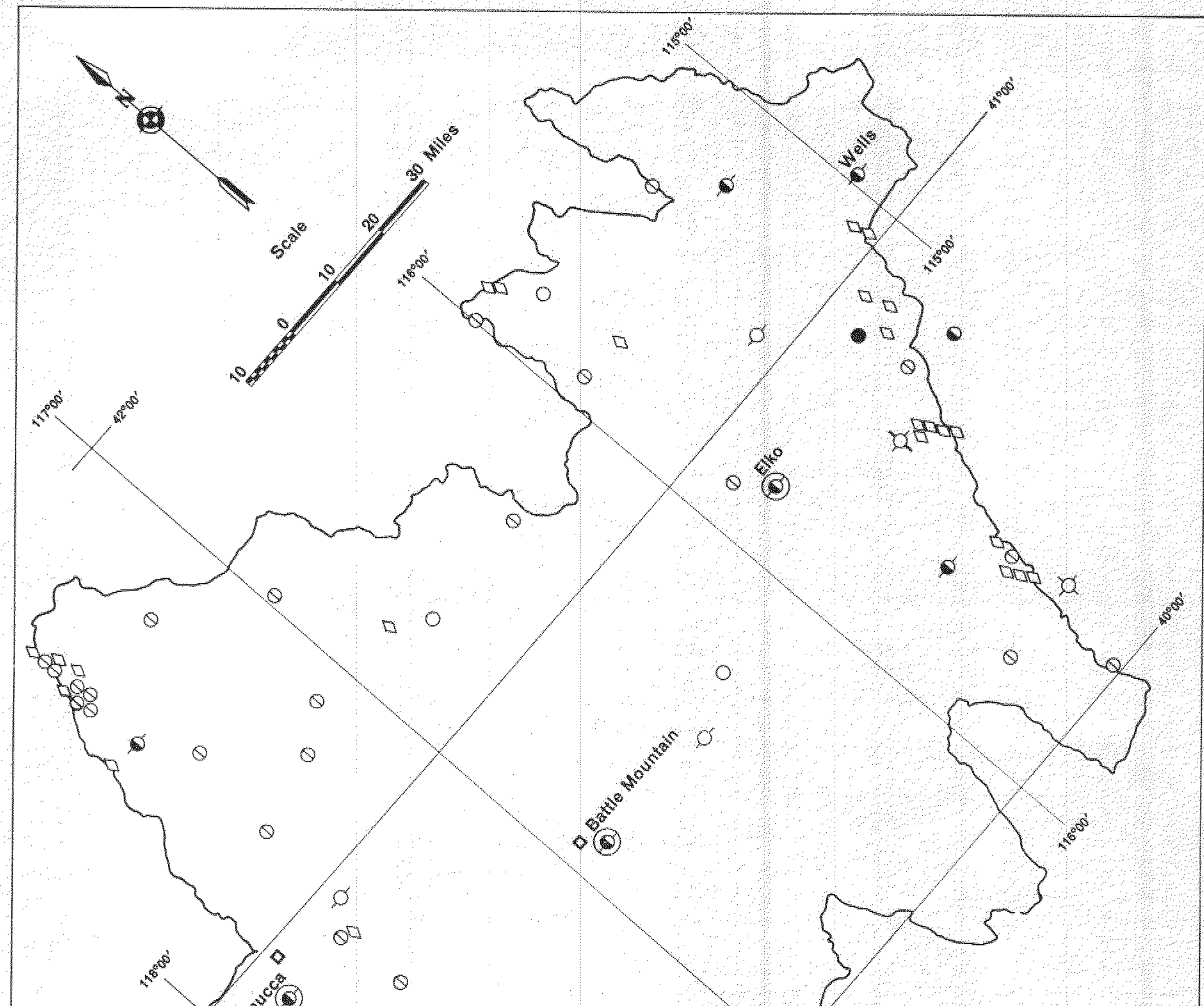


FIGURE A–1. Map showing location of selected climatic stations.

SURFACE WATER

DISCHARGE DATA

Basic data on streamflow in the Humboldt River basin since 1895 are available in various U.S. Geological Survey publications. Streamflow data for 1895 and 1896 are in U.S. Geological Survey Bulletin 140 and the Eighteenth Annual Report of the United States Geological Survey, Part IV, Hydrography, respectively. Water-Supply Papers containing streamflow records from 1897 to 1960 are listed in table A–2.

TABLE A–2. WATER–SUPPLY PAPERS CONTAINING STREAMFLOW RECORDS, 1896–1960

Year	No.	Year	No.	Year	No.	Year	No.	Year	No.
1897	16	1911	310	1925	610	1938	860	1951	1214
1898	28	1912	330	1926	630	1939	880	1952	1244
1899	38	1913	360	1927	650	1940	900	1953	1284
1900	51	1914	390	1928	670	1941	930	1954	1344
1901	66, 75	1915	410	1929	690	1942	960	1955	1394
1902	85	1916	440	1930	705	1943	980	1956	1444
1903	100	1917	460	1931	720	1944	1010	1957	1514
1904	133	1918	480	1932	735	1945	1040	1958	1564
1905	176	1919–20	510	1933	750	1946	1060	1959	1634
1906	212	1921	530	1934	765	1947	1090	1960	1714
1907–8	250	1922	550	1935	790	1948	1120	----	----
1909	270	1923	570	1936	810	1949	1150	----	----
1910	290	1924	590	1937	830	1950	1180	----	----

Monthly and yearly streamflow data have been compiled in the following U.S. Geological Survey Water-Supply Papers:

Water year	Water-Supply Paper
1895–1950	1314
1951–1960	1734

Beginning with the 1961 water year, the publication format was changed, and streamflow data were published for water years 1961, 1962, 1963, and 1964 in annual reports entitled, "Surface Water Records of Nevada."

Data concerning 35 long-term stream-gaging stations, of which only 15 have 20 complete years or more of streamflow records as of September 30, 1963, are summarized in part 1 of table A–3. The locations of these stations listed in part 1 of table A–3 are shown on plates 1 and 2. Part 2 of table A–3, an abbreviated version of part 1, lists short-term and seasonal streamflow data collected at 20 locations by the U.S. Geological Survey and the Humboldt River Water Distribution District. Additional seasonal discharge records were collected by the District, the data for which are on file at the Elko office of the District.

FLOOD DATA

A nearly complete qualitative summary of floods in the Humboldt River basin during the period 1861 to 1962 is available in a report published by the Nevada Department of Conservation and Natural Resources and the U.S. Department of Agriculture entitled, "Chronology of Flood Years and High Water Years, 1962." A description of the February 1962 flood on the Humboldt River is given in U.S. Geological Survey Circular 467 entitled, "Floods of February 1962 in Southern Idaho and Northeastern Nevada." In addition, the momentary maximum or maximum daily discharges for each year are published in Water-Supply Papers 1314 and 1734 and in the annual Statewide reports from 1961 on. Butler, Reid, and Berwick (1966)[1] list floods above a base for selected gaging stations. Table A–4 summarizes data on the maximum discharges at 35 long-term gaging stations.

Since 1961, 12 crest-stage gage stations have been established in the Humboldt River basin as part of the Statewide cooperative program with the Nevada Highway Department. Data collected at these stations are published in "Surface Water Records of Nevada." The program is directed toward obtaining data on maximum discharge and volume of flow from small drainage basins for use in designing highway bridges and culverts. Another part of this cooperative program is to make indirect measurements of unusual peak flows at ungaged sites. The results of these indirect measurements are published as miscellaneous measurements in "Surface Water Records of Nevada."

MISCELLANEOUS MEASUREMENTS

Miscellaneous streamflow measurements have been made for special-purpose studies, and include the series of seepage measurements made at 18 sites along the Humboldt River between the gaging stations at Comus (3275) and near Rose Creek (3315) and a series of streamflow measurements made on the tributaries between these stations (Hanson, 1963, p. 47–50). The data obtained are published in Water-Supply Paper 1714 and in "Surface Water Records of Nevada" for 1961,

[1]References cited in appendix are listed either in *selected references* at the end of the appendix or in *references cited* at the end of the main report.

