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WATER

USES • SUPPLIES • PROJECTIONS

An Introduction to Terms
and Reference Sources

Farm Economics Division
Economic Research Service
UNITED STATES DEPARTMENT OF AGRICULTURE

Growth Through Agricultural Progress

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An Introduction to Terms and Reference Sources

by

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INTRODUCTION

This study was intended to provide a compilation to expedite data-gathering phases of research and planning. The compilation was prepared as a reference for economists and others working in the field of water resources. Section I gives definitions of the more common terms found in water resource literature and other terms illustrating important physical relationships. Section II contains the major source materials that report the nationwide systematic inventory of water uses. Section III describes the data program for water supplies, and section IV summarizes projections made of future water uses and supplies.

Each major source of data is described in some detail by type of data, period for which data are available, geographic breakdown, and completeness of coverage. Related references are given.

SECTION I. DEFINITIONS OF SELECTED TERMS RELATING TO USE, OCCURRENCE, AND MOVEMENT OF WATER

This list of definitions is intended primarily for economists. It includes the more important terms that appear in reports on water uses and water availability. Included also are certain terms not in common use, but helpful in understanding important characteristics of water resources.

The list is divided into four sections: water uses, subsurface and ground water, movement of water, and soil moisture. Each section is headed by a citation of the major source; unless otherwise noted, definitions are based on this source.

The order of presentation is in terms of subject matter rather than alphabetical. Terms closely related to major terms are defined as part of a discussion following the major term. All terms are indexed in appendix A.

To make the definitions both intelligible to economists and of reasonable length, the author was forced to exercise a certain amount of discretion. Definitions that are exact quotations of the source are placed within quotation marks. When the definition given in the source is in the nature of a full and lengthy discussion of several aspects of the term, only the essential portion is quoted. In some instances, a definition was not expressly given in the source. Therefore, the author defined the term. These definitions do not carry quotation marks.

Readers interested in studies of flood control, soil and water conservation through land treatment, or watershed programs are referred to the set of definitions compiled by the U. S. Soil Conservation Service. 1/ Those interested in hydrology are referred to definitions prepared by the U. S. Geological Survey. 2/

Water Uses

MacKichan, K. A. Estimated Use of Water in the United States, 1955. U. S. Geol. Survey Cir. 398, 18 pp., illus. 1957.

Types

Withdrawal uses - "Withdrawal uses require that the water be removed from the ground or diverted from a stream or lake."

The major categories of withdrawal use, as defined by the U. S. Geological Survey are: Public supplies, irrigation, rural, self-supplied industrial, and water power. (For description see: Major categories p. 7.) Water power is considered a withdrawal use because ". . . even in run-of-river plants the water is diverted through the turbines and frequently the generation of water power has a very definite effect on streamflow."

Nonwithdrawal uses - "Nonwithdrawal uses do not require diversion" (or removal of water from the ground).

Nonwithdrawal uses are often classified as Flow uses, and Onsite uses. Flow uses include "water used within recognized stream channels", such as navigation, waste carrying, and sports fish habitat. Onsite uses cover "the use of water for programs designed to abate soil erosion and maintain soil moisture and for consumption by swamps and wetlands required as wildlife habitat." 3/

Ackerman and Löf define flow uses as uses that "in some way depend upon water in movement" such as hydropower and waste carrying. They define onsite uses more broadly as "those which can be most advantageously pursued on water that has only a slow rate of flow." Navigation, some forms of recreation, certain fisheries and wildlife support are cited as examples. 4/

1/ U. S. Soil Conservation Service, Engineering Division. Definitions and Conversions. Engineering Handbook, Hydrology, Sup. A, Sec. 4, pt. 5. n. d.

2/ Langbein, W. B., and Iseri, K. T. General Introduction and Hydrologic Definitions. Manual of Hydrology: Part 1. General Surface-Water Techniques. U. S. Geol. Survey Water-Supply Paper 1541-A, 29 pp., illus. 1960.

3/ U. S. Congress. Senate. Select Committee on National Water Resources. Water Supply and Demand. In Water Resources Activities in the United States, Report published as Committee Print 32, pursuant to S. Res. 48, 86th Cong., 2d sess., p. 15. Washington, D. C., U. S. Govt. Print. Off. 1960.

4/ Ackerman, E. A., and Löf, G. O. G. Technology in American Water Development. P. 48. Published for Resources For the Future, Johns Hopkins Press, Baltimore. 1959.

Consumptive use - "The quantity of water discharged to the atmosphere or incorporated in the products of the process in connection with vegetative growth or food processing, or incidental to an industrial process." 5/

By this definition, consumptive use is a measure of degree, expressible as a percentage and, strictly speaking, all uses are consumptive in varying proportion. While water uses involve changes in quality as well as quantity of water, the meaning of consumptive use is confined to the quantitative aspects. Net use, Depletion, Loss, and Disappearance are alternative terms for consumptive use. 6/ Some experts object to the term "loss," as many consumptive uses result in economic gains, and in this sense the water used up is not lost.

Major Categories

The five major categories of water use defined below are used by the U. S. Geological Survey. These are: Public supplies, rural, irrigation, self-supplied industrial, and waterpower.

A somewhat different classification is used by the Water and Sewerage Industry and Utilities Division of the U. S. Department of Commerce. 7/ This classification also consists of five categories of which three -- public water utilities, rural domestic, and irrigation -- are comparable to the corresponding U.S.G.S. categories. The remaining two Department of Commerce categories are: Industrial miscellaneous and steam electric utilities. The industrial and miscellaneous category is described in connection with the definition of self-supplied industrial use of water.

Public supplies - Public supplies are all uses made of water furnished by public supply systems.

Public supply systems may be publicly or privately owned. The amount of public supplies is measured at the source and includes conveyance losses. Public supplies include all uses made by the recipients of the water, primarily domestic uses, fire protection, street flushing, sprinkling of lawns, and industrial and commercial uses. Public supplies exclude irrigation except for a small amount of irrigation of gardens and farms by systems not primarily designed for this purpose.

5/ This definition was proposed by a task force of the American Water Works Association and adopted by the U. S. Geological Survey. See Water Conservation in Industry, Task Group Report. Jour. Amer. Water Works Assoc. 45(12):1251. Dec. 1953.

6/ U. S. Congress. Senate. Select Committee on National Water Resources. Water Supply and Demand. Report published as Committee Print 32, pursuant to S. Res. 48, 86th Cong., 1st sess., p. 15, illus. 1960; and Ackerman and Löf, p. 661. (See footnote 4, page 6.)

7/ Picton, W. L. Water Use in the United States, 1900-1980. U. S. Business and Defense Serv. Admin. Water Sewerage and Industry Utilities Division, p. 2. March 1960. Washington, D. C., U. S. Govt. Print. Off. 1960.

Rural - Rural uses are uses made in rural homes and for stock watering, with rural homes defined as "those not served by public supply systems."

Irrigation - "The artificial application of water to lands for agricultural purposes." 8/

The quantity of water used for irrigation has been defined in four ways by the U. S. Geological Survey.

Gross overall supply - "Water withdrawn plus evaporation and seepage from storage reservoirs when such one part of the system."

Water withdrawn from the source - "Water delivered (to farms) plus conveyance losses."

Water delivered to farms - "Water delivered to the farms includes evaporation and seepage from the (farm) distribution ditches as well as that transpired and evaporated from the cropped areas."

Water "transpired or evaporated from a cropped area."

Apparently, where storage reservoirs exist, whether on-stream or off-stream, withdrawal from the source is considered to be at the outlet of impounding structures. Therefore, withdrawls from the source are exclusive of losses from storage reservoirs. Gross overall supply is the sum of water withdrawn from the source, plus losses from storage reservoirs. U. S. Geological Survey estimates are made for water withdrawn from the source and water delivered to farms.

"The percentage of water applied that can be accounted for in soil-moisture increase" is defined as Irrigation efficiency. 9/ Irrigation efficiency must be specified in terms of water delivered to farms, water withdrawn from the source, or gross overall supply.

Self-supplied industrial - Use of water by industrial establishments exclusive of water furnished these establishments by municipal supplies.

The self-supplied industrial category as defined by U.S.G.S. includes fuel-electric power generated by public utilities but provides separate estimates for water used for this purpose. While it is not certain, it appears that the self-supplied industrial category does not include self-supplied water used for commercial or military purposes. Mining is included in the self-supplied industrial category.

8/ American Society of Civil Engineers, Special Committee on Irrigation and Hydraulics. Letter Symbols and Glossary for Hydraulics with Special Reference to Irrigation. Manuals of Engineering Practice 11, p. 22. New York. October 1935.

9/ Langbein, W. B. and Iseri, K. T. (See footnote 2, page 6.)

Industrial and miscellaneous uses of water - As defined by the Water and Sewerage Utilities Division of the Department of Commerce, this category includes all self-supplied uses other than rural, irrigation, and fuel power. The major uses in this category are manufacturing, mineral industry, commercial, and military.

Quantity withdrawn, or water withdrawn or withdrawal - "The entire quantity of water taken for use."

The U. S. Geological Survey mentions four terms: pumpage, water intake, water requirements, and duty of water, being used to convey the same meaning as water withdrawn. 10/

Water intake is generally in use in connection with industry. Water requirement and duty of water are used in irrigation. Water requirement or duty of water give the impression of a factor of production that is fixed in amount, whereas water withdrawn conveys the variability of the amount of water used in production.

Duty of water is often used in connection with specific points in an irrigation system such as gross duty for the amount of water at the point of diversion sometimes also called headgate duty. Net duty or farm duty are terms used for the amount of water delivered to a farm. Duty of water is also used for the amount applied to specified crops.

Quality of Water

Saline water - "Water containing more than 1,000 ppm (parts per million) of dissolved solids."

The term "saline water" applies regardless of the composition of the solids and not necessarily to salty (NaCl) water. The process of reclaiming otherwise unusable water by removing dissolved salts is demineralization, or conversion of saline water. 11/

Parts per million (ppm) is usually measured in milligrams per liter (that is $\frac{1}{1,000}$ of a gram per 1,000 cubic centimeters or 1 gram per million cc).

10/ A discussion of the terminology applied to the quantity of water used is given in: Industrial Water Conservation, Task Group Report, pp. 1251-1252. (See footnote 5, page 7.) Definitions of "water requirement" and the various adaptation of "duty of water" are given in the glossary for hydraulics, Manuals of Engineering Practice. (See footnote 8, page 8.)

11/ Jenkins, D. S., McNiesh, R. J., and Gottley, S. Conversion of Saline Waters. U. S. Dept. Agr. Yearbook 1955: 109.

Typical ocean water contains 35,000 ppm of dissolved salts. Fresh water is defined as containing less than 1,000 ppm, Brackish water is defined as containing 1,000-35,000 ppm. 12/

Biochemical oxygen demand (B.O.D.) - The quantity of dissolved oxygen required to stabilize decomposable organic matter. 13/

B.O.D. is determined by measuring in parts per million the dissolved oxygen content that a sample will absorb in a standardized 5-day incubation period. Water absorbing 3 ppm of dissolved oxygen suggests fairly clean water; water absorbing more than 5 ppm is of doubtful purity.

Sewage loads are frequently expressed in terms of population equivalent (P.E.) which is defined as daily sewage and related wastes from one person. 14/ By estimating the amount of oxygen required to stabilize one P.E., industrial, as well as municipal, wastes can be expressed as population equivalents. As measures of pollution, both P.E. and B.O.D. are limited only to those types of wastes that are broken down by chemical and biological action.

Subsurface and Ground Water

Tentative Statement of Terms With Definitions. Amer. Geophys. Union Trans. 1934: 289. Berkeley, Calif.

Lithosphere - "That part of the earth which is composed predominantly of rocks, including the products of rock-disintegration and other incoherent solid materials, together with everything within the rock crust."

The lithosphere contains the soil.

Subsurface water or subterranean water - "Water that occurs in lithosphere."

Zone of saturation - "The zone of the lithosphere in which the interstices of permeable rock or earth are completely filled with water under hydrostatic pressure."

A less technical version of the definition given is: "the zone in which the openings in the rocks are fully saturated and in which the water can flow under the influence of gravity, as it does in a river though much

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12/ Jenkins, D. S. Fresh Water from Salt. Sci. Amer. 196(3): 37, 38. March 1957. The Office of Saline Water, U. S. Department of the Interior draws the line between fresh and brackish water at 500 ppm dissolved solids.

13/ Ackerman, E. A. and Löf, G. O. G., pp. 39 and 659. (See footnote 4, page 6.)

