SIMULATED MONTHLY HYDROLOGIC DATA AND ESTIMATED FLOOD CHARACTERISTICS FOR CHERRY CREEK AT A PROPOSED RESERVOIR SITE NEAR TERRY, MONTANA

By Charles Parrett and Dave R. Johnson

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Multiply	By	To obtain
acre	0.4047	hectare
acre-foot (acre-ft)	1,233	cubic meter
cubic foot per second (ft^3/s)	766.3	cubic meter per second
cubic foot per second-hour (ft^3/s-h)	101.941	cubic meter
foot (ft)	0.3048	meter
inch (in.)	25.4	millimeter
mile (mi)	1.609	kilometer
square mile (mi^2)	2.590	square kilometer
ton	907.2	kilogram

Temperature in degrees Farenheit (°F) can be converted to degrees Celsius (°C) by the following equation:

$$°C = 5/9 \ (°F - 32)$$

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

Abbreviated water-quality unit used in this report:

    milligrams per liter (mg/L)

Water year: The 12-month period from October 1 through September 30. A water year is identified by the calendar year in which it ends.

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Abstract

Methods used to simulate a monthly hydro-logic budget for water years 1937-92 for the proposed Cherry Creek Reservoir (maximum volume about 14,100 acre-feet) are described and monthly results of the simulation are presented. The budget is based on recorded and estimated streamflow, precipitation, evaporation, and estimated reservoir seepage. The budget also includes water diversions from the Yellowstone River whenever the reservoir depth was less than 20 feet (minimum operating level of 2,260 feet) and outflows whenever the reservoir elevation exceeded a maximum operating level of 2,290 feet. Monthly suspended-sediment and dissolved-solids concentrations in the reservoir were estimated from regression relations between logarithms of concentration and streamflow for Cherry Creek and for the Yellowstone River near Sidney, Montana.

The results of the reservoir simulation indicate that flows from Cherry Creek, an intermittent stream having a drainage area of about 360 square miles, generally were adequate to maintain the reservoir elevation above the minimum operating level if no seepage loss occured. With a seepage loss of 3 cubic feet per second, flow diversions from the Yellowstone River were required for 34 percent of the months to maintain the reservoir elevation at minimum operating level. The reservoir elevation generally was maintained near maximum operating level for a seepage loss of 0 cubic feet per second, but generally was close to minimum operating level for a seepage loss of 3 cubic feet per second. Cumulative sediment deposition for the 56-year period was estimated to be about 138 acre-feet from Cherry Creek alone and only slightly more (149 acre-feet) when additional water was imported from the Yellowstone River.

The simulated concentration of dissolved solids in the reservoir showed a slightly increasing trend over time, interrupted by several large decreases, for no reservoir seepage loss. The maximum concentration for no seepage loss reached a maximum value of about 2,500 milligrams per liter in 1982. For a seepage loss of 3 cubic feet per second, water was imported from the Yellowstone River, and the concentration generally ranged from about 500 to about 1,200 milligrams per liter throughout the period.

Flood hydrographs and volumes for flood discharges having 25-, 50-, and 100-year recurrence intervals were estimated from synthetic 24-hour duration storms having total storm depths with recurrence intervals of 25, 50, and 100 years. These synthetic storms were used in a rainfall-runoff model (HEC-1) based on the Clark unit-hydrograph method to develop flood hydrographs from which volumes were computed. The peak discharges of the 25-, 50-, and 100-year flood hydrographs determined from the rainfall-runoff model compared closely to the 25-, 50-, and 100-year peak discharges determined from regional equations developed by the U. S. Geological Survey. The volume of the 100-year hydrograph developed from the HEC-1 model was about 11,250 acre-feet.

INTRODUCTION

The Bureau of Land Management proposes to construct a reservoir for recreation and fish-and-wildlife habitat enhancement on Cherry Creek in Prairie County, Mont. (Bureau of Land Management, 1991, p. 1-3). Hydrologic information is required for the design and management of the reservoir. Because Cherry Creek is an intermittent stream with highly variable flows, inflows to the proposed reservoir may need to be augmented at times by flow diversions from the

Yellowstone River to ensure that the reservoir depth at the dam is maintained at a specified minimum of 20 ft (minimum operating level of 2,260.0 ft) (D.G. Pistorius, Bureau of Land Management, written commun., 1992). For planning purposes, a monthly hydrologic budget is needed to determine the quantity and timing of diversions that would be needed from the Yellowstone River to maintain the minimum operating level.

The reservoir is expected to contain all inflow with the exception of occasional flood events that would cause the water in the reservoir to exceed a specified maximum operating level of 2,290.0 ft (D.G. Pistorius, Bureau of Land Management, written commun., 1992). Because water lost from the reservoir generally will be due to seepage and evaporation, the effects of accumulated sediment and dissolved solids in the reservoir need to be considered.

In addition to the monthly hydrologic budget and effects of accumulated sediment and dissolved solids, hydrographs and volumes for the 25-, 50-, and 100-year frequency floods also need to be determined for spillway design purposes. The U.S. Geological Survey, in cooperation with the Bureau of Land Management and the Montana Bureau of Mines and Geology, conducted a study to simulate a long-term monthly hydrologic budget for the proposed Cherry Creek Reservoir, estimate suspended-sediment loads and dissolved-solids concentrations in the reservoir, and estimate hydrographs and runoff volumes for the 25-, 50-, and 100-year floods on Cherry Creek. For purposes of the hydrologic analysis, it was assumed that a spillway or some other kind of reservoir outlet would allow outflows when the reservoir elevation exceeds a specified maximum operating level.

Purpose and Scope

This report presents results of simulations of the hydrologic budget, suspended-sediment loads and dissolved-solids concentrations, and estimates of the 25-, 50-, and 100-year flood hydrographs and volumes for Cherry Creek at the proposed reservoir site. The hydrologic budget is based on recorded and estimated streamflow, precipitation, evaporation, and reservoir seepage for water years 1937-92. The budget includes water diversions from the Yellowstone River whenever the reservoir elevation is less than 2,260.0 ft and reservoir outflows whenever the reservoir elevation exceeds 2,290.0 ft. Monthly streamflow and precipitation were estimated using a multi-station record-extension procedure. Pan-evaporation data were adjusted to simulate Cherry Creek reservoir evaporation. Monthly concentrations of suspended sediment and dissolved solids

were estimated from regression relations between these constituents and streamflow for Cherry Creek and the Yellowstone River. The suspended-sediment concentrations were used to compute loads and the cumulative sediment deposition in the reservoir. The dissolved-solids concentrations were used to compute loads and resultant increases in concentration over time. A rainfall-runoff simulation model was used to estimate flood hydrographs and volumes. Flood peaks were estimated by the simulation model and regional regression equations.

Site Description

The proposed dam site on Cherry Creek is located in northern Prairie County about 3 miles northeast of Terry, Mont. (fig. 1). Upstream from the proposed dam site, Cherry Creek drains about 360 mi^2 of sparsely populated, rolling uplands. The drainage system is well developed and the area is vegetated with medium-height grasses and scattered shrubs. The basin has moderate relief, with land surface elevations ranging from about 2,240 to 3,625 ft.

The climate of the Cherry Creek basin typically is continental with cold, dry winters and hot summers. Based on the 1951-80 period, mean monthly temperatures at Terry range from 72.0 °F in July to 11.5 °F in January. Based on the 1951-80 period, the average annual precipitation at Terry is 11.3 in., with 8.3 in. occurring from April through August. June is the wettest month with an average of 2.6 in. of precipitation, and March is the driest with an average of 0.2 in. (National Climate Data Center, 1990 and 1991).

At the proposed dam site (fig. 1), the bottom of the reservoir is at an elevation of approximately 2,240.0 ft. At the specified minimum operating level of 2,260.0 ft, the reservoir has a surface area of about 177 acres and a volume of about 2,100 acre-ft. At the specified maximum operating level of 2,290.0 ft, the reservoir has a surface area of about 569 acres and a volume of about 14,100 acre-ft.

Because of the sparse annual precipitation and lack of a mountain snowpack or large ground-water inflow to sustain base flows, Cherry Creek is an intermittent stream that commonly flows only when the prairie snow cover melts or in response to spring and summer rainstorms. The largest known flows have been the result of intense summer rainstorms.
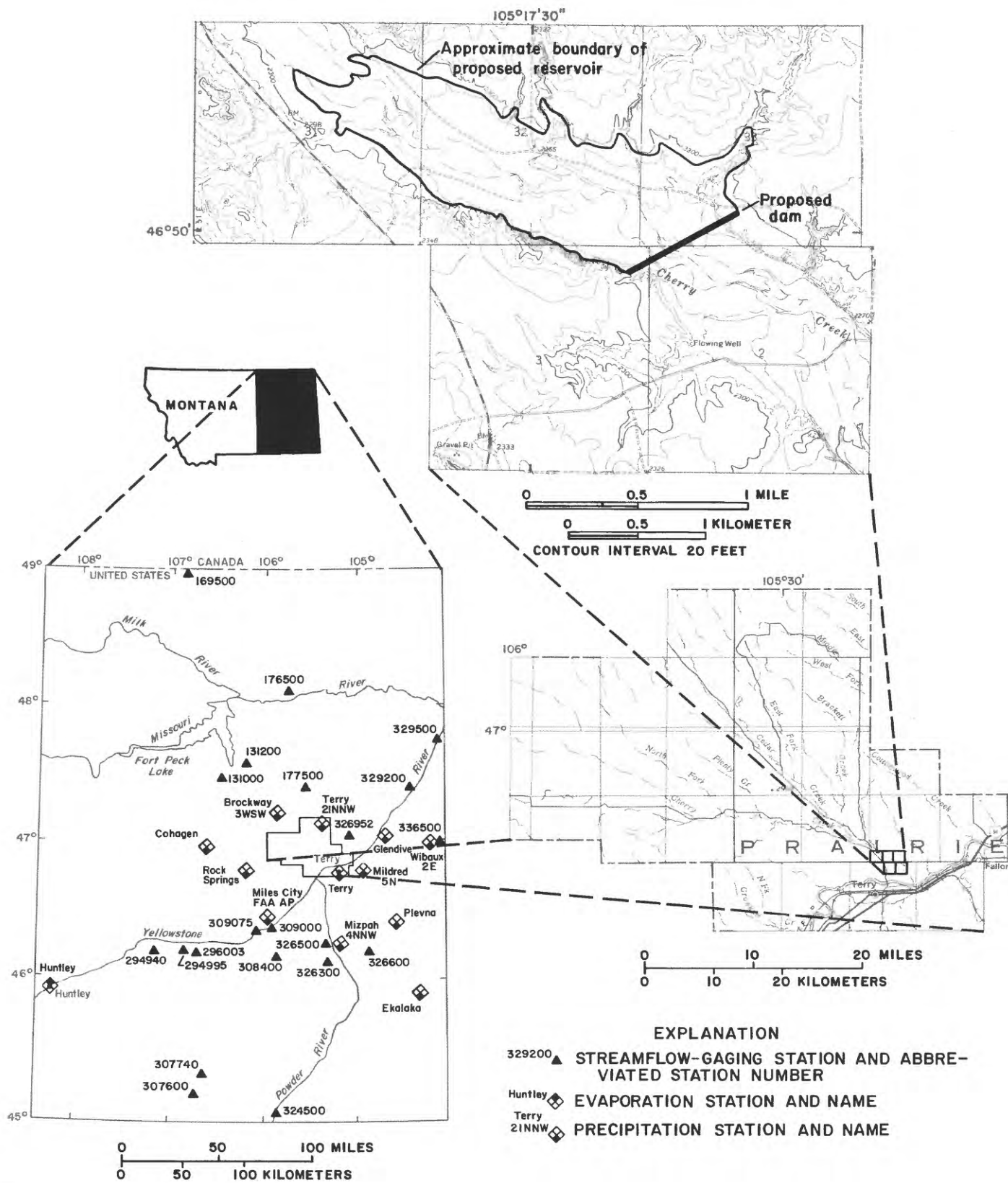
Figure 1. Location of Cherry Creek Basin and selected streamflow-gaging, evaporation, and precipitation stations.

Description of Available Data

Daily streamflow and annual peak-discharge data are available for Cherry Creek for water years 1980-81 and 1990-92 at the Cherry Creek near Terry gaging station (06326555) located near the upstream end of the proposed reservoir. Water-quality data are available for water years 1978-81 and 1990-92 for determination of suspended-sediment concentrations and water years 1978-81 for determination of dissolved-solids concentrations. For the Yellowstone River, the proposed source of supplemental water supply to the proposed reservoir, daily streamflow data for the Yellowstone River near Sidney gaging station (06329500) are available for water years 1934-92. At this site, water-quality data are available for water years 1972-81 and 1983-92 for determination of suspended-sediment concentrations and for water years 1964-81 for determination of dissolved-solids concentrations.

Monthly precipitation data are available for National Weather Service stations at Terry for most of the period 1950-92 and Terry 21NNW for most of the period 1951 and 1962-92. Average monthly precipitation for Cherry Creek Basin is presumed to be equal to the average of the monthly precipitation at the two National Weather Service stations.

Although some evaporation data are available for the Terry station, the period of record is short and data are sparse. Monthly evaporation data for most of the growing season (April through October) are available for the National Weather Service station at Huntley for the period 1911-92.

