UNITED STATES DEPARTMENT OF THE INTERIOR
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REGIONAL DRAFT-STORAGE RELATIONSHIPS FOR CENTRAL AND WESTERN UPPER PENINSULA OF MICHIGAN

by

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ILLUSTRATIONS

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ABSTRACT

Regional draft-storage relationships for central and western Upper Peninsula of Michigan are presented in this report. Storage requirements for the 5- and 20-year recurrence intervals were determined using the frequency-mass curve method and daily discharge records from 15 gaging stations. The relationships will be useful in making preliminary estimates of development potential and in comparing the development possibilities of different streams.

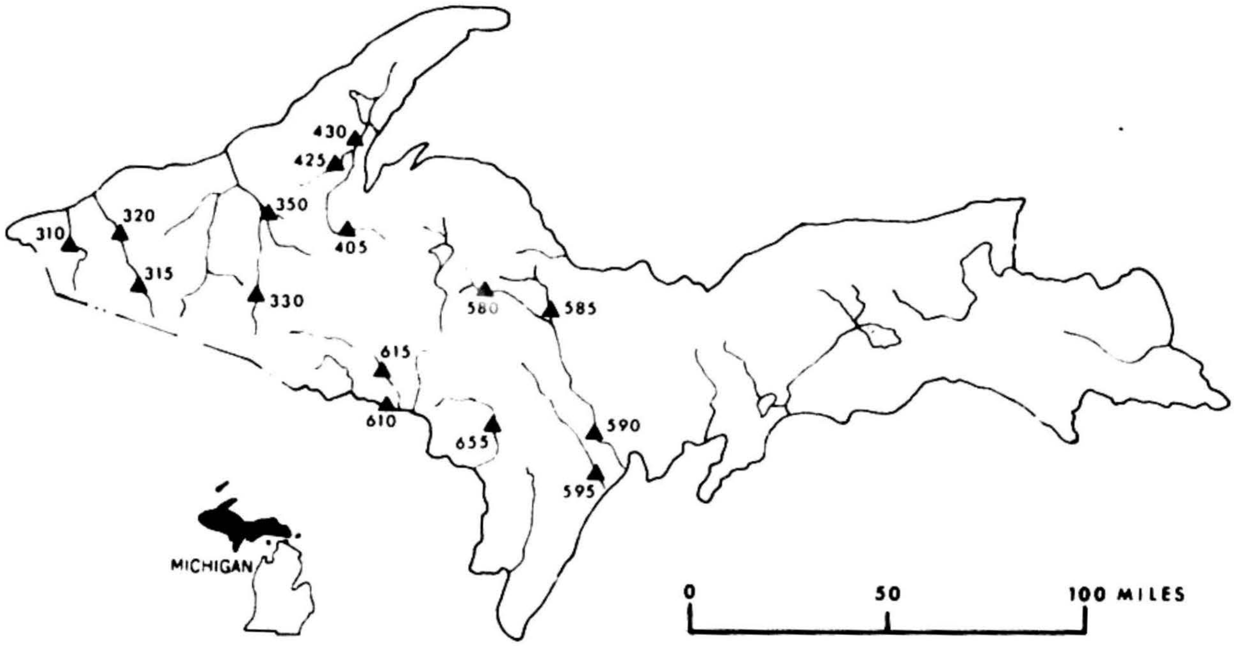
Carryover storage was investigated and was found to be unnecessary at draft rates of less than 50 percent of the mean annual flow. Carryover storage requirements are presented for the gaging station Middle Branch Escanaba River near Ishpeming.

INTRODUCTION

If at low flow a stream cannot supply needed water, storage impoundments must be considered or other supplemental sources of water sought. Where there are adequate data, the amount of storage required may be determined by analyzing streamflow records. It is often necessary, however, to estimate storage requirements for sites at which little streamflow data have been collected. This report presents a method of estimating storage requirements through the use of regional draft-storage relationships. The analyses are based on within-year storage requirements. Within-year storage is that storage which will be replenished each year by the high flow of a stream for release during subsequent low flow periods. Also presented is a draft-storage relationship that combines within-year and carryover storage for the gaging station on the Middle Branch Escanaba River near Ishpeming. Storage impoundments are currently being considered in this area.

An earlier report (Wiitala and others, 1967) presented the results of a comprehensive study of the water resources of the Marquette Iron Range area. One section of that report dealt with regional draft-storage relationships. Because of the continuing interest in and development of the area, this report updates that section of the earlier report, based on the longer periods of record which are now available.