14/ U. S. Congress, Senate. Select Committee on National Water Resources. Pollution Abatement. In Water Resources Activities in the United States, Report published as Committee Print 9, pursuant to S. Res. 48, 86th Cong. 2d sess., p. 2. Washington, D. C., U. S. Govt. Print. Off. 1960.

more slowly." 15/ To elaborate on the technical definition, definitions of "hydrostatic pressure" and "interstice" follow.

Hydrostatic pressure - "A pressure exerted uniformly and perpendicularly to all surfaces, as by a homogeneous fluid." 16/

The meaning of the statement that in the zone of saturation, the interstices are filled with water under hydrostatic pressure is as follows: Any particle of water in the zone of saturation is overlain by other particles of water so that the particle is subject to pressure of the water above. In other words, the particles of water in the zone of saturation are sufficiently close to each other to have the properties of a fluid.

Interstice - "A space or void in rock or earth not occupied by solid matter."

Interstices may be isolated or interconnected. Their size varies from openings between particles or grains of earth or rock to large tubular openings in soluble rocks or lavas.

Pores or pore spaces are alternate terms for interstices. 17/

Interstices may be classified as capillary, subcapillary, or supercapillary. A capillary interstice is small enough for water to be held at an appreciable height above the hydrostatic pressure level by capillarity, but not so small that molecular attraction from its walls extends across the entire space so that all the water in the interstice is held immobile against gravity and the pressures caused by evaporation.

Ground water - "Subsurface water occupying the interstices in the zone of saturation."

When the upper surface of the zone of saturation is under atmospheric pressure, the ground water is termed Free or unconfined ground water - When the upper surface is under hydrostatic pressure, it is termed Confined or artesian ground water. 18/ The surface of artesian ground water

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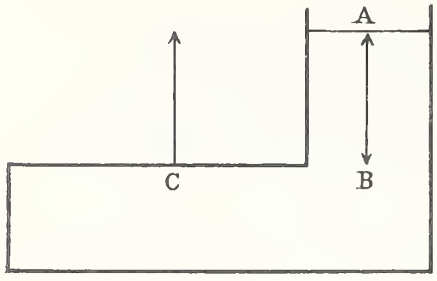
15/ McGuiness, L. L. The Water Situation in the United States With Special Reference to Ground Water. U. S. Geol. Survey Cir. 114, p. 4. June 1951.

16/ Webster's Dictionary. 2d ed. of the New International. Springfield, G. & C. Merrian Co. 1951.

17/ Thomas, H. E. Underground Sources of Water. U. S. Dept. Agr. Yearbook 1955:65.

18/ Muckel, D. C. Pumping Ground Water so as to Avoid Overdraft. U. S. Dept. Agr. Yearbook 1955: 296.

is overlain by impermeable material. This surface is subject to hydrostatic pressure caused by the weight from the water above as illustrated below for water in a vessel. 19/



A Free surface of water

B Hydrostatic pressure at B, proportional to AB

C Hydrostatic pressure at C against confined surface equal to hydrostatic pressure at B

Capillary fringe - "The belt of subsurface water overlying the zone of saturation in material having capillary interstices, some or all of which are filled with water that is continuous with the zone of saturation but held above that zone by capillary forces acting against gravity."

A capillary fringe exists only when the material immediately above the zone of saturation has capillary interstices. The capillary fringe is part of the zone of aeration and water from the capillary fringe will not flow into a well.

Water table - "The upper surface of the zone of saturation except where the surface is formed by an impermeable material."

When a capillary fringe exists, the water table is found below that fringe.

A perched water table above the main water table is frequently encountered. A perched water table exists when the main zone of saturation is overlain by unsaturated materials that contain an impervious formation. Above this impervious formation a local zone of saturation may occur. Ground water in such a zone is termed perched water and the upper surface is a perched water table. 20/

Zone of aeration - "The zone of the lithosphere in which the interstices of permeable rock or earth are not (except temporarily) filled with water under hydrostatic pressure."

Interstices in the zone of aeration contain either air and water or, if within the capillary fringe, may be filled with water held by capillarity.

Water in the zone of aeration is termed

Suspended water - Suspended water is classified as follows:

19/ Based on sketch by D. S. Ellis. In his Elements of Hydraulic Engineering, p. 10. D. Van Nostrand Co. Inc., New York, N. Y. 1947.

20/ Muckel, D. C. (See footnote 18, page 11.)

Hygroscopic water - Water adhering to solid particles and held against evaporation and gravity and not available to plants.

Capillary water - Water held as continuous films around solid particles and held against the combined forces of gravity and the forces resulting from the unbalanced surface pressure of films. Capillary water is partly available for plant extraction and evaporation.

A committee of the American Geophysical Union has suggested using the term

Pellicular water instead of capillary water. Under the proposal the term "capillary water" would be reserved for mobile water in the capillary fringe.

Mobile water - Water occupying films around solid particles in excess of capillary water. This water is free to move in any direction under the resultant of the forces of gravity and unbalanced surface pressure of films. It is frequently termed

Gravity water or

Free water. 21/

Aquifer, ground water reservoir - Water-bearing rock formations in the zone of saturation that yield sufficient water to be important as a source of supply. 22/

Aquifer and ground water reservoir are used interchangeably. Although there is no generally accepted distinction, ground-water reservoir often refers to the water-bearing formation over an extensive area.

The expression "important as a source of supply" expresses a relative concept and is interpreted in a given area in terms of needs and supply.

An artesian aquifer or artesian ground water reservoir - is one containing artesian or confined ground water. That is, the water becomes confined between two bodies of impermeable rock. This occurs when the water table is interrupted by an impermeable bed and water flows beneath the impermeable bed. 23/

21/ The term gravity ground water is sometimes used. A rather complex definition of this term is given by the American Society of Civil Engineers, but the term is approximately equivalent to "Gravity Water" applied to ground water. (Manuals of Engin. Pract., see footnote 8, page 8.) "Gravity Ground Water" is the water drawn from wells, where the zone of saturation is not overlain by an impermeable layer. Gravity ground water should not be used interchangeably with "free or unconfined ground water," which refers to the total body of ground water not overlain by impervious material.

22/ Thomas, H. E., p. 69. (See footnote 17, page 11.)

23/ McGuiness, L. L., p. 12. (See footnote 15, page 11.)

Movement of Water

For runoff and related terms - Langbein, W. B., and others. Annual runoff in the United States. U. S. Geol. Survey Cir. 52, p. 2. June 1949. 24/

For other terms pertaining to surface movement (except precipitation) - American Society of Civil Engineers, Special Committee on Irrigation and Hydraulics. Letters and Symbols and Glossary for Hydraulics With Special Reference to Irrigation. Amer. Soc. Civ. Engin., Manual Engin. Pract. 11, 39 pp., 1935.

For precipitation and subsurface movement - Tentative Statement of Terms With Definitions. Amer. Geophys. Union Trans. 1934: 289.

Precipitation and Surface Movement

Precipitation - "The process by which water in liquid or solid state is discharged out of the atmosphere."

Runoff - "The discharge of water in surface streams."

(1) Estimates of runoff are generally given for a drainage basin. According to U. S. Geol. Survey Cir. 52 "Current usage associates runoff only with natural sources and effects, excluding those of artificial storage, diversion, and the like." Thus the concept of runoff is one of total natural discharge in a drainage area through surface streams. It is not the actual discharge through surface streams; rather it is what the discharge or streamflow would be if there were no artificial effects.

In practice, runoff is estimated by considering only the simpler artificial effects such as stream diversion and storage. Although withdrawal of ground water often has definite effects on streamflow, this effect is usually not considered in estimating runoff from streamflow.

(2) Runoff is often defined as precipitation less evapotranspiration where Evapotranspiration is defined as the processes whereby water is returned to the atmosphere by evaporation from the surface of earth and by transpiration from the leaves of plants. 25/ Thus runoff is taken as the part of precipitation that enters surface streams after losses through evapotranspiration.

It is also often stated that runoff represents the total quantity of water produced in a drainage basin or region and is, in the long run, the upper limit on consumptive uses of water.

24/ For a detailed discussion of various definitions of runoff, see also: Davenport, R. W. Report of the Committee on Runoff. Amer. Geophys. Union Trans. (6): 876-885. 1946.

25/ Adapted from Thomas, H. E. Conservation of Ground Water. P. 15. Sponsored by the Conservation Foundation. McGraw-Hill, New York. 1951.

The statements of the two preceding paragraphs are only approximately true. Generally they will hold if outflow from a drainage area is largely through surface streams and net-subsurface outflow is negligible.

Water yield "is the total outflow from a drainage basin through either surface channels or subsurface aquifers." "That part of the discharge from a drainage basin that occurs through the ground water" is termed Ground water outflow. The term Underflow "is often used to describe the ground water outflow that takes place in valley alluvium (instead of the surface channel)." Another definition of underflow is "the downstream flow of water through the permeable deposits that underlie a stream and that are more or less limited by rocks of low permeability." 26/ For most larger drainage basins, the outflow of ground water is chiefly through surface streams and outflow may be considered negligible for ground water. In coastal areas, a certain amount of ground water flows directly into the ocean without first entering streams.

Water yield is not measurable directly in most situations and is often assumed to be equal to runoff.

Drainage basin, drainage area, catchment area, catchment basin

Watershed - "The area drained by a stream, or stream system."

"The divide between drainage basins" is another definition for watershed.

Conduit - Any channel for conveyance of water.

Aqueduct - (1) "A major conduit," (2) "the entire transmission main of a municipal water supply, which may consist of a succession of canals, pipes, or tunnels."

Discharge - "The quantity of water, silt, or other mobile substances passing along a conduit per unit of time."

Discharge is a measure of rate of flow, often in cubic feet per second. The terms "discharge", "flow", and "streamflow" are sometimes used interchangeably.

Conveyance loss - "Loss of water from a conduit."

Conveyance losses are due to evaporation, transpiration, and seepage from the conduit into the soil.

26/ Langbein, W. B. and Iseri, K. T. pp. 11, 20. (See footnote 2, page 6.)

Infiltration - The process by which liquid water enters into the soil or the zone of aeration.

> Infiltration is a major process of the several processes of absorption, which refers to entry of all water, vapor, or liquid into the lithosphere.

Percolation - The movement of ground water through small interconnected saturated interstices of rock and earth.

> Percolating water "as used in a legal sense, is limited to diffused ground water, unconnected with a stream or other definite body of water, although it may be tributary to and ultimately reach such."
>
> The legal definition is not clear as to the meaning of "stream or definite body of water." In nearly all ground water reservoirs, the water is in motion, although the rate of movement is slow.
>
> Thomas states:
>
> "If the characteristics of 'definite underground streams include the turbulent flow that characterizes practically all surface streams, this class becomes a small one indeed, ... If on the other hand laminar (smooth, without turbulence) flow through porous materials is included, this class will embrace all ground water reservoirs as fast as the requirements of the word 'definite' can be met by scientific investigation to delineate their boundaries." 27/

Seepage - "The process by which water percolates through the surface of the lithosphere."

> Effluent seepage is seepage out of the lithosphere from a zone of saturation. This occurs at such places as springs, and streams with surface below the adjacent water table.
>
> Influent seepage is seepage into the lithosphere, as from irrigation canals, or streams with surface above the water table.

Water spreading - "Absorption produced by spreading a surplus of streamflow over permeable soils."

> An important purpose of waterspreading is to replenish ground water and the process is therefore often termed Recharge.

27/ Thomas, H. E. P. 248. (See footnote 26, page 15.)

Tentative Statement of Terms With Definitions. Amer. Geophys. Union Trans. 1934: 289.

Soil moisture percentage - "This term usually refers to percentage of moisture in the soil based on the weight of oven-dry material."

> Since irrigation applications are generally expressed in inches per acre, soil moisture percentage is often converted from a weight percentage to inches of water per unit of depth, e.g. foot of soil.

Field capacity - "The amount of water retained in the soil after excess mobile water has drained away and the rate of downward movement has materially decreased following an application of water from rain or irrigation."

> Field capacity is usually expressed as percentage of dry weight. At field capacity, the capillary interstices are filled with water while supercapillary interstices have replaced their water, contained at saturation, with air. Slow downward movement of water continues after field capacity has been attained. For exact definition, the following should be stated. Soil texture, structure, uniformity and depth, rate of application of water, temperature of water, the degree to which evaporation and transpiration were eliminated by the test, free (presumably surface) drainage conditions, depth to the water table, time elapsed between application of water and taking of sample.