ESTIMATION OF MONTHLY DATA

To assess long-term characteristics of reservoir fluctuation and supplemental flow needs, a long period of record for components of the hydrologic budget is required. However, the periods of record for streamflow, precipitation, and evaporation in the Cherry Creek Basin are not concurrently long or complete. In addition, suspended-sediment and dissolved-solids data are discrete rather than continuous data and are from a relatively small number of samples. Therefore, data for each component need to be estimated to provide a long, concurrent period of record. Water years 1937-92 were selected as the period of record for the simulation of reservoir operation because they are considered to be representative of a wide range of hydrologic conditions, including the drought years in the late 1930's, the 1950's, and the 1980's and several wet years in the 1960's and 1970's. In addition, the 1937-86 base period was used in previous streamflow estima-

tion studies done for the Montana Departments of Fish, Wildlife and Parks (Parrett and others, 1989) and Natural Resources and Conservation (Parrett and Johnson, 1989, 1994), and using the 1937-92 base period for this study ensures that estimates from this study represent hydrologic conditions occurring during previous studies.

Hydrologic Budget

A monthly record-extension program developed by Alley and Burns (1983) was used to estimate monthly flows for Cherry Creek for the 1937-92 base period. This program uses a mixed-station procedure that selects the best base station from all those available in a region to estimate each month of missing data for a site. Thus, several base stations may be used for making estimates for a single site. The criterion for selection is to use the base station that results in the smallest standard error of prediction for that month. Once a base station is selected for estimating a missing monthly flow, several different curve-fitting techniques are available in the record-extension program for developing a relation between concurrent flows at the base station and the site requiring an estimate. The curve-fitting technique used in this study is the MOVE.1 (Maintenance of Variance Extension, Type 1) technique described by Hirsch and Gilroy (1984). This technique is preferred over ordinary least squares (OLS) regression techniques because MOVE.1 preserves the variance of the unextended record whereas OLS regression results in an extended record with a smaller variance than the unextended record.

Streamflow-gaging stations and their periods of record since 1937 that were used as potential base stations for the extension of flow records for Cherry Creek are listed in table 1. Also shown in table 1 is the number of times each station was used to estimate a missing monthly flow for Cherry Creek. The base station used most frequently, Big Dry Creek near Van Norman (06131000), was used to estimate 355 values of monthly flow. The average standard error of prediction, an error measurement used in the record-extension program that is always slightly greater than the standard error of estimate, for the 617 estimates made for Cherry Creek was 522 percent. Although this standard error of prediction may seem unacceptably large, the magnitude of the error needs to be considered. More than half of the 55 recorded monthly flows for Cherry Creek are 0 and the mean of the 55 values is 0.3 ft^3/s, resulting in a large number of zero and near-zero estimated flows. Thus, a large standard error in percent does not necessarily imply large absolute errors

Table 1. Streamflow-gaging stations used as potential base stations for record extension for Cherry Creek near Terry, Mont.

Station number	Station name	Period of record since 1937	No. of times station used to estimate missing flows for Cherry Creek
06131000	Big Dry Creek near Van Norman, Mont.	1940-69;1971-92	355
06131200	Nelson Creek near Van Norman, Mont.	1982-85;1988	29
06169500	Rock Creek below Horse Creek, near International Boundary	1957-92	0
06176500	Wolf Creek near Wolf Point, Mont.	1951-53;1982-92	133
06177500	Redwater River at Circle, Mont.	1937-71;1975-92	1
06294940	Sarpy Creek near Hysham, Mont.	1973-84	0
06294995	Armells Creek near Forsyth, Mont.	1975-84;1988-92	0
06296003	Rosebud Creek at mouth, near Rosebud, Mont.	1975-92	0
06307600	Hanging Woman Creek near Birney, Mont.	1974-84;1986-92	0
06307740	Otter Creek at Ashland, Mont.	1973-85;1988-92	0
06308400	Pumpkin Creek near Miles City, Mont.	1972-85;1987	1
06309000	Yellowstone River at Miles City, Mont.	1937-92	7
06309075	Sunday Creek near Miles City, Mont.	1975-84	9
06324500	Powder River at Moorhead, Mont.	1937-72;1975-92	0
06326300	Mizpah Creek near Mizpah, Mont.	1975-86	0
06326500	Powder River near Locate, Mont.	1939-92	0
06326600	O'Fallon Creek near Ismay, Mont.	1978-91	10
06326952	Clear Creek near Lindsay, Mont.	1982-85;1988	0
06329200	Burns Creek near Savage, Mont.	1958-67;1975-84	0
06329500	Yellowstone River near Sidney, Mont.	1937-92	72
06336500	Beaver Creek at Wibaux, Mont.	1938-69;1979-83	0

in individual estimates. Estimated and recorded monthly flows for the base period are shown in table 5 at the back of the report. The mean annual flow of Cherry Creek for the 1937-92 period is 3.9 ft³/s (2,800 acre-ft).

The same record-extension program used to extend flow records for Cherry Creek was used to extend the precipitation records for the 1937-92 base period for the National Weather Service stations Terry and Terry 21 NNW. In this instance, 12 other precipitation stations in eastern Montana were used as potential base stations. The potential base stations, their periods of record, and the number of times each was used to estimate missing values of monthly precipitation at either Terry or Terry 21 NNW are shown in table 2. The average standard error of prediction for the 181 estimates made for Terry was 96 percent, and the average standard error of prediction for the 291 estimates made for Terry 21 NNW was 71 percent. Estimated monthly precipitation depths, expressed in ft, for the Cherry Creek Basin for the base period are shown in table 6 at the back of the report. The estimated mean annual precipitation depth for the base period is 0.96 ft (11.5 in.).

Reservoir evaporation for the base period was estimated from pan-evaporation data collected at Huntley, Mont. Pan-evaporation data for Huntley are available for May through September for most years and for April through October for some years. Pan evaporation for months of missing data during the 1937-92 period was estimated using an OLS regression equation relating monthly pan evaporation to monthly mean maximum temperature at Huntley. The coefficient of determination (r^2) for the regression equation was 55 percent and the standard error of estimate was 18 percent. The measured and estimated values of monthly pan evaporation for the 1937-92 base period at Huntley were converted to estimated monthly pan evaporation at Terry by multiplying by the ratio of monthly mean maximum temperature at Terry to the monthly mean maximum temperature at Huntley. For example, for a month when the monthly mean maximum temperature at Terry was 80 °F and the monthly mean maximum temperature at Huntley was 75 °F, the estimated pan evaporation at Terry would be (80/75), or 1.067 times the measured or estimated pan evaporation at Huntley. The estimated monthly pan evaporation at Terry was converted to reservoir evaporation by multiplying by a

Table 2. Precipitation stations used as potential base stations for record extension for Terry and Terry 21 NNW, Mont.

[Symbol: --, not applicable]

Station name	Period of record since 1937	No. of times station used to estimate missing values of precipitation for Terry or Terry 21 NNW	
		Terry	Terry 21 NNW
Ekalaka	1937-91	1	40
Mizpah 4 NNW	1950-91	0	10
Wibaux 2 E	1949-92	0	19
Plevna	1937-91	13	13
Mildred 5 N	1980-91	0	1
Brockway 3 WSW	1960-91	1	5
Cohagen	1967-91	0	2
Rock Springs	1952-91	0	0
Miles City FAA AP	1937-91	75	26
Glendive	1937-92	91	174
Terry	[1]1950-92	--	1
Terry 21 NNW	[2]1950-51; 1962-92	0	--

[1]Twenty-five months of missing data during period.

[2]Fifteen months of missing data during period.

monthly pan coefficient. The coefficients were empirically derived by Knapp and others (1982, p. 81) and Kohler (1954, p. 140). Estimated monthly evaporation depths, expressed in ft, for the proposed Cherry Creek reservoir for the base period are shown in table 7 at the back of the report. The estimated mean annual evaporation depth for the period is 2.73 ft.

Suspended Sediment and Dissolved Solids

Monthly values of suspended-sediment concentration for Cherry Creek were estimated from an OLS linear regression equation relating the logarithm of suspended-sediment concentration, in milligrams per liter, to the logarithm of streamflow, in cubic feet per second (fig. 2). The log-linear regression equation was derived from 75 samples obtained under varying conditions of flow during the sampling period of record. The r^2 was 0.56, and the standard error of estimate was 278 percent.

Monthly values of dissolved-solids concentration for Cherry Creek were estimated from a similar equation relating the logarithm of dissolved-solids concentration, in milligrams per liter, to the logarithm of streamflow, in cubic feet per second (fig. 2). The regression equation for estimation of dissolved-solids concentration was based on 33 samples obtained under varying conditions of flow during the sampling period of record and had an r^2 of 0.65 and a standard error of estimate of 38 percent.

Log-linear OLS regression equations also were used to estimate the suspended-sediment and dissolved-solids concentrations of inflows from the Yellowstone River (fig. 3). The regression equation for estimation of suspended-sediment concentrations was based on 211 samples obtained from the Yellowstone River near Sidney during the sampling period of record and had an r^2 of 0.50 and a standard error of estimate of 148 percent. The equation for the estimation of dissolved-solids concentrations was based on 154 samples from the Yellowstone River near Sidney and had an r^2 of 0.31 and a standard error of estimate of 27 percent.

