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THE UNIVERSITY OF WYOMING

WATER RESOURCES RESEARCH INSTITUTE

P. O. BOX 3038, UNIVERSITY STATION

LARAMIE, WYOMING 82070

TELEPHONE: 766-2143
AREA CODE: 307

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CHARACTERISTICS OF WYOMING STOCK-WATER PONDS AND DIKE SPREADER SYSTEMS

Verne E. Smith July 1974

ABSTRACT

Based on information from all available studies, an evaluation was made of the characteristics and hydrologic processes related to Wyoming stock-water ponds and dike spreader systems. Capacity curves for various configurations of stock-water ponds were developed and maps of average annual evaporation, precipitation and runoff were compiled. The amount of water constituting beneficial use was examined and recommendations relative to water rights administration are presented.

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KEY WORDS: Beneficial use/Capacity curves/Dike spreader/Evaporation Hydrology/Precipitation/Stock-water ponds/Stream runoff/ Water rights/Wyoming

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INTRODUCTION

Water has always been an important factor in the production of crops and livestock in the west. In the early days of settlement, livestock generally roamed where they wanted, usually ranging where the grass and water were abundant. As more settlers pushed westward and the livestock industry expanded, the range became more crowded and confined. In many instances it became necessary to provide water from developed sources. With the advent of large earth-moving equipment, stock-water ponds became one of the more popular facilites for providing water.

Stock-water ponds are occasionally located on perennial streams, but they are usually found on ephemeral streams, i.e. streams that flow only when snowmelt or rainstorm runoff occurs. In many instances, such ponds efficiently utilize the limited available water resource, providing a year-round supply of water to arid regions. They frequently conserve water that: would otherwise runoff beyond the area of need (or even the state); might be absorbed in stream channels; or consumed by stream riparian vegetation.

Well placed ponds also improve range conditions. Where water supplies are too far apart, intensive grazing may occur near what water is available, inducing over utilization and erosion, while good forage at distant areas will remain ungrazed.

Stock-water ponds can provide significant reductions in flood peaks from small drainage basins, reducing flood damage and channel erosion. Additional benefits are sometimes derived for recreation. Where the pond can be maintained full most of the time, swimming, picnicking, fishing and water-fowl hunting may be enjoyed. It has been reported that in the east 150 to 300 pounds of fish may be removed annually from ponds of one to two acres of surface area and ten feet of depth (Hamilton and Jepson, 1940). Stock-water ponds can provide migratory fowl with breeding and resting habitat. Other wildlife, particularly deer and antelope, also benefit.

Dike spreader systems are another facility that has become popular on ephemeral streams in some areas of Wyoming for utilizing erradicably occurring runoff that might not otherwise be put to any beneficial use. These facilities are generally a series of dikes that spread runoff over an area for irrigation purposes.

Stock-water ponds and spreader dike systems have many interesting qualities. The purpose of this report is to examine the state-of-the-art relative to these facilities in Wyoming and to describe their characteristics.

HYDROLOGY OF STOCK-WATER PONDS

Considering a stock-water pond from the water budget approach, inputs to the reservoir include runoff, precipitation, seepage and condensation. Outputs include spillage, evaporation, evapotranspiration, seepage and animal consumption. Condensation is such a minor contributor that it can be ignored. Seepage into a reservoir does occur in some instances, but generally seepage is outflowing. Evapotranspiration, the use of water by plants plus evaporation of soil moisture, can be a significant factor. Since it is related closely to seepage, it will be considered under the section on seepage. Spillage is water that flows out of the reservoir after it is full. The amount of spillage is a function of the amount of upstream runoff, the reservoir capacity and the amount of water stored in the reservoir prior to runoff. The principal factors: evaporation, seepage, animal consumption, runoff, precipitation and sedimentation are analyzed individually in the following sections.

Animal Consumption: The number of livestock or game animals that may drink from a particular pond and graze the surrounding area varies considerably. In an arid or semi-arid area it is generally accepted that no more than 100 head of cattle, or equivalent other livestock or game can be grazed for any projected period within the service area of a single water facility without exceeding carrying capacity and causing damage to the range (Pacific Southwest Inter-Agency Committee, 1962). This value is for excellent range conditions. The amount of water consumed and the frequency of watering varies with seasons and local conditions. During hot, dry weather and when forage is dry, livestock consume more water than during cool weather or when forage is moist from rain, dew or snow. Cattle and horses are larger users of water per head than other range animals, requiring a maximum of about 10 gallons per head per day (Pacific Southwest Inter-Agency Committee, 1962; Hamilton and Jepson, 1940; Culler, 1961). For 100 head and 10 gallons per head-day, the annual consumption is 1.12 acre-feet per year. Since this value is based on maximum requirements, a value of 1 acre-foot per year can be considered adequate for consumptive use by 100 head of livestock in range areas of Wyoming.

Capacity Curves: One of the factors influencing evaporation and seepage losses from stock-water ponds is the shape of the reservoir. The surface area, wetted perimeter and depth all influence the losses. A measure of these characteristics can be obtained in a plot of the depth versus the storage capacity of the reservoir. A theoretical approximation for stock-water reservoir capacity curves can be determined by assuming that they conform to the shape of a pyramid.

The general limitations for stock-water dams are that the ponds formed have a capacity of no more than 20 acre-feet and that the dam be no more than 20 feet in height, with five feet of freeboard, i.e. 15 feet maximum water depth. The most efficient reservoir will minimize losses by having a minimum surface area and wetted perimeter. Such a reservoir will have the maximum allowable depth. Substituting a depth of 15 feet and a volume of 20 acre-feet into the equation for the volume of a pyramid, $V = 1/3\ AH$, where V is the volume, A is the top area and H is the depth, results in the surface area of 4 acres. Probably the least efficient pond that would be encountered or that should be considered would have a surface area of 10 acres for a volume of 20 acre-feet. Such a pond would have a maximum water depth of 6 feet. Figure 1 presents the capacity curves for these two reservoirs, which should represent the extremes of stock-water reservoirs constructed in Wyoming. To check the pyramid configuration assumption, data for reservoir No. 32 of the Cheyenne River Basin Study (Culler, 1961, p. 23) were plotted on figure 2. The similarity in the shape of the curves appears to confirm the assumption. Other reservoir data were available to further check the curves.