TABLE A–3. SUMMARY OF SELECTED STREAMFLOW RECORDS IN THE HUMBOLDT RIVER BASIN, NEVADA

PART I. Long-term streamflow records

Station number	Station name	Location	Drainage area (sq mi)	Period of record	Annual discharge in acre-feet for complete years of record: Years	Mean	Maximum	Minimum	Annual discharge for reference period in acre-feet: Years	Mean	Median	Lower quartile	Upper quartile	Irrigated land upstream from gage in acres: Decreed and permitted	Estimated annual average
3130	Starr Creek near Deeth	Lat 41°01′, long 115°16′, in NE¼ sec. 12, T.36 N., R.59 E., 2 miles upstream from mouth and 3 miles southeast of Deeth.	[1]60	[2]1913, 1914–28, [3]1931, [3]1935, [3]1937–42	11	18,900	38,700	7,390	....	....	....	....	....	[1]5,000	....
3150	Marys River near Deeth	Lat 41°19′, long 115°16′, in NW¼ sec. 31, T.40 N., R.60 E., 300 ft east of Mala Vista ranch house, 19 miles north of Deeth.	355	[2]1903, [2]1912, 1913–28	15	36,850	71,500	12,700	....	....	....	....	....	....	....
3155	Marys River above Hot Springs Creek, near Deeth	Lat 41°15′, long 115°17′, in NE¼SE¼ sec. 24, T.39 N., R.59 E., 13 miles north of Deeth.	415	[3]1938–42, 1944–63	20	41,630	91,880	14,060	1912–63	39,900	[1]36,000	[1]26,000	[1]51,000	7,150	5,000
3160	Secret Creek near Halleck	Lat 40°52′00″, long 115°16′20″, in NE¼NW¼ sec. 1, T.34 N., R.59 E., 11 miles southeast of Halleck.	[1]34	1917–24	5	[1]13,400	27,400	6,200	....	....	....	....	....	....	....
3165	Lamoille Creek near Lamoille	Lat 40°41′30″, long 115°28′30″, in NE¼ sec. 6, T.32 N., R.58 E., 300 ft downstream from Elko-Lamoille powerplant.	[1]25	1915–23, [3]1931, [3]1935, [3]1937–42, 1944–63	27	30,840	46,200	14,840	1912–63	29,300	29,800	23,900	34,700	0	0
3170	Lamoille Creek near Halleck	Lat 40°55′40″, long 115°26′20″, in SW¼ sec. 9, T.35 N., R.58 E., 1½ miles southeast of Halleck.	245	[2]1913, 1914–19 [3]1931, [3]1935	6	[1]33,600	84,600	13,400	....	....	....	....	....	....	....
3175	North Fork Humboldt River at Devils Gate, near Halleck	Lat 41°11′, long 115°33′, in SE¼ sec. 13, T.38 N., R.57 E., 16 miles north of Halleck.	[1]830	1914–21, 1944–63	28	51,330	143,600	10,540	1912–63	47,800	45,500	22,000	63,800	16,600	13,000
3180	North Fork Humboldt River near Halleck	Lat 40°56′, long 115°53′, in SE¼ sec. 9, T.35 N., R.57 E., 150 ft downstream from Southern Pacific Railroad bridge, 6 miles west of Halleck.	[1]1,020	[2]1898–1900, [2]1904–14, [3]1935, [3]1937–42	8	[1]67,400	174,000	14,620	1912–63	[1]33,000	....	....	....	18,400	15,000
3185	Humboldt River near Elko	Lat 40°56′, long 115°38′, in NE¼NE¼ sec. 11, T.35 N., R.56 E., 10 miles northeast of Elko.	[1]2,800	[2]1895, 1896–1902, 1945–63	26	160,700	348,200	25,800	1931–63	141,000	135,000	[1]73,000	[1]200,000	95,800	60,000
3190	South Fork Humboldt River near Lee	Lat 40°34′, long 115°33′, in SE¼ sec. 16, T.31 N., R.57 E., 400 ft downstream from Kleckner Creek, 2½ miles east of Lee.	[1]54	[2]1945, 1946–55	10	48,650	68,590	29,100	1946–63	[1]48,000	[1]50,000	[1]35,000	[1]59,000	[1]1,100	....
3195	Huntington Creek near Lee	Lat 40°33′, long 115°43′, in SW¼ sec. 19, T.31 N., R.56 E., 6 miles west of Lee.	[1]770	1949–63	15	23,090	63,500	5,360	1946–63	[1]24,000	[1]24,000	[1]9,000	[1]35,000	17,500	....
3200	South Fork Humboldt River above Dixie Creek, near Elko	Lat 40°41′05″, long 115°48′45″, in NW¼SW¼ sec. 5, T.32 N., R.55 E., 10½ miles south of Elko.	[1]1,150	1949–63	15	75,290	145,700	20,200	1912–63	78,100	....	....	....	36,200	....
3205	South Fork Humboldt River near Elko	Lat 40°43′25″, long 115°49′45″, in NE¼NW¼ sec. 30, T.33 N., R.55 E., 10 miles southwest of Elko.	[1]1,310	[2]1896–1922, 1924–32, 1937–63	59	90,500	195,600	11,800	1912–63	78,200	73,200	45,200	102,000	37,200	25,000
3210	Humboldt River near Carlin	Lat 40°43′40″, long 116°00′30″, in sec. 21, T.33 N., R.53 E., 5½ miles east of Carlin.	[1]4,310	1944–63	20	227,300	512,200	46,060	1931–63	220,000	[1]210,000	[1]130,000	[1]280,000	143,000	85,000
3215	Susie Creek near Carlin	Lat 40°56′, long 115°58′, in SW¼ sec. 12, T.35 N., R.53 E., 17 miles northeast of Carlin.	82.5	1956–58	3	[1]4,400	4,580	4,290	....	[1]3,300	....	....	....	189	....
3220	Maggie Creek at Carlin	Lat 40°43′10″, long 116°05′40″, in sec. 26, T.33 N., R.52 E., 700 ft upstream from highway bridge, ½ mile east of Carlin.	[1]400	[2]1913–24, [3]1931, [3]1935, [3]1938–42	9	16,800	33,700	2,950	....	[1]15,000	[1]13,000	[1]4,100	[1]20,000	3,460	3,300
3225	Humboldt River at Palisade	Lat 40°36′25″, long 116°12′05″, in SE¼SE¼ sec. 35, T.32 N., R.51 E., ½ mile downstream from Palisade.	[1]5,010	1903–6, 1912–63	56	255,600	636,400	25,170	1912–63	251,000	238,000	122,000	315,000	148,000	90,000

See footnotes on page 85.

TABLE A-3—(Continued)

Station number	Station name	Location	Drainage area (sq mi)	Period of record	Annual discharge in acre-feet for complete years of record: Years	Mean	Maximum	Minimum	Annual discharge for reference period in acre-feet: Years	Mean	Median	Lower quartile	Upper quartile	Irrigated land upstream from gage in acres: Decreed and permitted	Estimated annual average
3230	Pine Creek near Palisade	Lat 40°35'45", long 116°10'25", in NW¼SE¼ sec. 1, T.31 N., R.51 E., 1¼ miles southeast of Palisade.	999	[2]1912, 1913–14, [2]1946, 1947–58	14	9,630	28,810	3,390	1912–63	[1]9,400	[1]6,800	[1]4,100	[1]10,000	[4]3,740	5,600
3235	Humboldt River near Argenta	Lat 40°40'45", long 116°38'45", in SE¼NW¼ sec. 2, T.32 N., R.47 E., 3 miles east of Argenta.	[1]7,490	[2]1946, 1947–63	17	199,100	600,800	43,440	1912–63	218,000	[1]200,000	[1]98,000	[1]270,000	----	----
3245	Rock Creek near Battle Mountain	Lat 40°49', long 116°35', in NE¼ sec. 17, T.34 N., R.48 E., 22 miles northeast of Battle Mountain.	[1]875	[2]1896, [2]1918–29, 1946–63	23	22,660	95,540	2,100	1912–63	21,100	[1]14,000	[1]6,000	[1]30,000	4,380	----
3250	Humboldt River at Battle Mountain	Lat 40°39'15", long 116°55'10", in NE¼NE¼ sec. 17, T.32 N., R.45 E., 1 mile northeast of Battle Mountain.	[3]8,870	[2]1896–98, [2]1921–24, 1946–63	21	218,600	587,100	39,460	1912–63	208,000	[1]180,000	[1]90,000	[1]260,000	194,000	----
3255	Reese River near Ione	Lat 38°51', long 117°28', in NE¼ sec. 3, T.11 N., R.40 E., 8 miles southeast of Ione.	[1]53	1952–63	12	7,530	19,960	1,700	----	[1]8,500	----	----	----	0	----
3270	Humboldt River near Valmy	Lat 40°48', long 117°04', in NE¼NW¼ sec. 30, T.34 N., R.44 E., 3½ miles east of Valmy.	[1]11,500	[2]1950, 1951–58	8	218,600	562,700	34,700	1912–63	186,000	[1]150,000	[1]76,000	[1]220,000	----	----
3275	Humboldt River at Comus	Lat 41°00', long 117°19', in SE¼ sec. 14, T.36 N., R.41 E., at Comus siding of Southern Pacific Railroad, 9 miles northeast of Golconda.	[1]12,100	[2]1895–1909, 1911–26, 1946–63	49	198,400	688,100	26,700	1912–63	175,000	140,000	66,400	212,000	[4]206,000	----
3280	Pole Creek near Golconda	Lat 40°54'50", long 117°31'50", in N½NE¼ sec. 13, T.35 N., R.39 E., 4 miles southwest of Golconda.	10.7	1961–63	3	[1]3,000	3,590	2,020	----	----	----	----	----	0	----
3285	Little Humboldt River at Chimney dam site, near Paradise Valley	Lat 41°24', long 117°11', in NE¼ sec. 36, T.41 N., R.42 E., 300 ft downstream from confluence of North and South Fork, 25 miles east of Paradise Valley.	[1]720	1942–50	9	17,660	50,160	6,700	----	[1]17,000	----	----	----	2,110	----
3290	Little Humboldt River near Paradise Valley	Lat 41°25', long 117°22', in SE¼ sec. 20, T.41 N., R.41 E., 9½ miles southeast of Paradise Valley.	[1]1,030	[2]1922–28, 1944–63	25	17,450	64,330	6,170	1931–63	16,900	[1]13,000	[1]9,500	[1]22,000	4,450	----
3295	Martin Creek near Paradise Valley	Lat 41°32'00", long 117°25'40", in NW¼SW¼ sec. 12, T.42 N., R.40 E., 7 miles northeast of Paradise Valley.	172	1922–63	42	21,940	63,940	5,910	1912–63	22,700	20,200	16,200	29,100	49	----
3300	Cottonwood Creek near Paradise Valley	Lat 41°33', long 117°35', in SW¼ sec. 3, T.42 N., R.39 E., 5 miles northwest of Paradise Valley.	[1]13	1925–34	9	----	7,990	987	----	[1]5,000	----	----	----	11	----
3305	Cottonwood Creek at Paradise Valley	Lat 41°31'00", long 117°32'30", in NW¼ sec. 25, T.42 N., R.39 E., 300 ft west of Paradise Valley Post Office.	57.4	1944–51	7	7,310	15,960	916	----	----	----	----	----	4,320	----
3309	Humboldt River near Winnemucca	Lat 41°00'00", long 117°43'15", in SW¼NE¼ sec. 17, T.36 N., R.38 E., 2 miles north of Winnemucca.	[1]14,600	1960–63	3	[1]141,000	258,800	22,800	----	----	----	----	----	----	----
3315	Humboldt River near Rose Creek	Lat 40°52'05", long 117°59'45", in SE¼NW¼ sec. 36, T.35 N., R.35 E., 5¾ miles southwest of Rose Creek, 15½ miles southwest of Winnemucca.	[1]15,200	1948–63	15	154,200	535,800	21,480	1912–63	155,000	[1]110,000	[1]56,000	[1]180,000	[4]224,000	----
3330	Humboldt River near Imlay	Lat 40°41'30", long 118°12'10", in SE¼SW¼ sec. 25, T.33 N., R.33 E., 4 miles northwest of Imlay.	[1]15,700	1935–41, 1945–63	24	118,000	522,200	18,830	1912–63	[5]149,000	[1]110,000	[1]50,000	[1]170,000	[4]226,000	----
3350	Humboldt River near Rye Patch	Lat 40°28'00", long 118°18'20", in SW¼NE¼ sec. 18, T.30 N., R.33 E., 1,000 ft downstream from Rye Patch Dam, 1½ miles northwest of Rye Patch.	[1]16,100	[2]1896–1922, [2]1924–32, 1935–41, 1943–63	49	140,500	504,000	6,220	----	[6]124,000	----	----	----	[4]226,000	----
3360	Humboldt River near Lovelock	Lat 40°03'05", long 118°28'05", in SE¼NW¼ sec. 11, T.25 N., R.31 E., 9 miles south of Lovelock.	[1]16,600	1912–27, 1950–59	20	53,860	344,000	0	----	[7]50,000	----	----	----	[4]266,000	----