The regression relations shown in figures 2 and 3 are poor, as indicated by the large amount of scatter about the regression lines. Nevertheless, the authors considered them adequate to provide reasonable estimates of the average concentrations of suspended sediment and dissolved solids for monthly mean flows for Cherry Creek and the Yellowstone River near Sidney. For the 1937-92 base period, the concentration of suspended sediment for the average flow in Cherry Creek was 240 mg/L and for the average flow in the Yellowstone River was 450 mg/L. Similarly, the concentration of dissolved solids for the average flow in Cherry Creek was 1,040 mg/L and for the average flow in the Yellowstone River was 420 mg/L.
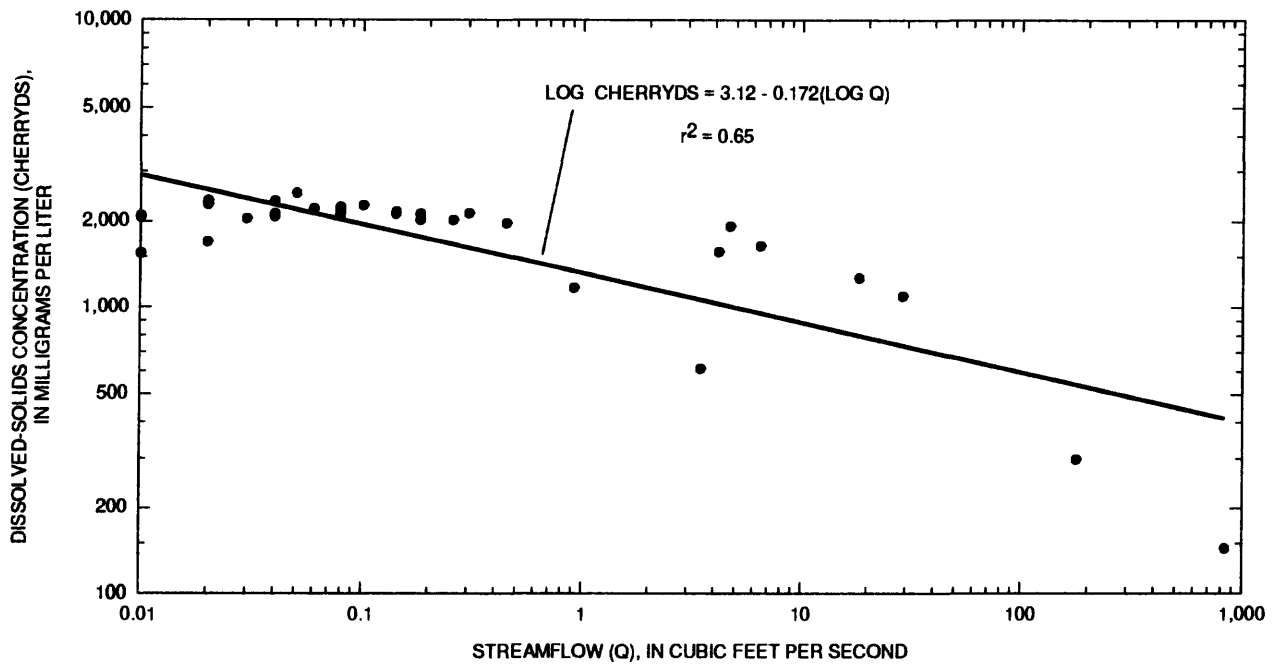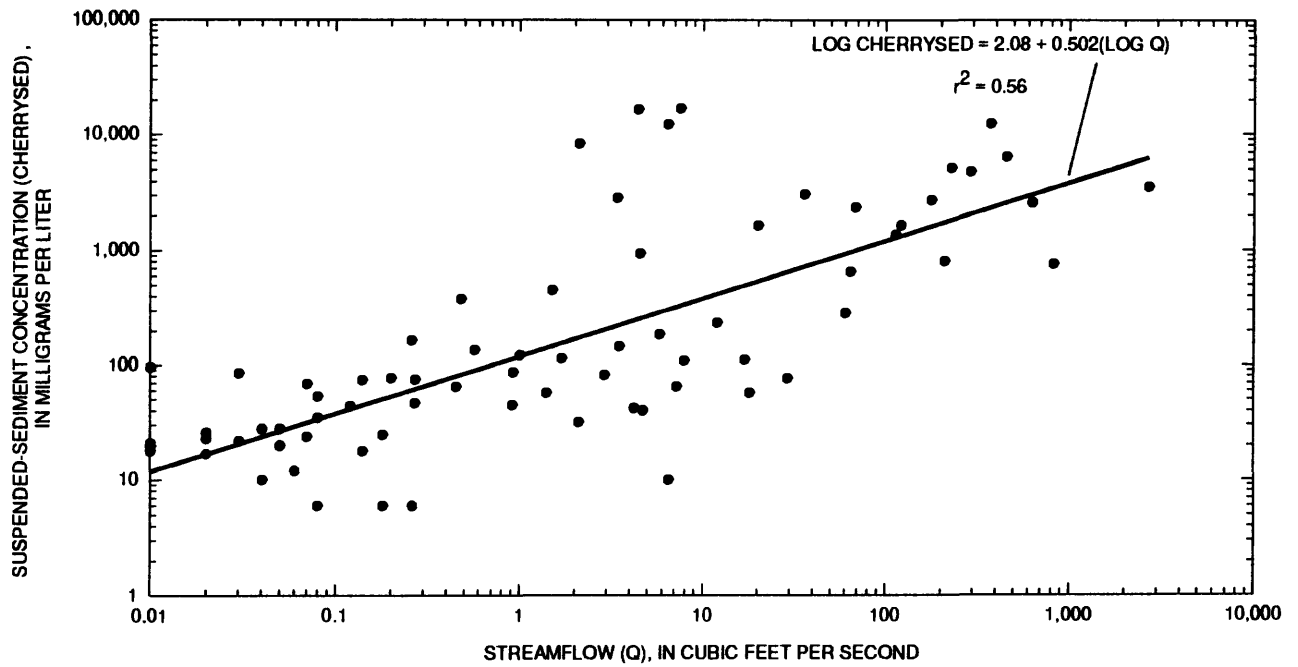
Figure 2. Regression relations for suspended-sediment and dissolved-solids concentrations for Cherry Creek near Terry, Mont.
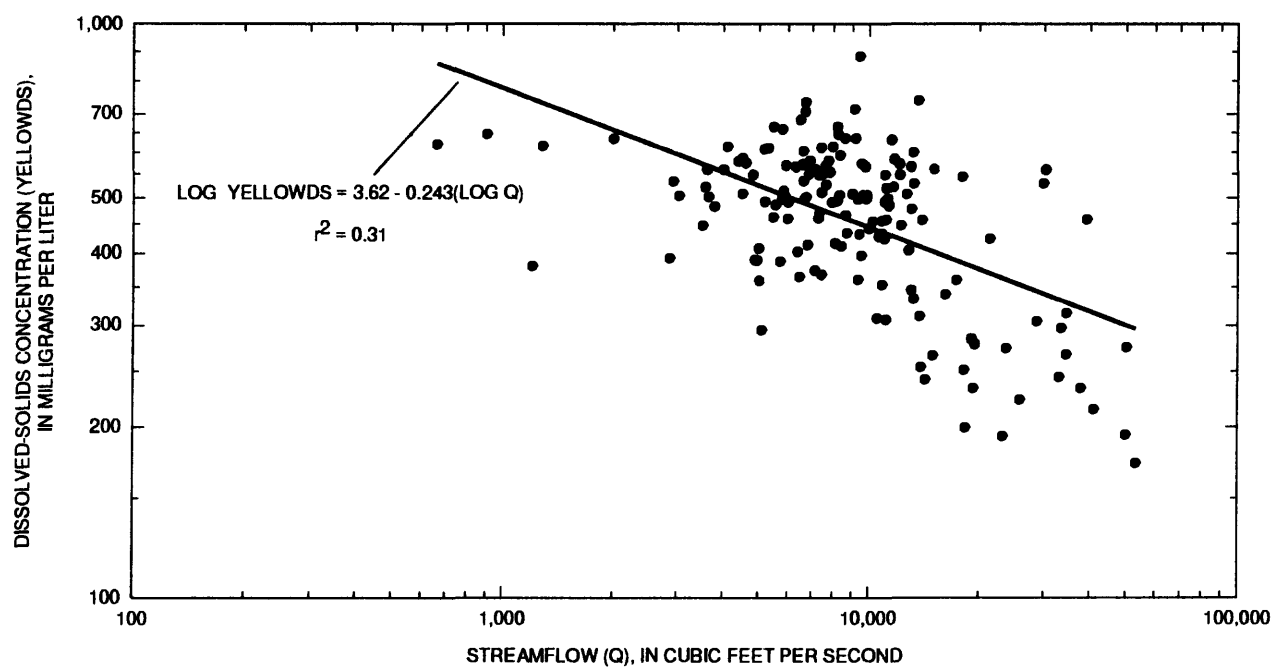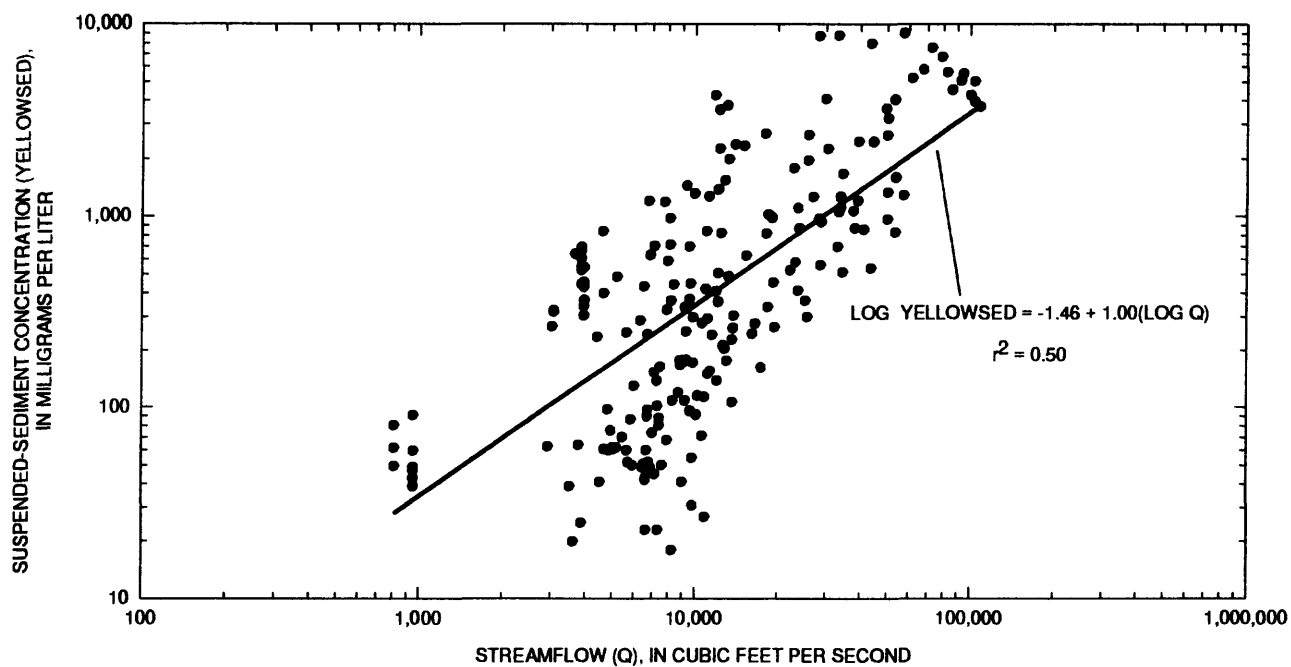
Figure 3. Regression relations for suspended-sediment and dissolved-solids concentrations for Yellowstone River near Sidney, Mont.

SIMULATION ALGORITHMS

Simulation of monthly conditions in the proposed reservoir requires that components of the hydrologic budget and suspended-sediment and dissolved-solids concentrations and loads be computed on a monthly basis. The equations and procedures for simulating the hydrologic budget and suspended-sediment and dissolved-solids concentrations and loads are described in the following two sections. The algorithms are based on the assumption that Yellowstone River inflows are added to the reservoir as needed at the end of the month after all other computations for Cherry Creek inflows, precipitation, seepage, and evaporation are completed. Actual reservoir operation would require some forecasting of flows from Cherry Creek and perhaps day-to-day inflows from the Yellowstone River to ensure that minimum reservoir elevations were always met.

Hydrologic Budget

The monthly hydrologic budget for the proposed Cherry Creek reservoir can be described by the following mass-balance equation:

$$I_i - O_i = V_i - V_{i-1}, \tag{1}$$

where I_i and O_i are the reservoir inflow and outflow, respectively, for month i;

V_i and V_{i-1} are the reservoir volumes at the end of months i and i-1, respectively; and all terms are expressed in units of volume as acre-ft.

The components of each term in the mass-balance equation and the algorithm for making computations are described below.

Sources of inflow to the proposed Cherry Creek reservoir include Cherry Creek, the Yellowstone River whenever reservoir elevation falls below 2,260.0 ft, and precipitation over the reservoir surface. Although a flowing well is known to exist near the proposed reservoir, ground-water inflow to the reservoir was considered to be negligible because Cherry Creek is known to be an ephemeral or intermittent stream throughout its length. Outflows include reservoir seepage losses, evaporation, and flows through the principal reservoir outlet or the spillway whenever the maximum operating level of 2,290.0 ft is exceeded.

Reservoir volume at the beginning of the 1937-92 simulation period was presumed to be that for the minimum operating level of 2,260.0 ft. For all subsequent months, the relation between reservoir elevation

and volume was determined from a reservoir elevation-capacity table. The elevation-capacity table was based on data furnished by the Bureau of Land Management (1991). An abbreviated elevation-capacity table is shown in table 8 at the back of the report.

Reservoir seepage loss is the hydrologic-budget component that probably is least accurately known. Because of the lack of reliable information, two different values of reservoir seepage were used in the hydrologic-budget computations to determine the relative effects of possible error in the seepage term. The lowest possible value of seepage loss (0 ft³/s) was used for one set of computations and a value (3 ft³/s) used in a previous study for Cherry Creek by the Bureau of Reclamation (Calcagno and Parish, 1990) and presumed to be conservatively large was used in the second set of computations.

Equation 1 is not explicitly solvable for reservoir volume because several components of monthly inflow volume (precipitation and inflows from the Yellowstone River) and outflow volume (evaporation and outlet flows) are dependent upon reservoir elevation or volume. Accordingly, the following multi-step solution procedure was used. First, Cherry Creek was initially considered to be the only source of reservoir inflow, and seepage loss was initially considered to be the only source of outflow. Equation 1 was modified, rearranged, and solved for a trial value of reservoir volume, $\hat{V}_i$, as follows:

$$\hat{V}_i = C_i \times (CHERRY_i - SEEP) + V_{i-1}, \tag{2}$$

where C_i is a conversion factor used to convert the units for monthly flow, in cubic ft per second, to volume, in acre-feet, and is equal to 1.9835 times the number of days in month i;

$CHERRY_i$ is the inflow, in cubic feet per second, from Cherry Creek for month i;

SEEP is the seepage loss, in cubic feet per second, from the reservoir (either 0 or 3); and the other terms are as previously defined.

After $\hat{V}_i$ was computed using equation 2, the elevation-capacity table for the reservoir was used to determine the reservoir elevation, $\hat{E}_i$, corresponding to $\hat{V}_i$, and precipitation and evaporation depths were algebraically added to the reservoir elevation to obtain a revised, more correct reservoir elevation, E_i:

$$E_i = \hat{E}_i + (P_i - EVAP_i), \tag{3}$$

where P_i and $EVAP_i$ are, respectively, the monthly precipitation and evaporation depths in ft.

Before the reservoir volume for the end of month i was calculated, the reservoir elevation was checked to ensure that it was not below the minimum operating level of 2,260.0 ft or above the maximum operating level of 2,290.0 feet. If the reservoir elevation was below 2,260.0 ft, the Yellowstone River inflow in cubic feet per second, $YELLOW_i$, was calculated as the difference between the reservoir volumes corresponding to 2,260.0 ft and E_i divided by the conversion factor, C_i:

$$YELLOW_i = (V_{min} - V_{Ei})/C_i, \qquad (4)$$

where V_{min} and V_{Ei} are the reservoir volumes, obtained from the reservoir elevation-capacity table, corresponding to elevations 2,260.0 and E_i, respectively; and

C_i is as defined for equation 2.

Similarly, if E_i exceeded the maximum operating level, the rate of reservoir outlet flow, $OUTFLOW_i$, in cubic feet per second was calculated as follows:

$$OUTFLOW_i = (V_{Ei} - V_{max})/C_i, \qquad (5)$$

where V_{max} is the reservoir volume corresponding to the maximum operating level of 2,290.0 ft and the other terms are as previously defined.

Finally, the reservoir volume for the end of month i, V_i, was calculated as follows:

$$V_i = V_{Ei} + (YELLOW_i - OUTFLOW_i) \times C_i \qquad (6)$$

where all terms are as previously defined. For reservoir elevations between 2,260.0 ft and 2,290.0 ft, $YELLOW_i$ and $OUTFLOW_i$ are both equal to 0.0.

Suspended-Sediment Load and Dissolved-Solids Concentration

After the hydrologic-budget algorithm was used to simulate reservoir inflow and outflow components, volumes, and elevations, the monthly suspended-sediment loads to the reservoir and concentration of dissolved solids in the reservoir were simulated based on the assumptions that chemical reactions or stratification within the reservoir were insignificant. The equation for calculating suspended-sediment load to the reservoir is as follows:

$$LOAD_i = K_i \times (CHERRYSED_i \times CHERRY_i + YELLOWSED_i \times YELLOW_i), \qquad (7)$$

where $LOAD_i$ is the suspended-sediment load to the reservoir for month i, in tons;

K_i is a conversion factor used to convert concentration units, in milligrams per liter, times discharge units, in cubic feet per second, to load units, in tons, and is equal to 0.0027 times the number of days in month i;

$CHERRYSED_i$ is the concentration of suspended sediment in Cherry Creek for month i, in milligrams per liter;

$CHERRY_i$ is the monthly average inflow to the reservoir from Cherry Creek, in cubic feet per second;

$YELLOWSED_i$ is the concentration of suspended sediment in the Yellowstone River for month i, in milligrams per liter; and

$YELLOW_i$ is the monthly average inflow to the reservoir from the Yellowstone River, in cubic feet per second.