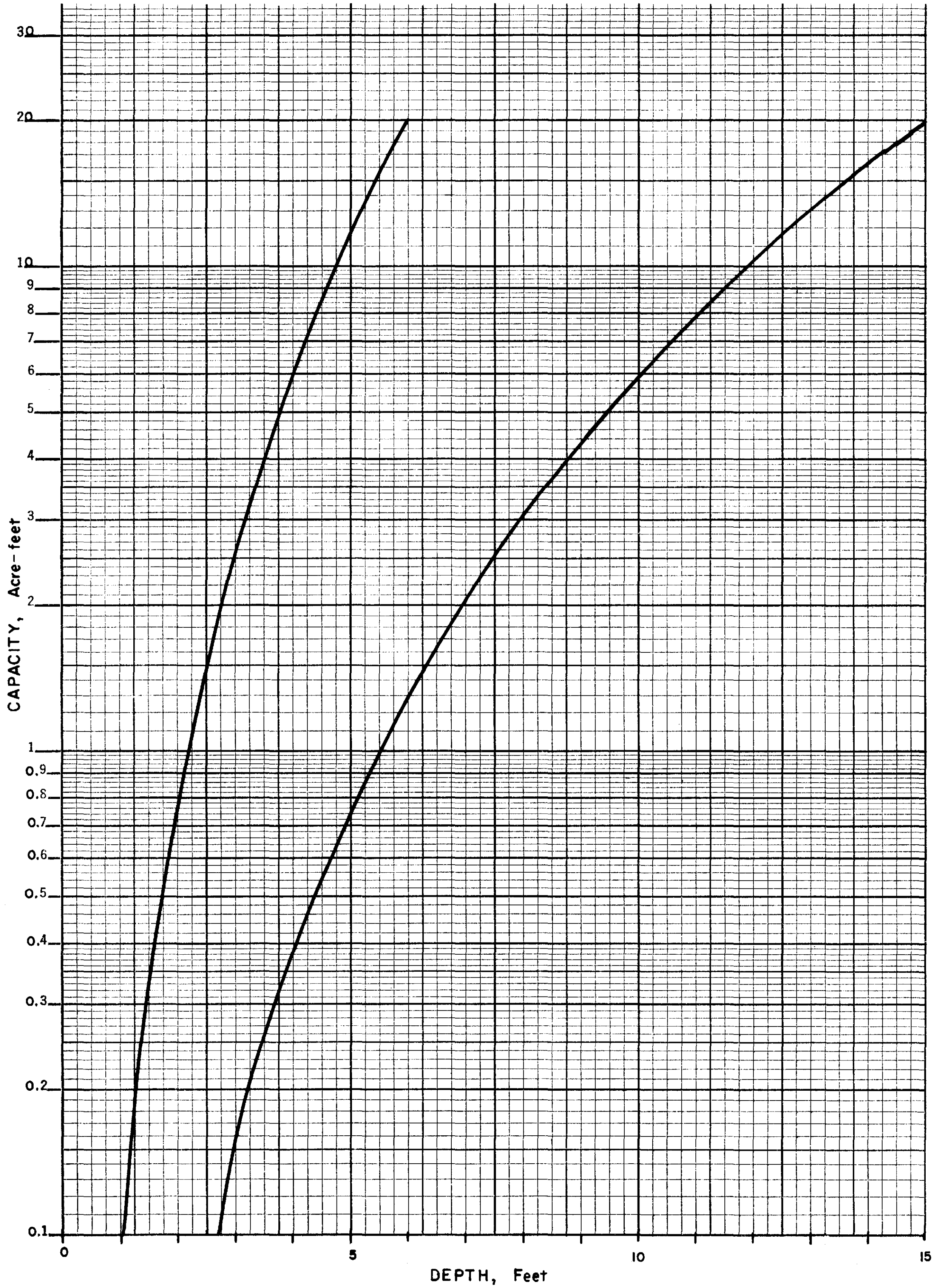


FIGURE 1. ENVELOPING CAPACITY CURVES FOR STOCK-WATER RESERVOIRS.

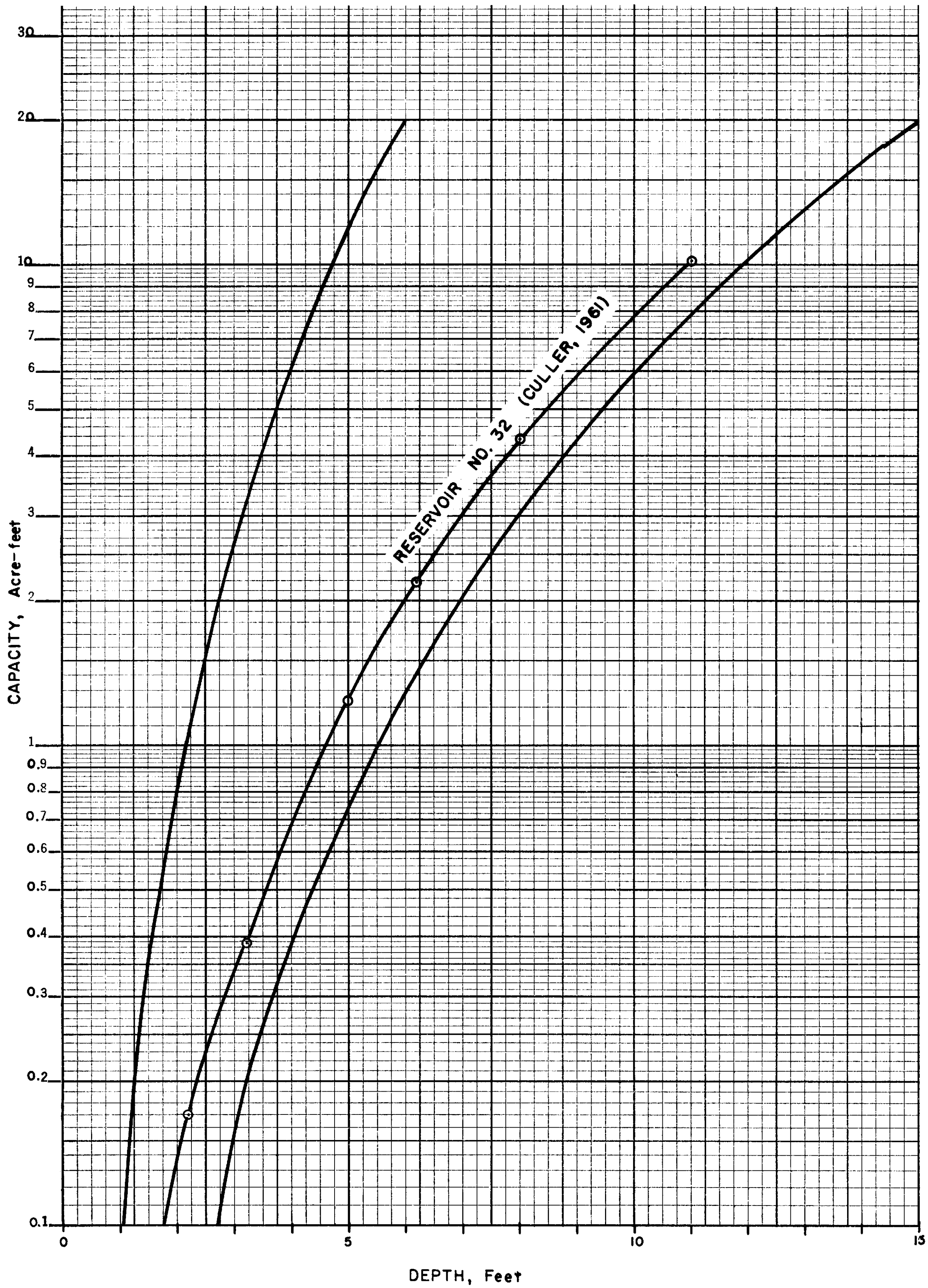


FIGURE 2. CAPACITY CURVE OF STOCK-WATER RESERVOIR NUMBER 32.

The similarity in the shape of the enveloping curves makes it possible to easily approximate the capacity curve for any stock-water reservoir. Knowing the full capacity and depth, several points can be proportioned horizontally between the curves and plotted. It is also easy to calculate the points from the volume-height relationship, $V = (\frac{H}{H_f})^3 V_f$, where V is the volume at height, H, and V_f is the volume at full height H_f. For example, a pond with a 10 acre-foot capacity and 10 foot full depth has a volume at 8 feet of $V = (8/10)^3 \times 10 = 5.12$ acre-feet, and a volume at 4 feet of $V = (4/10)^3 \times 10 = 0.64$ acre-feet.

Depressions constructed in the ground known as stock-water pits are generally considered to be a special kind of stock-water pond. The volume of a stock-water pit can be estimated by the equation of a prismoid, $V = \frac{H}{6} (A_t + A_b + 4A_m)$, where H is the depth, A_t is the top area, A_b is the bottom area and A_m is the area of the section midway between the top and bottom. Livestock can readily negotiate a 3:1 slope, but steeper slopes probably should not be permissable as they are deleterious to land around the perimeter of the pit. For a volume of 20 acre-feet, 15 feet of depth and 3:1 side slopes, the bottom dimensions of a prismoid with square top and bottom sections is 194.6 feet square. This represents a larger pit than probably would ever be constructed, but it serves as a limiting boundary for stock-water pit capacity curves. The practical lower limit can be represented by a 20 acre-foot by 15 foot deep pit with 6:1 slopes. Such a pit would have bottom dimensions of 18.7 feet square. The curves for these pits are presented in figure 3.

Knowing the full capacity and depth, any stock-water pit can be closely approximated by interpolating between these curves. Table 1