TABLE A-3—(Continued)

PART II. Short term and seasonal streamflow records.

Station number	Station or stream name	Location	Drainage area (sq mi)	Period of record—Total available data	Estimated annual discharge in acre-feet: Years	Mean	Years	Mean	Remarks
3125	Bishop Creek near Wells	Lat 41°15′, long 114°47′, in sec. 27, T.29 N., R.62 E., 2 miles upstream from Trout Creek, 10 miles north of Wells.	125	[2]1910–11	1910	10,000			No diversions or regulation upstream during this period
	Herder Creek	SW¼SW¼ sec. 3, T.36 N., R.60 E., 5 miles southeast of Deeth.	[1]7	[3]1935, [3]1949–59	1952–59	[8]4,800	1912–63	[8]4,900	Upstream diversions of 200 to 2,000 acre-feet per year
	Ackler Creek	NW¼NW¼ sec. 10, T.36 N., R.60 E., 5 miles southeast of Deeth.	[1]11	[3]1935, [3]1949–59	1949–59	7,600	1912–63	7,600	No diversions upstream
	East Fork Boulder Creek	SW¼ sec. 29, T.36 N., R.60 E., 7 miles south of Deeth.	[1]10	[3]1935, [3]1949–59	1951–59	[8]10,000	1912–63	[8]10,000	Upstream diversions of 40 to 1,000 acre-feet per year
	West Fork Boulder Creek	SE¼SW¼ sec. 30, T.36 N., R.60 E., 7 miles south of Deeth.	[1]9	[3]1935, [3]1949–59	1951–59	[8]11,000	1912–63	[8]11,000	Upstream diversions of 400 to 1,200 acre-feet per year
3135	Marys River at Marys River Cabin, near Deeth	Lat 41°32′, long 115°16′, in NE¼ sec. 24, T.42 N., R.59 E., at Marys River Cabin, half a mile upstream from Deep Creek, and 36 miles north of Deeth.	[1]76	[2]1913–14	1914	50,600	1912–63	30,000	No diversions upstream
3140	Hanks Creek near Deeth	Lat 41°28′, long 115°16′, in NW¼ sec. 6, T.41 N., R.60 E., 600 ft upstream from mouth and 32 miles north of Deeth.	[1]70	[2]1913–14	1914	11,600	1912–63	7,000	
3145	Marys River at Buena Vista Ranch near Deeth	Lat 41°26′, long 115°15′, in NW¼ sec. 19, T.41 N., R.60 E., 1½ miles north of Buena Vista Ranch, near Deeth.	[1]300	[2]1913–14	1914	68,800			Upstream diversions
	Humboldt River at Deeth	Near sec. corner common to secs. 25, 26, 35, and 36, T.37 N., R.59 E., at U.S. Highway 40, at Deeth.		[3]1931, [3]1935, [3]1937–39	1937–39	40,000			Total flow in Humboldt and Marys Rivers plus Anderson ditches. Upstream diversions
	Reed Creek	NE¼ sec. 3, T.35 N., R.59 E., at county road, 8 miles east of Halleck.	[1]6	[3]1952–54	1952–54	1,000	1912–63	1,000	
	Talbot Creek	NE¼NE¼ sec. 28, T.33 N., R.58 E., 2½ miles east of Lamoille.	[1]7	[3]1935, [3]1938, [3]1952–59	1952–59	[8]7,000	1912–63	[8]7,200	Upstream diversions of 120 to 800 acre-feet per year
	Thorpe Creek	SW¼SW¼ sec. 10, T.33 N., R.58 E., 3 miles northeast of Lamoille.	[1]17	do.	1952–59	[8]8,600	1912–63	[8]9,000	Upstream diversions of 120 to 800 acre-feet per year
	Soldier Creek	SW¼SE¼ sec. 32, T.34 N., R.59 E., 8 miles northeast of Lamoille.	[1]8	[3]1935, [3]1938, [3]1952–53	1952–53	4,600	1912–63	4,300	No upstream diversions
	Secret Creek	NE¼NE¼ sec. 33, T.35 N., R.59 E., at county road, above 71 Ranch, 9 miles southeast of Halleck.	[1]40	[3]1935, [3]1937–41, [3]1952–54	1952–54	9,900	1912–63	11,000	Upstream diversions
	Rabbit Creek	SW¼SW¼ sec. 1, T.32 N., R.57 E., 3½ miles south of Lamoille.	[1]6	[3]1940, [3]1952–59	1952–59	8,100	1912–63	8,500	No upstream diversions
	Susie Creek	NW¼ sec. 25, T.33 N., R.52 E., at U.S. Highway 40, 1½ miles east of Carlin.	[1]190	[3]1931, [3]1935, [3]1938–42, [3]1951–54	1935, 1938–42	4,900	1912–63	5,000	About 190 water-right acres upstream
	Maggie Creek	Sec. 4 or 5, T.33 N., R.52 E., about 5 miles north of Carlin (exact location on map uncertain).		[3]1951–59	1951–59	20,000			Major diversions upstream
3240	Rock Creek at Rock Creek Ranch near Battle Mountain	Lat 41°06′, long 116°43′, in sec. 7, T.37 N., R.47 E., 1,000 ft below diversion dam at mouth of canyon and 35 miles north of Battle Mountain.		[2]1915–17					
3260	Reese River near Berlin	Lat 38°54′, long 117°29′, in SW¼ sec. 16, T.12 N., R.40 E., just upstream from mouth of Illinois Creek, and 7 miles east of Berlin.		[2]1913–16	1914	18,900			Small diversion upstream
3265	Big Creek near Austin	Lat 39°21′, long 117°09′, in sec. 9, T.17 N., R.43 E., near Toiyabe National Forest boundary and 14 miles southwest of Austin.	[1]9	[2]1914, [2]1916					Small diversion upstream

[1]Approximate.
[2]Fragmentary.
[3]Seasonal discharge record collected by Humboldt River Water Distribution District.
[4]Under Humboldt River Decrees, additional irrigated acreage not covered by these Decrees.
[5]Includes flow in Humboldt-Lovelock Irrigation, Light and Power Company's feeder canal.
[6]With Rye Patch Reservoir operating, adjusted to reference period.
[7]Estimated discharge if Rye Patch Reservoir had been operating during reference period.
[8]Adjusted for water diverted upstream.