Daily discharge records at 15 gaging stations in central and western Upper Peninsula (fig. 1) were used in preparing regional draft-storage relationships. Flow records at these stations range from 16 to 30 years; regulation has not affected their suitability for use in this



EXPLANATION

▲ Gaging station

595 Downstream order number

310. Black R. nr. Bessemer
315. Presque Isle R. at Marenisco
320. Presque Isle R. nr. Tula
330. M. Br. Ontonagon R. nr. Paulding
350. E. Br. Ontonagon R. nr. Mass
405. Sturgeon R. nr. Sidnaw
425. Otter R. nr. Elo
430. Sturgeon R. nr. Arnheim
580. M. Br. Escanaba R. nr. Ishpeming
585. E. Br. Escanaba R. at Gwinn
590. Escanaba R. at Cornell
595. Ford R. nr. Hyde
610. Brule R. nr. Florence
615. Paint R. at Crystal Falls
655. Sturgeon R. nr. Foster City

Figure 1.--Locations of gaging stations, central and western Upper Peninsula of Michigan.

study. The records of daily discharge for each station were processed by computer to obtain (1) the number of days of flow between selected limits of discharge (flow-duration data), (2) the lowest mean discharge, in each climatic year, for selected numbers of consecutive days (low-flow frequency data), and (3) the statistics of annual discharge. These data provide the basis for development of draft-storage relationships.

DEVELOPMENT OF REGIONAL DRAFT-STORAGE RELATIONSHIPS

Regional draft-storage relationships were developed using a method suggested by H. C. Riggs (written communication, 1964). The method involves relating storage requirements, as defined from frequency-mass curves, to an index of low flow. In this study, values of low-flow frequency and flow duration were evaluated as low-flow indexes. The 90 percent point on the flow duration curve was selected as the most suitable index of low flow.

To determine storage requirements, low-flow frequency curves for selected periods were drawn for each gaging station. These curves related lowest average discharge to recurrence interval. Frequency-mass curves, which relate volume to period of minimum discharge, were derived from the low-flow frequency curves, and were drawn for the 5- and 20-year recurrence intervals. Lines representing draft rates were drawn on the frequency-mass curves, and corresponding storage requirements were determined. Values of draft, storage, and low-flow index were reduced to rates or volumes per square mile. Relating these parameters provided the regional draft-storage curves shown in figures 2 and 3. Adjustments for evaporation and seepage losses have not been made in this analysis.