Initial moisture deficiency - "The amount by which the actual moisture - content of a given soil-zone (usually root-zone) is less than field capacity at the beginning of a rainy season."

Permanent wilting percentage, Permanent wilting point, Wilting point - The moisture content of the soil, expressed as percentage of dry weight, at which plants wilt and fail to recover when placed in a dark, moist atmosphere. 28/

> Readily available moisture - The soil moisture from field capacity down to the permanent wilting percentage. 29/
>
> The term,
>
> Available moisture is sometimes used to designate the moisture content of the soil between permanent wilting percentage and field capacity. 30/

28/ Taylor, S. A., and Salter, C. S. When To Irrigate and How Much Water To Apply. U. S. Dept. Agr. Yearbook 1955: 372.

29/ Veihmeyer, F. J., and Hendrickson, A. H. Irrigating Orchards in Dry Regions. U. S. Dept. Agr. Yearbook 1955: 458.

30/ Frevert, R. K., and others. Soil and Water Conservation Engineering. P. 93. John Wiley and Sons, N. Y. 1955.

Soil moisture tension - The force or pressure per unit area with which water is retained in the soil. 31/

> As the percentage of soil moisture increases toward the permanent wilting percentage, rate of entry of water into plant roots is impaired. Dissolved salts in the soil further impair the availability of water to plants by increasing the osmotic pressure of the soil solution. There is evidence that the effects of moisture tension and osmotic pressure are additive. The sum of these two forces has been called the total soil moisture stress. 32/

SECTION II. NATIONWIDE DATA ON WATER USE

This section contains a listing of sources on water uses that are periodically available on a nationwide basis. Attention is also called to section IV. "Projections of Future Uses and Supplies," as reports on future water uses usually include data on present uses. In particular, the publications printed for use of the U. S. Senate Select Committee on Water Resources pursuant to Senate Resolution 48, 86th Congress, contain considerable data on water use in recent years.

Senate Resolution 48 authorized studies to be made concerning the relationship of water resource activities to the national interest. Of 32 committee prints issued under the title, "Water Resources Activities in the United States," several include data on recent water use. In particular, Committee Prints 7 to 14, 17, 18, 27 and 32 (see pp. 47-51 for titles and type of data) contain data on water use for 1954 or more recent years.

Federal Programs for Collection of Data on Water Use. Notes on Hydrologic Activities, Bul. 10, 43 pp., Washington, D. C. U. S. Govt. Print. Off. 1959, was prepared by the U. S. Public Health Service under the auspices of the Inter-Agency Committee on Water Resources, Subcommittee on Hydrology. Investigators interested in data pertaining to particular regions may find additional sources in the compilation cited. The present report concentrates on nationwide sources.

MAJOR WITHDRAWAL USES

MacKichan, K. A. Estimated Use of Water in the United States, 1955. U. S. Geol. Survey Cir. 398, 18 pp., illus. 1957.

Type of data

Public supplies, ground water and surface withdrawals, population served, and quantity used by industry.
Rural use, ground water and surface withdrawals.
Irrigation water delivered to farms and conveyance losses, from ground water, surface sources, and reclaimed sewage.
Self-supplied industrial withdrawals, ground water, fresh and saline surface water, reclaimed sewage, including withdrawals for generation of fuel-electric power by public utilities for condenser cooling and other uses.

31/ Taylor, S. A., and Salter, C. S. (See footnote 28, page 17.)
32/ Wadleigh, C. M. Soil Moisture in Relation to Plant Growth. U. S. Dept. Agr. Yearbook 1955: 360.

Air-conditioning, self-supplied industrial ground and surface withdrawals, and withdrawals from public supplies.
Withdrawals for production of waterpower.
Long-term average runoff of major drainage regions.
Known artificial recharge by sources of water used.

Period for which data are available

The first estimate was made for 1950 (U.S. Geol. Surv. Cir. 115). It is expected that future reports will be prepared for 5-year intervals.

Geographic breakdown

States and 19 major drainage regions.

Completeness of coverage

Compilations were prepared with the aid of district offices of the U. S. Geological Survey. More detailed geographic breakdowns of the data were not prepared. Principal sources of data are the individual source materials summarized in this report, and reliability of estimates vary with completeness of coverage of individual sources. The data for municipal use (public supplies) are reported as the most accurate, and those for industrial use (self-supplied industrial) the least accurate.

Estimates are limited to withdrawal uses and are exclusive of reservoir evaporation. Waterpower generation is considered a withdrawal use and probably includes mechanical as well as hydroelectric waterpower.

Additional information available

Picton, W. L. (See footnote 7, page 7.)

PUBLIC SUPPLIES

U. S. Public Health Service Reports

Municipal Water Facilities, Communities of 25,000 and Over. Continental United States and Territorial Possessions as of January 1, 1960. U. S. Pub. Health Serv. Pub. 661, 91 pp. 1960.

Type of data

Name of community or district.
Estimated population served by facility.
Year operation started.
Number of services and meters.
Ownership, public or private.
Source of supply, name of streams or lakes where possible, or number of wells.
Storage facilities for raw and treated water.
Safe daily yield during driest period of record, maximum ground water draft that can be sustained for 5 days.
Transmission capacity from distant impoundments or sources.
Type of treatment prior to use and treatment capacity.
Plant output maximum hour, day, month, and average.
Average plant output by domestic, commercial, industrial, and public use.
Type of laboratory control at the plant.
Pumping capacity.

Affirmative or negative replies to question: Will distribution system satisfy maximum demand?
Types of improvements needed.

Period for which data are available

Biannual.

Geographic breakdown

Individual communities or districts listed by States.

Completeness of coverage

Apparently all communities over 25,000 included.

Individual items of information for individual communities frequently missing. Data on average water output nearly complete. Breakdown of average output by type of use frequently missing.

Additional information available

Statistical summaries of Water Supply for Communities of 25,000 and over, are made for the United States and individual States. These summaries are prepared by the U. S. Public Health Service, Division of Water Supply and Pollution Control, Basic Data Branch. They are usually mimeographed.

National summaries usually appear also in the Journal of the American Water Works Association (for example, 1955 summary in Vol. 49, December 1957, 1956 summary in Vol. 50, August 1958).

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Municipal Water Facilities Inventory as of January 1, 1958. U. S. Pub. Health Serv. Pub. 775, 9 vols. 1960.

Type of data

Name of community.
Estimated population served.
Year operation started.
Ownership, public and private.
Number of services and meters.
Source of supply, specific name of lake or stream when possible, or number of wells.
Maximum dependable draft on source.
Maximum rated plant capacity.
Average daily plant output.
Type of treatment.
Type of laboratory control.
Storage in distribution system, (exclusive of long-term supply balancing storage).
Types of improvements needed.

Period for which data are available

A complete water and sewerage inventory was made for 1945 (Inventory of Water and Sewage Facilities in the United States 1945, Federal Security Agency, U. S. Public Health Service, Cincinnati, Ohio, 1948). Out of print. A second inventory was made in 1954. Inventory of Municipal Water Facilities for Larger Communities. 1954. Washington, D. C., U. S. Pub. Health Serv. 1955.

It is expected that inventories of municipal water facilities for all communities will be conducted every 5 years.

Geographic breakdown

Individual communities listed by States.

The inventory is in nine volumes corresponding to nine administrative regions of the Public Health Service. Regional boundaries are along State lines.

Completeness of coverage

The 1954 inventory was made with the cooperation of State Health Departments. Organized community water facilities for all communities of over 10,000 (1950 census) are included. For communities with a 1950 population of 5,000 to 10,000 a sample of about 40 percent was included. Information on plant output is fairly complete.

In the 1958 inventory, coverage was extended to include all places of 100 population or more in 1950, having water-supply systems. A list of places of 100 or more population not having supply systems is also given.

Additional information available

Mimeographed summaries for the United States and individual States are usually prepared by the U. S. Public Health Service, Division of Water Supply and Pollution Control, Basic Data Branch.

American Water Works Association

Staff Report. A Survey of Operating Data for Water Works in 1955. Jour. Amer. Water Works Assoc. 49(5): 553-696. May 1957.

Type of data

Physical

Population served.
Source, ground, surface, mixed, purchased.
Total water produced and distributed.
Number of services and meters, domestic, commercial, industrial, and public.
Types of improvements and treatment.

Financial and management

Type of ownership.
Rate schedules (in blocks of 1,000 to 1,000,000 cubic feet per month).
Income from residential, commercial, industrial, public, and other types of services.
Expenses, capital additions, disposition of earnings, book value of system.

Period for which data are available

The American Water Works Association conducted similar surveys for 1950 and 1945. These were reported in Jour. Amer. Water Works Assoc., vol. 45, June 1953, and vol. 40, Feb. 1948. Future reports are planned.

Geographic breakdown

Individual communities listed in alphabetical order.

Completeness of coverage

Questionnaires were mailed to 1,100 water utilities serving populations of 10,000 or more. Returns were tabulated for 497 utilities. These serve a total population of just over 70 million - more than 60 percent of the total population served by all water utilities. Utilities reporting furnished near complete response for all items.

Types of data obtained in 1945 and 1950 surveys are similar to those obtained for 1955.

Additional information available

Statistical analyses of averages, ranges, frequencies, and trends were published following each survey in the Journal of the American Water Works Association. (For 1945, vol. 40, Oct. 1948; for 1950,vol. 45, Dec. 1953; for 1955, vol. 49, Dec. 1957.)

INDUSTRIAL WATER USE

U. S. Bureau of the Census Reports

Manufacturing

U. S. Census of Manufactures: 1954. Industrial Water Use. U. S. Bur. Census Bul. MC-209, 52 pp., illus. 1957. (Preprint of section in U. S. Census of Manufactures: 1954, vol. 1, Summary Statistics.)

Type of data

Distribution of manufacturing establishments by gross water intake (tables 1, 2, 3.)

For establishments with water intake of 20 million gallons or more in 1954 (tables 4, 5, 6.)

Number of establishments.
Water intake by purpose: all purposes, and (1) process, (2) cooling and air-conditioning, (3) boiler feed, sanitary, and other.
Water intake by source: all sources, fresh and brackish. For fresh, a breakdown of amount from public water systems, company surface systems and company groundwater systems.
Water discharged, total.
Number of establishments recirculating or reusing water, and water required if there were no recirculation or reuse.
Amount of water treated prior to use and prior to discharge. Number of establishments treating water prior to recirculation.

For establishments with less than 20 million gallons intake 1954, estimated total intake (table 7.)

Period for which data are available

Water use data were first included in the 1954 Census of Manufactures. For manufacturing establishments with an intake of 20 million gallons or more, similar data are reported in: U. S. Bur. of the Census: Annual Survey of Manufactures, 1953, pp. 124-130. 1955.

The next U. S. Bureau of Census report on water use in manufacturing will be for 1959.

Geographic breakdown

Selected counties, and 18 water use regions, approximating river basins, with boundaries along county lines, and total U. S.

Completeness of coverage

For the water-use-by-region breakdown, only those industries and industry groups are listed that reported an intake of 10 billion gallons of water or more in 1954. For the county breakdown, only counties with industrial water use of 5 billion gallons or more in 1954 are listed and only the total for all industries within the county is shown. For both water-use regions and counties, the number of employees of reporting establishments is given.

For establishments with less than 20 million gallons annual use in 1954, only the total intake for major industry groups in the United States is given. Water use for these establishments was estimated rather than obtained by inquiry and was placed at about 2.5 percent of all industrial water use.

Additional information available

To personnel of other government agencies and research organizations, data are available on I.B.M. cards.

Manufacturing, Mining and Utility Steam
Electric Power Generation

U. S. Census of Manufactures: 1954. Industrial Water Use Supplement. U. S. Bur. Census Bul. MC-209 Sup., 51 pp. 1960.

Type of data

For manufacturing, mineral industries and utility steam generating establishments: Water intake and discharge, water required if there were no recirculation or reuse (table 1).

Data similar to those reported, for manufacturing establishments with water intake of 20 million gallons or more in 1954, in bulletin MC-209 for:

Electric utility steam generating plants, also power generation (table 6).
Manufacturing establishments with intake of 20 million gallons or more, generating electric power (table 5).
Manufacturing establishments with intake of 20 million gallons or more recirculating water (table 3).
Manufacturing establishments with intake of 20 million gallons or more recirculating water and generating electricity (table 4).

Data similar to those reported for mineral industries in bulletin M.I.F. (see p. 24) - with data added on number of establishments total and number recirculating water.