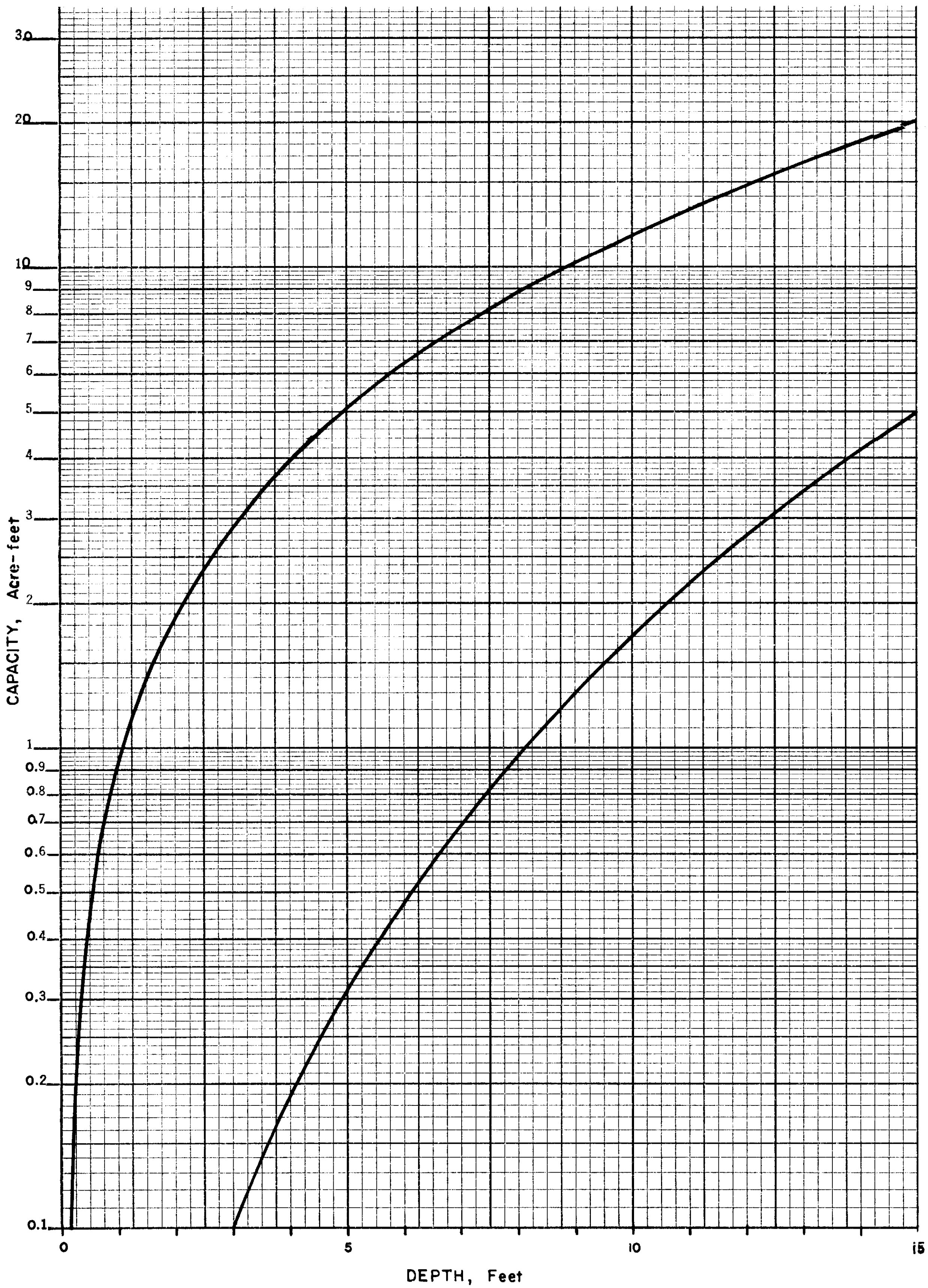


FIGURE 3. ENVELOPING CAPACITY CURVES FOR STOCK-WATER PITS.

is a tabulation of the vertical differences of the two curves and the ordinates of the lower curve for various depths. This table can be used to interpolate between the curves. To estimate a curve, first find the difference in capacities between the curve to be estimated at full depth and the lower curve at that same depth. Then calculate the ratio of that difference to the value in column 3 of Table 1 at that same depth. Next multiply the ratio by the values in column 3 of Table 1 for other depths. Finally add the ratio-product values to the corresponding lower curve ordinates of column 2 to obtain the ordinates of the desired curve.

To illustrate, suppose the capacity curve for a 10 acre-foot, 12 foot deep pit is desired. At 12 feet the capacity difference between the desired curve and the lower curve is 10.00 - 2.74 = 7.26 feet. The ratio is 7.26 ÷ 12.03 = 0.6035. At 11 feet the desired curve ordinate is 0.6035 x 10.99 + 2.18 = 8.81 acre-feet. Ordinates at other depths were calculated and are plotted in figure 4 as the proportioned curve No. 1. To check the accuracy of the procedure a capacity curve for a pit of 10 acre-foot capacity, 12 foot depth and 4:1 slopes was computed by the prismoidal formula and plotted on figure 4. The differences between the curves are quite small. Similarly a comparison was made for a 3 acre-foot pit with 10 feet depth and 6 to 1 slopes. These curves are presented as the No. 2 curves in figure 4. The differences are less than 0.2 acre-feet which are not very significant. The procedure appears to provide reasonably good approximations for stock-water pit capacity curves.

TABLE 1

VALUES FOR DETERMINING THE CAPACITY
CURVE OF A STOCK-WATER PIT

Depth Feet (1)	Ordinates of Lower Curve Acre-Feet (2)	Envelope Curves Ordinate Difference (3)
1	0.01	0.89
2	0.05	1.80
3	0.10	2.76
4	0.19	3.73
5	0.31	4.74
6	0.47	5.77
7	0.69	6.80
8	0.96	7.85
9	1.29	8.91
10	1.70	9.95
11	2.18	10.99
12	2.74	12.03
13	3.40	13.04
14	4.15	14.03
15	5.00	15.00

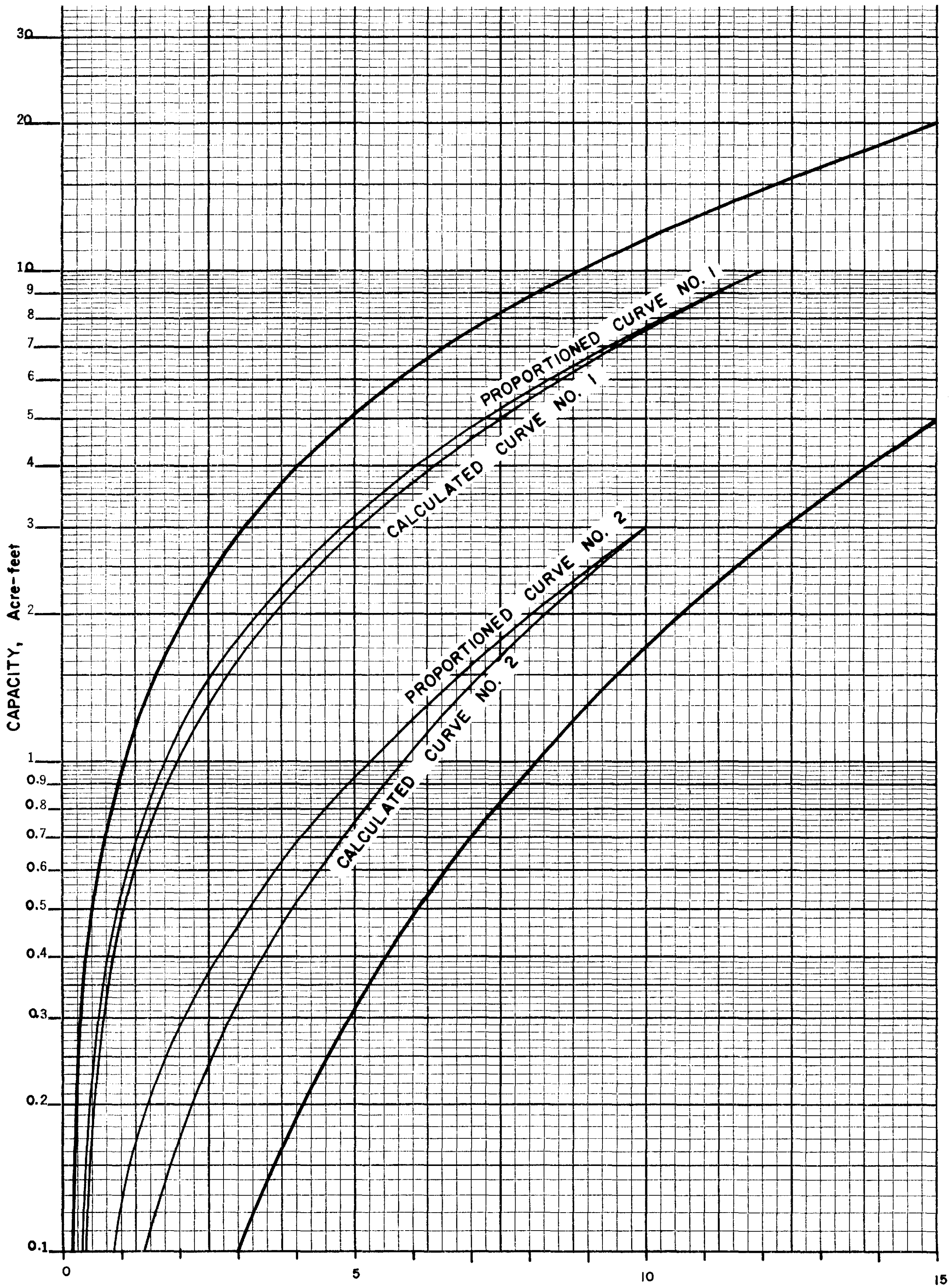


FIGURE 4. COMPARISON OF ESTIMATED AND CALCULATED STOCK-WATER PIT CAPACITY CURVES.

Seepage: The amount of seepage that occurs from a stock-water pond is quite variable, being subject to a number of factors. The most important factor is the underlying geology. Ponds on permeable soil have high seepage losses while ponds on impermeable rock formations have little loss. The viscosity of water can be a significant factor in shallow ponds. As the water temperature changes from 32°F in the winter to 60°F in the summer the viscosity decreases by about one-third. The seepage consequently may be increased by 50 percent. The depth of water is important since the percolation rate and the seepage rate are directly proportional to water depth. The shape of the reservoir is also a factor. A pond with a small wetted perimeter (circumference) will have less seepage than one with a larger wetted perimeter. The infiltration and percolation rates along the cross-section of a pond will also vary due to deposited sediments on the bottom that usually are less permeable than the natural soil.