TABLE A-4. MAXIMUM DISCHARGE AT SELECTED GAGING STATIONS

Station number	Station name	Drainage area (sq mi)	Period of record	Maximum Discharge: Date	Maximum Discharge: Discharge (cfs)
3130	Starr Creek near Deeth	[1]60	1913–24	June 9, 1921	[2]391
3150	Marys River near Deeth	355	1912–28	May 8, 1922	[2]616
3155	Marys River above Hot Springs Creek, near Deeth	415	1944–63	Feb. 12, 1962	4,210
3160	Secret Creek near Halleck	[1]34	1917–24	Apr. 23, 1921	[2]375
3165	Lamoille Creek near Lamoille	[1]25	1915–16, 1918–20, 1922, 1944–63	June 4, 1957	[3]794
3170	Lamoille Creek near Halleck	245	1913–19	June 5, 1914	556
3175	North Fork Humboldt River at Devils Gate, near Halleck	[1]830	1914–19, 1921, 1944–63	Feb. 11, 1962	10,400
3180	North Fork Humboldt River near Halleck	[1]1,020	1898, 1899, 1905–9, 1912, 1913	April 16, 17, 1899 Feb. 13, 1962[4]	[2]1,580 5,220
3185	Humboldt River near Elko	[1]2,800	1896–1902, 1945–63	Feb. 13, 1962	7,070
3190	South Fork Humboldt River near Lee	[1]54	1945–55	May 27, 1951	935
3195	Huntington Creek near Lee	[1]770	1949–63	Feb. 10, 1962	2,160
3200	South Fork Humboldt River above Dixie Creek, near Elko	[1]1,150	1949–63	Feb. 11, 1962	2,760
3205	South Fork Humboldt River near Elko	[1]1,310	1897–1909, 1911–18, 1921, 1924–32, 1937–63	Feb. 11, 1962	2,830
3230	Pine Creek near Palisade	999	1912–14, 1946–58	Mar. 27, 1952 Feb. 11, 1962[4]	1,010 3,140
3235	Humboldt River near Argenta	[1]7,490	1946–63	Feb. 15, 1962	6,000
3245	Rock Creek near Battle Mountain	[1]875	1896, 1918–23, 1946–63	Feb. 11, 1962	4,800
3250	Humboldt River at Battle Mountain	[1]8,870	1897, 1921–24, 1946–63	May 3, 4, 1952	[5]5,800
3255	Reese River near Ione	[1]44	1952–63	July 27, 1956	512
3270	Humboldt River near Valmy	[1]11,500	1950–58	May 5, 6, 1952	[5]5,800
3275	Humboldt River at Comus	[1]12,100	1895–1908, 1911–23, 1925, 1926, 1946–63	May 6, 1952	5,860
3280	Pole Creek near Golconda	10.7	1961–63	Aug. 5, 1961	[1]4,000
3285	Little Humboldt River at Chimney dam site, near Paradise Valley	[1]720	1942–50	Jan. 22, 1943[1]	4,000
3290	Little Humboldt River near Paradise Valley	[1]1,030	1922–23, 1925–27, 1944–63	Feb. 2, 1952	1,100
3295	Martin Creek near Paradise Valley	172	1922–27, 1929–33, 1935–63	Jan. 21, 1943	9,000
3300	Cottonwood Creek near Paradise Valley	[1]13	1926–29, 1931–33	Mar. 19, 1932	183
3305	Cottonwood Creek at Paradise Valley	57.4	1945–51	Mar. 19, 1950	794

3210	Humboldt River near Carlin	[1]4,310	1944–63	Feb. 14, 1962	6,160
3215	Susie Creek at Carlin	82.5	1956–58	Jan. 15, 1956	184
3220	Maggie Creek at Carlin	[1]400	1914–24	May 7, 1922 Feb. 12, 1962[4]	[2]800 2,440
3225	Humboldt River at Palisade	[1]5,010	1903–5, 1912–63	Feb. 12, 1962 Feb. 28, 1910[4]	6,610 [1]17,000
3309	Humboldt River near Winnemucca	[1]14,600	1961–63	July 7, 1963	1,350
3315	Humboldt River near Rose Creek	[1]15,200	1948–63	May 8, 1952	5,810
3330	Humboldt River near Imlay	[1]15,700	1936–41, 1945–63	May 9, 1952	6,080
3350	Humboldt River near Rye Patch	[1]16,100	1896–98, 1900–09, 1911–22, 1927, 1928, 1930, 1931, 1936–41, 1944–63	May 11, 12, 1952	4,720
3360	Humboldt River near Lovelock	16,600	1914–16, 1921, 1922, 1926, 1951–59	May 19, 1952	3,540

[1]Approximate.
[2]Maximum observed discharge.
[3]Caused by failure of upstream diversion dam.
[4]Outside of period of record.
[5]Maximum daily discharge.

1962, and 1963. For this study, a series of streamflow measurements were made during the 1964 and 1965 water year by the Humboldt River Water Distribution District at 26 sites, and a series of low-flow measurements were made along the Humboldt River in early September and early November 1964. Parts of these data are published in "Surface Water Records of Nevada" for 1964, and the rest of the data will be published in the 1965 edition of the above report.

Additional miscellaneous streamflow measurements have been made at sites within the Humboldt River basin. Measurements made by the Geological Survey have generally been published in the Annual Water-Supply Papers for The Great Basin, Part 10, prior to 1961 and in "Surface Water Records of Nevada" since then. Numerous measurements made by the Humboldt River Water Distribution District in conjunction with the distribution of water from the Humboldt River and its tributaries are filed in their Elko Office. Also, the Nevada Fish and Game Commission has made a number of measurements which are filed in their Reno office.

INTERPRETATIVE AND RELATED REPORTS

A series of reports, collectively entitled, "Water and Related Land Resources, Humboldt River Basin, Nevada," (Nevada Department of Conservation and Natural Resources and U.S. Department of Agriculture, 1962–65) on subbasins of the Humboldt River, contain selected information on water resources and use. Cohen (1963 and 1964a) in Nevada Water Resources Bulletins 24 and 27 concerning the Humboldt River Research Project conducted on an area near Winnemucca during 1959–64 discussed the water resources. Some information on surface water is contained in areal ground-water investigations.

Several reports, the most recent by Hennen (1964), relating to the distribution of water for irrigation in the Humboldt River basin have been prepared by the Nevada Department of Conservation and Natural Resources. Also, reports (Mashburn and others, 1935 and 1943) on the adjudication of water rights for the Humboldt River and Little Humboldt River have been prepared by the State Courts. Additionally, court records of adjudications in the basin are on file in the State Courts.

GROUND WATER

WELL DATA

Information on wells within the Humboldt River basin is on file in the State Engineer's office. Well drillers file this information in accordance with the requirements of State Ground Water Law. In areas where ground-water studies have been made, field inventories of wells and available information are included in the resultant report. The available well data are relatively complete as of the end of the field investigation in the respective areas. These data commonly include depth of well, casing diameter, depth to water, drillers' log, and approximate location. They also may include, results of test or development pumping, and types of pumping equipment.

WATER-LEVEL RECORDS

Periodic water-level measurements commonly are made in areas where ground-water studies extend over a moderate period of time. Thus, in the study of the Winnemucca section, periodic water-level measurements were made at some 150 observation points during a several-year period.

Similarly, the Department of Conservation and Natural Resources has made periodic water-level measurements during the last 5 years in about 37 wells in the general area of Boulder Valley and Battle Mountain. Depending upon the purposes of study, water-level measurements may be made continuously with water-stage recorders or as infrequently as about one measurement a year. Information on water-level records and fluctuations generally is given in the reports covering the specific area.

Under a general program of water-level observation, periodic measurements have been made by the Geological Survey on 75 wells in the Humboldt River basin. Water-level data for these wells have been published in Nevada Water Resources Bulletin 3 and subsequently in several Geological Survey Water-Supply Papers. The locations of these wells are shown in figure A–2. Table A–5 gives the well locations, periods of record, and published reports in which the data are given.

SPRING DATA

Most springs having defined flow have been appropriated under the Surface Water Law. Locations of these springs are on file in the State Engineer's office. Many of the springs have been measured at least once in conjunction with their appropriation or adjudication. Many of the larger springs have been described briefly in Water-Supply Papers by Meinzer (1927) and Stearns and others (1935). A recent report (Lamke and Moore, 1965, table 2) lists several of the well-known springs in the Humboldt River basin. Only a few springs in the basin have been measured and none have been measured frequently or continuously to establish their flow characteristics. The discharge and chemical quality of water from springs is discussed in ground-water reports.

The locations of some of the larger and better-known springs are shown on figure A–3. Some of the data for these springs are given in table A–6. However, many other springs occur within the basin. Most of the latter springs occur in the mountains and alluvial apron areas, have small yields, and usually are used for watering stock.

PUMPAGE INVENTORIES

Ground water is pumped to some extent throughout the Humboldt River basin. Most of the pumped wells are used for stock, ranch, and domestic supply. The widespread distribution of these wells and the small average rates of pumping have a negligible effect on the hydrologic system of the basin. For many years ground water has been pumped for public supply at Battle Mountain, Elko, Lovelock, Wells, and Winnemucca as well as at many other communities. Collectively the annual pumpage for these purposes probably is not more than 6,000 or 7,000 acre-feet.

No basin-wide inventory of annual pumpage has been made. However, the number of wells drilled for irrigation in the last few years has increased every year. It seems likely that pumpage for irrigation probably did not exceed about 50,000 acre-feet in 1964 but can be expected to increase rapidly as more wells are put into operation. Pumpage for municipal, domestic, and stock and industrial use also is increasing.