Although reservoir outflows were significant for some months, outflows were negligible or absent during most months. Therefore, it was assumed that all suspended sediment would be deposited in the reservoir. This assumption is considered to be conservative in that computations assuming no sediment loss in outflows would tend to overestimate sediment deposition in the reservoir. Because the cumulative sediment loading to the reservoir results in a reduced reservoir capacity, sediment volume also was computed as:

$$LOADVOL_i = LOAD_i \times (0.000656), \qquad (8)$$

where $LOADVOL_i$ is the volume of suspended sediment delivered to the reservoir during month i, in acre-ft;

$LOAD_i$ is as defined for equation 7; and

0.000656 is a conversion factor for converting tons of sediment to acre-ft based on an assumed unit weight of sediment of 70 lb/ft^3.

The cumulative total volume of sediment in the reservoir for any month i is:

$$VOL_i = VOL_{i-1} + LOADVOL_i, \qquad (9)$$

where VOL_i and VOL_{i-1} are the cumulative total volumes of sediment at the end of months i and i-1, respectively, in acre-ft; and

$LOADVOL_i$ is as defined for equation 8.

Mass balance calculations were used to compute the concentration of dissolved solids in the reservoir at the end of each month. The change in total mass of dissolved solids in the reservoir from the end of a previous month, i-1, to the current month, i, is expressed as:

$$CHANGE_i = [(RESCONC_i \times V_i) - (RESCONC_{i-1} \times V_{i-1})] \times K_i/C_i, \tag{10}$$

where $CHANGE_i$ is the change in mass of dissolved solids in the reservoir during month i, in tons;
$RESCONC_i$ and $RESCONC_{i-1}$ are the concentrations of dissolved solids, in milligrams per liter, in the reservoir at the ends of months i and i-1, respectively;
V_i and V_{i-1} are the reservoir volumes in acre-feet, at the ends of months i and i-1, respectively; and the other terms are as previously defined.

The change in mass of dissolved solids in the reservoir results from a mass gain from inflows from Cherry Creek and the Yellowstone River and a mass loss from reservoir outlet flows and seepage. The mass gain in dissolved solids during month i can be expressed as:

$$GAIN_i = K_i \times (CHERRYDS_i \times CHERRY_i + YELLOWDS_i \times YELLOW_i), \tag{11}$$

where $GAIN_i$ is the mass gain in dissolved solids in the reservoir during month i, in tons;
$CHERRYDS_i$ is the concentration of dissolved solids in Cherry Creek for month i, expressed in milligrams per liter;
$YELLOWDS_i$ is the concentration of dissolved solids in the Yellowstone River for month i in milligrams per liter; and
$CHERRY_i$ and $YELLOW_i$ are as previously defined for equation 7.

The mass loss of dissolved solids during month i can be expressed as:

$$LOSS_i = K_i \times (OUTFLOW_i + SEEP) \times (RESCONC_i + RESCONC_{i-1})/2, \tag{12}$$

where $LOSS_i$ is the mass loss in dissolved solids from the reservoir during month i in tons;

$(RESCONC_i + RESCONC_{i-1})/2$ represents an average value of concentration of dissolved solids in the reservoir during month i based on the concentrations at the end of months i and i-1; and all other terms are as previously defined.

To satisfy the condition of mass balance of dissolved solids in the reservoir, the change in dissolved solids during month i has to equal the mass gain in dissolved solids minus the mass loss in dissolved solids:

$$CHANGE_i = GAIN_i - LOSS_i. \tag{13}$$

Substituting the expressions in equations 10 and 12 for the change and loss terms in equation 13 and

solving for the concentration of dissolved solids at the end of month i, $RESCONC_i$, yields the following:

$$RESCONC_i = [(RESCONC_{i-1}) \times V_{i-1} \times (C_i/K_i) + GAIN_i - (K_i/2) \times (SEEP + OUTFLOW_i) \times RESCONC_{i-1}]/ [V_i \times (C_i/K_i) + (K_i/2) \times (SEEP + OUTFLOW_i)], \tag{14}$$

where all terms are as previously defined.

SIMULATION RESULTS

The hydrologic-budget, suspended-sediment, and dissolved-solids algorithms were used to compute monthly inflows from the Yellowstone River and reservoir elevations, volumes, sediment volumes, and dissolved-solids concentrations for the 1937-92 base period for the two different values of reservoir seepage. Because the simulations showed that Yellowstone River inflows were required for only 4 months during the first year when reservoir seepage was 0 ft³/s, no table or figure is shown for that value of seepage. The results of the simulations for Yellowstone River inflows for a reservoir seepage of 3 ft³/s are shown in table 9 at the back of the report and are displayed graphically in figure 4. Simulation results for reservoir outflows, elevations, volumes, sediment volumes, and dissolved-solids concentrations are shown graphically in figures 5-10.

For a reservoir seepage loss of 0 ft³/s, simulations indicate that inflows from the Yellowstone River were required for only 4 months in 1937 to maintain minimum operating water levels in the reservoir. The maximum monthly inflow from the Yellowstone River was 1.3 ft³/s, and the average annual required inflow was less than 0.01 ft³/s. In general, reservoir inflows from Cherry Creek were adequate to keep the reservoir elevation above the minimum operating level when seepage from the reservoir was 0 ft³/s.

For a reservoir seepage of 3 ft³/s, table 9 and figure 4 show that Yellowstone River inflows were required for 226 months out of 672, or 34 percent of the months, to keep reservoir elevations above the minimum operating level. The maximum monthly Yellowstone River inflow was 5.1 ft³/s, and the average annual inflow was 1.0 ft³/s.