Retabulation of data given in MC-209 with minor revisions (U. S. and regional data only for establishments with intake of 20 million gallons).

Period for which data are available

Similar data on water use in 1959 will be available from the Bureau of the Census for manufacturing establishments and from the Federal Power Commission for steam electric utility plants. The U. S. Bureau of Mines surveyed water use for mineral industries

for 1960. Separate reports will be prepared by the Bureau of Mines and the Federal Power Commission. The Census of Manufactures will publish a report similar to MC-209 supplement dealing with water use in manufacturing and containing summary data on water use by steam electric utility plants and mineral industry.

Geographic breakdown

Manufacturing industries: States within 18 water use regions. Mineral industries and steam electric utilities: Water use regions.

Completeness of coverage

Data on manufacturing plants generating electricity or recirculating water are given for U. S. totals only by industry and industry groups.

Mining

U. S. Census of Mineral Industries: 1954. Energy, Water and Selected Supplies: Bulletin MIF. 19 pp. illus. 1957. (Preprint of section in U. S. Census Mineral Industries: 1954, Vol. I, Summary and Industry Statistics.)

Type of data

Water intake, except mine water, total, per production worker, and per dollar value added.
Water discharged except mine water.
Source of water intake except mine water, public water system, company surface water systems, company ground-water systems, combinations not specified.
Mine water used, drained, and discharged.
Gross water use -- the estimated total amount of water that would have been required if no water had been recirculated.

Period for which data are available

Water use data in mining were reported for the first time in the 1954 Census of Mineral Industries. The U. S. Bureau of Mines has surveyed water use in mineral industries for 1960. The results will appear in a report by the Bureau of Mines and in summary form in a U. S. Bureau of Census Report similar to MC-209 supplement.

Geographic breakdown

U. S. total by major industries and industry groups and States by total water use only.

Completeness of coverage

Coverage was nearly complete. For establishments with a total water intake and water pumped for drainage of less than 10 million gallons in 1954 only total water intake and discharge, except mine water, and source of intake were requested, but a very significant number of such small users reported fully on data of the other type which were included in the tabulations.

Additional information available

All data are available on I.B.M. cards.

U. S. Census of Mineral Industries: 1954, Vol. I, Summary and Industry Statistics. Reports on industry statistics include water-intake total and per production worker for major segments of industry groups by important States. In table 13 all "Type of

Data" listed for MIF above are given for the industry group by States.

U. S. Census of Mineral Industries: 1954, Vol. II, Area Statistics. All "Type of Data" listed for MIF above are given in table 6 of the State reports by industry groups and industries within the State. No data on water use are available on a county basis. For important mining counties, other types of data, including number of establishments, employment, value of shipments, value added in mining, and wages are reported. However, the reporting is rather incomplete. Number of establishments by industries are reported for all counties.

Preliminary mimeographed reports have been prepared by the U. S. Bureau of Mines on water use in the mineral industry in 1954, 1958, and projections for 1980 and 2000: MacMillan, R. T. Special report - preliminary. U. S. Bureau of Mines. Water Use in the Mineral Industry. Vol. I. River Basins (Water Use Regions), January 1960. Vol. II. Metropolitan areas, May 1960.

IRRIGATION

U. S. Bureau of the Census Reports

Irrigation of Agricultural Land

U. S. Census of Agriculture: 1950. Vol. III, Irrigation of Agricultural Land. Washington, D. C. U. S. Govt. Print. Off. 1952.

Type of data

Amount and source of water delivered to farms, with conveyance losses.

Other data

Type of organization furnishing water and acres served by each type.
Irrigation works and equipment of the organization furnishing water.
Cost to farmers of water delivered per acre and per acre-foot.
Capital investment and indebtedness and arrears on indebtedness of organizations.
Arrears in payments by farms to organizations, total and per acre irrigated.
Acreage, both artificially drained and in need of drainage, served by organizations.

Period for which data are available

Decennially since 1910. The 1960 census reports data for 1959. In previous census reports, data on water use were for the year preceding the date on the Census Volume.

Geographic breakdown

The census report for 1950 covers 17 Western States, Arkansas, Louisiana, and Florida. For 1960, 17 Western States and Louisiana are included.

Data in 1950 are presented for States, counties, major drainage basins, and three subclassifications of major basins. For 1960, data are planned for States, major and submajor drainage basins.

Completeness of coverage

General

A brief account follows of the relation between the Census of Agriculture and Census of Irrigation.

The Census of Irrigation covers irrigation enterprises that furnish water to farms for irrigation. Except for the 1940 census, when estimates were made of water delivered to farms by all enterprises, data on water use are limited to larger enterprises designated as multiple farm enterprises in 1950 and irrigation organizations in 1960. The 1960 Census of Irrigation was limited to irrigation organizations. Irrigation organizations are enterprises that furnish water to farms excluding farms that furnish water for themselves, or to several other farms. In 1950, estimates concerning water delivered per acre on all irrigated land were obtained by assuming the same rate of water use on all land as the rate reported by multiple farm enterprises. Consequently, reliability of estimates for geographic areas depends partly upon the extent to which the area was served by multiple farm enterprises.

The regular Census of Agriculture obtains data from individual farmers regarding crops irrigated, and source of irrigation water including name of irrigation company, and related data. Since 1950, information from the Census of Agriculture has been closely coordinated with information obtained from the Census of Irrigation.

Comparability of data in decennial reports - Data on water use prior to 1940 are available only by States, although acres irrigated are given for counties and drainage basins. Water use data for years before 1940 reported by multiple farm enterprises are useful for only rough approximations since amounts per acre entering canals and delivered to irrigators combine primary and supplemental irrigation.

Data on amount of water per acre for 1940, 1950, and 1960 are not comparable without prior adjustment, as the acreage irrigated by the total quantity of water reported for each multiple farm enterprise was derived from Censuses of Irrigation prior to 1950 and primarily from the Census of Agriculture in 1950. The Census of Irrigation of 1940 overreported acres irrigated and consequently the rate per acre tends to be lower. In 1960, acreage irrigated from organization sources is given as reported by the Census of Agriculture and also as reported by the Census of Irrigation.

Water delivered to farms

1950

Approximately 50 percent coverage of total acreage irrigated, reported separately for primary and supplemental irrigation and available for all geographic breakdowns. Percentage of coverage, however, varies widely. Calculated averages of total water delivered per acre are provided, based on the assumption that average deliveries per acre for all primary and supplemental irrigation equals that of enterprises reporting. (Summary Tables 32, 54. State Reports: County Table 2, part 4 of 4, Drainage Basin table 1, part 4 of 4).

Completeness of coverage can be checked by comparing primary and supplemental acreage for which quantities of water are reported, to the total acreage of primary and supplemental irrigation by single and multiple farm enterprises (County table 2, parts 3 and 4 of 4, Drainage Basin table 1, parts 3 and 4 of 4).

1960

In 1960, farmers interviewed for the Census of Agriculture reported what percentage of water used for irrigation on their farms came from (1) wells from their own or neighboring farms, (2) surface sources from their own or neighboring farms, and (3) irrigation organizations. The total acreage irrigated on each farm was multiplied by the reported percentage of water coming from each source, and thus equivalent acreages irrigated by types of source were recorded for each farm. These acreage equivalents were summed by geographic units giving the equivalent acres irrigated by (1) ground water sources on farms, (2) surface sources on farms, and

(3) irrigation organization sources.

Water delivered to farms by irrigation organizations will also be available in the census report. Although not done by the census, the total equivalent acres irrigated by irrigation organizations can be divided into the water deliveries by organizations to derive an estimate of water delivered per equivalent acre served by organizations. However, applying the same rate per acre to all irrigated land would involve the assumption that the amount of water applied per acre irrigated is independent of the source of supply. Further, in some areas, only a small part of the water for irrigation is obtained from organizations.

Source of water delivered to farms

1950

The 1950 breakdown of acreages irrigated by source of water is usable only for rough approximations of water delivered to farms from various sources. Land irrigated is reported by a mixed class: Surface and Ground Water. Also, land irrigated by more than one enterprise is counted under each enterprise in the tabulation of acreage irrigated by source. (Summary tables 22, 46, and 47, State table 2, County table 2, part 1 of 4, Drainage Basin table 1, part 1 of 4.)

1960

1960 data on the equivalent acres served by ground and surface farm sources and by irrigation organizations is available by States, major and sub-major drainage basins as explained. However, estimating deliveries from ground and surface sources from census data would involve the assumption that equal rates of water were applied regardless of source of supply. The total amount of water delivered by irrigation organizations coming from ground and surface sources will be reported by States and drainage basins.

Conveyance losses

1950

Conveyance losses are given for multiple farm enterprises. Reported losses are only rough approximations of losses from all sources combined. Reported losses probably account for the bulk of the total but their proportion would be difficult to estimate. Reported losses also include losses on deliveries for nonirrigation uses. Further, reported losses exclude losses in conveyance on water received from reporting enterprises by other enterprises but include losses in conveyance of water delivered by reporting enterprises to other enterprises. Because of limited coverage, water delivered by reporting enterprises is more than water received by reporting enterprises. Another difficulty is posed by reporting enterprises operating in more than one geographic division. The total conveyance losses for such enterprises are reported in each division, thus causing a certain amount of overreporting in each division. (Summary tables 31, 53, County table 2, part 4 of 4, Drainage Basin table 1, part 4 of 4).

1960

Information on conveyance losses by irrigation organizations is available in the 1960 census for States and drainage basins. The 1960 figures will be improved over the 1950 estimates by (1) allocation of conveyance losses between geographic units for organizations operating in several such divisions so that there will be no overcounting; (2) quantity of water delivered to reporting irrigation organizations will be the same as quantity received by reporting organizations, so that conveyance

losses will include the total losses resulting from deliveries to farms, other organizations, and nonirrigation uses. Some approximation of conveyance losses by source of water may be possible. As in 1950, data will be limited to irrigation organizations.

Other data

From 1950 to 1960, both type of irrigation organization for which the data were obtained, and type of data included varied. Only a brief description can be given here. In 1950, data were obtained for all enterprises that supply water for irrigation, including single farms that provide water for their own use. In 1960, the data were obtained only from irrigation organizations and probably exclude farms that furnish water to a few neighboring farms only.

The 1960 census contains no data on costs of water, irrigation works and equipment, indebtedness, arrears, or land served by artificial drainage.

Additional information available

Maps showing location of irrigated lands are prepared by the U. S. Bureau of the Census in conjunction with the Census of Irrigation, for example, Location of Irrigated Lands 1949, 17 Western States, Louisiana, Arkansas, and Florida, Washington, D. C., U. S. Govt. Print. Off. n. d.

Additional data relating to irrigation uses of water may be available from Offices of State Engineers, or State Departments of Irrigation or Water Resources.

Irrigation in Humid Areas

U. S. Census of Agriculture: 1954. Vol. III, Special Reports, Part 6, Irrigation in Humid Areas. Washington, D. C., U. S. Govt. Print. Off. 1956.

Type of data

Data on water use

None but data on: Acres irrigated by crops.
Number of irrigations per season.
Source of water applied.

Other data

Method of water application.
Source of power for pumping.
Number of pumps, storage facilities.
Costs of irrigation.
Answer to question: Has anyone challenged the legality of your right to use the water you have used for irrigation?

Period for which data are available

First report for 1954 and 1955. Second report will cover the year 1960. Reports will probably continue at 5-year intervals.

Geographic breakdown

In the first report, 28 States not covered by the Census of Irrigation were included. Future reports will include those States not covered by the Census of Irrigation.

In the 1960 census report the States included were the same as those included in the first report plus Arkansas and Florida. The first report gives data by States only. Future reports will include data by States and important irrigation counties.

Completeness of coverage

General

Mail questionnaires are sent to all farm operators reporting irrigated land in the regular Census of Agriculture. For the 1954 survey, nonrespondents with 100 or more irrigated acres were visited. The 1954 survey of irrigation covered 93 percent of the irrigated acreage reported by the census. The report for 1960 covers farmers who reported irrigation in 1959 when contacted for the regular Census of Agriculture.

Data relating to water applied on farms

For 1954 and 1955, only the total acreage irrigated is given (table 16). Number of irrigations per season is reported by farms rather than acres.

In the 1960 census report, the number of irrigations was reported by acres, rather than farms.

Source of water applied

For 1954 and 1955, the acreage irrigated is given by source (table 3). However, of a total of some 546,000 acres irrigated in 1954, some 135,000 acres were irrigated from mixed sources.