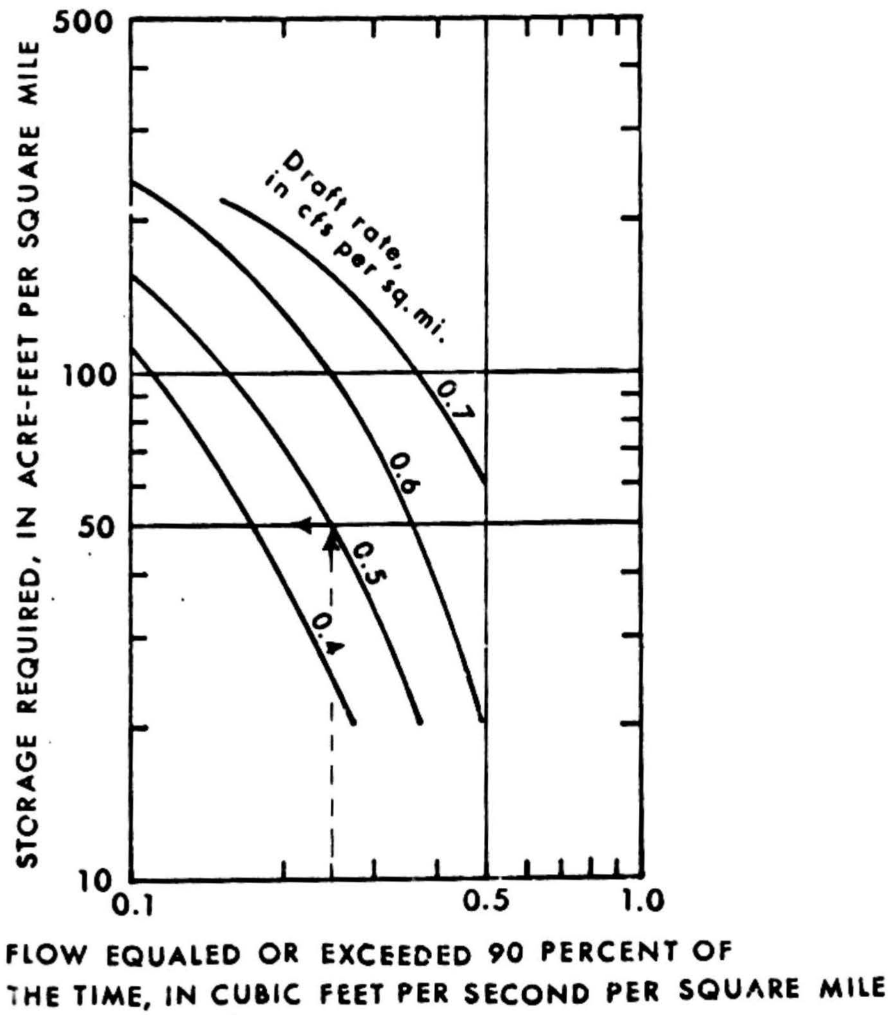


Figure 2.--Regional draft-storage curves for a 5-year recurrence interval, central and western Upper Peninsula of Michigan.

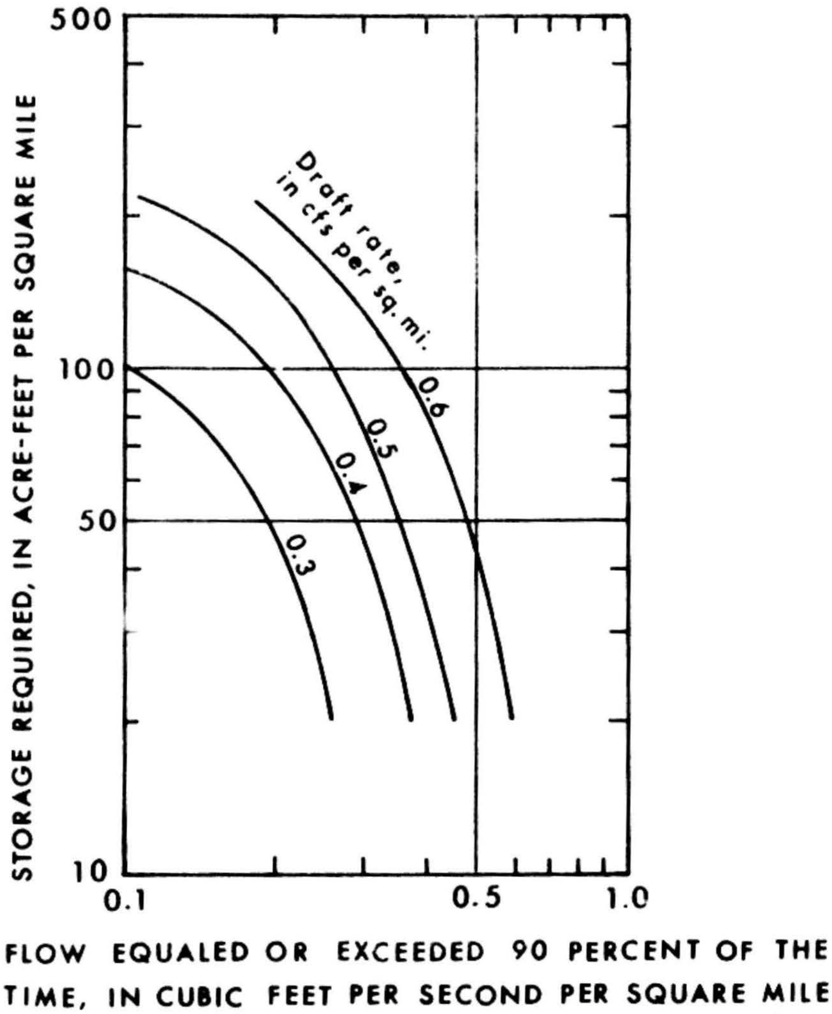


Figure 3.--Regional draft-storage curves for a 20-year recurrence interval, central and western Upper Peninsula of Michigan.