Figure 5 shows simulated monthly reservoir outflows for a seepage loss of 0 ft³/s, and figure 6 shows simulated monthly reservoir outflows for a seepage loss of 3 ft³/s. In general, outflows occurred about twice as often and were greater for conditions of no seepage loss. Supplemental inflows from the Yellowstone River primarily serve to balance the water lost as seepage and do not necessarily increase
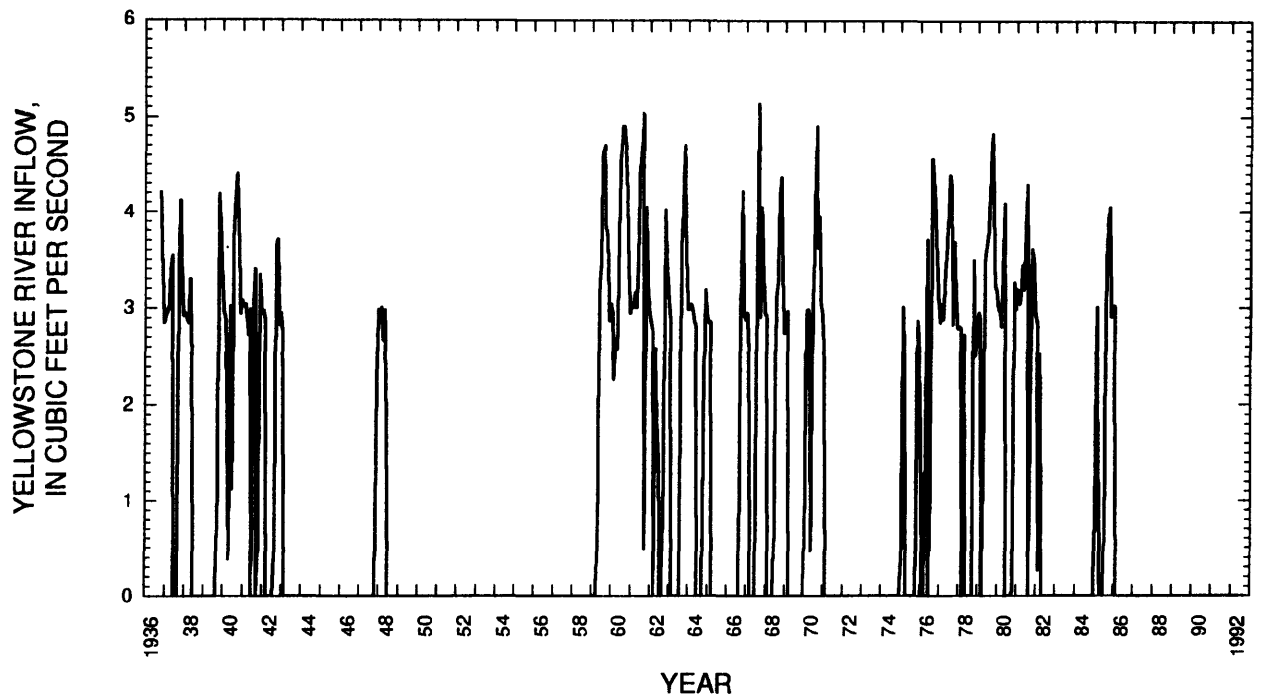
Figure 4. Simulated inflows to proposed Cherry Creek Reservoir near Terry, Mont., from the Yellowstone River for a reservoir seepage loss of 3 cubic feet per second.
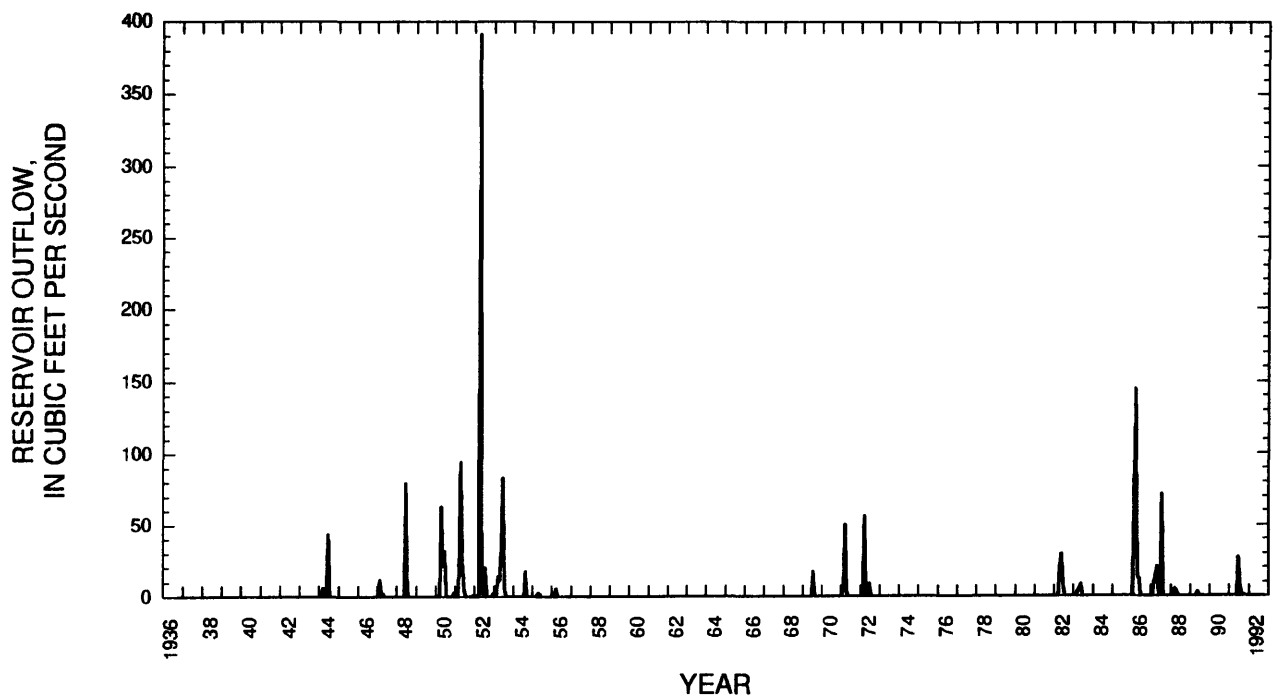
Figure 5. Simulated outflows from proposed Cherry Creek Reservoir near Terry, Mont., for condition of no seepage loss.
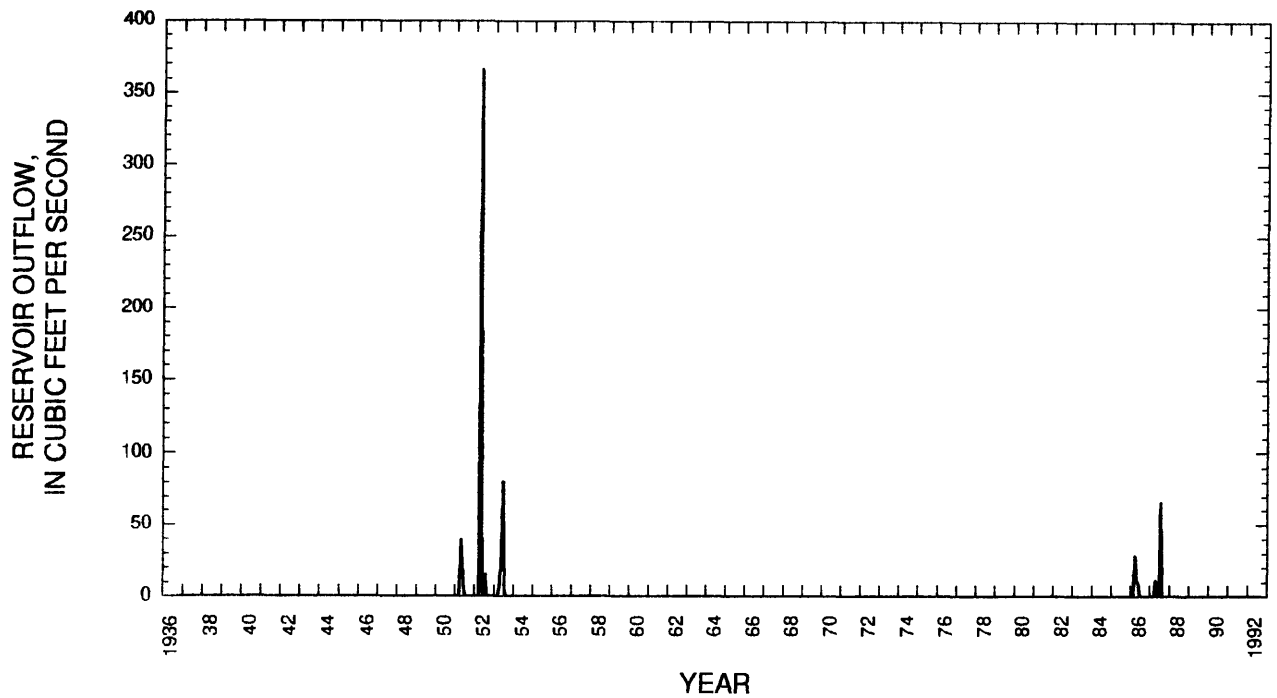
Figure 6. Simulated outflows from proposed Cherry Creek Reservoir near Terry, Mont., for a reservoir seepage loss of 3 cubic feet per second.
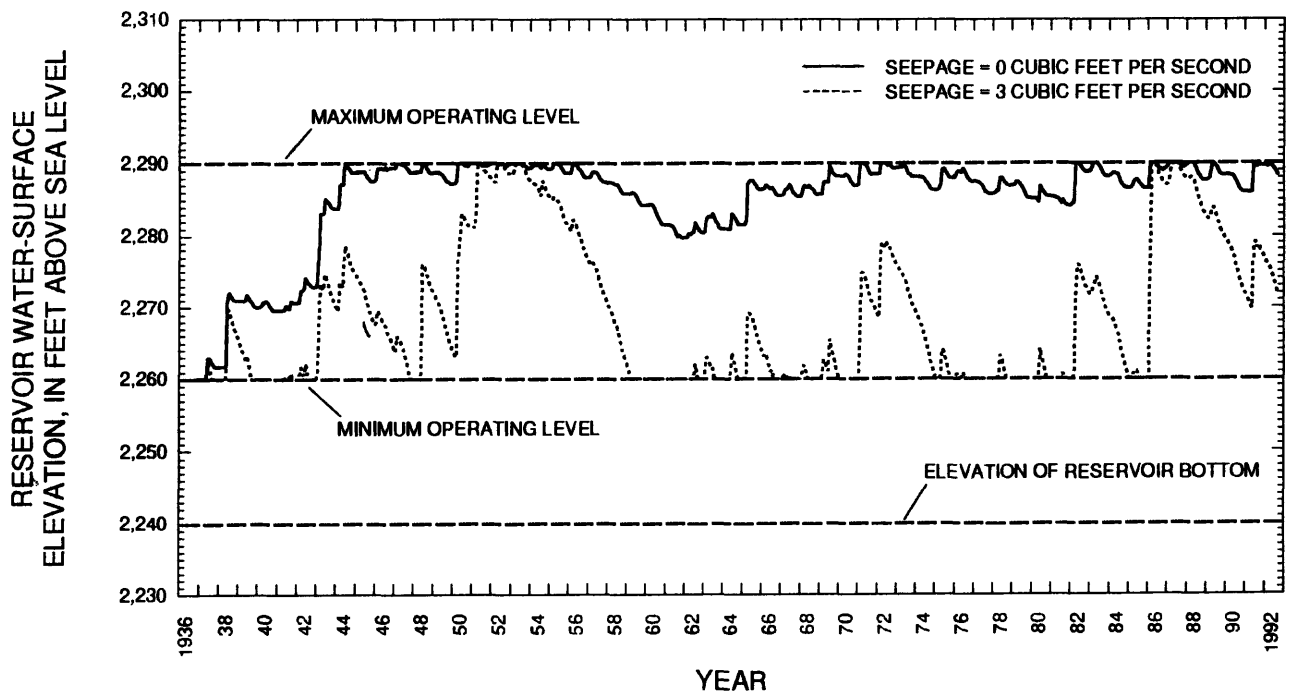
Figure 7. Simulated water-surface elevation of proposed Cherry Creek Reservoir near Terry, Mont., for two rates of reservoir seepage loss.
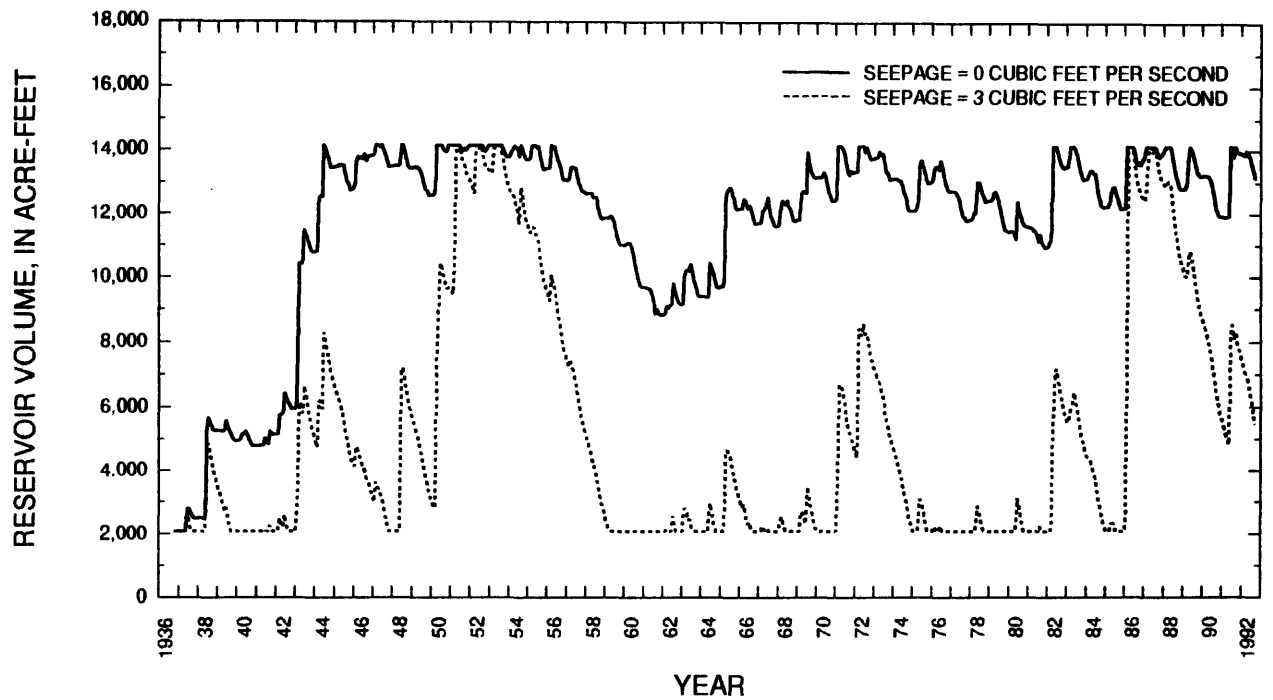
Figure 8. Simulated volume of proposed Cherry Creek Reservoir near Terry, Mont., for two rates of reservoir seepage loss.
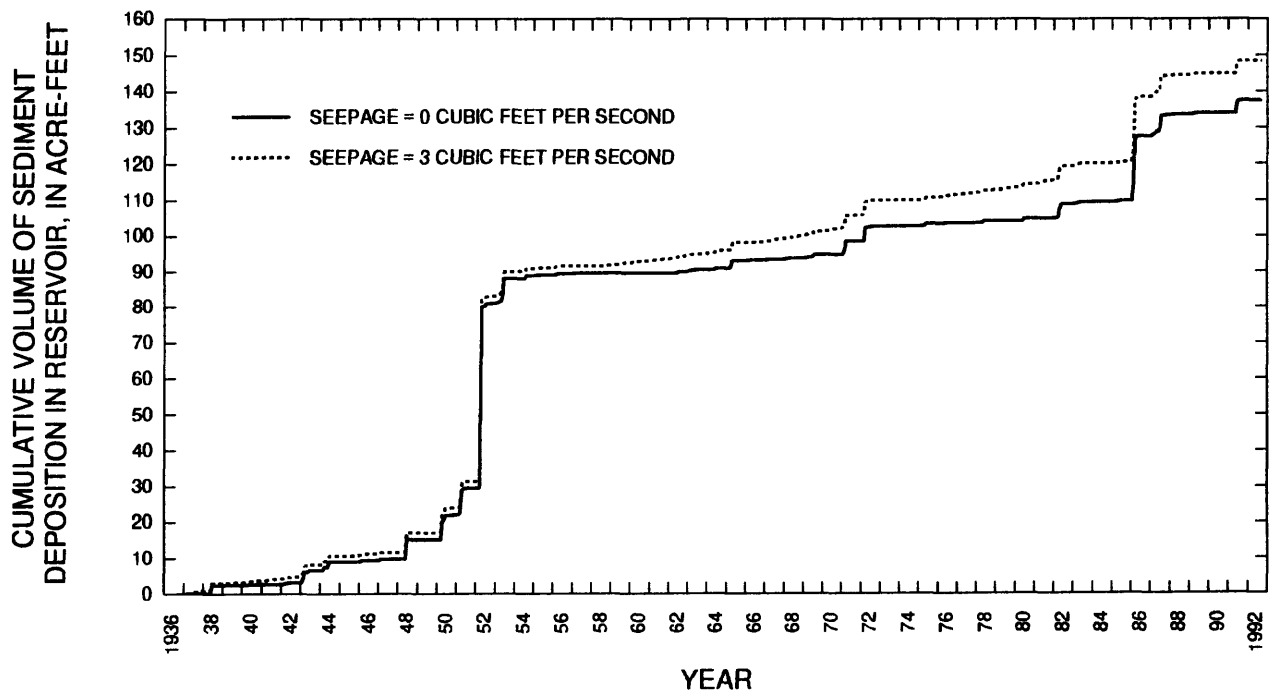
Figure 9. Simulated cumulative volume of sediment deposition in proposed Cherry Creek Reservoir near Terry, Mont., for two rates of reservoir seepage loss.
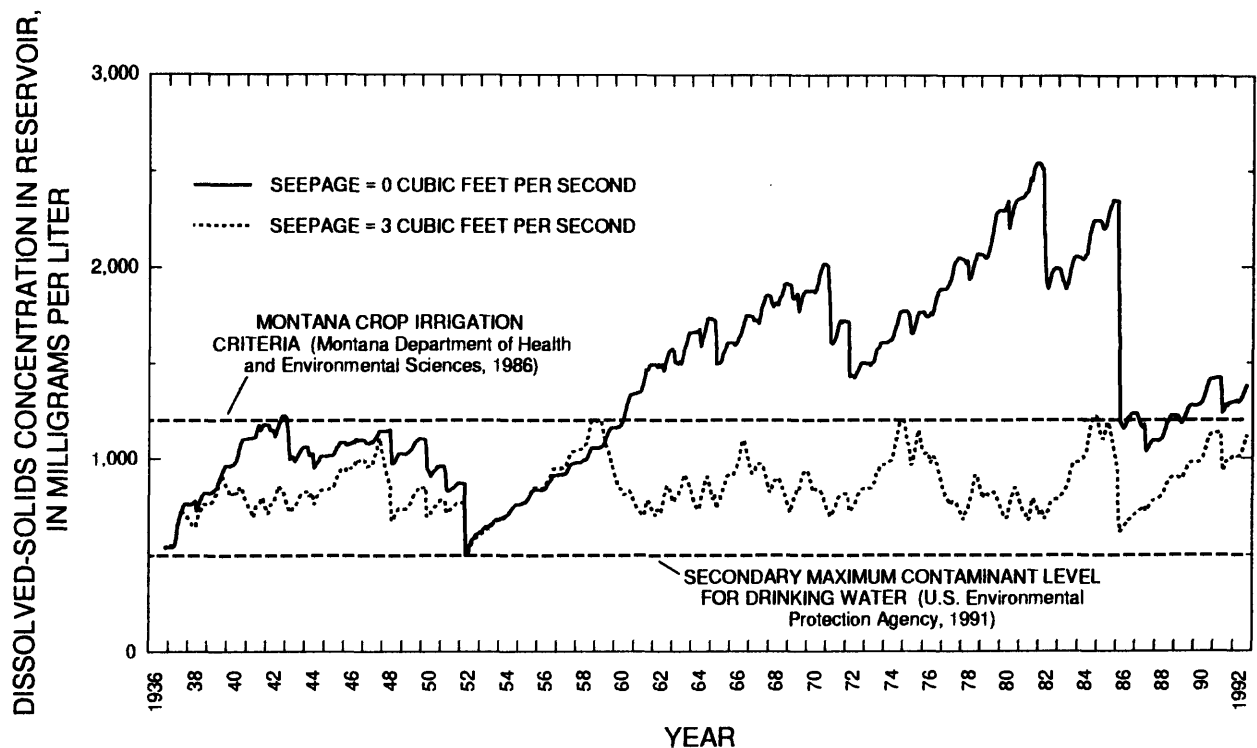
Figure 10. Simulated concentration of dissolved solids in proposed Cherry Creek Reservoir near Terry, Mont., for two rates of reservoir seepage loss.

outflow from the reservoir.