A limited amount of ground water has been pumped for irrigation, beginning about 20 years ago with a few wells in Paradise and Grass Valleys. During the last several years, pumpage for irrigation has increased considerably. The increase has been related to land development

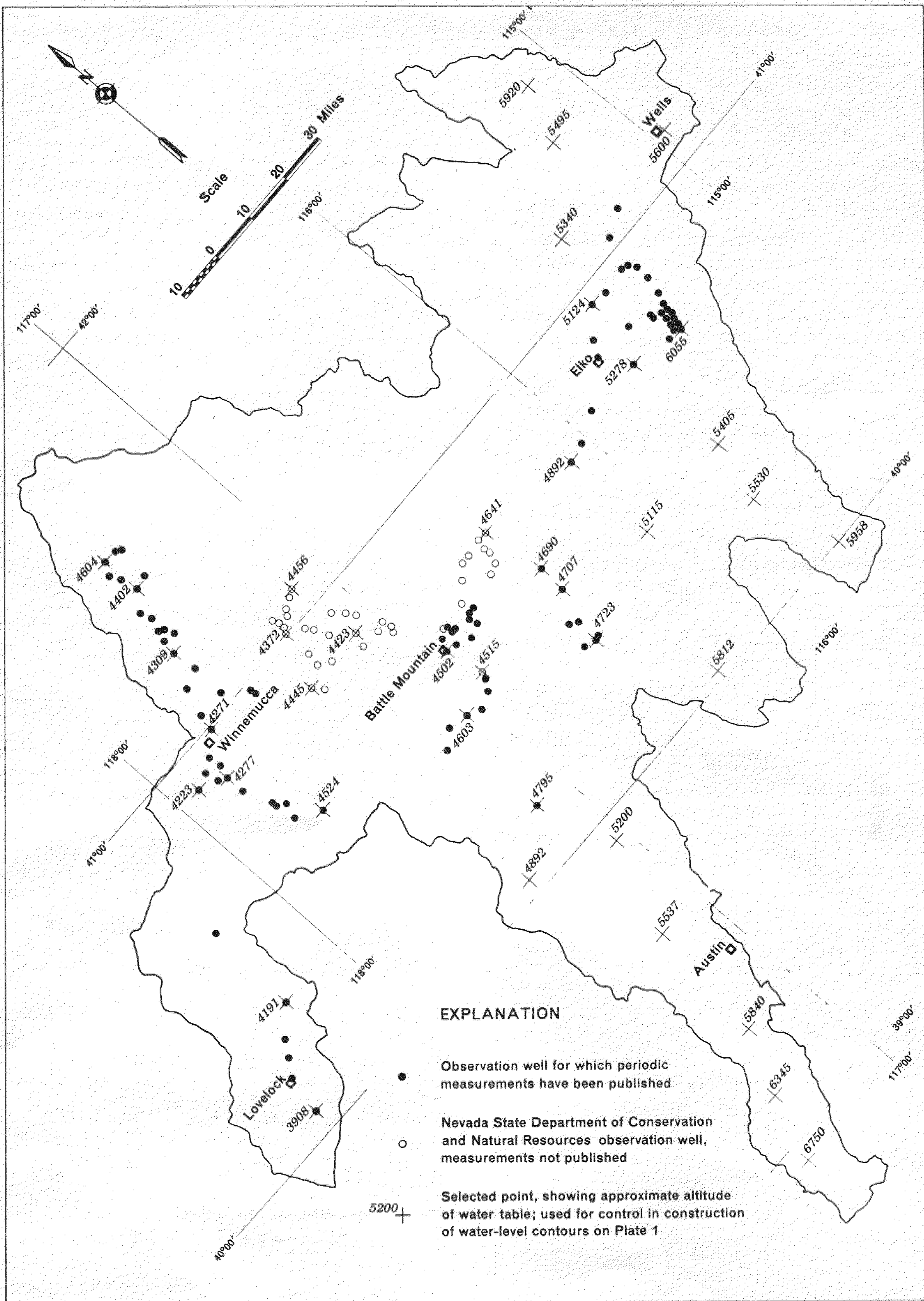
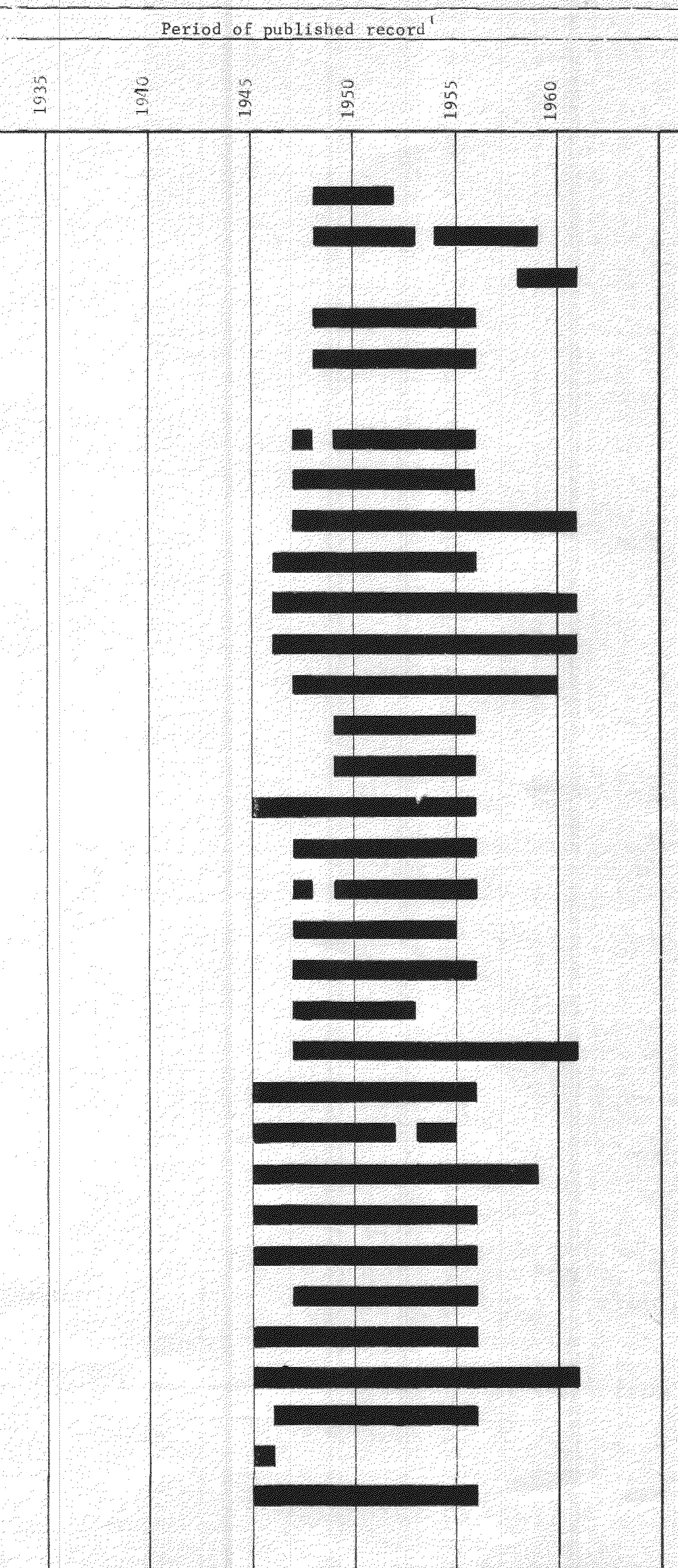


FIGURE A–2. Map showing location of selected observation wells.

TABLE A-5—(Continued)

PART I—(Continued)

Location	Owner and common name of well as described in publication
	Eureka County
29/48-3d1	U. S. Geological Survey
29/48-34c1	Dan Filippini
29/48-34c2	Dan Filippini
30/49-6a1	U. S. Geological Survey
31/49-5c1	Wm. Connelly
	Humboldt County
35/36-14c1	Charles Hilyer
35/37-2b1	Henry Harrar
35/37-8d2	D. H. McNinch
35/37-14d3	Kenneth Eddie
35/37-28b1	U.S. Bureau of Land Management
35/37-34a2	Unknown
36/38-16c1	Geo. Hay Co.
36/40-19d1	Diamond S. Ranch
36/40-30aa1	Diamond S. Ranch
37/38-2a1	U.S. Bureau of Land Management
37/38-33d1	Geo. Hay Co.
37/39-33d1	Bullhead Ranch
38/39-28d1	Cordoza
39/39-3c1	Gerhard Miller Sr.
39/39-11b1	George Miller Sr.
39/39-16d1	Dwight C. Vedder
39/39-24b1	Dwight C. Vedder
39/39-33c1	Unknown
40/39-10d1	Unknown, formerly C. L. Lewis
40/39-26b1	Henry McCleary Timber Co.
41/40-6c1	J. Boggio
41/40-22d1	Ernest Gondra
41/40-30a1	Shelton School
42/39-25c1	U.S. Bureau of Land Management
42/40-14c1	J. M. Freeman
42/40-15d1	C. E. Roberts
42/40-18a1	E. C. Lye