USE OF REGIONAL DRAFT-STORAGE CURVES

To use the regional draft-storage curves for defining storage requirements it is necessary to know the drainage area, the index of low flow, and the quantity of water (draft rate) desired. For example, assume that a proposed site has a drainage area of 100 square miles, and that a draft rate of 50 cubic feet per second (cfs), or 0.50 cfs per square mile (50÷100) is required for operation. Assume further that the 90 percent flow duration value (low-flow index) is 25 cfs, or 0.25 cfs per square mile (25÷100), and that an inadequate water supply can be tolerated once in 5 years on the average. On figure 2, move vertically from 0.25 on the abscissa to the 0.50 cfs per square mile draft rate curve. From that point, move horizontally to the ordinate to determine the storage required. Fifty acre-feet per square mile, or 5,000 acre feet (50 x 100) of storage is indicated, without adjustment for evaporation or seepage losses.

For sites where no discharge data are available, the low-flow index can be estimated by making low-flow measurements and correlating them with concurrent discharges at nearby stations having defined low-flow indexes. If possible, the measurements should be made on different recessions and in different seasons, to obtain the most reliable correlation. Also, drainage areas must be determined so that the low flow and storage data can be reduced to rates and volumes per square mile.

Indexes of low flow for stations in the Marquette Iron Range are shown in the report by Wiitala and others (1967). Indexes at other sites in central and western Upper Peninsula can be obtained from the report "Statistical Summaries of Michigan Streamflow Data" (Knutilla, 1970).

Use of the regional draft-storage curves will give reasonable estimates of storage requirements on unregulated streams in central and western Upper Peninsula when uniform draft rates are contemplated. The curves show the probability of a deficiency, but not its magnitude or duration. They should not be extrapolated. The curves will be useful in making preliminary estimates of development potential and in comparing the development possibilities of different streams.

DEVELOPMENT OF CARRYOVER STORAGE CURVES

Frequently water must be stored during wet years and released during dry years if a desired draft rate is to be maintained. Storage required for this purpose is termed "carryover storage". In the southwestern part of the United States, the variability f streamflow and the relation of demand to supply is such that carryover storage has long been a controlling factor in the design of storage reservoirs. Carryover storage is now becoming a factor in the Midwest, and should be considered when the draft rate exceeds about 50 percent of the mean annual flow of a stream. Carryover storage (with a 5 percent chance of deficiency) was analyzed for the 15 gaging stations used in this study. It was found that the point above which carryover storage is needed ranges from 50 to 74 percent (median value, 64 percent) of the mean annual flow.

Computations of carryover storage for this study were by a method suggested by C. H. Hardison (written communication, 1968). In this method, carryover storage is computed by applying probability routing to selected frequency distributions of annual discharge. The reservoir capacity is subdivided into layers, and a probability is assumed for each layer. For a given draft rate and given frequency distribution of inflow, the distribution of the contents at the end of the year is computed to see if it checks with initial assumptions. (The probability distribution of reservoir contents at the end of the year is inherently equal to the distribution at the start of the year.)

Carryover storage requirements are computed based on the assumption that inflow for each year is uniform throughout the year. Thus, an additional amount of storage is required to adjust for within-year variations in streamflow. For draft rates lower than the lowest annual flow, no carryover storage is required. For higher draft rates, within-year and carryover storage requirements are combined by adding an adjustment factor to the carryover storage requirements.

Using data for the 15 gaging stations in the central and western parts of the Upper Peninsula, several attempts were made to regionalize carryover draft-storage relationships. Various parameters that are descriptive of streamflow were evaluated, but relationships obtained were not within acceptable limits of accuracy. Because of projected developments on the Middle Branch Escanaba River, however, draft-storage curves for the gaging station near Ishpeming were developed. Figures 4 and 5 show curves that combine within-year and carryover storage requirements for 5 and 10 percent chances of deficiency. No adjustments for evaporation or seepage losses have been included in this analysis.