Seepage losses can be separated into two components: water that percolates outward around the pond and through the dam, and water that percolates down into the ground water. The proportion of seepage water that goes to one place or the other varies considerably. Two of the reservoirs observed in the Cheyenne River Basin Study (Culler, 1961) were found to be typical of each extreme. Seepage loss from the one was almost entirely due to peripheral seepage while the seepage from the other was almost entirely all contributed to ground water.

Observations of reservoir water depths over time (Culler, 1961; Langbien et al., 1951) show that immediately after a rise in the water level from runoff, the seepage loss rate is greatest. This is primarily due to water flowing into the area just submerged to satisfy soil moisture and bank storage. As the water level recedes, part of this water is regained from bank storage. The remainder of the water is retained as soil moisture or is lost to evapotranspiration. Evaporation of water from the soil, and plant transpiration varies with the water level and is difficult to quantify. Reservoirs that experience large water level fluctuations appear to have greater seepage losses than those with more stable water levels (Langbien _et al._, 1951).

Water that seeps through or under the dam is usually apparent in the moist soil, lusher vegetation or standing water below the dam. For those ponds which had this type of seepage in the Cheyenne River Basin Study (Culler, 1961) these conditions varied from a distance of a few tens of feet to one-half mile. This seepage water is generally lost to evapotranspiration or ground water on ephemeral streams. However, the seepage does reduce channel losses that would otherwise occur during runoff. During very wet years, when stream beds remain nearly saturated, much of the dam seepage is not lost but rather indirectly increases downstream runoff.

Seepage water that percolates to ground water is generally considered to be lost, unless it can be traced to springs, wells or effluent stream flow. No evidence of this type of regained water was found in the Cheyenne River Basin Study (Culler, 1961).

Seepage in stock-water ponds has been determined indirectly as the difference between total reservoir recession and evaporation, where evaporation is estimated from the energy budget equation or from Class A Pan observations. In the study made in Arizona (Langbien _et al._, 1951), seepage rates ranged from 0.05 to 0.3 feet per month. The study area was underlain by a thick soil mantle overlying low-permeability rock formations which should have low seepage rates.

In the Cheyenne River Basin Study (Culler, 1961), areas underlain by dense shale had low loss rates and areas of sandy soil overlying losely consolidated sandstone and conglomerate rock had high loss rates. The rates varied from a negative seepage (water gain) to 9.65 feet per month for a very small reservoir.

To determine what might be considered a typical seepage loss rate in Wyoming, the seepage losses from the observed reservoirs of the Cheyenne River Basin Study (Culler, 1961) were examined. Data on other reservoirs were not available. The observed seepage from reservoirs of about 20 acre-feet or less capacity that did not appear to have seepage gain or excessive losses were averaged for 1953. The reservoirs used were numbers 3, 5A, 6A, 6B, 7, 7A, 7B, 10, 10B, 19, 25, 34, 36, 38, 39, 41, 42, 43, 43A, 56 and 57. The data for 1953 were used because that year had fairly complete data for representative reservoirs and had more nearly normal runoff than 1954. The calculated average seepage was 0.5 feet per month, or 6 feet per year.

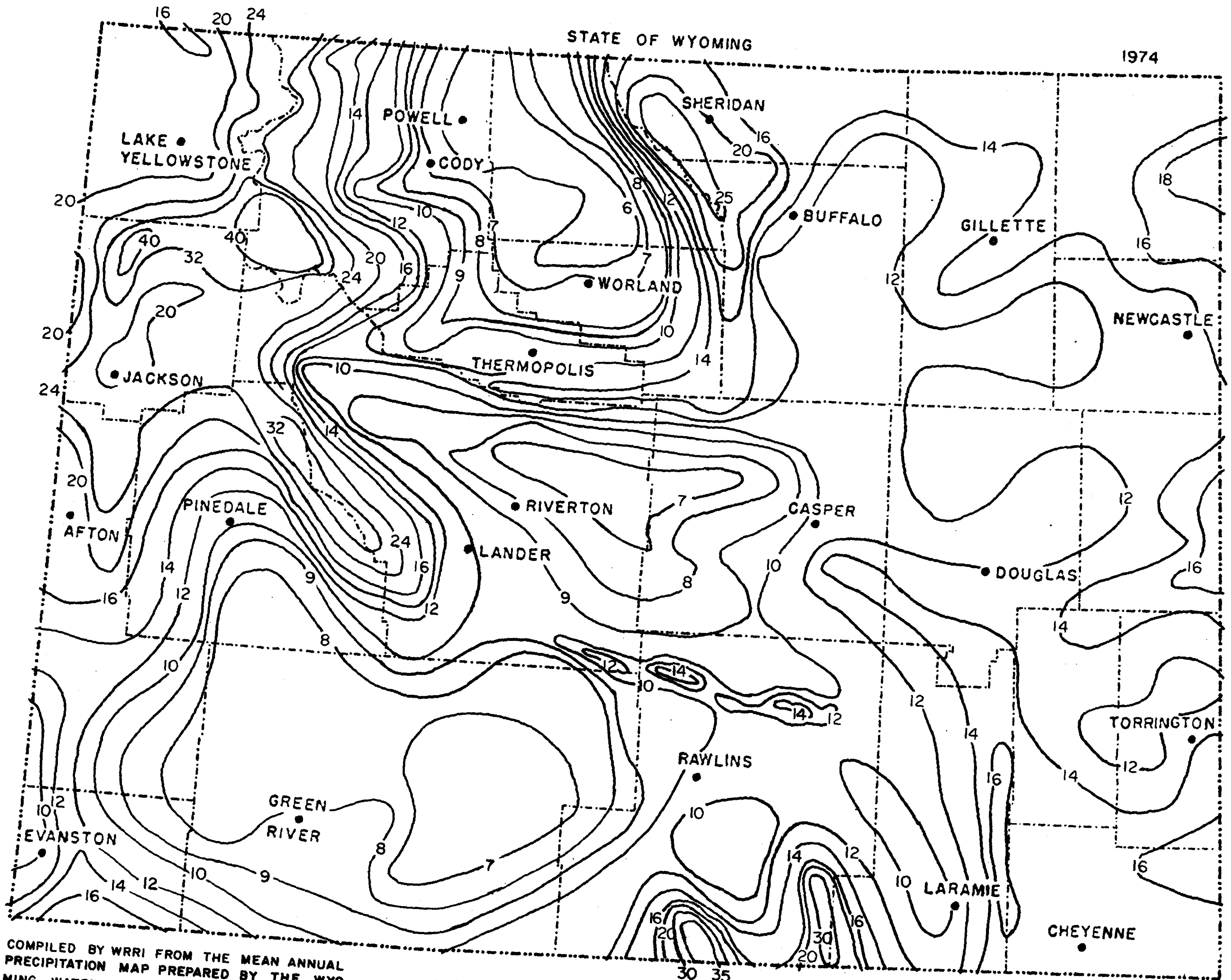
<u>Precipitation and Runoff</u>: Precipitation in Wyoming varies considerably areally and temporally. Mountainous areas receive a relatively large amount of precipitation in the form of snow. This water provides approximately 80 percent of the runoff of Wyoming. The plains areas receive lesser amounts of precipitation, and runoff frequently occurs only from summer rainstorms whose distribution and frequency are highly variable. Most of the annual precipitation in the plains areas is absorbed in the soil, with runoff occurring only from high-intensity

storms. Less than 2 percent of the annual precipitation resulted in runoff to the gaged streams in the Cheyenne River Basin (Culler, 1961).

Precipitation falling on reservoirs is a direct gain and is generally accounted for in the net evaporation. Figure 5 is a map of normal annual precipitation for Wyoming compiled from the Wyoming Water Planning Program Precipitation Map (Wyoming Water Planning Program, 1973, p. 23) and adjusted to reflect higher amounts in some of the mountainous areas indicated by the Normal Annual Total Precipitation Map of the United States (Environmental Science Services Administration, 1966).

The geology, topography, and vegetation of an area are factors that give additional variability to runoff. Since it is generally desirable to have a water supply that is available throughout the year, methods for determining annual runoff for the plains areas were examined. In the mountains, streams are generally perennial and the water supplies more reliable.

The flood frequency studies examined (Carter and Green, 1963; Patterson, 1966) were found to be of little use because the smallest drainage areas presented in the graphs are 10 and 50 square miles, much larger than the drainage area of many stock-water ponds. The triangular hydrograph method (Soil Conservation Service) was examined next. Assuming the average annual rainstorm to have a recurrence period of two years, the 24-hour precipitation for Wyoming plains areas ranges from 0.8 to 1.8 inches (Weather Bureau, 1968). The soil cover complex numbers for range lands in Wyoming range from 36 to 89 (Soil Conservation Service). Based on these values, the runoff from the precipitation-runoff curves varies from 0 to 0.86 inches annually. Unfortunately, adequate soils information is not available for most portions of the



COMPILED BY WRRI FROM THE MEAN ANNUAL PRECIPITATION MAP PREPARED BY THE WYOMING WATER PLANNING PROGRAM AND THE NORMAL ANNUAL TOTAL PRECIPITATION MAP PUBLISHED BY ESSA (1966).