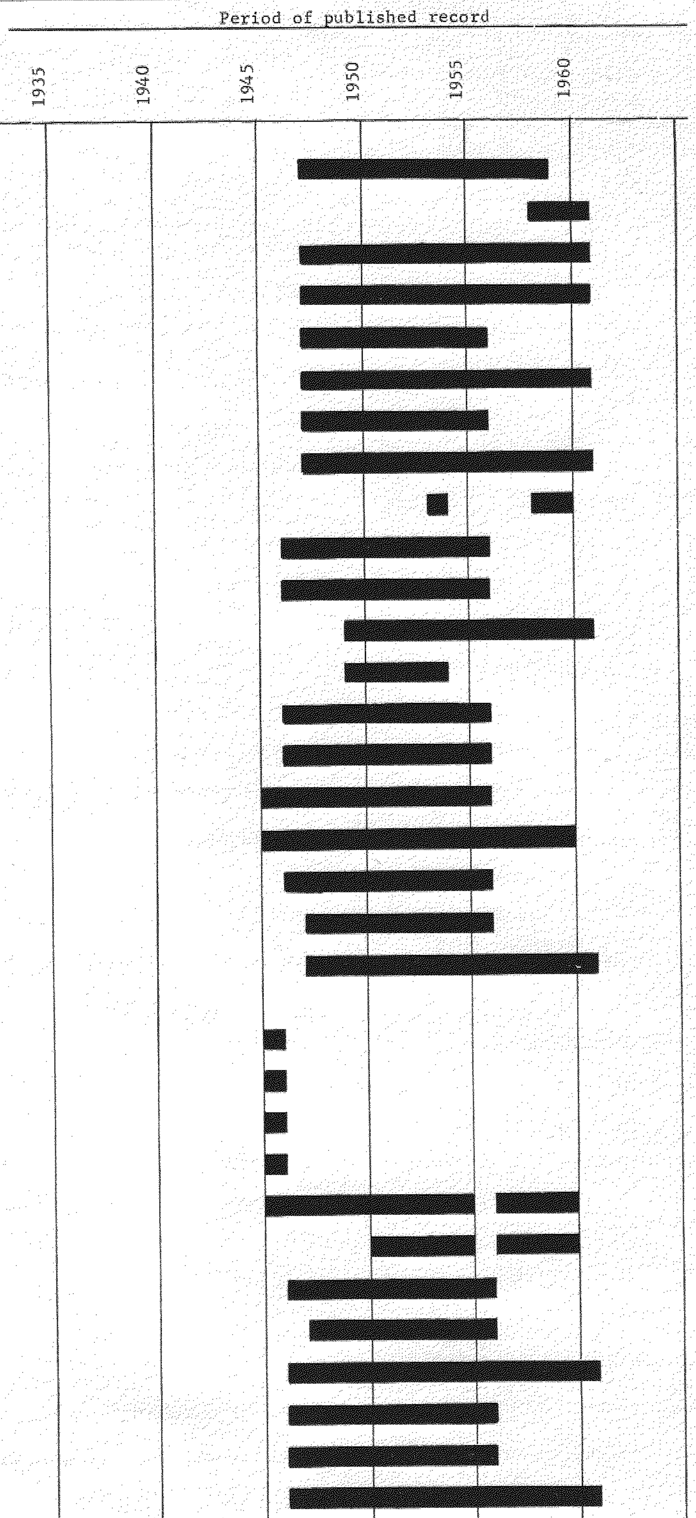


See footnote on page 94.

TABLE A-5—(Continued)

PART I—(Continued)

Location	Owner and common name of well as described in publication
	Lander County
27/43-33cd1	Unknown, at Watts
29/48-29c2	Beowawe Farms
30/42-24cc1	U.S. Bureau of Land Management
30/43-9aa1	Copper Canyon Mining Co.
30/44-18ad1	Copper Canyon Mining Co.
30/44-22cb1	Unknown at Dillon
30/45-4bd1	Martin Jenkins Ranch
30/45-18aa1	U.S. Bureau of Land Management
30/48-33c1	H. J. Buchaneau
32/45-2a1	E. Marvel
32/45-9ab1	Unknown
32/45-11d1	U.S. Geological Survey
32/45-11d2	U.S. Geological Survey
32/45-20b1	R. M. Clark
32/45-22c1	Unknown
32/46-10d1	U.S. Bureau of Reclamation
32/46-11d1	U.S. Bureau of Reclamation
32/46-16d1	U.S. Bureau of Reclamation
32/46-27ba1	Southern Pacific Co.
32/48-31bb1	Humboldt Petroleum Co.
	Pershing County
25/31-4c1	T. O. Roberts
27/31-26c1	Pershing Co. General Hospital
27/32-7a1	C. Elges
28/32-28a1	H. Marker
29/33-33c1	Southern Pacific Co.
32/33-28d1	Cliff & Cecil Campbell
32/38-18b1	U.S. Bureau of Land Management
32/38-36b1	Fred Kerlee
33/37-24a1	Lloyd Sweeney
33/37-24d1	Lloyd Sweeney
33/38-32b1	U.S. Bureau of Land Management
34/37-22a1	J. Ballard



[1]Measurements of water levels prior to 1946 are contained in State of Nevada Water Resources Bulletin No. 3. Measurements made in 1946 and subsequent years are published in a series of U.S. Geological Survey Water-Supply Papers entitled "Water Levels and Artesian Pressures in Observation Wells in the United States, Part 6. Southwestern States and Territory of Hawaii." The following Water-Supply Papers contain measurements for the period of time indicated: No. 1170, from 1946–50; No. 1196, 1951; No. 1226, 1952; No. 1270, 1953; No. 1326, 1954; No. 1409, 1955; and No. 1770, from 1956–60.

TABLE A-5—(Continued)

PART II. Miscellaneous measurements of selected wells published in previous reports.

Type of publication	Area	Year published	Number of wells for which information was published
State of Nevada Department of Conservation and Natural Resources Bulletins:			
No. 2	Lovelock Valley	1946	20
No. 10	Paradise Valley	1949	136
No. 12	Vicinity of Elko	1951	15
State of Nevada Department of Conservation and Natural Resources Reconnaissance Series:			
No. 2	Pine Valley	1961	15
No. 5	Imlay Area	1962	11
No. 19	Antelope and Middle Reese River Valley	1963	65
No. 29	Grass Valley	1964	59
No. 31	Upper Reese River Valley	In press	65
No. 33	Lovelock Valley	In press	37
No. 35	Huntington Valley	In press	65
U.S. Geological Survey Water-Supply Papers:			
425-D	Reese River Basin	1918	30
1581	Crescent Valley	1961	30

TABLE A-6. LARGER AND BETTER-KNOWN SPRINGS LOCATED WITHIN THE HUMBOLDT RIVER BASIN

More detailed information on these springs is available in the reference listed. The abbreviations listed under references refer to:

WRB—Nevada Water Resources Bulletin.
Rec.—Nevada reconnaissance series report.
WSP—U.S. Geological Survey Water-Supply Paper.

Map no.	Name	Location	Discharge (gallons per minute)	Date measured	Reference	Remarks
		Elko County				
1	Carlin Springs	Sec. 33, T.33 N., R.52 E., 1½ miles southwest of Carlin.	2,700 est.		Dept. of Conservation	Carlin water supply.
2	Elko Hot Springs	SE¼ sec. 21, T.34 N., R.55 E., 1 mile southwest of Elko.	450 est.		do.	
3	Holland Springs	NE¼ sec. 20, T.33 N., R.58 E., 1½ miles northeast of Lamoille.	900 est.		do.	Several springs.
4	Hot Creek Springs	Sec. 32, T.43 N., R.60 E., 35 miles north of Deeth.	450 est.		do.	
5	Hot Springs	Sec. 15, T.39 N., R.59 E., 14 miles north of Deeth.	350		do.	
6	Spring Creek	Sec. 8, T.37 N., R.57 E., 22 miles northeast of Elko.	2,000 est.		do.	
7	Willow Creek Springs	Sec. 31, T.31 N., R.57 E., 5 miles northeast of Jiggs.	600 est.		do.	
		Eureka County				
8	Hot Springs	Sec. 12, T.28 N., R.52 E., 27 miles south of Carlin.	2,000 est.	1960	Rec. 2, p. 26	Six springs.
		Humboldt County				
9	Golconda Hot Springs	SE¼ sec. 29, T.36 N., R.40 E., at Golconda.	200 est.	1962	WRB 24, p. 73	Total flow of thermal springs.
10	Hot Springs	Sec. 35, T.37 N., R.43 E., 33 miles northeast of Winnemucca.	2,000 est.		Dept. of Conservation	
		Lander County				
11	Hot Springs	NE¼ sec. 23, T.27 N., R.43 E., 34 miles south of Battle Mountain.	450 est.	1918	WSP 679B, p. 161	Several springs.
12	Izzenhood Ranch Springs	T.35 N., R.45 E., 20 miles north of Battle Mountain.	1,000 est.	1917	WSP 679B, p. 160	
13	Beowawe Geysers	Secs. 17, 18, T.31 N., R.48 E., 8 miles southwest of Beowawe in Eureka and Lander Counties.	50		WSP 679B, p. 161	About 35 springs on tufa terrace and nearby lowland.

under provisions of the Desert Land Act, in areas such as upper Reese River valley and middle Reese River-Antelope Valleys. However, pumpage also has increased as the result of efforts to supplement deficient surface-water supplies during drought years or for expanded irrigation activities on existing ranches.

It is estimated that about 150 wells may be pumped for irrigation in the Humboldt River basin. Of these about half are used to irrigate land withdrawn under the Desert Land Act and provide the entire irrigation supply, if the land is farmed. The remaining wells are used during part of almost every year, principally to supplement surface-water supplies.

Pumpage inventories, or estimates, have been made at the time of ground-water investigations, some of which are several years old and thus do not necessarily reflect current conditions. Available estimates of annual pumpage in acre-feet, for irrigation are:

Battle Mountain-Boulder Valley (Loeltz and Malmberg, 1961, p. 14)	2,200
Crescent Valley (Loeltz and Malmberg, 1961, p. 14)	2,000
Grass Valley (Cohen, 1964b, p. 2)	5,000
Middle Reese River-Antelope Valleys (Crosthwaite, 1963, p. 14)	4,000
Upper Reese River Valley (Eakin, Moore, and Everett, 1965, p. 35)	3,000
Paradise Valley (Loeltz and Malmberg, 1961, p. 15)	6,500
Humboldt River valley near Winnemucca (Cohen, 1963, p. 74)	4,000

AREAL INVESTIGATIONS

The most intensive ground-water studies made within the Humboldt River basin are those in the Humboldt River valley between Comus and Rose Creek—commonly referred to as the Winnemucca area. These studies (Cohen, 1963 and 1964a) were made as a part of the Humboldt River Research Project during the period 1959–64, and included data on most phases of ground water with particular emphasis on its interrelation with the Humboldt River. Areal ground-water resource evaluations have been made in 9 other areas as shown in figure A–4. Other local or special purpose studies have been made.

CHEMICAL QUALITY OF WATER

Cohen (1962d, 1963, and 1964a) describes the water quality of both surface and ground water in the Humboldt River valley near Winnemucca. Variations in water quality and the relation between water quality and the source and movement of water are emphasized as well as the suitability of the water for domestic and agricultural uses. The studies were based on more than 225 chemical analyses of water samples which were collected in July and August 1961, November and December 1961, and April and May 1962.