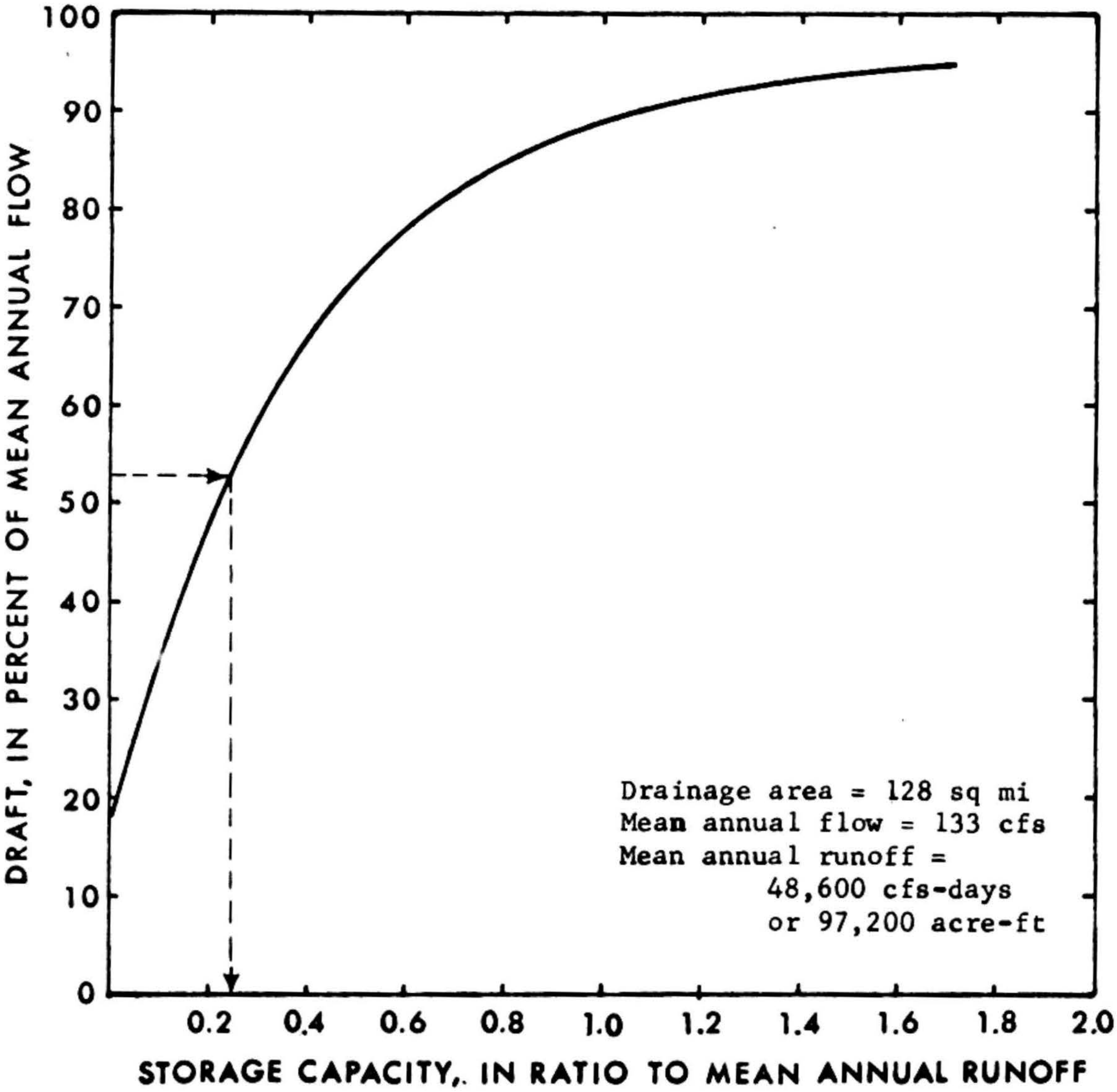


Figure 4.--Carryover storage requirements for a five-percent chance of deficiency, Middle Branch Escanaba River near Ishpeming, Mich.