In the survey of irrigation in humid areas for 1960, each farmer was asked what percentage of his total water supply came from various sources. By multiplying the acreage irrigated on each farm by the percentage of irrigation water coming from each source, estimates will be provided of the equivalent acreage irrigated by major sources of water. No data are given on amount of water used.

Conveyance losses

The survey of irrigation gives no information on conveyance losses. In 1954 and 1955, there was very little transportation of water. This is likely to be true for 1960, though to a somewhat lesser extent as Florida and Arkansas will be included in the report of irrigation in humid areas.

Other data

Only a brief summary of other data is given here. The general organization of the tables in the first report is to present for individual States the number of farms reporting, the acreage irrigated, and the costs of irrigation. These data are presented by source of water, source of power, method of water application, frequency distribution of acreages irrigated per farm, year irrigation began, and separation by farms with and without constructed storage. Cost data are from 6,414 farms on which irrigation began in 1946 or later. Costs are presented as totals, per farm, and per acre and are for: (1) all costs; (2) costs of irrigation equipment; (3) leveling and ditching; and (4) storage and well construction. Per acre cost figures appear to be obtained by dividing each cost item by the total acreage reported irrigated in 1954 by all farms reporting costs and not by the acreage on the farms reporting the particular item of cost. The 1960 report will carry no data on costs, number of pumps, or legality of water use.

Additional information available

The U. S. Soil Conservation Service has prepared guides for irrigation design for each of the 28 States included in the 1954 census. These guides present recommended amounts of water to be applied per irrigation. The recommendations are for individual crops and are given by soil groups. They are based on specified assumptions regarding efficiency of the water-distribution system and depletion of available moisture from field capacity. It is therefore necessary to adjust these recommendations if used in combination with the census survey of humid area irrigation in deriving estimates of amounts of water applied under farm conditions.

ELECTRIC POWER GENERATION

Federal Power Commission Reports

Steam Electric Power

Water Requirements of Utility Steam Electric Generating Plants - 1954. U. S. Fed. Power Com. DC-57, 3 pp. 1957. (See also U. S. Census of Manufactures: 1954, p. 23.)

Type of data

Intake, total, fresh, and brackish.
Source of supply, self-operated ground (probably surface source), wells, and public supply system.
Steam generation in kilowatt-hours.
Intake, discharge to ground (probably surface discharge), evaporation, and increase in intake that would be required if water for condensing and cooling had not been reused in the plant, total and per kilowatt-hour.

Period for which data are available

For 1954. Similar data will be available for 1959.

Geographic breakdown

By States and geographic areas (group of States).

Completeness of coverage

Data were reported for plants of 25,000 kilowatt-hours capacity and expanded to 100 percent based on total utility steam generation in each State. Coverage ranges from about 75 to nearly 100 percent except for States with relatively small steam generation.

Additional information available

Individual plant reports may be available from the Federal Power Commission. In addition to the type of data listed above, these reports contain other data including: Installed generating capacity, net generation, peak hourly demand, cost of plants, production expenses, fuel used, and number of employees. Plants are reported by name of utility company and of plant, Federal Power Commission Electric Supply Area, and location of plant by city and State.

Similar reports on individual plants are published in annual supplements to: "Steam Electric Plant Construction Cost and Annual Production Expenses 1938-1947." F.P.C.

S-72. Data relating to water use were reported for 1954 only.

For breakdown by drainage basins of water use by utility steam generating plants, see: U. S. Census of Manufactures: Subject Bulletin MC-209. (See page 23 of this report.)

For annual data on generation, see Federal Power Commission press release 11,076, p. 32.

Hydroelectric Power

Hydroelectric Power Resources of the United States, Developed and Undeveloped, 1957. U. S. Fed. Power Com. F.P.C. P-32, 196 pp. n. d.

Type of data

Data on water use

None published (see: Additional information available), but data on average annual generation and gross head for existing hydroelectric plants and undeveloped powersites.

Other data - existing and authorized hydroelectric plants

Ownership, Federal, other publicly owned, privately owned (presumably utility), industrial plant.
Name of owner and of plant.
Plants operating under F.P.C. license.
Installed capacity, main and auxiliary.
Installed capacity, existing, being installed and planned ultimate, for Federal hydroelectric plants in operation, under construction and authorized.
Installed capacity, existing, initial, and planned ultimate capacity and ultimate annual generation for hydroelectric plants existing and under construction with planned ultimate capacity of 100,000 kw, and more.

Other data - undeveloped powersites

Installed capacity that could be developed.

Period for which data are available

Data as of January 1, 1957. A 1953 edition by the same title was prepared by the Federal Power Commission. Periodic future reports may be expected.

Geographic breakdown

Most data are reported for individual plants with name of river given. Individual plants are listed by 14 major drainage basins (table 2) that conform to U. S. Geological Survey boundaries used in annual reports of surface water supplies, and by States (table 4). Summaries are presented for drainage basins (table 1) and for States (tables 3 and 5).

The same breakdown is followed for undeveloped powersites (tables 10 to 15).

Completeness of coverage

General

Data on existing power development are based on individual hydroelectric plant

reports with capacity of 100 kw. or more. Estimated generating capacity of undeveloped powersites assumes reasonable river regulation of flow by storage. Undeveloped power estimates include projects on which economic feasibility has been demonstrated and projects indicating engineering feasibility and promise, at some time, of economic feasibility. Included in the listing of undeveloped sites are sites where additional capacity could be installed with increments in capacity and generation shown.

Water use

The quantity of water passing through turbines is available only in the unpublished individual plant reports. Quantity of water can be approximated from published data by use of the formula:

$$\text{kw-hr} = \frac{QheT}{11.8}$$

(William P. Creager and Joel D. Justin, Hydroelectric Handbook, 2d ed. John Wiley, N. Y. 1950, p. 155.)

Where: kw-hr = kilowatt-hours
T = period of time in hours
Q = average discharge during the period in cubic feet per second
e = plant efficiency, expressed as a fraction
h = productive head in feet

The data given include kw-hr, T, and the gross head, rather than the productive head, h. Therefore, to estimate water use, Q, it is necessary to estimate plant efficiency, e, and to adjust this estimate to allow for the use of gross head rather than the smaller productive head (for details, see Creager and Justin, pp. 151-161). Creager and Justin estimated the efficiency of large modern hydroelectric plants to be 80 to 83 percent. In its estimates for water use in 1950, the Geological Survey assumes an average hydroelectric plant efficiency of 80 percent (U.S.G.S. Cir. 115). It is not known whether this estimate includes an allowance for use of gross rather than productive head.

Additional information available

Unpublished individual plant reports include some data on water use per kilowatt-hour and plant efficiency adjusted for losses from gross head.

In press release 11,076, August 5, 1960, revised from earlier releases, the Federal Power Commission estimates: (1) Energy requirements of electric utilities, 1958, 1959, and 1980 by class of use and 8 power-supply regions, (2) energy and peakload requirements of utilities by 8 power regions, and nonutility totals, 1958, 1959, and 5-year intervals to 1980, (3) utility peakloads 1958, 1970, and 1980 for 48 power-supply areas, (4) installed capacity, hydro, steam (includes nuclear) and internal combustion and total generation for utilities and industrial establishments, 1958 for 8 power regions, 1959, national totals, and (5) total utility and industrial capacity needed, hydro, steam and internal combustion, 1959 and 5-year intervals to 1980.

MILITARY

Water Supply Data of the Military Installations Located in the United States and Territories

(Compiled by the Technical Division, Director of Construction, Office of the Assistant Secretary of Defense (Properties and Installations). Issued for official Government

Agency use only. At no time will the reports or any data on military water supplies be given out for general public or business information).

Type of data

Water obtained from all sources, total, maximum month and day.
Self-supplied water, total and source of supply.
Purchased water from off-base suppliers, total, maximum month and day and name of supplier.
Capacities of installation systems, ground and elevated storage, treatment works, if any, and pumps.

Period for which data are available

The report for fiscal year 1961 became available July 1, 1961. Future reports are expected to be available at 5-year intervals.

Geographic breakdown

Data available for each individual installation, State, or Territory.
Installations are listed by States in alphabetical order of cities or towns located nearby.

Completeness of coverage

The report for FY 1960 covers all military installations in the United States and Territories as reported by the military departments which had a water use of 5,000 or more gallons per day.

Additional information available

Monthly reports of daily data are made by the installations. Specific nonclassified information may be requested through district or regional offices of the military departments. Data for military manufacturing plants operated by private contractors or for classified operations would not be available.

Reports on sewage disposal of military installations similar to those on water use became available July 1, 1961.

Copies of the 1955 report are no longer available, but data therein may be found in the regional offices of the U. S. Public Health Service, the U. S. Geological Survey, and the U. S. Business and Defense Administration, Water and Sewage Utilities Division.

RURAL

No detailed surveys were made of this category of water use, which comprises only 1 to 2 percent of all withdrawal uses exclusive of waterpower. U. S. Geol. Survey Cir. 398 includes estimates of rural water use by States and major drainage regions. More detailed estimates require data on per capita consumption rates combined with data showing rural population and livestock numbers.

Withdrawals for rural population

Rural population. - Rural population is defined as population not served by public-water supply systems. Rural population is not enumerated but must be estimated by deducting population served by public supplies from total population. Sources

available for such estimates are not completely satisfactory as they vary in time period covered and in other respects.

The Municipal Water Facilities Inventory of the U. S. Public Health Service estimates 1958 population served by public supplies. (See p. 20.) Coverage is for all communities that had a population of 100 or more in 1950. Total population by States, counties, and minor civil divisions is available from the decennial census of population.

The percentage of the rural population served by running water might be approximated from the decennial census of housing, which reports the total number of dwelling units and the number of dwelling units without piped running water for the total and for rural nonfarm and farm dwellings by counties. In using these figures, it should be recognized that the Census definition of rural population does not correspond to the definition of rural population for purposes of estimating water use.

Per capita withdrawals. - Per capita withdrawals in rural homes with running water vary; they were estimated for 1955 at an average of 60 gallons a day per capita in U.S.G.S. estimates. This average per capita consumption is equal to that reported for 1945 by Langbein for cities of 500 population (Amer. Water Works Assoc. Jour. Vol. 41, No. 11, Nov. 1949). Public Health Surveys of per capita use of water in small communities provides the basis for estimating use per person in specific areas.

The Geological Survey estimated per capita use in homes without running water for 1955 at an average of 10 gallons per day.

Withdrawals for farm animals

Number of animals. - Numbers of farm animals are reported in the Census of Agriculture by counties and are available for minor civil divisions.

Per capita withdrawals. - Per capita water consumption for various livestock classes varies widely. Some estimates are provided by Sykes (U. S. Dept. Agr. Yearbook 1955, p. 14) and in U. S. Geol. Surv. Cir. 398. Additional estimates may be available from State agricultural experiment stations.

Rural withdrawals for miscellaneous farm uses

Primary miscellaneous farm uses are probably spraying of crops and animals, cleaning, and uses connected with milk production. Estimates can be based on census of agriculture data on crop acreages and livestock numbers, combined with prevailing practices obtained by agricultural experiment station recommendations and estimates.

WASTE CARRYING

U. S. Public Health Service Reports

National Water Quality Network. Annual Compilation of Data, October 1, 1958 - September 30, 1959. U. S. Pub. Health Serv. Pub. 663, 323 pp. 1959.

Type of data

Radioactivity determinations.
Plankton population.
Organic chemicals.
Chemical, physical, and bacteriological analyses including:
  Temperature;

Dissolved oxygen, biochemical and chemical oxygen demand;
Ph, alkalinity, and hardness;
Chlorine demand, chloride;
Ammonia-nitrogen, sulfates, phosphates;
Color, turbidity, and
Coliforms, total dissolved solids.
Trace elements.

Period for which data are available

The program was started in October 1957. Reports are issued annually on a water-year basis (October 1 to September 30).

Geographic breakdown

Sampling stations at or near cities distributed throughout the country. Stations usually located near intakes of water systems, listed by State, river, and subbasin.

Completeness of coverage

It is expected that the network will be expanded to 250 to 300 stations. Types and frequencies of observations will be modified to reflect experience and needs.

At some of the stations, not all of the measures were taken.

Additional information available

See Water Supply Category: Surface Water Quality.

A supplement to the first quality network report (October 1, 1957 - September 30, 1958), contains a partial summary of the original data, including radioactivity, organic chemicals, and plankton population. Summaries are given for the United States and 15 major river basins for radioactivity, and for the United States and major rivers or lakes for organic chemicals and plankton population. For radioactivity, ranges are presented for individual stations; stream loadings of organic chemicals in tons per day are also reported on a monthly basis for individual stations. Data are reported in: U. S. Public Health Service Pub. 663, Supplement I, Washington, D. C., U. S. Govt. Print. Off. 1959.