Figure 7 shows simulated reservoir elevations throughout the base period for the two rates of reservoir seepage loss. For a reservoir seepage of 0 ft³/s, reservoir elevations generally were maintained near the maximum operating level throughout most of the base period. For a reservoir seepage of 3 ft³/s, reservoir elevations varied between the minimum and maximum operating levels, but generally were closer to the minimum operating level.

Figure 8 shows simulated reservoir volumes for the two rates of reservoir seepage loss and corresponds to figure 7. For a reservoir seepage of 0 ft³/s, reservoir volume was fairly constant after the initial filling period and generally was near 14,000 acre-ft except for a dry period in the early 1960's. For a reservoir seepage of 3 ft³/s, reservoir volume varied from 2,100 acre-ft to 14,000 acre-ft, but generally was closer to 2,100 acre-ft.

Figure 9 shows the simulated cumulative sediment deposition in the reservoir for the two rates of reservoir seepage loss. Because of the additional sediment inflow in supplemental water diverted from the Yellowstone River, the cumulative volume of sediment deposition is slightly greater for a reservoir seep-

age of 3 ft³/s than it is for a seepage of 0 ft³/s. The minimum reservoir volume of 2,000 acre-ft is not substantially decreased by 56 years of sediment deposition for either rate of sediment loading (138 to 149 acre-ft).

Figure 10 shows the effects of the two rates of reservoir inflows and seepage loss on the simulated concentration of dissolved solids in the reservoir. For a seepage loss of 3 ft³/s, Yellowstone River water is imported and the concentration of dissolved solids ranges from about 500 to about 1,200 mg/L. For a seepage loss of 0 ft³/s, Cherry Creek is the sole source of inflow and the concentration of dissolved solids shows a slightly increasing trend throughout the base period, interrupted by several large decreases when inflows were large. The concentration reaches a maximum value of about 2,500 mg/L in 1982. Thus, although a reservoir seepage loss of 3 ft³/s requires substantially more supplemental inflow from the Yellowstone River and results in reservoir elevations and volumes substantially less than those for a full reservoir, the water quality, as measured by concentration of dissolved solids, is better for the condition of greater seepage and the importation of water from the Yellowstone River.

ESTIMATES OF FLOOD HYDROGRAPHS AND VOLUMES

Because only 3 years of annual peak-discharge data are available for Cherry Creek, regional equations developed by the Geological Survey for estimating flood peaks at ungaged sites were used to estimate flood discharges having recurrence intervals of 25, 50, and 100 years (Omang, 1992, p. 64). The estimated peak discharges and associated recurrence intervals are shown in table 3.

Table 3. Flood discharges and recurrence intervals for Cherry Creek near Terry, Mont.

Discharge, in cubic feet per second	Recurrence interval, in years
4,520	25
6,240	50
8,640	100

To estimate hydrographs and runoff volumes associated with the 25-, 50-, and 100-year peak discharges, a rainfall-runoff simulation model developed by the U.S. Army Corps of Engineers (HEC-1) that is based on the Clark unit-hydrograph method was used to simulate runoff from basin-averaged precipitation excess on the Cherry Creek Basin. Precipitation excess is the total precipitation input to the basin minus infiltration and detention losses. Total precipitation input for each peak discharge was a synthetic storm having a 24-hour duration. Hourly values of precipitation for the 25-, 50-, and 100-year recurrence intervals were obtained from depth-duration data compiled by the National Weather Service (Miller and others, 1973) and corrected for the Cherry Creek drainage area by using a depth-area adjustment developed by the U.S. Soil Conservation Service and modified by Parrett (1986). The 24-hour-duration synthetic storm for each recurrence interval was developed by assigning the largest hourly value of rainfall depth to the 16th hour of the storm, the second and third largest values to the 15th and 14th hour, respectively, the fourth largest to the 17th hour, and so on in an alternating fashion until values were assigned to all 24 hours of the storm (Cudworth, 1989, p. 58-61). The resultant synthetic storm hyetograph for the 100-year recurrence interval is shown in figure 11.

Infiltration and detention losses were estimated using the Curve Number method developed by the U.S. Soil Conservation Service (1972). This method requires that a Curve Number characterizing the ability of the land surface to absorb precipitation be assigned to a basin. The Curve Number ranges from 0 to 100 where 0 represents a totally porous land surface that absorbs all precipitation and 100 represents a land surface that has no absorption or detention. Based on a previous study in northeastern Montana (Parrett, 1986), the basin-average Curve Number for Cherry Creek was assumed to be 80.0.

For the Clark unit-hydrograph method, two variables are required to define a unit hydrograph for a basin. One variable, time of concentration (T_c), is a measure of the time required for a particle of water to travel from the farthest point in the basin to the basin outlet. The second variable, basin-storage coefficient (R), is a measure of the effect of temporary basin storage on the shape of the hydrograph. T_c and R can be determined for a specific basin by analyzing one or more recorded storms and flood hydrographs or by using regional equations developed from recorded hydrograph data at numerous sites. A regional equation developed by Holnbeck and Parrett (1993) having a coefficient of determination (r^2) of 0.91 and a standard error of estimate of 0.16 log units was used to calculate T_c as 13.6 hours. Although Holnbeck and Parrett also developed a regional equation for R, this equation was not used because of its small coefficient of determination (0.47) and large standard error of estimate (0.39 log units). Instead, a recorded flood hydrograph for June 25, 1991 was used to estimate an R value for Cherry Creek. The recorded flood hydrograph had a peak discharge of 4,720 ft³/s and an estimated flood volume of 2,300 acre-ft (fig. 12). As discussed by Sabol (1988), R was estimated from the recorded flood hydrograph by dividing the flood volume remaining at the inflection point of the recession limb of the hydrograph by the discharge at the inflection point (fig. 12). The value of R estimated from the recorded flood hydrograph for June 25, 1991 was 7 hours.

Flood hydrographs based on a runoff Curve Number of 80.0, a T_c of 13.6 hours, an R of 7 hours, and 24-hour duration synthetic storms having recurrence intervals of 25, 50, and 100 years are shown in figure 13. The peak discharges and flood volumes determined from the Clark unit-hydrograph method are shown together with the peak discharges determined from Geological Survey regional equations in table 4.

As shown in table 4, the peak discharges for the 25-, 50-, and 100-year synthetic storms as determined from the Clark unit-hydrograph analysis are close to the corresponding peak discharges determined from Geological Survey regional equations. Thus, the flood volumes determined from the Clark unit-hydrograph method are also presumed to be reasonable.
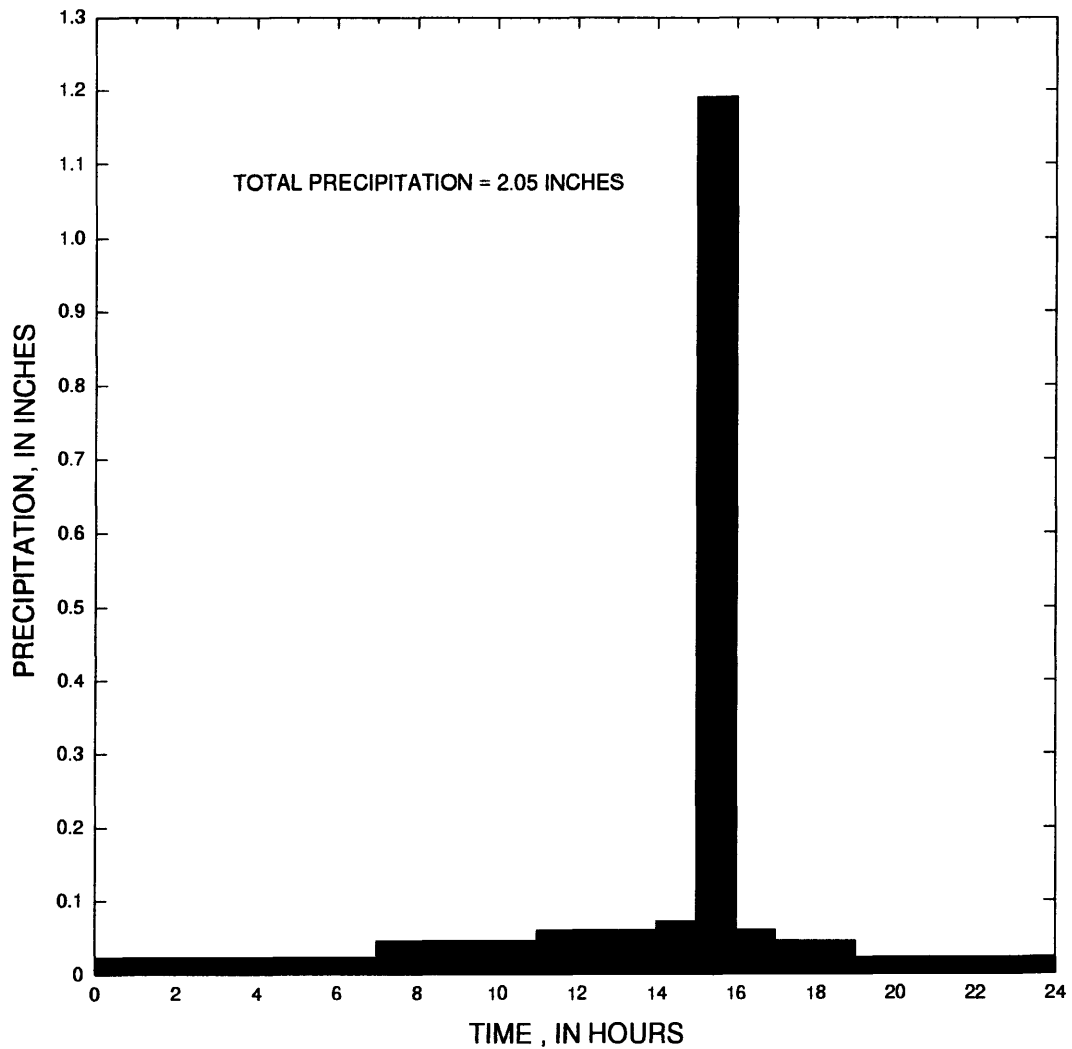
Figure 11. Synthetic 100-year storm hyetograph for Cherry Creek Basin near Terry, Mont.

Table 4. Peak discharges and flood volumes for Cherry Creek near Terry, Mont., for specified recurrence intervals

Peak discharge, in cubic feet per second, for specified method		Flood volume, in acre-feet	Recurrence interval, in years
Regional equation	Clark unit-hydrograph		
4,520	4,610	6,090	25
6,240	6,490	8,450	50
8,640	8,670	11,250	100