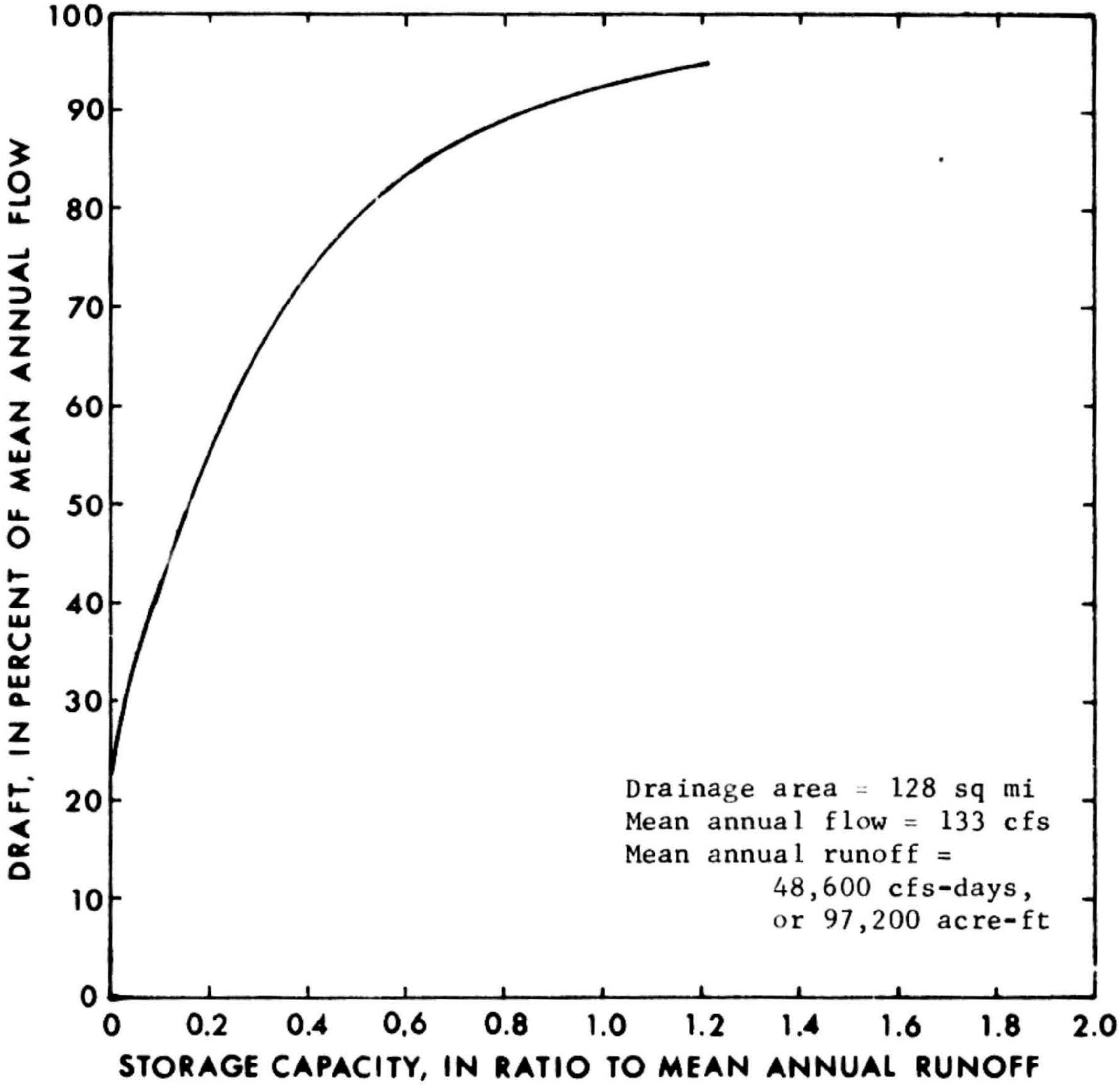


Figure 5.--Carryover storage requirements for a ten-percent change of deficiency, Middle Branch Escanaba River near Ishpeming, Mich.

USE OF CARRYOVER STORAGE CURVES

Assume that (1) a reservoir site is under consideration near the gaging station on the Middle Branch Escanaba River near Ishpeming, (2) the desired draft rate is 70 cfs, and (3) a five percent chance of deficiency is tolerable. On figure 4 move horizontally from 53 percent (70 cfs÷133 cfs) on the ordinate to the draft-storage curve. From that point, move vertically to the abscissa. The storage, in ratio to mean annual runoff, is 0.25, or 24,300 acre-ft (0.25 x 97,200).

SUMMARY

Regional draft-storage relationships have been developed for recurrence intervals of 5 and 20 years for central and western Upper Peninsula of Michigan. Estimates of storage requirements for a given draft rate can be made using the curves included in the report, provided the drainage area is known and discharge equaled or exceeded 90 percent of the time is known. Values of drainage area and 90 percent duration discharge for many locations are given in the reports cited in the selected references. Ninety percent duration discharge may be determined at ungaged sites by correlation of miscellaneous measurements with concurrent flows at gaging stations. Drainage areas may be determined from available maps.

Based on analyses of records collected at 15 gaging stations, carryover storage (with a 5 percent chance of deficiency) is unnecessary at draft rates of less than 50 percent of the mean annual flow. Curves relating carryover draft-storage requirements are presented for the gaging station Middle Branch Escanaba River near Ishpeming.

SELECTED REFERENCES

Knutilla, R. L., 1967, Flow Characteristics of Michigan Streams: U.S. Geol. Survey open-file report.

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Wiitala, S. W., Newport, T. G., and Skinner, E. L., 1967, Water Resources of the Marquette Iron Range Area, Michigan: U.S. Geol. Survey Water-Supply Paper 1842.