Report for State data may be available from State Departments of Health.

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1957 Inventory. Municipal and Industrial Waste Facilities. A Cooperative State-Federal Report. U. S. Pub. Health Serv. Pub. 622, 9 vols. 1958.

Type of data

Name of community, sewer or sanitary district, institution, or industry.
Population served or number of plant employees.
Type of sewer system for communities and districts. For industries, type of industry.
Average daily waste flow. For industries, whether flow is cooling water or process waste flows.
Population equivalent or average daily flow for which system was designed, or both.
Type of treatment.
Name of watercourse or lake to which treatment-plant effluent or untreated wastes are discharged.
Population equivalent (BOD) of the untreated waste, and of the treated waste that is discharged.
Minimum streamflow, duration and frequency.

Pollution abatement needs.
Primary downstream water uses within area affected by the wastes discharged.

Period for which data are available

Many State agencies have annual inventory data beginning 1953 but the 1957 inventory is the first national inventory since: Inventory of Water and Sewage Facilities in the United States 1945, Federal Security Agency, U. S. Public Health Service, Cincinnati, Ohio, 1948. (Out of print.)

Geographic breakdown

Individual communities, districts, or industries listed by States. Entries indicate name of major drainage basin, subbasin, stream, and watercourse mileage of waste discharge. The inventory is in nine volumes which correspond to Public Health Service administrative regions and are summarized by major drainage basins.

Completeness of coverage

Essentially all municipalities. Judging from individual State reports incorporated into the national inventory, reporting may be incomplete, particularly on industrial sewage facilities and streamflow. Population equivalent of untreated waste, and waste discharged, daily flows of waste, and capacity of system design data are frequently missing, particularly for industries.

Additional information available

National summaries are prepared of Municipal Sewage Works by States and major drainage basins (for example U. S. Pub. Health Serv. Pub. 609, 1958). Municipal Sewage Treatment Needs have been summarized by States (U. S. Pub. Health Serv. Pub. 619, 1958).

Reports on water pollution are contained in the Water Pollution Series of the Public Health Service. These include summary reports for U. S. major drainage basins and subbasins and comprehensive program documents. Another Public Health Service Series entitled, Clean Water Digest Series, contains brief popular reports for major regions on pollution problems and progress and need for waste treatment.

Summary reports on sewage and waterworks construction awards are available for 1959 in: Sewage and Waterworks Construction-1959. U. S. Public Health Service Pub. 758, 1960. References to publications on contract awards since 1952 are included also. Other Public Health Service publications carry periodic summaries entitled: Water and Sewage Bond Sales in the United States. Data on bond sales are available from July 1956.

Major Public Health Service publications dealing with supply, quality, and other aspects of water are listed in: U. S. Public Health Serv. Bibliography Ser. 22, also listed as U. S. Pub. Health Serv. Pub. 243: Source Materials on Water Pollution Control. Revised 1958. U. S. Pub. Health Serv., Division of Water Supply and Pollution Control, Washington 25, D. C.

NAVIGATION

U. S. Department of the Army, Corps of Engineers

Waterways and Harbors

Waterborne Commerce of the United States. Annual. Parts 1-4, U. S. Army Engineer Division Offices, part 5, Board of Engineers for Rivers and Harbors,

Washington, U. S. Department of the Army, Corps of Engineers.

Part 1. Atlantic Coast.
Part 2. Gulf Coast, Mississippi River System, and Antilles.
Part 3. Great Lakes.
Part 4. Pacific Coast, Alaska, and Hawaii.
Part 5. Waterborne Commerce of the United States (National Summary).

Type of data

Controlling depth of waterway or harbor actual minimum depth, and project depth (authorized).
Total tonnage and passenger traffic over last 10 years.
Annual tonnage by types of commodities, direction of movement, and combined total ton miles.
Number of trips by direction of movement, type of vessel, draft of vessel in feet, and total net register tonnage and passengers.

Period for which data are available

Annual reports.

Geographic breakdown

Individual rivers, canals, and intracoastal waterways, ports, and harbors with account of location and length of reach to which data pertain.

Completeness of coverage

Essentially all movement of commodities and passengers, foreign and domestic, exclusive of military shipments and transport in U. S. Army or Navy vessels, or vessels operated by the Defense Department.

Additional information available

The Bureau of Water Carriers and Freight Forwarders of the Interstate Commerce Commission maintains a list of common and contract water carriers by major waterways. Excluded are private carriers and carriers handling only exempt commodities. The freight rates of common carriers are on file with the Interstate Commerce Commission and are identified by both the company and the I.C.C. tariff number.

Committee Print 11, Future Needs for Navigation, by Senate Select Committee on Water Resources, contains data on critical flows required for navigation by major waterways.

SECTION III. NATIONWIDE DATA ON WATER SUPPLIES

Only a brief summary is given here as the subject has been covered elsewhere.

A more detailed and complete account of type of data and publications is given in:

I. Inter-Agency Committee on Water Resources, Subcommittee on Hydrology. Principal Federal Sources of Hydrologic Data. Notes on Hydrologic Activities, Bul. 8. Vol. I. July 1956. (The report, which was prepared under the direction of Walter B. Langbein, U. S. Geol. Survey, is labeled "For Administrative Use Only.")

For an analytical appraisal of the growth, extent, use, and adequacy of water supply information and other hydrologic data see:

II. Langbein, W. B., and Hoyt, W. G.: Water Facts for the Nation's Future, Uses and Benefits of Hydrologic Data Programs. Sponsored by the Conservation Foundation. The Ronald Press Co., New York, 1959.

Principal sources of data on surface and ground water supplies are the Water Supply Papers of the U. S. Geological Survey published by the U. S. Govt. Print. Off., Washington, D. C. These are listed and indexed in:

III. U. S. Department of Interior, Geol. Survey. Publications of the Geological Survey. Washington, D. C., U. S. Govt. Print. Off. May 1958.

"Publications of the Geological Survey" is printed every 5 years and obtainable free of charge from the Geological Survey. Yearly supplements and monthly lists of publications are issued free of charge.

In the discussion of surface and ground water supplies, the three references are referred to as references I, II, and III.

Attention is called to Section IV: Projections of Future Uses and Supplies. In particular, Committee Prints 1, 3, 4, and 32 of the Senate Select Committee on Water Resources contain nationwide data on water supply. Committee Print 6 has some data for individual States; 13 contains maps on rainfall, runoff, and evaporation. Prints 19 and 20 have data for Alaska and Hawaii; 21 and 23 carry data on possible increases in water supply from reduction of evaporation and transpiration; and 31 contains information on potential increases in supply through weather modification and demineralization in selected areas.

STREAMFLOW

Surface Water Supplies of the United States. Annual. U. S. Geol. Survey Water-Supply Papers.

Type of data

Location and description of type of gage and drainage areas.
Period for which records are available, average and extremes of discharge during period of record.
Appraisal of quality of record, diversions, storage, and other artificial causes affecting measurements, reference to revisions of earlier records.
Stage discharge relationship.
Daily, monthly, and annual totals, mean and extremes in streamflow and when feasible, annual runoff under natural conditions.
Monthly contents of reservoirs and lakes.

Period for which data are available

Annually, for water year, October 30 to September 1. Period of record of individual stations varies widely. Each water supply paper has reference table to earlier reports for the same area. Monthly and annual data are summarized for the period of record. (See Additional information available.)

Geographic breakdown

Reports are issued in 18 volumes covering 14 major drainage areas. Individual stations are indexed. (See Additional information available.)

Completeness of coverage

As of September 30, 1957, measurements had been made by the U. S. Geological Survey at 13,750 gaging stations, of which 7,030 were in operation including those of Alaska and Hawaii. Records of discharge at points other than regular gaging stations are also reported, as is a list of gaging stations operated by agencies other than the U. S. Geol. Survey. Included also are references to reports on stage and discharge during major floods. Other pertinent references are given.

Additional information available

U. S. Geological Survey. Compilation of Records of Surface Waters of the United States Through September 1950. U. S. Geol. Survey Water-Supply Papers 1301 to 1318. These papers summarize monthly and annual data on streamflow, runoff, and reservoir content for the period of record. Individual records are listed in the order in which they appear in the annual papers on surface water supplies.

U. S. Geol. Survey. Index of Surface Water Records to September 30, 1955, U. S. Geol. Survey Cirs. 381 to 396. These circulars contain a list of gaging stations, with drainage area and period of record.

U. S. Geol. Survey in collaboration with Department of Resources and Development, Water Resources Division, Canada. Water Resources Review (monthly). This report gives monthly, annual, and spring summaries of streamflow and flood conditions, levels of reservoirs, and ground water for the United States and parts of Canada.

MacKichan, K. A. Estimated Use of Water in the United States, 1955. U. S. Geol. Survey Cir. 398. 1957. This report contains estimates of runoff for 19 major drainage regions.

Langbein, W. B., and others. Annual Runoff in the United States. U. S. Geol. Survey Cir. 52. 1949. This report contains a map of the United States showing isograms of average annual runoff.

Thornwaite, C. W., Mather, J. R., and Carter, D. B. 3 Water Balance Maps of Eastern North America. Resources for the Future, Inc., Baltimore. 1959. This report shows computed mean annual potential evapotranspiration, water deficit, and water surplus.

Harbeck, E. G., Jr., and Langbein, W. B. Normals and Variation in Runoff, 1921-1945. U. S. Geol. Survey, Water Resources Rev., U. S. and Canada, Sup. 2, 1949. This report shows computed runoff for 124 gaging stations in the United States and Canada for each of 25 years. Runoff is classified as normal, deficient, and excessive. Coefficient of variation and extremes are given.

Thomas, N. O., and Harbeck, E. G., Jr. Reservoirs in the United States. U. S. Geol. Survey. Water-Supply Paper 1360-A, 1956. This report lists individual reservoirs with total capacity of 5,000 acre-feet or more and natural lakes having a usable capacity of 5,000 acre-feet or more, by location, ownership, use, and major characteristics.

For distribution of gaging stations by length of record, areal density by States and additional types of data available, see reference I. Reference I also has a summary of surface-supply measuring activities and reports by agencies other than the U. S. Geological Survey. For a discussion of adequacy of coverage, see reference II.

Quality of Surface Waters of the United States. Annual. U. S. Geol. Survey Water-Supply Papers.

Type of data

Chemical analysis

Location of gage and drainage area.
Period for which records are available, averages, and extremes for period of record.
Mineral content analysis, dissolved solids, hardness, percentage of sodium, absorption ratio, specific conductance, ph, water temperature.
Mean discharge during period of observation.

Sediment

Location of gage and drainage area.
Period for which records are available, average and extremes for period of record.
Suspended sediment concentration and tons per day. Periodic analysis of particle size distribution is usually included. In a very few instances, particle size analysis is given for bedload for a limited number of observations per year.
Mean discharge during period of observation.

Period for which data are available

Annual report for water year since 1941.

Geographic breakdown

Individual stations listed in downstream direction. Reports are issued in four volumes covering 14 major drainage areas.

Completeness of coverage

Chemical

About 480 regular sampling stations were maintained in recent years (reference II). For these stations, data are composites of several days with one or more samples per month. Weighted annual averages are given. Less frequent observations not permitting computation of annual averages are reported for many other points.

Sediment

A maximum of 170 regular stations for measurement of suspended sediment load were reported for 1957 (reference II). Sediment samples were collected daily at most of these stations, and monthly and annual totals are given. Less frequent sediment samples were collected at many other points.

Additional information available

See Water-Use: WASTE CARRYING. U. S. Public Health Service Reports.

Lohr, E. W. and Love, J. K. The Industrial Utility of Public Water Supplies, 1952. U. S. Geol. Survey Water-Supply Papers 1299 and 1300. 1954. (1299, States East of the Mississippi River, 1300, States West of the Mississippi River.) Report contains chemical analyses similar to those given in Water Supply Papers entitled, "Quality of Surface Waters of the United States." Included are analyses of the water supply of

1,300 places including all places of 15,000 or more population. Analyses usually include data for raw and finished water.

U. S. Geol. Survey. Quality of Surface Waters for Irrigation, Western United States. U. S. Geol. Survey Water-Supply Papers, published annually since 1951. In 1954, data were reported for 82 of a contemplated network of 106 stations west of the Mississippi main stem to be sampled with particular reference to irrigation water use. The types of data are similar to those in the chemical analyses of the water-supply papers: Quality of Surface Waters of the United States, and the same stations are included in both reports. The data in: Quality of Surface Waters for Irrigation, are in a form more generally used for evaluating the chemical quality of irrigation water.