Miller (1950) described the quality of Humboldt River water with emphasis on its suitability for agricultural use. Water samples were collected several times a month between 1941 and 1949 from the Humboldt River at Palisade, Comus, Callahan Bridge, and below Rye Patch Reservoir.

At the gaging station (3350) below Rye Patch Reservoir, daily samples have been collected during the periods December 1951 to September 1958, October 1959 to September 1961, and May 1962 to the present (1966). At Palisade gaging station (3225) daily samples were collected for the period May 1962 to August 1964. Subsequently daily sampling has been continued at the gaging station near Carlin (3210). These data are published annually in the U.S. Geological Survey Water-Supply Paper series under the title "Quality of Surface Waters in the United States, Parts 9–14."

During this investigation, a limited number of samples was collected at additional points along the Humboldt River and the principal tributaries. These and the three daily sampling locations are shown in figure 31.

The quality of both surface and ground water and its suitability for agricultural uses is described in water-resources reconnaissance reports by Cohen (1964b), Crosthwaite (1963), Eakin (1962), Eakin, Moore, and Everett (1965), Everett and Rush (1965), and Rush and Everett (1965) for Grass Valley, Antelope and middle Reese River Valleys, the Imlay area, upper Reese River valley, Lovelock Valley, and Huntington Valley, respectively.

The report "Analyses of municipal water supplies of Nevada," published by the Nevada State Department of Health in 1962, includes analyses for eight localities in the Humboldt River basin.

Samples of water submitted by Nevada residents also are analyzed by the Agricultural Experiment Station to determine suitability for

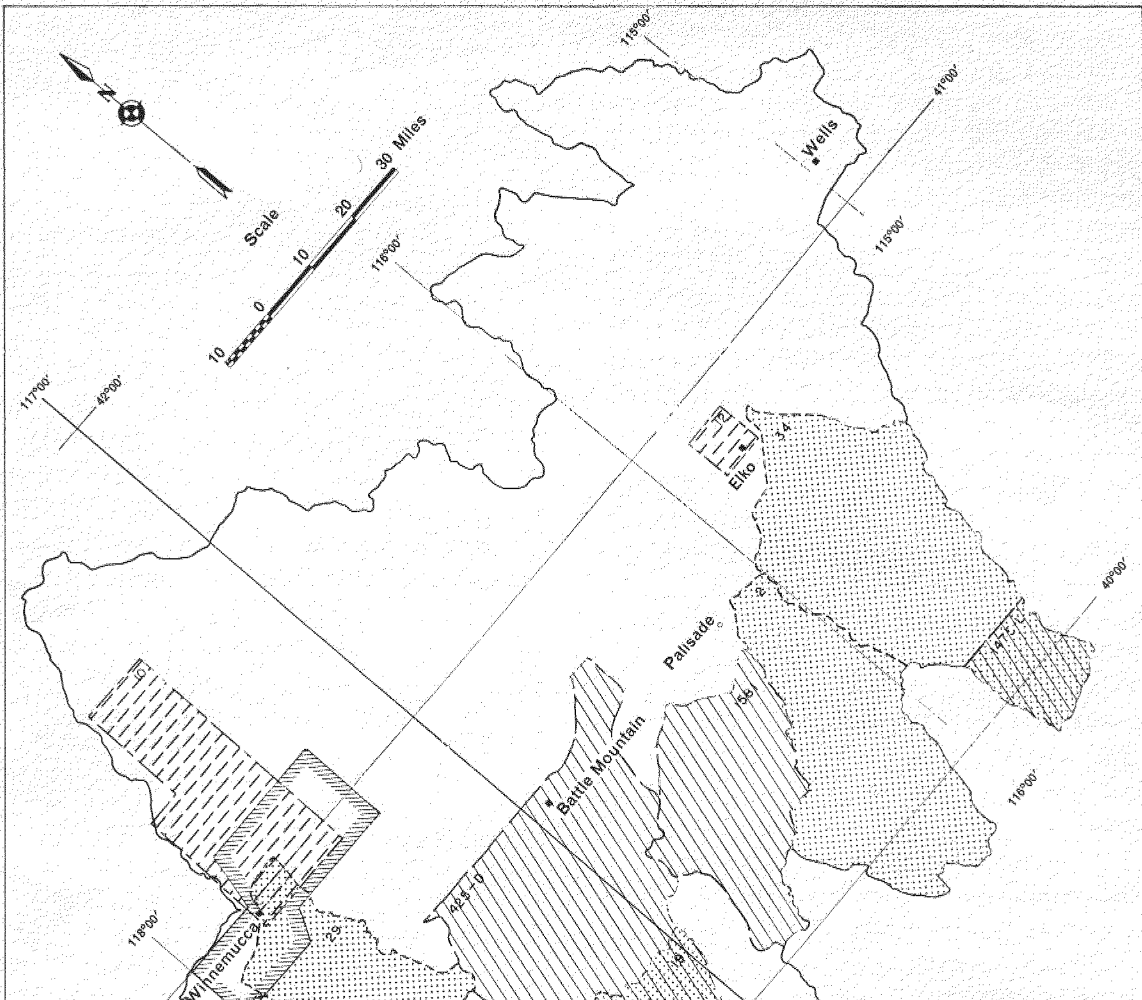


FIGURE A-4. Map showing location of areal ground-water studies.

irrigation. Similarly, samples of water submitted to the Nevada Department of Health are analyzed to determine suitability for domestic use. Many samples have been analyzed by these two agencies and their results are on file in the respective offices.

GEOLOGY

A substantial amount of geological investigation has been made in the Humboldt River basin. To a large extent investigations have been oriented toward clarification of the Paleozoic and Mesozoic stratigraphy and the structure of the region. More recently, increased attention has been given to the Tertiary rocks. Only a small part of the total geologic effort has been directed to Quaternary geology within the basin.

Plate A–1 is a generalized geologic map of the Humboldt River basin and is after the geologic map of Nevada, compiled by K. M. Tagg and others *in* Mineral and Water Resources of Nevada (U.S. Geological Survey and Nevada Bureau of Mines, 1964). The present map contains a few modifications by the same authors made since the map was published. That report also contains concise statements of the various aspects of the complex geology relating to the Humboldt River basin. These include articles by J. H. Stewart on the Precambrian and Lower Cambrian rocks, R. J. Roberts on the Paleozoic rocks, N. J. Silberling on the Mesozoic rocks, J. P. Albers on the Tertiary and Quaternary rocks, R. R. Coats on the intrusive rocks, and R. E. Wallace on the structural evolution. Table 2 of that publication lists the published references used in the preparation of the geologic map of Nevada. Figure 5 of that publication shows areas of geologic mapping at scales of 1:250,000 or larger. Residual areas are shown as provisional and subject to revision upon completion of more detailed mapping. Within the Humboldt River basin, geologic mapping in some degree is available for most of the basin. Some areas have been studied in substantial detail. However, for a large part of the basin, principally in Elko and Lander Counties, the geology is known only in general terms.

Most of the localized studies for hydrologic purposes have been made as a part of the Humboldt River Research Project. For example, Bredehoeft (1963) mapped valley-fill deposits in the lower Humboldt River basin and prepared local lithofacies maps based on interpretation of drillers' logs. Hawley and Wilson (1965) examined the Quaternary geology in the Winnemucca area. Dudley and McGinnis (1964) conducted experiments with seismic refraction and electrical resistivity instruments in the vicinity of Winnemucca. Cartwright, Swinderman, and Gimlett (1964) made a gravity survey to explore the possibility of a bedrock high in the Rose Creek area southwest of Winnemucca. The relation of geology to groundwater hydrology is included in the reconnaissance studies which have been made in nine valley areas of the basin. (See fig. A–4.) Much of the published information on geology in the Humboldt River basin is given in the list of selected references.

MAPS

TOPOGRAPHIC MAPS

Topographic maps provide a valuable base in mapping various features and data pertaining to the hydrology of an area. For the entire Humboldt River basin, topographic maps are now available at the following scales:

(a) 1:1,000,000, contour interval 1,000 feet; Map of Nevada prepared by the Nevada Bureau of Mines from the 1:1,000,000 U.S. aeronautical charts; available in ozalid prints.

(b) 1:500,000, contour interval 500 feet; Map of Nevada, prepared by U.S. Geological Survey, 1964. Available from U.S. Geological Survey, Map Information Office, Menlo Park, California, Denver, Colorado, or Washington, D.C.

(c) 1:250,000, contour interval 200 feet; Series of 1° by 2° quadrangles, prepared by the Army Map Service, with limited revision by the U.S. Geological Survey. Available through U.S. Geological Survey, Map Information Office. Humboldt River basin area is included in part on Elko, Ely, Lovelock, McDermitt, Millett, Reno, Tonopah, Winnemucca, and Wells quadrangles of this series.

Large scale topographic maps are available for parts of the Humboldt River basin. Figure A–5 shows the distribution of available topographic maps at a scale of 1:62,500, about one mile to the inch. Topographic maps published at a scale of 1:24,000 are available in the vicinity of Elko. However, blue-line prints can be obtained for a number of areas where 1:62,500-scale maps have been published. All published and large-scale blue-line topographic maps are available through the U.S. Geological Survey, Map Information Office, Menlo Park, California.

The Soil Conservation Service prepared a topographic map of the flood plain of the Humboldt River between Comus and Rose Creek, near Winnemucca, for use in the Humboldt River Research Project. The map, which is at the scale of 1:24,000 and which has a contour interval of 2 feet, is on file at their office in Reno.