MEAN ANNUAL PRECIPITATION
(IN INCHES)
FIGURE 5.

NOTE: ISOHYETAL LINES IN MOUNTAINOUS AREAS WERE DEVELOPED FROM VERY LIMITED DATA AND SHOULD BE USED WITH CAUTION.

state, so these values can only serve as an estimate of the range of average annual runoff values.

The Soil Conservation Service (1971, p. 6) provides a map for estimating drainage area required for ponds in the United States. Since this map is based on general information for the entire country, it was felt that the map probably is not precise enough to provide very accurate estimates in a state such as Wyoming in which the runoff is highly variable, areally. Similarly, the runoff nomographs presented in the Pacific Southwest Interagency Committee report (1962) were not used.

The most comprehensive study that could be found on ephemeral stream runoff in the west is the Cheyenne River Basin Study (Culler, 1961). Headwater runoff was estimated from weekly observations of a number of representative reservoirs in the basin for 1951 through 1954. Average headwater runoff for the study drainage basins are tabulated in Table 2 along with the basin runoff at the gaged stations for the study period and for their historical record. The percentage of the study period runoff to the historical runoff at the gaged stations were calculated and applied to the study headwater runoff to obtain the estimated average headwater runoff.

Channel losses result partially from water storage in the channel bed and banks. This water is lost to evapotranspiration when streams dry up. Channel losses are highly variable, depending among other things, upon the frequency and duration of runoff. Most of the stream channels in the Cheyenne River Basin are composed of permeable alluvium and are subject to significant channel losses (Culler, 1961). Table 2

TABLE 2

CHEYENNE RIVER BASIN RUNOFF

Station	Study * Headwater Runoff (Inches)	Study Period* Streamgaging Station Runoff (Inches)	Historical Streamgaging Station Runoff (Inches)	Study to Historical Runoff (Percent)	Estimated Historical Headwater Runoff (Inches)
Lance Creek at Spencer	0.35	0.18	0.17	106	0.33
Cheyenne River near Spencer	0.23	0.13	0.15	83	0.28
Beaver Creek near Newcastle	0.57	0.22	0.34	65	0.88
Cheyenne River near Spencer Excluding Lance Creek at Spencer	0.15	0.10	0.14	71	0.21

*Culler, 1961

indicates that the headwater unit runoff ranges from 1 1/2 to over 2 times the lower drainage unit runoff, of which a large amount of the difference is probably attributable to channel losses.

For the remainder of the state, streamflow records were examined and the unit runoff was estimated from those streamgaging stations for which the plains area runoff could be separated and diversion or regulation were not excessive. At least twenty years of data were used wherever possible and for stations with shorter records the data were extended by correlation with nearby stations. A factor of 2 was applied to the lower basin streamgaging station runoff to get headwater runoff estimates.

The estimates were based on the following streamgaging stations: Belle Fourche River below Moorecroft; Belle Fourche River below Keyhole Reservoir; Belle Fourche River at Wyoming-South Dakota State Line; Niobrara River at Wyoming-Nebraska State Line; Little Missouri River near Alzada; Little Powder River near Broadus; South Fork Powder River near Kaycee; Powder River at Arvada less the South Fork Powder River near Kaycee, North Fork Crazy Woman Creek below Spring Draw, Middle Fork Crazy Woman Creek near Greub and Powder River near Kaycee; Clear Creek near Arvada less Clear Creek near Buffalo, Rock Creek near Buffalo and Piney Creek at Kearney; Powder River at Moorhead less Clear Creek near Arvada and Powder River at Arvada; Goose Creek below Sheridan less Big Goose Creek near Sheridan and Little Goose Creek in Canyon; Tongue River at State Line less Big Goose Creek near Sheridan, Tongue River near Dayton, Little Tongue River near Dayton and Wolf Creek at Wolf; Little Wind River near Riverton less South Fork Little Wind River near Fort Washakie, North Fork Little Wind River at Fort Washakie, Middle Popo Agie below the Sinks, North Popo Agie River Near Milford and Little Popo Agie near Lander; Muskrat Creek near Shoshone; Fivemile Creek above Wyoming Canal; Muddy Creek near Pavillion; Badwater Creek at Lybyer Ranch; Bridger Creek near Lysite; Dry Creek near Bonneville; Badwater Creek at Bonneville less Badwater Creek at Lysite, Bridger Creek near Lysite and Dry Creek near Bonneville; Badwater Creek at Lysite less Badwater Creek at Lybyer Ranch; Fifteen Mile Creek near Worland; Nowood Creek near Tensleep; Sage Creek near Rawlins less Sage Creek below Adams Reservoir; Muddy Creek near Shirley; Sage Creek above Pathfinder Reservoir; Sand Creek near Alcova; Sweetwater River near Alcova less Sweetwater River near South Pass City and Rock Creek at Atlantic City; Horse Creek near Alcova; Canyon Creek near Alcova; Poison Spider Creek near Goose Egg; Deer Creek at Glenrock less Deer Creek in Canyon; Wagonhound Creek near LaBonte; Rawhide Creek Lingle; Sybille Creek below Mule Creek; Chugwater Creek at Chugwater; Horse Creek near Meriden; Lodgepole Creek near Federal; South Fork Lodgepole Creek near Federal; Big Sandy Creek near Farson less Big Sandy Creek at Leckie Ranch; Pacific Creek near Farson; Muddy Creek near Baggs; and Yellow Creek near Evanston.

From the runoff estimates, a map of average annual runoff in the plains areas was prepared and is presented in figure 6. The isopleth lines, particularly in the areas of sparse runoff data, were drawn taking general precipitation, topography and soils data into account. The map may be subject to some inaccuracy, but it is believed that it represents as good a map as can be compiled from available information. Future observations of runoff on ephemeral streams would be very beneficial and undoubtedly could improve the accuracy of this map.

Evaporation: One of the principal causes of water loss in reservoirs is evaporation. A stock-water reservoir studied by Langbein *et al.* (1951) in Arizona had an evaporation loss of about 64 inches in one year.

Being shallow, stock-water ponds are subject to more evaporation than larger reservoirs so their evaporation pan coefficients are higher. In detailed summer observations, Culler (1961) obtained coefficients of 0.94, 0.94 and 0.86 for stock-water pond evaporation correlated to Class A Pan evaporation at Angostura Dam, Keyhole Dam and Whalen Dam, respectively. Assuming that these coefficients are applicable throughout Wyoming and adjusting for winter conditions, an average annual Class A Pan coefficient of 0.93 was determined.

Using plates 2 and 3 of the United States Evaporation Maps (Kohler *et al.*, 1959), a map of average annual gross stock-water pond evaporation was compiled for Wyoming and is presented in figure 7. Stock-water pond evaporation values were obtained by multiplying the values of the isopleths of plate 2 times the appropriate ratio of $\frac{0.93}{0.70}$ or $\frac{0.93}{0.71}$. These ratios are the derived stock-water pond Class A Pan coefficient over the Class A Pan coefficients for Wyoming from plate 3.

The actual evaporation from a stock-water pond can be considered to be the net evaporation, which is the gross evaporation minus annual precipitation. This evaporation at any point in Wyoming can be estimated using figures 5 and 7.