The flood volume for the 100-year storm is about 11,250 acre-ft. Monthly runoff for Cherry Creek can exceed the 100-year flood volume for months having more than one large storm or for months having prolonged snowmelt runoff in addition to one or more storms. For example, the estimated monthly mean flow for Cherry Creek for April 1952 (table 5) was 390 ft³/s or about 23,200 acre-ft. In many basins in northeastern Montana, large floods in April 1952 caused record peak and monthly mean discharges as a result of April storms coupled with exceptionally large amounts of snowmelt runoff.
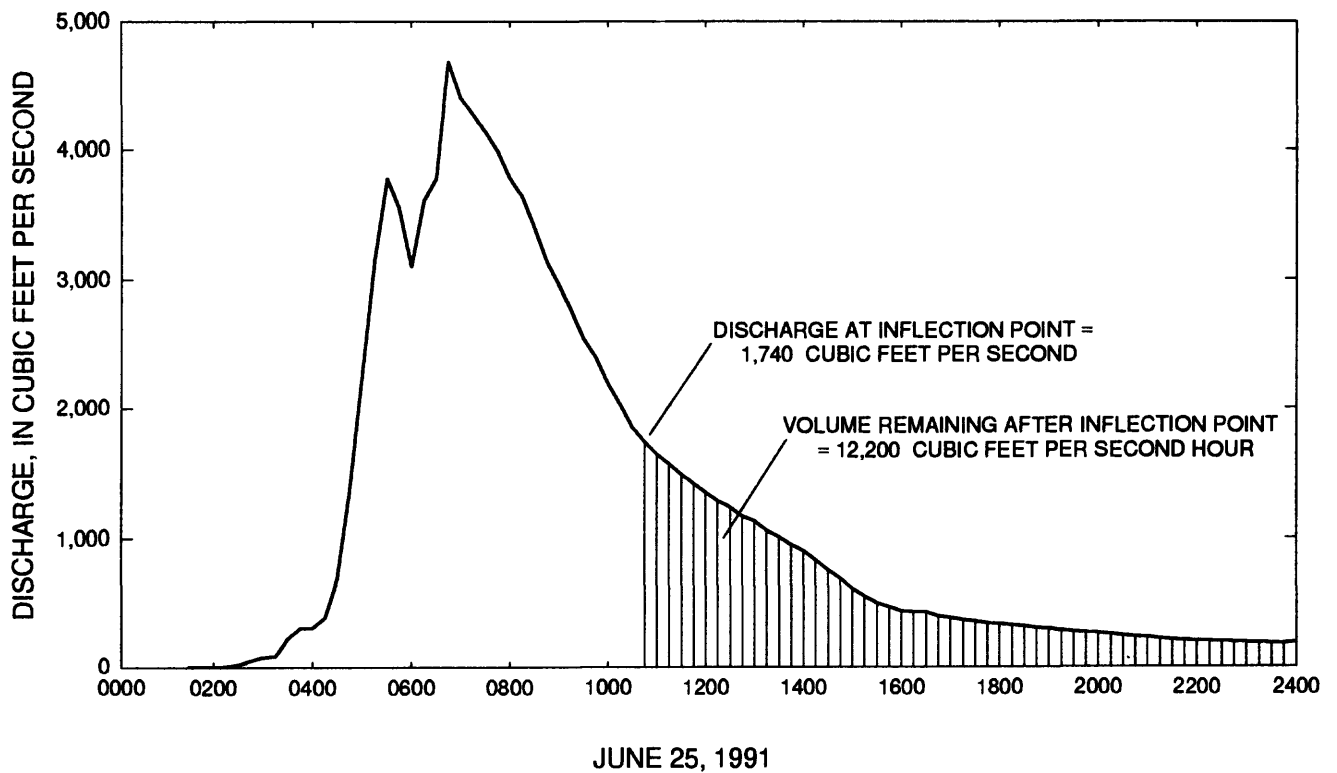
Figure 12. Hydrograph for Cherry Creek near Terry, Mont., for the flood of June 25, 1991.
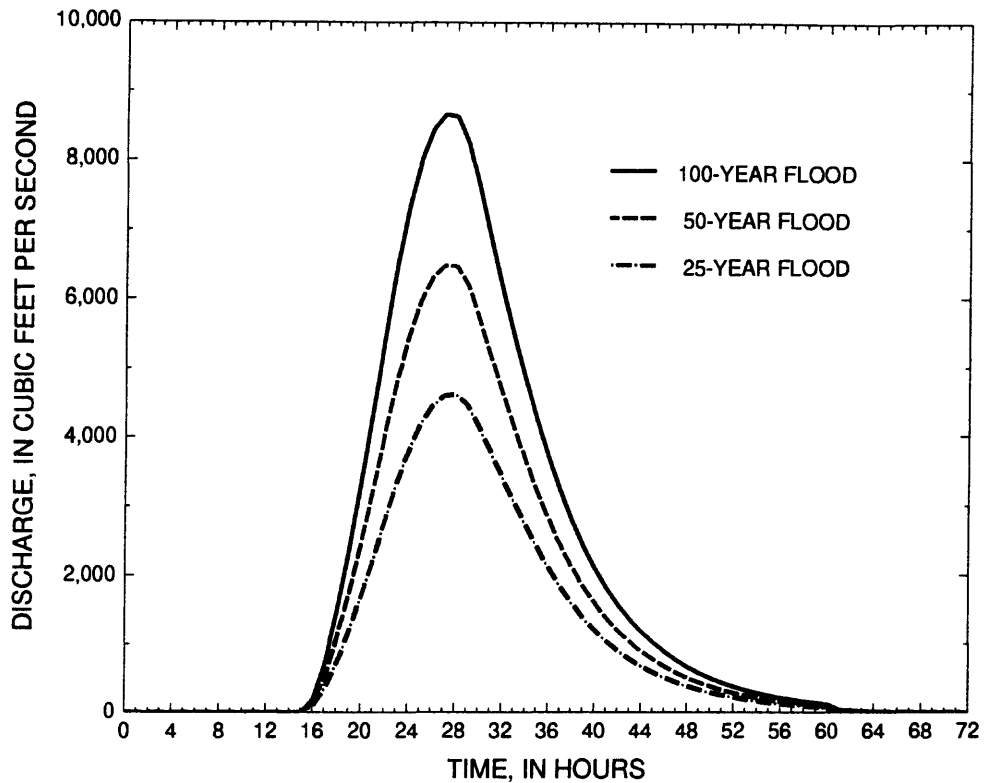
Figure 13. Synthetic hydrographs for 25-, 50-, and 100-year floods for 24-hour duration storms for Cherry Creek near Terry, Mont.

SUMMARY

A reservoir for recreation and fish-and-wildlife habitat enhancement is proposed for Cherry Creek, an intermittent stream near Terry, Mont. A hydrologic budget for the proposed Cherry Creek Reservoir was simulated for the 1937-92 base period. Streamflow and precipitation were estimated for months of missing data using a multi-station record-extension procedure. Evaporation was estimated from nearby pan-evaporation rates that were extrapolated by using monthly mean maximum-temperature ratios. Water diversions from the Yellowstone River were included in the budget whenever reservoir elevations dropped below a specified minimum operating level of 2,260.0 ft. Outflows from the reservoir were considered on a monthly basis only when the reservoir elevation exceeded a maximum operating level of 2,290.0 ft. Monthly suspended-sediment and dissolved-solids concentrations in the reservoir were estimated for the simulation period from regression relations between concentration and streamflow for Cherry Creek near Terry, Mont., and for the Yellowstone River near Sidney, Mont.

Because of the uncertainty about reservoir seepage loss, reservoir simulations were based on two values of seepage. One value was the lowest possible seepage loss, 0 ft³/s, and the other value was a constant loss rate of 3 ft³/s that was used in a previous investigation of Cherry Creek Reservoir by the Bureau of Reclamation. The results of the reservoir simulations showed that inflows from Cherry Creek generally were adequate to keep the reservoir elevation above the minimum operating level if no seepage occurred. For a simulated reservoir seepage of 3 ft³/s, inflows from the Yellowstone River were required 34 percent of the months. The average monthly inflow from the Yellowstone River required to maintain the minimum reservoir operating level was about 1.0 ft³/s for a reservoir seepage of 3 ft³/s. With minimal Yellowstone River inflows, the reservoir elevation generally was maintained near the maximum operating level under conditions of no seepage, but generally was close to the minimum operating level for a seepage of 3 ft³/s.

Cumulative sediment deposition in the reservoir was 149 acre-ft for a reservoir seepage of 3 ft³/s and 138 acre-ft for a reservoir seepage of 0 ft³/s. The additional sediment deposition for a seepage of 3 ft³/s came from supplemental water diverted from the Yellowstone River. The concentration of dissolved solids in the reservoir showed a slightly increasing trend interrupted by several large decreases when seepage was 0 ft³/s and reached a maximum value of about 2,500 mg/L in 1982. The concentration of dissolved solids ranged from about 500 to 1,200 mg/L throughout the base period for a reservoir seepage of 3 ft³/s. Water quality in the reservoir, as measured by the concentration of dissolved solids, thus is better for a reservoir seepage of 3 ft³/s because of the importation of water from the Yellowstone River.

Flood volumes for flood discharges having 25-, 50-, and 100-year recurrence intervals were computed from 24-hour duration synthetic storms having 25-, 50-, and 100-year recurrence intervals. The synthetic storms were used in the HEC-1 rainfall-runoff model to estimate flood hydrographs based on the Clark unit-hydrograph method. The resultant flood hydrographs were used to compute flood volumes. One variable used in the Clark unit-hydrograph method, time of concentration (T_c), was computed from a regional equation previously developed by the U.S. Geological Survey. The other variable used in the Clark unit-hydrograph method, basin-storage coefficient (R), was estimated by analyzing a recorded flood hydrograph for the flood of June 25, 1991. Rainfall infiltration and detention losses were estimated using the Curve Number approach. Based on a previous study in northeastern Montana, the basin-average Curve Number used for the Cherry Creek basin was 80.0. The peak discharges of the 25-, 50-, and 100-year flood hydrographs determined from the Clark unit-hydrograph method compared closely to 25-, 50-, and 100-year peak discharges determined from regional equations developed by the U.S. Geological Survey. The volume of the 100-year flood hydrograph determined from the Clark unit-hydrograph method was about 11,250 acre-ft.

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DATA

Table 5. Recorded and estimated monthly mean flow for Cherry Creek near Terry, Mont., for water years 1937-92

Water year	Mean streamflow for indicated month, in cubic feet per second											
	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.
1937	0	0	0	0	0	0	0	0.3	13	1	0	0
1938	0	0	0	0	0	.1	0	.6	47	8	0	0
1939	0	0	0	0	0	.2	0	.9	5	.2	0	0
1940	0	0	0	0	0	1	2	.4	2	.3	.8	0
1941	0	0	0	0	0	.2	.2	.1	5	.4	.6	5
1942	.4	.1	0	0	0	10	.2	.8	9	.1	.1	.1
1943	.4	.4	0	0	29	46	1	.2	16	.6	.2	0
1944	0	.4	.4	0	0	27	2	.4	39	2	.4	0
1945	.1	.1	0	0	.2	.9	.2	.1	.5	0	0	0
1946	0	.3	.3	2	15	2	.1	.2	.6	2	0	.4
1947	.6	.1	0	.1	15	.1	3	.3	.5	.1	.3	.1
1948	.1	.1	0	0	0	.3	.2	1	88	3	0	0
1949	0	0	0	0	0	.2	.9	.2	0	0	0	0
1950	0	0	0	0	0	2	83	22	32	4	.3	.3
1951	3	4	3	2	.9	19	95	24	6	0	0	3
1952	1	2	1	0	.5	.2	23,200	8	3	23	4	0
1953	3	2	3	2	2	14	11	33	84	8	.3	.2
1954	1	.1	.1	0	3	.4	2	.1	1	0	24	.4
1955	.1	.1	.1	0	.4	6	3	.8	.8	3	.1	0
1956	0	0	0	0	0	16	.2	.2	.1	.5	.2	0
1957	0	0	0	0	.6	5	.2	.2	.1	0	.2	0
1958	0	0	0	0	.1	.1	.1	0	.1	.6	0	0
1959	.1	0	0	0	0	.2	2	.3	.4	.1	0	.1
1960	.1	.1	.1	0	.7	.4	.8	.3	0	0	0	0
1961	0	0	0	0	.1	.1	0	0	0	0	.1	3
1962	0	0	0	.1	.2	4	.2	.7	2	12	.3	0
1963	.2	0	0	0	16	2	.5	.6	3	.2	0	0
1964	0	0	0	0	0	.1	.3	.6	18	2	.1	.1
1965	0	0	0	0	.1	4	45	4	2	3	.7	.2
1966	.1	.1	.1	0	0	5	.3	.2	.4	6	.9	.1
1967	0	.1	.1	0	.5	6	1	4	4	.3	0	1
1968	.1	0	0	0	8	6	.3	0	1	2	.2	0
1969	0	0	.1	0	0	13	2	1	.8	24	0	0
1970	.1	0	0	0	.1	.1	0	3	1	.8	.1	.2
1971	.1	.1	0	.1	34	51	3	.5	.4	0	0	.1
1972	2	.1	0	0	0	69	1	2	11	.5	7	.2
1973	.2	.1	0	.3	.1	.4	1	.3	2	.1	.4	.4
1974	.1	.1	.1	.2	.1	.4	.1	.3	.5	.3	1	.1
•1975	.1	.2	.1	0	0	.2	3	19	1	.8	2	.1
1976	.4	.1	.3	1	6	2	.6	0	7	.3	.4	0
1977	0	0	0	0	.1	.2	.3	.2	.1	.4	0	.5
1978	0	0	0	0	0	3	.7	16	2	1	1	2
1979	.2	.3	.2	0	0	4	2	.3	.8	.8	.5	0
1980	0	0	0	0	0	.2	.2	0	21	.1	.4	0
1981	.1	.1	0	0	0	.1	.1	0	0	.4	7	.1
1982	0	0	0	0	3	.5	56	29	10	.5	1	0
1983	0	0	.1	.4	5	9	7	9	.3	2	1	0
1984	0	0	0	.2	2	2	.7	.3	1	0	.1	0
1985	0	0	0	0	0	2	7	5	4	0	.9	0
1986	0	0	0	0	94	9,220	14	13	2	0	.3	.4
1987	2	2	2	2	13	13	22	2	2	76	2	.6
1988	1	3	2	.9	2	6	4	3	0	0	.1	0
1989	0	0	0	0	0	3	11	7	1	0	.1	0
1990	0	0	0	0	0	.2	.2	.1	.1	0	.1	0
1991	0	0	0	0	0	0	.2	.3	62	12	.1	7
1992	0	0	.1	0	0	.1	.9	.2	0	.4	.2	0

Table 6. Estimated monthly precipitation at proposed Cherry Creek Reservoir near Terry, Mont., for water years 1937-92