OTHER BASE MAPS

Early in the Humboldt River Research Project Studies, the Soil Conservation Service prepared planimetric base maps of the Humboldt River basin at several scales. These maps were based on the 1:250,000-scale topographic quadrangles, referred to above.

AERIAL PHOTOGRAPHY

Aerial photography is available for the entire Humboldt River basin. This photography was flown during the middle 1950's and was used to prepare the 1:250,000-scale topographic quadrangles. Most of the flying was at an altitude of 40,000 to 60,000 feet and provides photographs at a scale of approximately 1 mile to an inch. Almost all of the 1:62,500 topographic quadrangles were constructed from aerial photography flown for that purpose.

Additional low-altitude photography of the Humboldt River flood plain near Winnemucca was used by the Soil Conservation Service in preparation of the large-scale topographic map of the flood plain.

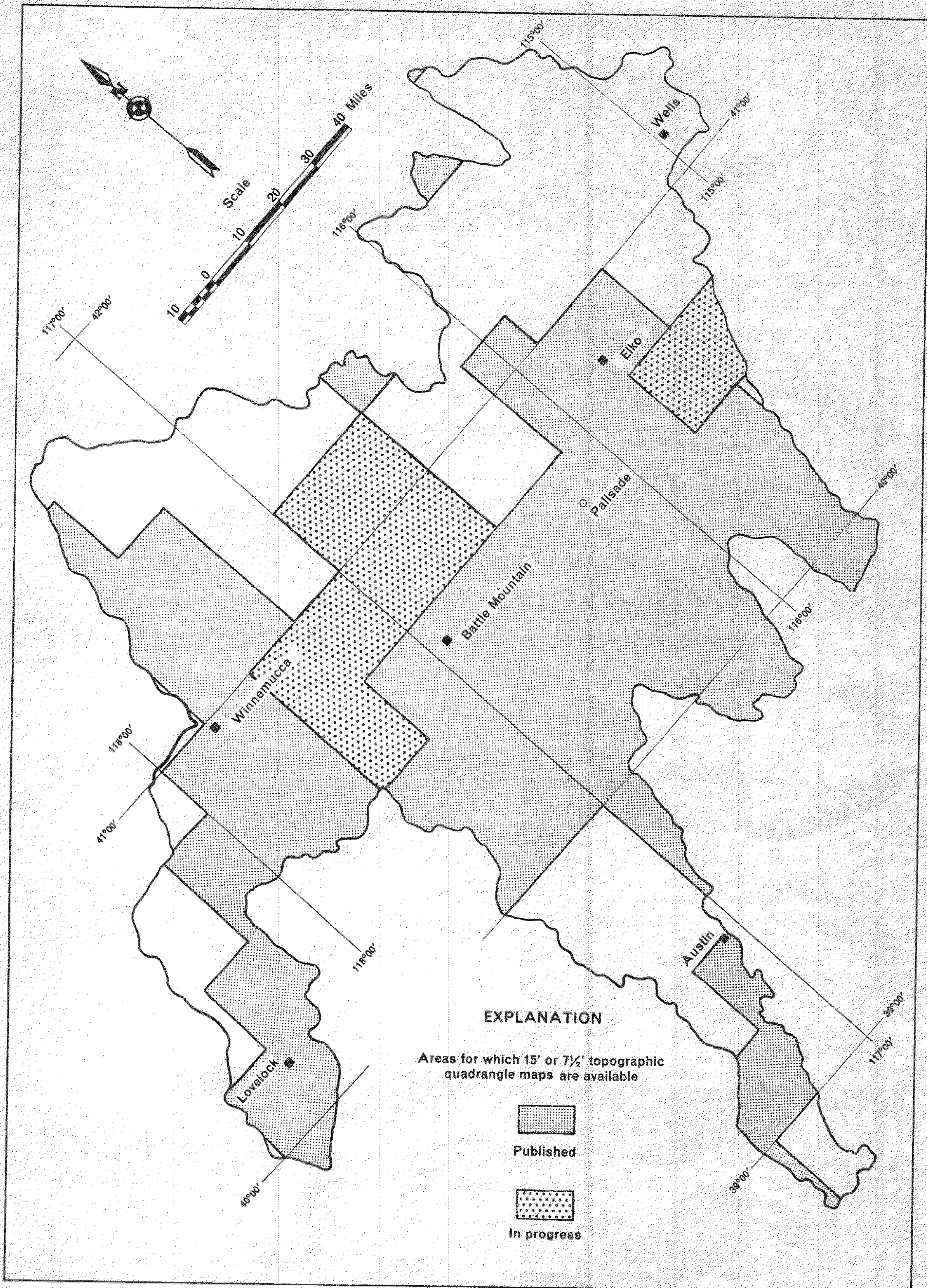


FIGURE A-5. Map showing topographic coverage as of April 1, 1965.

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(30)

EXPLANATION

QUATERNARY
- Qa — Alluvium

TERTIARY AND QUATERNARY
- QTv — Volcanic rocks

TERTIARY
- Tu — Rocks, undifferentiated
- Ts — Sedimentary rocks

MESOZOIC OR TERTIARY
- TMzi — Intrusive igneous rocks

MESOZOIC
- Mzu — Rocks, undifferentiated

MISSISSIPPIAN THROUGH PERMIAN
- PMs — Sedimentary rocks

CAMBRIAN THROUGH DEVONIAN
- D€s — Sedimentary rocks

PRECAMBRIAN AND CAMBRIAN
- €p€q — Quartzose sedimentary rocks

Pzu — Undifferentiated rocks, mainly Paleozoic

PRECAMBRIAN
- P€m — Metamorphic rocks

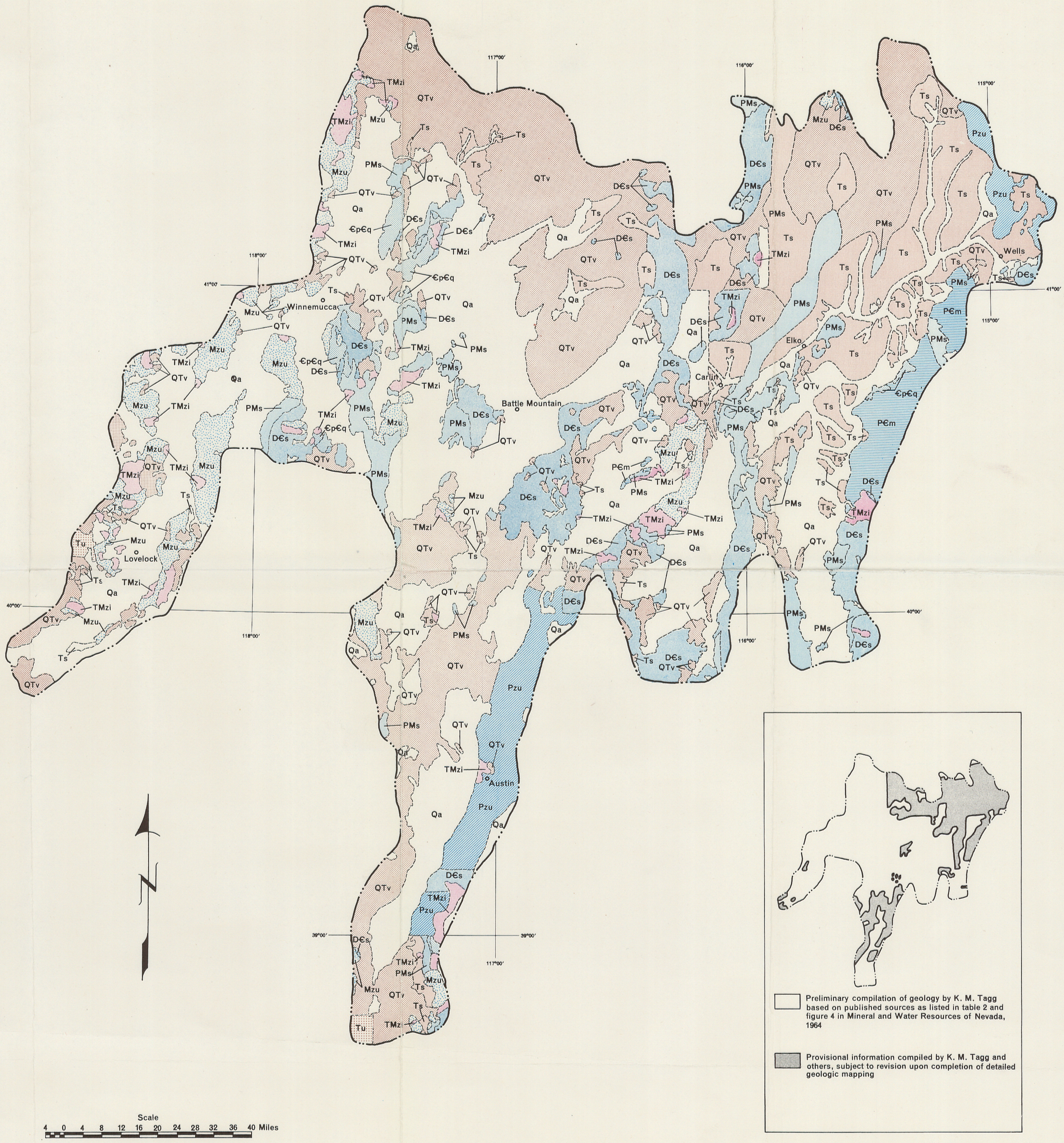

PLATE A-1.—GENERALIZED GEOLOGIC MAP OF THE HUMBOLDT RIVER BASIN, NEVADA