Sedimentation: Sedimentation in reservoirs is a function of several factors, including soil type and composition, vegetation, land slope, geology, channel characteristics, precipitation and runoff rates. Several of these factors, particularly vegetation, change with time, further

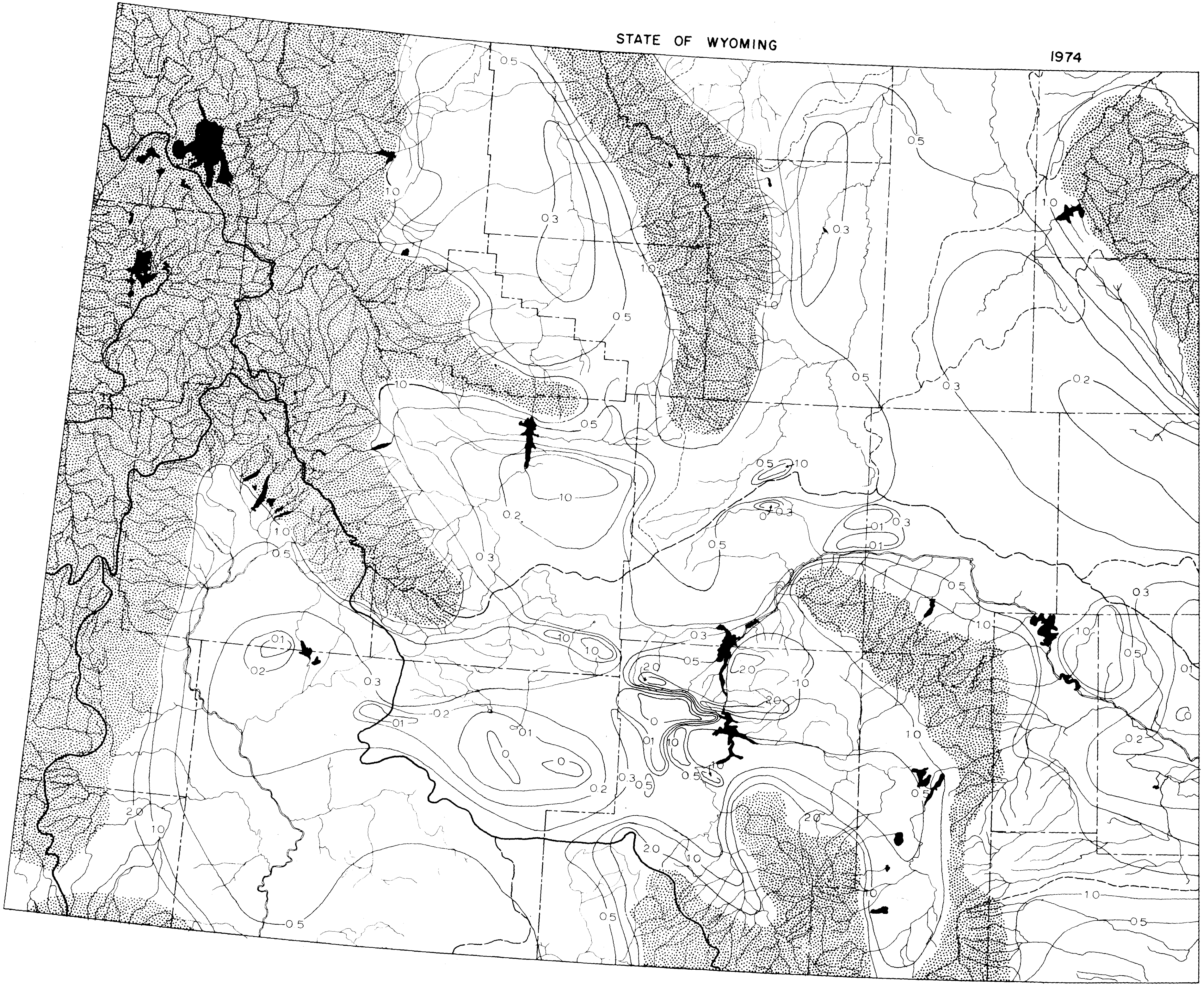


FIGURE 6.

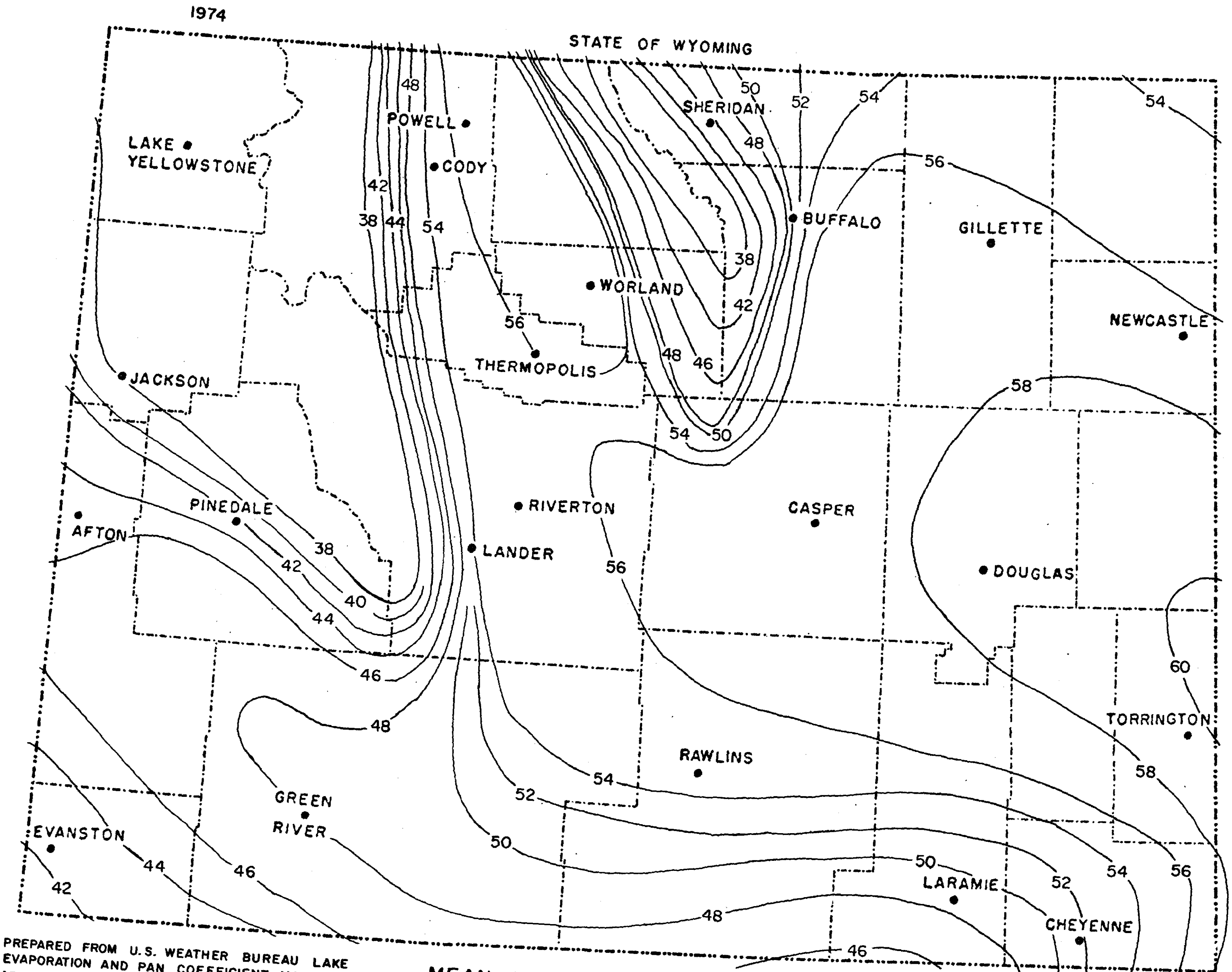
MEAN ANNUAL RUNOFF IN PLAINS AREAS OF WYOMING
(in inches)

PREPARED BY WRRI FROM AVAILABLE HYDROLOGIC, GEOLOGIC, TOPOGRAPHIC AND VEGETATION DATA AND STUDIES OF WYOMING.

Note: Runoff values at particular points may vary from those presented hereon due to the scarcity of data in some areas.

KEY

MOUNTAINOUS AREA



PREPARED FROM U.S. WEATHER BUREAU LAKE EVAPORATION AND PAN COEFFICIENT MAPS (T.P. 37) AND AN AVERAGE STOCKWATER POND PAN COEFFICIENT DERIVED FROM PREVIOUS STUDIES.

MEAN ANNUAL STOCK-WATER POND GROSS EVAPORATION
(IN INCHES)
FIGURE 7.

complicating the estimation of sedimentation rates. Some conservation practices to reduce sedimentation are given in the Pacific Southwest Inter-Agency Committee Report (1962).

The effect of precipitation can be seen from observations made in the Grahm Draw Basin of the Wind River Basin from 1940 through 1954 (King, 1959). The study indicated that the average annual sediment yield was 0.8 acre-feet per square mile. The amounts of sedimentation were found to fluctuate greatly from year to year, primarily due to precipitation. The greatest sediment yield was observed from an intense local rainstorm with about one inch of excess precipitation in June, 1954. The storm produced 3.18 acre-feet of sediment per square mile.

Four types of erosion were identified in the Cheyenne River Basin Sediment Study (Hadley and Schumm, 1961): sheet erosion, the removal of soil by a thin layer of runoff that is not concentrated in well-defined channels; gullying, the cutting of new stream channels; bad lands, the combination of highly intensified sheet and gully erosion; and stream bank cutting, caused by stream shifting or widening in alluvial deposits.

From observations made on 99 reservoirs between 1950 and 1954 Hadley and Schumm (1961) found the average annual rates of sediment accumulation to range from 0. 13 to 1.8 acre-feet per square mile, depending upon the geological formation. Individual reservoir average annual rates ranged from 0.03 to 4.21 acre-feet per square mile. Their observations indicated a decrease in sediment yield with increase in drainage area. This inverse relationship was attributed to absorption of water in channels together with a downstream trend toward gentler slopes and wider flood plains, providing opportunity for sediment deposition.