U. S. Geol. Survey. Saline Water Resources of Texas. U. S. Geol. Survey Water-Supply Paper 1365, 1956; Preliminary Survey of the Saline Water Resources of the United States, Water-Supply Paper 1374, 1957; Saline Water Resources of North Dakota, Water-Supply Paper 1428, 1958. These papers are the first resulting from a continuing program of evaluating saline water supplies.

Publications of the Inter-Agency Committee on Water Resources, Subcommittee on Hydrology.

Inventory of published and unpublished chemical analysis of Surface Water in the Western United States - Notes on Hydrologic Activities, Bul. 2. October 1948. Available for administrative use only.

Inventory of published and unpublished chemical analysis of Surface Water in the Eastern United States - Notes on Hydrologic Activities Bul. 6. 1954.

Inventory of published and unpublished Chemical Analysis of Surface Water in the Western United States, 1947-55 - Notes on Hydrologic Activities, Bul. 9. 1959.

Publications of the Subcommittee on Sedimentation, Inter-Agency Committee on Water Resources.

Inventory of Published and Unpublished Sediment Load Data in the U. S. Sedimentation Bul. 1. April 1949. Available for administrative use only.

Inventory of Published and Unpublished Sediment Load Data in the United States, Supplement 1946 to 1950. Sedimentation Bul. 4. April 1952. Available for administrative use only.

Summary on Reservoir Sedimentation Surveys Made in the United States Through 1950. Sedimentation Bul. 5. August 1953. Available for administrative use only.

For additional references, and particularly for information obtained by agencies other than the Geological Survey, see reference I. These include the Bureau of Reclamation, the Tennessee Valley Authority, the International Boundary Commission, the Corps of Engineers, the U. S. Department of Agriculture, and the U. S. Public Health Service.

The following publications interpret the significance of water quality:

Hem, J. D. Study and Interpretation of the Chemical Characteristics of Natural Water. U. S. Geol. Survey Water Supply Paper 1473. 1959.

Richards, L. A., ed. Diagnosis and Improvement of Saline and Alkali Soils.

U. S. Dept. Agr. Handbook 60, Ch. 5, Quality of Irrigation Water, pp. 69-82. 1954.

Wilcox, L. V. Classification and Use of Irrigation Waters. U. S. Dept. Agr. Cir. 969, 19 pp., illus. 1955.

Lunin, Jesse and Gallatin, M. H. Brackish Water for Irrigation in Humid Areas. U. S. Agr. Res. Serv. ARS 41-29, 12 pp., illus. 1960.

GROUND WATER SUPPLIES

Water Levels and Artesian Pressures in Observation Wells in the United States. Annual. U. S. Geol. Survey Water-Supply Papers.

(Note: The Federal Observation Well Program, though the only regular nationwide series on ground water, constitutes only a small part of available ground water data. Attention is therefore called to: Additional information available, listed below).

Type of data

Location of observation well, owner of well, use if any, diameter and depth, geologic formation, whether water table or artesian.
Water level in well with reference to land or mean sea level. Wells equipped with recorder graphs have daily records; monthly or weekly observations are generally reported for others.
Period for which records are available and highest and lowest levels of water in observation well during period.

Period for which records are available

Annual reports for calendar year since 1935.

Geographic breakdown

Reports are issued in 6 volumes corresponding to six groups of States. Data for wells are listed by counties and States and shown on maps.

Completeness of coverage

Langbein reports in reference II that some 7,000 observation wells were in operation in recent years. The reports include an introductory statement for each State interpreting water-level fluctuations and trends, and precipitation and pumpage.

Additional information available

The bulk of ground-water data are contained in individual reports covering specific areas. References I and II contain a map showing percentage adequacy of ground-water information as of 1950. In reference I, p. 9, it is stated that:

> Perhaps a quarter of the country is covered by basic reports, some a good deal more complete than others, describing the general geology and occurrence and quality of ground water. For the rest of the country only reconnaissance studies have been made, or none at all; . . . .

Listed below are two references to aid location of detailed ground-water data:

Vorhis, R. C. Bibliography of Publications Relating to Ground Water Prepared

by the Geological Survey and Cooperating Agencies 1946-1955. U. S. Geol. Survey Water-Supply Paper 1492, 1957. The bibliography contains brief abstracts, an index, and reference to earlier bibliographies.

Thomas, H. E. The Conservation of Ground Water. Sponsored by the Conservation Foundation. McGraw-Hill, N. Y. 1951. Contains a discussion of the place of ground water in the hydrologic cycle, problems related to ground-water use and maps showing major aquifers and areas with wells having declining water levels and encroachment of inferior water. The appendix has 1949 estimates of pumpage from major ground-water reservoirs and an index of localities, listing type of problem and page reference to text. A selected bibliography of ground-water studies listed by areas is included.

SECTION IV. PROJECTIONS OF FUTURE WATER USES AND SUPPLIES

In this section, summaries are presented of two sources of nationwide projections of withdrawal uses. A third covers all water uses.

In the preceding section, a summary was presented of the Federal Power Commission, Hydroelectric Power Resources of the United States Developed and Undeveloped, containing estimates of future hydroelectric power and Federal Power Commission press release 11,076, projecting future power needs.

Within the framework of variations of the hydrologic cycle and ground-water storage, the supply of water is a physically fixed quantity. The concept of projections in water supplies is therefore interpreted as change in availability and quality of water in the hydrologic cycle. In this context, projections of dependable supply are available in the second source. Data on storage needed to increase the dependable supply are contained in Committee Prints 3 and 32, of the third source. Increases in supply through vegetative management, reduction of evaporation, seepage, and losses from nonbeneficial vegetation, are found in Committee Prints 21 and 23 of the third source.

Augmenting usable water supplies through demineralization and weather control is largely in the development stage. Some projections on these two items are found in:

Ackerman, E. A., and Löf, G.O.G. Technology in American Water Development, pp. 345 and 375. Published for Resources for the Future, by the Johns Hopkins Press, Baltimore. 1959.

The same estimates are given in Committee Print 31. The estimate for augmentation of water supply through demineralization is also given in a report carried out under contract for the U. S. Department of the Interior, Office of Saline Water:

U. S. Bureau of Reclamation. Potential Use of Converted Sea Water for Irrigation in Parts of California and Texas. Saline Water Conversion Program. Off. Saline Water Res. and Develop. Rpt. 3. April 1954.

Attention is called to U. S. Geol. Water-Supply Papers 1365, 1374, and 1428, containing preliminary surveys of supplies of saline waters in Texas, the United States, and South Dakota. These papers are the first of a planned series on saline water resources.

For comparative costs of demineralization by various processes of brackish and sea water 1952, 1957, and anticipated 1960-70, see:

U. S. Congress, Senate. Saline Water Conversion. Hearings before the Subcommittee on Irrigation and Reclamation, March 20 and 21, 1958. 85th Congress, 2d sess., p. 116. Washington, D. C., U. S. Govt. Print. Off. 1958.

Although it does not contain quantitative projections, a comprehensive review of the potential and technical aspects of weather control is found in:

Advisory Committee on Weather Control. Final Report of the Advisory Committee on Weather Control. Vol. 1, Conclusions and Recommendations; Vol. II, Detailed Technical Reports. Washington, D. C., U. S. Govt. Print. Off. 1958.

An analytical appraisal of water projections is found in:

Ciriacy-Wantrup, S. V. Conceptual Problems in Projecting the Demand for Land and Water. Calif. Agr. Expt. Sta., Giannini Foundation Paper 176. Berkeley, Calif. May 1959.

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Picton, W. L. Water Use in the United States, 1900-1980. U. S. Business and Defense Admin., Water and Sewerage Industry and Utilities Div., 6 pp., illus., Washington, D. C., U. S. Govt. Print. Off. 1960.

Type of data

Projections of withdrawals from ground and total, fresh water intake and consumption for irrigation, public use, self-supplied industrial and miscellaneous, steam electric utilities.

Period for which projections are available

1900 to 1940 by decades, from 1940 to 1980 by 5-year intervals. Projections are periodically revised and republished.

Geographic breakdown

Nationwide totals only.

Completeness of coverage

Based on national projections of population and per capita withdrawals from public supplies, estimates of total irrigated acreage and per acre withdrawals, relationship of industrial water use to Index of Manufactures, power requirements and withdrawals per kilowatt-hour.

Additional information available

One of the earlier projections of national water use, now obsolete, may be found in:

President's Materials Policy Commission. Resources for Freedom. Vol. 5, p. 94. 82d Cong. 2d sess., H. Doc. 527. Washington, D. C., U. S. Govt. Print. Off. 1952.

Present and future investments in water resources are estimated in:

Picton, W. L. Water Resources Development, Capital Investment Values, 1900-1975. U. S. Business and Defense Serv. Admin., Water and Sewerage Industry and Utilities Div. 11 pp., illus. Washington, D. C., U. S. Govt. Print. Off. 1959.

Woodward, D. B. Availability of Water in the United States With Special Reference to Industrial Needs by 1980. Thesis 143, M57-76, 1956-1957. (Copy on file at the Industrial College of the Armed Forces, Washington, D. C.)

Type of projections

Withdrawals for domestic, industrial (including thermal, electric) and agricultural uses, total consumptive use and gross and dependable supply of water.

Period for which projections are available

1980 compared with 1955.

Geographic breakdown

Seventeen major drainage regions.

Completeness of coverage

Projections based on appraisal of magnitude and regional distribution of trends. Discussion of principles and brief summary of water supply situation and problems for each region.

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U. S. Congress. Senate. Select Committee on National Water Resources. Water Resource Activities in the United States. Reports published as Committee Prints 1 to 32, 86th Cong., 1st and 2d sess. Washington, D. C. U. S. Govt. Print. Off. 1959 and 1960. (Prints are summarized with recommendations in: Report of the Select Committee on National Water Resources. 87th Cong. 1st sess., S.R. 29, 1961).

Type of data

Projections of water use and supply

Water use in irrigation, land treatment and structures in agriculture, municipal use, major manufacturing and mining industries, waste dilution, navigation, power, fish and wildlife, and flood control. Storage required to attain various levels of dependable flow. Comparison of total requirements and supply. Potential increases in supply through evaporation, vegetative and seepage control, weather modification, saline conversion in selected areas.

Other projections

Population, municipal sewage loads. Costs of municipal water supply and waste treatment, power, and western reclamation.

Other contents

Discussion of various aspects of water supply, use and conservation, and flood control, related factual data. Review of technology, public activities, needed research, action and policy recommendations.

For additional detail, see list of committee prints and summary table of type of projections in each print (pp. 47-51.)

Period for which data are available

Generally 1980, 2000, and 1954 or other recent year.

Geographic breakdown

Twenty-two water-resource regions with boundaries along county lines, some projections by States and selected standard metropolitan areas. Separate reports for Alaska and Hawaii.

Completeness of coverage

Projections of future water use are found primarily in Committee Prints 7 to 14, 18, 29, and 32.

Other projections of water use and population are also found in Committee Prints 3, 5, 6, 17, 19, and 27. Projections of increased supply through technology are found in Committee Prints 21, 23, and 31.

Most projections were based on one or more of the three alternative estimates of future population prepared by Resources for the Future. In some, alternative projections were prepared for all three future population levels (Committee Print 12) others employed only the median level, (Prints 8, 13, 18, 29, 32) or the median and high level (Prints 7 and 9.) Other projections were based on census population projections to 1980 combined with independent estimates for 2000 (Print 10) or on existing water-resource programs (Prints 11, 14, and 15.) Regional population estimates were generally prepared independently.

Projections were generally made on the basis of national requirements and estimates of future population, gross national product, employment, and related data. Projections were made independently by Federal agencies within a limited time and with varying consideration of costs and available water supply. In some instances, projections by different agencies vary for similar items. In the case of agriculture, rough checks were made of how much water might be available for irrigation considering future development and striking increases in the efficiency of water use were estimated. In the case of most other withdrawal uses, only the most obvious limitations of water supply were recognized and only limited assumptions of future increases in efficiency in water use were made. Waste dilution requirements were geared to maintaining four milligrams per liter of dissolved oxygen in streams. For wildlife habitat, projected water requirements were based on expected increases in hunting with no consideration of water supplies.