Water year	Precipitation for indicated month, in feet											
	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.
1937	0.01	0.02	0.04	0.02	0.01	0.01	0.02	0.05	0.14	0.23	0.01	0.07
1938	.05	.01	.02	.01	.04	.05	.01	.15	.18	.16	.05	.03
1939	.08	.03	.02	.03	.02	.01	.04	.12	.31	.04	.07	.04
1940	.01	0	.02	.01	.03	.03	.12	.11	.21	.16	.04	.03
1941	.17	.02	.01	0	.01	.01	.09	.18	.17	.05	.17	.47
1942	.08	.02	.01	0	.04	.01	.05	.24	.40	.09	.06	.09
1943	.05	.01	.01	.08	0	.01	.01	.10	.49	.21	.16	.02
1944	.10	.01	0	.03	.01	.05	.09	.10	.82	.02	.17	.06
1945	0	.05	0	.02	0	.04	.02	.22	.14	.02	.08	.16
1946	.03	.04	.02	.01	.01	.02	.03	.25	.16	.56	.09	.46
1947	.20	.02	.03	.01	.01	.06	.11	.04	.30	.21	.22	.02
1948	.02	.02	0	.01	0	.03	.06	.13	.38	.47	.10	.03
1949	0	.02	.01	.03	.02	.02	.01	.13	.11	.13	.04	.01
1950	.15	0	.03	.02	.03	.12	.12	.09	.26	.08	.10	.17
1951	.05	.01	.02	.01	.03	.01	.02	.12	.18	.16	.29	.06
1952	.03	.03	.04	.03	.05	.03	0	.09	.14	.20	.02	.07
1953	0	.07	.01	.03	.04	.04	.17	.33	.23	.18	.31	.03
1954	.13	0	.02	.04	.01	.03	.08	.05	.24	.05	.26	.09
1955	.03	.01	.01	.02	.04	.01	.08	.30	.13	.15	0	.01
1956	.07	.02	.04	.01	.01	.01	.01	.18	.05	.12	.29	.01
1957	.01	.03	0	.02	.01	.03	.12	.14	.28	.09	.11	.06
1958	.02	.07	0	0	.01	.01	.07	.02	.27	.27	.03	.01
1959	.08	.05	.02	.03	.02	0	.05	.07	.15	.02	.02	.14
1960	.03	.02	.01	.01	.01	.02	.06	.07	.05	.12	.08	0
1961	.02	0	.01	0	.02	.01	.14	.12	.08	.16	.04	.23
1962	.03	0	.01	.02	.01	.05	.01	.39	.22	.36	.03	.05
1963	.11	.04	.01	.02	.03	.03	.22	.10	.45	.09	.06	.21
1964	0	0	0	.02	.01	.02	.11	.18	.29	.07	.26	.01
1965	.01	.03	.02	.04	.01	.02	.07	.11	.32	.23	.07	.07
1966	0	.02	.01	.02	.01	.02	.06	.08	.21	.13	.18	.03
1967	.01	.03	.01	.01	.02	.03	.12	.09	.38	.09	0	.16
1968	.07	.01	.01	.03	.01	.03	.02	.18	.40	.05	.35	.08
1969	.03	.01	.05	.04	.01	.03	.12	.15	.19	.20	.01	0
1970	.03	0	.03	.02	0	.01	.16	.23	.13	.12	0	.13
1971	.04	.04	.02	.11	.02	.03	.07	.08	.18	.01	.06	.10
1972	.38	.03	.01	.02	.04	.02	.03	.21	.24	.11	.09	.09
1973	.02	.01	.03	.01	.05	.03	.30	.07	.39	.01	.07	.36
1974	.01	0	.07	0	.01	.02	.04	.20	.08	.20	.12	.01
1975	.06	.06	.01	0	0	.10	.17	.26	.42	.12	.06	.02
1976	.13	.06	.01	0	0	.02	.08	.09	.19	.23	.08	.04
1977	.04	0	.01	.04	.01	.03	0	.11	.18	.07	.15	.31
1978	.18	.04	.06	.05	.06	0	.03	.33	.22	.09	.07	.13
1979	.01	.05	.02	.01	.04	.01	.04	.07	.07	.14	.01	0
1980	.01	0	0	0	.02	.01	.04	.01	.23	.08	.23	.08
1981	.18	.06	0	0	0	.01	.02	.14	.16	.07	.21	.05
1982	.09	.04	.01	.05	.01	.01	0	.33	.20	.09	.07	.21
1983	.16	0	.06	0	0	.06	0	.21	.12	.09	.03	.07
1984	.01	0	.01	.01	0	.05	.07	.06	.21	0	.07	.08
1985	.01	.02	.01	.01	0	.02	.06	.07	.02	.13	.17	.10
1986	.03	.03	.01	.03	.03	0	.03	.25	.16	.09	.03	.39
1987	.03	.01	0	.01	.01	.08	.02	.39	.13	.10	.21	.09
1988	0	0	0	.05	.02	.03	.02	.07	.06	.02	.08	.13
1989	.03	.01	.02	.03	.01	.04	.32	.21	.08	.27	.10	0
1990	.06	.05	0	.05	0	0	.09	.07	.17	.07	.12	.02
1991	.04	.04	0	.01	0	.01	.19	.29	.26	.04	.01	.36
1992	.03	.03	0	.01	0	.03	.36	.09	.14	.04	.13	.05

TABLE 6   23

Table 7. Estimated monthly evaporation at proposed Cherry Creek Reservoir near Terry, Mont., for water years 1937-92

Water year	Evaporation depth for indicated month, in feet											
	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.
1937	0.37	0.12	0	0	0	0.03	0.13	0.28	0.29	0.50	0.54	0.37
1938	.38	.06	0	.01	0	.04	.09	.17	.32	.40	.47	.37
1939	.38	.05	.03	.04	0	.04	.11	.24	.26	.46	.47	.39
1940	.35	.22	.10	0	0	.04	.05	.24	.35	.47	.61	.41
1941	.41	0	.04	.01	.02	.04	.08	.20	.31	.46	.46	.24
1942	.32	.14	0	0	0	.03	.10	.16	.30	.50	.47	.30
1943	.37	.08	0	0	.02	0	.12	.16	.28	.49	.50	.36
1944	.43	.16	.05	.02	0	.01	.13	.24	.23	.43	.49	.32
1945	.46	.06	0	0	0	.04	.09	.17	.23	.45	.47	.30
1946	.41	.06	0	.01	.01	.07	.15	.18	.32	.51	.49	.27
1947	.22	.03	0	0	0	.01	.11	.20	.23	.49	.48	.32
1948	.41	.03	0	0	0	.01	.11	.20	.26	.43	.49	.41
1949	.43	.10	0	0	0	.01	.15	.21	.31	.42	.46	.27
1950	.22	.26	0	0	0	0	.09	.17	.29	.37	.38	.27
1951	.40	.03	0	0	0	0	.09	.25	.25	.39	.38	.26
1952	.25	.09	0	0	0	.01	.13	.18	.35	.43	.36	.33
1953	.43	.08	.02	.05	.02	.05	.07	.15	.26	.45	.35	.29
1954	.47	.20	.04	0	.04	0	.13	.19	.31	.55	.48	.37
1955	.32	.22	.06	0	0	0	.11	.18	.33	.43	.54	.39
1956	.44	0	0	0	0	.03	.12	.19	.45	.52	.48	.42
1957	.41	.11	.03	0	0	.02	.09	.20	.30	.52	.51	.32
1958	.26	.06	.09	.05	0	.01	.12	.25	.25	.35	.52	.42
1959	.40	.10	0	0	0	.05	.12	.21	.38	.51	.53	.40
1960	.28	0	.05	0	0	.04	.16	.34	.48	.69	.64	.47
1961	.40	.11	0	.02	.05	.08	.15	.26	.48	.64	.66	.33
1962	.34	.06	0	0	0	.02	.21	.25	.43	.55	.55	.45
1963	.46	.16	.06	0	.04	.08	.15	.26	.41	.59	.71	.48
1964	.51	.17	0	.01	.02	.04	.16	.30	.33	.65	.60	.47
1965	.46	.08	0	0	0	0	.13	.29	.39	.53	.62	.29
1966	.47	.14	.02	0	0	.05	.14	.37	.47	.67	.60	.43
1967	.37	.04	0	0	.03	.03	.15	.27	.33	.61	.64	.43
1968	.40	.11	0	0	.02	.09	.19	.26	.29	.53	.48	.40
1969	.43	.10	0	0	0	.02	.19	.32	.36	.50	.61	.44
1970	.23	.17	.03	0	.02	.02	.13	.25	.43	.53	.58	.35
1971	.34	.08	0	0	0	.04	.12	.27	.40	.53	.60	.31
1972	.31	.15	0	0	0	.07	.16	.19	.45	.49	.57	.42
1973	.34	.09	0	0	.01	.07	.13	.30	.47	.58	.62	.35
1974	.44	.02	.02	0	.03	.07	.16	.22	.41	.63	.48	.42
1975	.47	.12	.04	0	0	.02	.07	.21	.37	.56	.56	.48
1976	.35	.08	0	0	.03	.03	.15	.30	.36	.60	.65	.42
1977	.34	.14	.04	0	.04	.04	.19	.32	.47	.59	.53	.40
1978	.38	.06	0	0	0	.03	.20	.22	.41	.50	.56	.44
1979	.38	0	0	0	0	.03	.09	.30	.47	.59	.51	.52
1980	.43	.06	.07	0	0	.02	.23	.33	.41	.61	.53	.46
1981	.37	.16	0	.06	.02	.07	.17	.19	.37	.56	.59	.54
1982	.28	.17	0	0	0	.02	.09	.26	.32	.50	.62	.41
1983	.34	.04	0	.03	.04	.06	.16	.29	.40	.55	.66	.46
1984	.34	.10	0	0	.03	.05	.10	.28	.36	.59	.68	.43
1985	.29	.08	0	0	0	.03	.14	.35	.44	.54	.55	.36
1986	.34	0	0	.03	0	.09	.10	.30	.38	.51	.56	.33
1987	.38	.05	.06	.02	.04	.05	.17	.28	.42	.45	.53	.41
1988	.38	.19	.05	0	0	.07	.14	.28	.53	.58	.63	.42
1989	.41	.12	0	0	0	0	.10	.25	.39	.60	.52	.44
1990	.25	.14	0	0	0	.05	.11	.22	.39	.57	.57	.57
1991	.37	.19	0	0	.05	.05	.16	.26	.42	.56	.61	.43
1992	.32	.04	.05	.06	.05	.09	.20	.28	.40	.43	.50	.49

Table 8. Capacity of proposed Cherry Creek Reservoir near Terry, Mont., for various reservoir elevations

[Symbol: --, not applicable]

Reservoir elevation, in feet above sea level	Reservoir capacity, in acre-feet, for indicated elevation									
	Incremental reservoir elevation, in tenths of a foot									
	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
2,240	0	0	0	0	0	0	0	0	0	0
2,241	0	0	0	0	0	0	0	0	0	0
2,242	0	0	0	0	0	0	0	0	0	0
2,243	7	7	7	8	8	8	8	8	9	9
2,244	33	33	34	34	34	35	35	35	36	36
2,245	71	72	72	73	73	74	74	74	75	75
2,246	120	120	120	120	120	120	120	130	130	130
2,247	180	180	190	190	190	190	190	190	190	190
2,248	260	260	260	260	260	260	260	260	260	270
2,249	340	340	350	350	350	350	350	350	350	350
2,250	440	440	440	450	450	450	450	450	450	450
2,251	550	550	550	560	560	560	560	560	560	560
2,252	670	680	680	680	680	680	680	680	680	690
2,253	810	810	810	810	810	810	820	820	820	820
2,254	950	960	960	960	960	960	960	960	970	970
2,255	1,100	1,100	1,100	1,100	1,100	1,100	1,100	1,100	1,100	1,100
2,256	1,300	1,300	1,300	1,300	1,300	1,300	1,300	1,300	1,300	1,300
2,257	1,500	1,500	1,500	1,500	1,500	1,500	1,500	1,500	1,500	1,500
2,258	1,700	1,700	1,700	1,700	1,700	1,700	1,700	1,700	1,700	1,700
2,259	1,900	1,900	1,900	1,900	1,900	1,900	1,900	1,900	1,900	1,900
2,260	2,100	2,100	2,100	2,100	2,100	2,100	2,100	2,100	2,100	2,100
2,261	2,300	2,300	2,300	2,300	2,300	2,300	2,300	2,300	2,300	2,300
2,262	2,600	2,600	2,600	2,600	2,600	2,600	2,600	2,600	2,600	2,600
2,263	2,800	2,800	2,800	2,800	2,800	2,800	2,800	2,800	2,800	2,800
2,264	3,100	3,100	3,100	3,100	3,100	3,100	3,100	3,100	3,100	3,100
2,265	3,300	3,300	3,400	3,400	3,400	3,400	3,400	3,400	3,400	3,400
2,266	3,600	3,600	3,600	3,600	3,600	3,700	3,700	3,700	3,700	3,700
2,267	3,900	3,900	3,900	3,900	3,900	4,000	4,000	4,000	4,000	4,000
2,268	4,300	4,300	4,300	4,300	4,300	4,300	4,300	4,300	4,300	4,300
2,269	4,600	4,600	4,600	4,600	4,600	4,600	4,600	4,600	4,600	4,600
2,270	4,900	4,900	4,900	4,900	4,900	4,900	4,900	4,900	4,900	4,900
2,271	5,300	5,300	5,300	5,300	5,300	5,300	5,300	5,300	5,300	5,300
2,272	5,600	5,600	5,600	5,600	5,600	5,600	5,600	5,600	5,700	5,700
2,273	6,000	6,000	6,000	6,000	6,000	6,000	6,000	6,000	6,000	6,000
2,274	6,400	6,400	6,400	6,400	6,400	6,400	6,400	6,400	6,400	6,400
2,275	6,800	6,800	6,800	6,800	6,800	6,800	6,800	6,800	6,800	6,800
2,276	7,200	7,200	7,200	7,200	7,200	7,200	7,200	7,200	7,200	7,200
2,277	7,600	7,600	7,600	7,600	7,600	7,600	7,600	7,600	7,600	7,600
2,278	8,000	8,000	8,000	8,000	8,100	8,100	8,100	8,100	8,100	8,100
2,279	8,500	8,500	8,500	8,500	8,500	8,500	8,500	8,500	8,500	8,500
2,280	8,900	8,900	8,900	8,900	9,000	9,000	9,000	9,000	9,000	9,000
2,281	9,400	9,400	9,400	9,400	9,400	9,400	9,400	9,400	9,400	9,400
2,282	9,900	9,900	9,900	9,900	9,900	9,900	9,900	9,900	9,900	9,900
2,283	10,400	10,400	10,400	10,400	10,400	10,400	10,400	10,400	10,400	10,400
2,284	10,900	10,900	10,900	10,900	10,900	10,900	10,900	10,900	10,900	10,900
2,285	11,400	11,400	11,400	11,400	11,400	11,400	11,400	11,400	11,400	11,400
2,286	11,900	11,900	11,900	11,900	11,900	11,900	12,000	12,000	12,000	12,000
2,287	12,500	12,500	12,500	12,500	12,500	12,500	12,500	12,500	12,500	12,500
2,288	13,000	13,000	13,000	13,000	13,000	13,000	13,000	13,100	13,100	13,100
2,289	13,600	13,600	13,600	13,600	13,600	13,600	13,600	13,600	13,600	13,600
2,290	14,100	--	--	--	--	--	--	--	--	--

TABLE 8   25