Hadley and Schumm (1961) developed a multiple regression equation for sediment accumulation having reservoir capacity, relief ratio and drainage areas as the independent variables. This relationship appears to give fairly reasonable estimates within the Cheyenne River Basin.

Since sedimentation is so variable, no attempt was made to develop general relationships for Wyoming. Sedimentation will occur and its effect on reservoirs is to reduce their capacity, as shown in figure 8. The curves are for assumed conditions of an average annual sedimentation accumulation of 0.25 acre-feet on the bottom of a 20 acre-foot, 10 foot deep reservoir. The new, 4-year and 20-year capacity curves are presented. The top of the reservoir is used as datum. As long as water remains in the reservoir, the efficiency of use for stock-water purposes is unchanged (the decrease in volume for a water level drop from 10 feet to 8 feet is 9.76 acre-feet for the new reservoir and is the same for the reservoir after 20 years). But the overall efficiency decreases since the lower holding capacity is lost.

The ability of stock-water ponds to trap sediment generally provides a downstream benefit by reducing sediment from a reservoir is sometimes a difficult process which can be more expensive to accomplish than to construct a new reservoir, if a suitable new site is available. Since a reservoir will eventually fill with sediment, but provides a downstream benefit in doing so, consideration should be given to the possibility of transferring a stock-water pond right to a new site. Such a transfer should require proof that the effective life of the old reservoir has been reached, that a suitable new site is available and that no conflicts with existing water rights will be created. Consideration

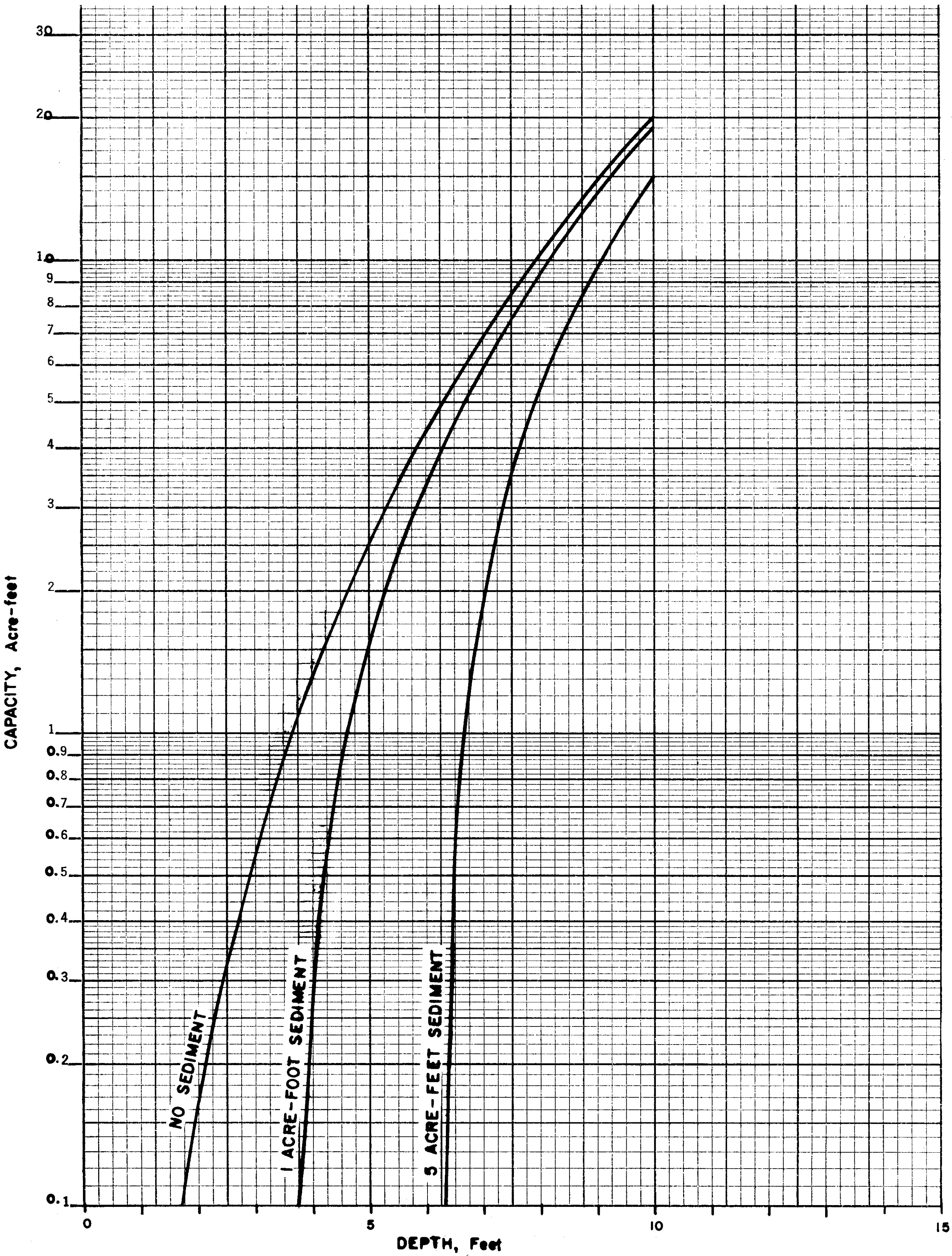


FIGURE 8. EFFECT OF SEDIMENT ON STOCK-WATER POND CAPACITY.

must also be given, in such a proposal, to abandonment laws since, if the reservoir capacity has been lost through sedimentation for five years or more, then it might be best to abandon or cancel the right on the existing site and make a new water right filing for the new site.

STOCK-WATER POND CRITERIA

General Considerations: Water rights are an important aspect of stock-water ponds. The priority of right for reservoirs is established by the filing date as in other types of water filings and beneficial use is the basis, measure and limit, not to exceed statutory limitations, of a water right.

There may be particular instances in which a stock-water pond conflicts with downstream rights and the amount of water constituting a stock-water pond right is a consideration in such conflicts. An appropriation for stock consumption alone would not provide a practical allocation to stock-water ponds because of the natural physical processes acting on the pond. A reasonable amount should be allowed for evaporation and seepage losses. Since a water supply should generally be reliable for the entire year, it is recommended that the average annual values of consumption, evaporation and seepage be used to determine the beneficial use appropriation amount.

Beneficial Use on Ephemeral Streams: The average annual beneficial use on ephemeral streams can be considered to be 6 feet for seepage, the net evaporation determined from figures 5 and 7, and the annual animal consumption. The seepage and evaporation amounts can be converted from depth to volume using the appropriate capacity curve. The annual animal consumption, as previously described, can be considered to be one acre-foot.

The allocation for seepage is an average value. Ponds with less seepage may provide some carry-over storage. Ponds with greater seepage will be of questionable merit since they will not provide a reliable water supply. Seepage reduction measures (Pacific Southwest Inter-Agency Committee, 1962) should be applied to ponds with high seepage losses.

Looking at figures 5 and 7, a net evaporation of about 50 inches in the Big Horn Basin appears to be the greatest in the state. The minimum likely to occur in an ephemeral stream area is about two feet. An average value for much of the plains appears to be about 3 1/2 feet.

Combining seepage with the typical net evaporation gives an annual loss of 9 1/2 feet. For the 20 acre-foot, 15 foot high capacity curve of figure 1, the loss would be about 19 acre-feet, assuming an initially full reservoir with no inflow during the year. Allowing one acre-foot for livestock consumption results in a use of 20 acre-feet.

A shallower reservoir or one with less capacity would be depleted in less than a year. If the same reservoir initially had a depth of 10 feet of water, then a loss of 3 feet to evaporation and seepage plus 1/2 acre-foot to livestock use, had an inflow that filled the reservoir and then lost 6 1/2 feet to evaporation and seepage plus 1/2 acre-foot to livestock use, the total loss would be about 21.4 acre-feet. There are a number of possible inflow conditions, each resulting in somewhat different depletions. Assuming similar conditions for a stock-water pit, such as curve 1 of figure 4, the depletion is 12 acre-feet.

Since sedimentation gradually changes reservoir capacity and the inflow sequences are variable, it is recommended that the amount of water appropriated per year for a stock-water reservoir on an ephemeral stream be established as the new,full capacity. This amount should serve the purpose for which the facility is intended.

Stock-water Pond Spacing on Ephemeral Streams: Occasionally stock-water ponds are constructed adjacent to each other with the intention that twice as much water be retained and therefore available for use. Unfortunately there is little or no benefit gained from the additional pond for stock-water purposes. The livestock consumption constitutes only a small portion of the water depletion. The large depletions are attributable to evaporation and seepage. These losses will occur simultaneously in both ponds, with the possible exception of some seepage loss from the upper pond being gained by the lower pond. Thus losses are generally doubled. Nothing is usually gained from the additional stored water, and in some instances the water could be of benefit to downstream users.