Additional information available

For alternative approach and results regarding projections of irrigated land, see:

Ruttan, V. W. Projections of Irrigated Acreage and Water Requirements for Western Water Resources Regions. Western Resources Conference 1960. Univ. of Colorado Press. Boulder, 1961.

Publications of the Senate Select Committee on National Water Resources

Report of the Select Committee on National Water Resources, pursuant to Senate Resolution 48, 86th Congress, together with Supplemental and Individual Views. S.R. 29, 87th Cong. 1st sess., Washington, D. C., U. S. Govt. Print. Off. 1961.

Report 29 contains a detailed discussion of present and anticipated future water problems of the United States with data, conclusions and Recommendations. The history of the Senate Select Committee on Water Resources and the findings of the 32 Committee Prints are summarized in Report 29.

List of committee prints

Issued by the Select Committee on National Water Resources 1959-60 under the title: Water Resource Activities in the United States. The prints, subject matter, localities, and contributors are indexed in: Water Resource Activities in the United States. Index for Committee Prints 1 to 32.

Background

Print number	
1	Water Facts and Problems. U. S. Geological Survey. (Pictorial charts).
2	Reviews of National Water Resources During the Past Fifty Years. Legislative Reference Service, Library of Congress.
3	National Water Resources and Problems. U. S. Geological Survey.
4	Surface Water Resources of the United States. U. S. Geological Survey. (Maps and tabulations).
5	Population Projections and Economic Assumptions. Census Bureau, Senate Select Committee, and Resources for the Future.
6	Views and-comments of the States. Report by States on their water resources and problems.

Projections of future needs

7	Future Water Requirements for Municipal Use. U. S. Public Health Service.
8	Future Water Requirements of Principal Water-Using Industries. Business and Defense Services Administration, U. S. Department of Commerce, and Bureau of Mines, U. S. Department of the Interior.
9	Pollution Abatement. U. S. Public Health Service.
10	Electric Power in Relation to the Nation's Water Resources. Federal Power Commission, Rural Electrification Administration, Edison Electric Institute, American Public Power Association, and Resources for the Future.
11	Future Needs for Navigation. U. S. Department of the Army, Corps of Engineers.
12	Land and Water Potentials and Future Requirements for Water. U. S. Department of Agriculture.
13	Estimated Water Requirements for Agricultural Purposes and Their Effects on Water Supplies. U. S. Department of Agriculture.
14	Future Needs for Reclamation in the Western States. U. S. Bureau of Reclamation.
15	Floods and Flood Control. U. S. Department of the Army, Corps of Engineers.
16	Flood Problems and Management in the Tennessee River Basin. Tennessee Valley Authority.
17	Water Recreation Needs in the United States. U. S. National Park Service.
18	Fish and Wildlife and Water Resources. U. S. Fish and Wildlife Service.
19	Water Resources of Alaska. U. S. Department of the Interior.
20	Water Resources of Hawaii. U. S. Department of the Interior.

Techniques for meeting needs

21	Evapo-Transpiration Reduction. U. S. Departments of the Interior

Print number

and Agriculture.

22 Weather Modification. U. S. Weather Bureau and Dean A. M. Eberle, South Dakota State College.

23 Evaporation Reduction and Seepage Control. U. S. Bureau of Reclamation.

24 Water Quality Management. U. S. Public Health Service.

25 River Forecasting and Hydrometeorological Analysis. U. S. Weather Bureau.

26 Saline Water Conversion. U. S. Department of the Interior, Office of Saline Water.

27 Application and Effects of Nuclear Energy. U. S. Atomic Energy Commission.

28 Water Resources Research Needs. U. S. Department of Agriculture.

29 Water Requirements for Pollution Abatement. Prof. George Reid, University of Oklahoma.

30 Present and Prospective Means for Improved Reuse of Water. Abel Wolman Associates.

31 The Impact of New Techniques on Integrated Multiple-Purpose Water Development. E. A. Ackerman & Associates.

32 The Supply of and Demand for Water in the United States. Resources for the Future.

TYPE OF PROJECTIONS IN WATER RESOURCES ACTIVITIES
IN THE UNITED STATES
(Senate Select Committee on National Water Resources)

Print number	Water use								Costs	Water supply	Other	Remarks
	Municipal	Agriculture	Industry	Power	Recreation	Navigation	Commercial fisheries					
1												Water use 1950-1980 illustrated graphically
3			X						X	X		Storage needed for selected dependable flows, storage of water containing radio-active waste
5											Population, G.N.P. industrial production	
6												State reports, some projections of water use, primarily municipal and population
7	X								X			
8			X								Employment in water-using industries, population, G.N.P. industrial production	
9									X		Municipal sewage loads B.O.D. stream loading	
10				X					X		Power generation, installed capacity	
11						X			X			
12		X									Land use, yields, production	

-Continued

TYPE OF PROJECTIONS IN WATER RESOURCES ACTIVITIES
IN THE UNITED STATES -Continued
(Senate Select Committee on National Water Resources)

Print number	Water use								Costs	Water supply	Other	Remarks
	Municipal	Agriculture	Industry	Power	Recreation	Navigation	Commercial fisheries					
13		X									Land treatment, storage structures. Reduction in sedimentation	Water required on-site and downstream
14		X							X		Acres irrigated, crops produced, storage, power	Bureau of Reclamation projects
15											Flood damages, flood control programs, physical works, cost	Corps of Engineers projects
17					X						Visits to recreational sites	
18					X		X				Number, man-days, and expenditures for outdoor recreation, commercial, fresh water dependent fish catch	
19	X		X	X					X		Potential hydropower, acres irrigated	Alaska only
21										X		Evapotranspiration reduction by vegetative management
23										X		Reduction of evaporation, seepage, loss from non-beneficial plants
26									X			Cost of demineralizing saline water

-Continued

TYPE OF PROJECTIONS IN WATER RESOURCES ACTIVITIES
IN THE UNITED STATES -Continued
(Senate Select Committee on National Water Resources)

Print number	Water use								Costs	Water supply	Other	Remarks
	Municipal	Agriculture	Industry	Power	Recreation	Navigation	Commercial fisheries					
27			X	X					X		Nuclear generating capacity	Water for nuclear power and industry. Costs for conversion of saline water with nuclear power
29	X		X						X			Requirements for waste dilution at alternate levels and costs of waste treatment
30												Cost estimates of reused water compared to water of other sources
31										X		Supply from weather control and demineralization, selected areas
32	X	X	X	X	X	X	X		X	X	Population, output of major water using industries, water for waste dilution	Synthesis of other prints

APPENDIX A. INDEX OF DEFINITIONS

APPENDIX B. LIST OF SOURCES DISCUSSED IN DETAIL IN PREVIOUS SECTIONS

Section II. Nationwide Data on Water Use

Major withdrawal uses

MacKichan, K. A. Estimated Use of Water in the United States, 1955. U. S. Geol. Survey Cir. 398, 18 pp., illus. 1957.

Public supplies

U. S. Public Health Service. Municipal Water Facilities, Communities of 25,000 and over, continental United States and Territorial Possessions, as of January 1, 1960. U. S. Pub. Health Serv. Pub. 661, 91 pp. 1960.

U. S. Public Health Service. Municipal Water Facilities Inventory as of January 1, 1958, U. S. Pub. Health Serv. Pub. 775, 9 vols. 1960.

American Water Works Association. Staff Report. A Survey of Operating Data for Water Works in 1955. Jour. Amer. Water Works Assoc. 49(5): 553-696. May 1957.

Industrial water use

U. S. Census of Manufactures: 1954. Industrial Water Use. U. S. Bureau of Census Bul. MC-209, 52 pp. illus. 1957.

U. S. Census of Manufactures: 1954. Industrial Water Use Supplement. U. S. Bureau of Census Bul. MC-209 Sup., 51 pp. 1960.

U. S. Census of Mineral Industries: 1954. Energy, Water and Selected Supplies. U. S. Bureau Census Bul. MIF. 19 pp. illus. 1957.

Irrigation

U. S. Census of Agriculture: 1950. Vol. III, Irrigation of Agricultural Lands. Washington, D. C., U. S. Govt. Print. Off. 1952.

U. S. Census of Agriculture: 1954. Vol. III, Special Reports, Part 6, Irrigation of Humid Areas. Washington, D. C., U. S. Govt. Print. Off. 1956.

Electric power generation

Federal Power Commission. Water Requirements of Utility Electric Steam Generating Plants - 1954. U. S. Federal Power Comm. DC-57, 3 pp., 1957.

Federal Power Commission. Hydroelectric Power Resources of the United States, Developed and Undeveloped, 1957. U. S. Federal Power Comm. F.P.C. P-32. 196 pp. n. d.

Military

Office of the Assistant Secretary of Defense. Water Supply Data of the Military Installations Located in the United States and Territories for the Fiscal Year 1960. Off. of Asst. Sec. Defense Properties and Installations. 1961. Issued for official Government Agency use only.

Waste carrying

U. S. Public Health Service. National Water Quality Network. Annual Compilation of

Data, October 1, 1958 - September 30, 1959. U. S. Pub. Health Serv. Pub. 663, 323 pp. 1954.

U. S. Public Health Service. 1957 Inventory. Municipal and Industrial Waste Facilities. U. S. Pub. Health Serv. Pub. 622. 9 vols. 1958.

Navigation

U. S. Department of the Army, Corps of Engineers, Waterborne Commerce of the United States. Annual. Parts 1-4, U. S. Army Engineer Division Offices, Part 5, Board of Engineers for Rivers and Harbors, Washington, D. C., U. S. Department of the Army, Corps of Engineers.

Section III. Nationwide Data on Water Supplies

Streamflow

U. S. Geological Survey. Surface Water Supplies of the United States. Annual. U. S. Geol. Survey Water-Supply Papers.

Surface water quality

U. S. Geological Survey Annual. Quality of Surface Waters in the United States. Annual. U. S. Geol. Survey Water-Supply Papers.

Ground water supplies

U. S. Geological Survey. Water Levels and Artesian Pressures in Wells in the U. S. Annual U. S. Geol. Survey Water-Supply Papers.

Section IV. Projections of Future Water Uses and Supplies

Picton, W. L. Water Use in the United States 1900-1980, U. S. Business and Defense Serv. Admin. Water and Sewerage Industry and Utilities Division. 6 pp. illus., Washington, D. C., U. S. Govt. Print. Off. 1960.

Woodward, D. B. Availability of Water in the United States With Special Reference to Industrial Needs by 1980. Thesis 143, M 57-76. 1956-1957. (Copy on file at the Industrial College of the Armed Forces. Washington, D. C.)

U. S. Congress, Senate. Select Committee on National Water Resources. Water Resource Activities in the United States. Reports published as Committee Prints 1 to 32, 86th Cong., 1st and 2d sess., Washington, D. C., U. S. Govt. Print. Off. 1959 and 1960.

APPENDIX C. CONVERSION FACTORS

Adapted primarily from: Departments of the Army and the Air Force. Military Water Supply. Army Technical Manual No. 5-295, Air Force Technical Order No. 00-105 C-4. Washington, D. C., August 6, 1956. Tables XVII and XVIII.

Volumes and weights of water

1 acre-foot equals	325,851	gallons
	43,560	cubic feet
	1,233,456	liters

1 U. S. gallon equals	0.133681	cubic foot
	3.78533	liters
	8.3	pounds
1 cubic foot equals	7.48052	U. S. gallons
	28.3163	liters
	62.4	pounds
1 liter equals	0.264177	U. S. gallon
	0.035315	cubic foot
	2.2	pounds
1 pound 50° F equals	0.11986	U. S. gallon
	0.016023	cubic foot
	0.45372	liter
1 cubic mile equals	3,379,200	acre feet

Rates of flow and use

1 cubic foot per second equals	448.831	gallons per minute
	1.98347	acre feet per 24 hours
	0.646317	million U. S. gallon per day
1,000 U. S. gallons per minute equals	2.2280	cubic feet per second
	4.4192	acre feet per 24 hours
	1.440	millions U. S. gallons per day
1 acre-foot per 24 hours equals	0.50417	cubic foot per second
	226.286	gallons per minute
1,000 acre feet per 365 days equals	1.3813	cubic feet per second
	619.96	gallons per minute
	0.8927	million U. S. gallon per day
1 million U. S. gallons per day equals	1.5472	cubic feet per second
	694.444	gallons per minute
	3.0689	acre feet per 24 hours
	1.1201	thousands of acre feet per 365 days
1 inch runoff per 365 days equals	0.0737	cubic foot per second per square mile
	47613	gallons per day per square mile