To illustrate, suppose two, 20 acre-foot, 15 foot deep ponds were constructed adjacent to each other in an area with average conditions of 3 1/2 feet evaporation and 6 feet seepage. Assuming that the lower pond gains one-half of the seepage of the upper pond, the losses would be 9 1/2 feet in the upper pond and 6 1/2 feet in the lower pond. From figure 1 the losses would be 19 acre-feet in the upper pond and 16.4 acre-feet for the lower pond. Adding one acre-foot for livestock consumption gives a total depletion of 36.4 acre-feet. This loss is 16.4 acre-feet greater than that for one pond, but 3.6 acre-feet of carry-over storage is gained. The benefit of the additional water over the resource loss is questionable, particularly since this example is for efficient ponds. As the spacing between ponds increases, the seepage gained by the lower pond will decrease and any carry-over storage benefits will be lost.

The question then arises as to what should be the spacing between ponds. Ponds should serve the needs of livestock without causing any loss in production, but they should not be so close together as to cause unnecessary water depletion. Optimum spacing is dependent upon a number of factors, including terrain, temperatures, range grazing capacity, kind of livestock, grazing management and fencing patterns. For an unfenced, rolling range, the limits of one to three miles have been suggested. In unfenced, rough country one-half mile to one mile has been recommended (Pacific Southwest Inter-Agency Committee, 1962; Hamilton and Jepson, 1940). Since conditions vary greatly throughout the state and fenced pastures must be considered, it is recommended that one-half mile be considered the minimum permissible distance between stock-water ponds on land under the same ownership. This distance should not impose any appreciable hardship upon the landowners, and will prevent water wastage that could be in conflict with public interests.

For the case of stock-water ponds on the same stream but on land of different ownership, no conflict of appropriation will exist if the downstream pond is junior. However, if an application is made for construction of a new pond above an existing adjudicated pond, sufficient drainage area should be allowed to provide water to that existing pond. The amount of the right of the existing pond has been recommended above to be the new capacity of that pond. The drainage area that should be provided can be estimated from the average annual runoff map of figure 6. For example, consider an application submitted to construct a pond upstream from an existing 10 acre-feet pond under different ownership in the lower Powder River Basin. The average annual runoff from figure 6 is 0.5 inches. The drainage area required to yield an average of 10 acre-feet per year is Area = $\frac{\text{Capacity x 12}}{\text{Average Runoff}} = \frac{10 \text{ x } 12}{0.5} = 240$ acres. This amount of drainage area should be provided to supply water to the existing pond.

It is possible for the drainage area of the senior pond to not be immediately upstream as long as sufficient drainage is provided, i.e. the upper pond can be located near the lower pond. The lower pond will still get its full amount of water, partly from spillage through the upper pond. However, the upper pond should include a headgate or other regulation structure for dry years. The lower pond can then receive the water to which it is entitled, but would not receive as spillage. Similarly where insufficient drainage area exists, an upstream junior pond can be allowed if a regulation structure is provided for the purpose of passing water downstream to the pond of senior right. Consideration should be given to proper spacing of reservoirs by the applicant and his engineer.

Existing stock-water ponds of record generally do not include drainage area or adjacent land ownership information. To apply the recommended procedure to new applications, drainage area and ownership information will have to be obtained from maps and ownership records. This will require time, but appears unavoidable. It is recommended that the drainage area and land ownership be made part of the required information of future applications.

The situation may arise in which an application is made to construct a stock-water pond above a diversion right on an ephemeral stream (such as a dike spreader system). Again sufficient drainage area should be provided to supply the existing right, or a headgate or other regulation structure should be required. To determine the drainage requirement, a conversion between flow rate and volume must be made. Based on the information presented in the Cheyenne River Basin Study (Culler, 1961), it is assumed that on the average there are two runoff occurrences per year and that they last for two days. Thus the runoff volume right for a dike spreader system irrigating 140 acres with 2 cubic feet per second would be 16 acre-feet per year. In an area with 0.5 inches of average annual runoff the required area would be 384 acres.

<u>Stock-water Ponds on Perennial Streams</u>: It is recommended that the average beneficial use of stock-water ponds on streams that flow all year be considered to be one acre-foot for livestock consumption plus the net evaporation from figures 5 and 7. Since seepage frequently is a gain to perennial stream ponds, no seepage allowance is recommended for the average case.

Net evaporation will generally be less than that estimated for ephemeral streams since gross evaporation is less and annual precipitation is greater in the areas of perennial streams. The range of values from figures 5 and 7 for net evaporation in and around mountainous areas appears to be from 0 to about 40 inches.

Since the reservoir remains full, the evaporation loss would be the full surface area times the net evaporation. For a pond with two acres of surface area and 40 inches of evaporation, the water use would be 6.7 acre-feet for evaporation plus 1 acre-foot for livestock consumption or 7.7 acre-feet per year.

The reasoning used on spacing between ponds on ephemeral streams applies as well to ponds on perennial streams. The minimum permissible spacing of one-half mile between stock-water ponds on land of the same ownership is recommended.

On a stream which is fully appropriated to prior rights, any reservoir constructed upstream from existing rights should provide a regulation structure to accommodate downstream rights. An alternate solution would be to permit construction of an off-stream reservoir with appropriate diversion rights.

DIKE SPREADER SYSTEMS

Relatively few studies have been made on dike spreader systems. The most extensive study appears to be one done by the U. S. Geological Survey on a spreader system on Box Creek in the Cheyenne River Basin in 1956 and 1957 (Hadley, McQueen _et al_., 1961). They had difficulty in obtaining good runoff data primarily because of the lack of good gaging sites. In a hydrological study of streams in the Wind River and Fifteen Mile Creek basins (King, 1959), spreader systems were observed on Logan Draw and the Lower Fraser Draw from 1952 to 1954. Unfortunately, there were no rainstorm runoff occurrences to these systems during the study period.

Dike spreader systems can be very beneficial by providing irrigation water to lands that otherwise would not support much vegetation. In the Box Creek system the flood plain generally produces two cuttings of hay plus winter pasture. Additional benefits are derived from the abatement of flood flows and reduction of erosion and sedimentation. The Box Creek study indicated sediment load reductions of 70 to 84 percent. The stream is reported to have been a sizable gully years ago. Tree felling into the channel and later dike construction have caused the gully to fill, creating the productive hay and pasture land.

Dike spreader systems, as with any irrigation practice, will cause depletion of runoff. The amount of depletion is subject to a number of factors including soil permeability, antecedent soil moisture, vegetation, land slopes and the flow rate of the water. The amount of water constituting a right should be determined in the same manner as it is for other direct diversion or supplemental rights.

Dike spreader systems should provide some means of regulation of water for administration purposes. If none is provided, diversions can be excessive. For example, the Box Creek spreader system irrigates about 360 acres. Assuming one cubic foot per second per 70 acres, the right would amount to about 10 acre-feet per day. The retained water observed (Hadley and McQueen, 1961) during storm runoff ranged from 27 to 100 acre-feet per day, indicating the need for regulation.

If senior rights exist downstream from a spreader system, provision for permitting that appropriated water to pass downstream must be built into the system.

Dike spreader systems that divert more water than permissible by statute but for which no downstream appropriations presently exist, can be required to provide a regulation structure if a downstream right is appropriated in the future. This requirement is specified in the State Engineer's Regulations (1974):

> "In the event of a request for regulation in the drainage in which the spreader dike system is located, the applicant may be required to install a structure at the principal diversion dam which would make it possible to adequately control and regulate the amount of water diverted at that point, and to pass any water to which the applicant is not entitled on downstream."

SUMMARY

Stock-water ponds and dike spreader systems provide a number of benefits to public interest by furnishing water for beneficial use that might otherwise be subject to downstream losses, by decreasing erosion and flooding, by improving water quality and, in some cases, providing recreation opportunities.

These ponds and spreader systems are subject to water rights law and administration. A dike spreader system can be considered to be similar to other water diversions and the amount of the water right determined in the same manner. Dike spreader systems must provide some means of passing water to downstream appropriations. A beneficial use of water for stock-water ponds can be considered to be composed of the average annual net evaporation, seepage and animal consumption. For ponds on ephemeral streams, the recommended right is the new capacity of the particular pond. One acre-foot per year for animal consumption plus the average annual net evaporation is recommended as the amount of the right for ponds on perennial streams.

A stock-water pond with an adjudicated right on an ephemeral stream should be entitled to sufficient upstream drainage area to obtain its right from average annual runoff. If sufficient drainage is not provided, then a structure to regulate the water should be required on the junior upstream facilities.

On land of the same ownership the recommended minimum spacing is one-half mile.

The recommendations presented herein are based on all the available information that could be found relative to stock-water ponds and dike

spreader systems. It is hoped that the information will be useful to persons involved in water resource planning, management and administration.

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