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WATER QUALITY - A FACTOR IN ARKANSAS RIVER DEVELOPMENT a/

by

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Presented before the Tulsa Chamber of Commerce
July 22, 1957

One of the first requisites for intelligent planning of the utilization and control of water and for the administration of laws relating to its use, is data on the quantity, quality, and mode of occurrence of water supplies. The collection, evaluation, interpretation, and publication of such data constitute the primary function of the Water Resources Division of the United States Geological Survey. Since 1895 the Congress has made appropriations to this agency for investigations of the water resources of the Nation. In 1929 the Congress adopted the policy of dollar-for-dollar cooperation with State and local governmental agencies for water-resources investigations. The Geological Survey's Federal-State cooperative program of quality-of-water investigations in Oklahoma was started in 1944 in cooperation with the Oklahoma Planning and Resources Board. Since July of this year the program has been carried on cooperatively with the newly created Oklahoma Water Resources Board.

The chemical quality of surface waters in Oklahoma fluctuates widely due to the continuing alteration of mineral concentrations as water progresses through the hydrologic cycle. The hydrologic cycle, shown in figure 1, illustrates the many natural factors such as climatic conditions, solubility of rock materials on and beneath land surface, evaporation from open water surfaces, and transpiration by plants that

a/ Approved for presentation and duplication by Director, U. S. Geological Survey.

greatly influence the degree of mineralization and ultimately the utility of the water. Other factors of no less importance are those caused by activities of man, such as return flow from irrigation water, mine drainage, oil-field wastes, municipal sewage, and industrial-process wastes. The combined effects of all these factors determine the suitability of water for its three main consumptive uses: municipal, industrial and agricultural.

In 1952 the Oklahoma Society of Professional Engineers issued a report on "The Problem of Municipal and Industrial Water Supplies for Oklahoma", in which it was stated that an average of about 37 million acre-feet of water leaves the State annually, or enough water to irrigate about 37 million acres of land with 12 inches of water. Many readers of the report have overlooked the word "average" in this statement, and the figure has been rather widely quoted and accepted as a fact that Oklahoma is losing 37 million acre-feet of good water each year. However this figure is the total of the average annual flow of the Arkansas and Red River systems at the eastern edge of the State. During the water year 1945 (October 1944 to September 1945), for instance, this flow was about 74 million acre-feet, and in 1940 it was only 11.9 million acre-feet; or about 200 percent and 32 percent, respectively, of the long-term average. In addition to this wide variability in the amount of water leaving the State, the chemical quality also fluctuates widely and at times the water is unsuitable for irrigation or any other consumptive use because of high concentrations of dissolved minerals.

Each of three main consumptive uses of water require rather exacting chemical quality standards in determining the suitability of a potential supply. The U. S. Public Health Service defines an acceptable potable water supply as one which is clear, colorless, odorless, pleasant to the taste, and free from toxic salts. It should not contain an excessive amount of soluble minerals and substances or any chemical employed in treatment. The chemical substances which may be present in natural or treated waters preferably should not occur in excess of the following concentrations:

Table 1

Constituents	Should not exceed (parts per million)
Iron (Fe) and Manganese (Mn) together	0.3
Fluoride (F)	1.5
Magnesium (Mg)	125
Chloride (Cl)	250
Sulfate (SO_4)	250
Dissolved solids	500 (1,000 permitted)
1/ Nitrate (NO_3)	44

1/ Standard recommended by Oklahoma State Department of Health

One part per million represents a unit weight of a substance in a million unit weights of water, such as one pound per million pounds of water, etc. A part per million is 0.0001 percent by weight. The Geological Survey made a study of the municipal water supplies of Oklahoma during 1951-52. 1/ Of the 368 communities served by public water-supply systems, 277 met all chemical-quality standards shown in table 1, and 91 were deficient by at least one of the standards. Tulsa is included in

1/ Dover, T. B., Chemical Character of Public Water Supplies of Oklahoma, Oklahoma Planning and Resources Bulletin No. 8, 1953.

the 277 communities meeting all the standards.

Some of the standards shown in table 1 are recommended merely on the basis of taste, and for use in interstate carriers subject to Federal Quarantine regulations. Other standards are mandatory upper limits that can be tolerated for human consumption. Concentrations of iron and manganese exceeding about 0.3 ppm cause stains and discolorations on fabrics and porcelain fixtures. However these constituents are relatively easy to remove at the water treatment plant, and in the selection of potential surface water supplies, information as to occurrence is important primarily for proper design of treatment facilities.

Fluoride is being recognized more and more as an important feature of drinking water. Fluoride concentrations in drinking water up to about 1.5 ppm help to prevent dental cavities in children. However Dean (1936) and others have shown that as the concentrations progressively increase above 1.5 ppm it will cause dental fluorosis of the teeth in their formative stages of growth, and they become mottled, stained, and disfigured. Very few surface waters in Oklahoma contain appreciable quantities of fluoride, and there are no present or potential surface-water supplies that exceed the 1.5 ppm mandatory upper limit recommended by the U. S. Public Health Service. There are a number of ground-water sources in the State that exceed this limit, and at the time of 1951-52 municipal water-supply study, 12 of the 368 supplies were using water in which fluoride exceeded 1.5 ppm. All of these 12 supplies were from ground-water sources. Treatment facilities are readily available for the addition of controlled amounts of fluoride to water supplies, but there is no economical way to remove excessive amounts.

Nitrates in water are considered to be the final oxidation product of nitrogenous material. The quantities usually present have no effect on the value of water for ordinary uses. However when the nitrate concentration is excessive it is not advisable to use such water as a source of drinking water for small children. It is sometimes the cause of a condition commonly referred to as "blue babies",and can be fatal unless water of low nitrate content is substituted. Very few surface waters in the State contain appreciable quantities of nitrate, and there are no present or potential surface-water supplies that exceed the 44 ppm upper limit recommended by the Oklahoma State Department of Health. A few streams contain rather high momentary nitrate concentrations in the immediate vicinity of sewage outflow from cities using complete sewage treatment where high nitrate concentrations are produced as the final oxidation product of nitrogenous material. Examples are the Verdigris River below the inflow of Tulsa sewage and the Deep Fork and North Canadian Rivers below the inflow of Oklahoma City sewage where nitrate concentrations up to about 100 ppm are observed. However these rivers recover rather rapidly as the sewage inflow is mixed and diluted by normal river flow. There are some ground-water sources in the State that exceed 44 ppm and at the time of the 1951-52 municipal water-supply study, 39 of the 368 supplies were using water with nitrate concentrations exceeding 44 ppm. All 39 supplies were from ground-water sources. There is no economical way to remove excessive amounts of nitrate from water.

The limits shown in table 1 for magnesium, sulfate, chloride, and dissolved solids are based mainly on the taste of water. Mineral constituents in water, within reasonable limits, add to its potability because they are responsible for its pleasant taste. If there were no chemicals dissolved in water, it would have the flat taste of rain water. However chloride concentrations exceeding about 250 ppm imparts a salty taste to the water; increasing amounts of calcium and magnesium imparts a bitter taste to the water; excessive amounts of magnesium sulfate (epsom salts) will cause temporary, minor stomach disturbances; and water with a mineral content exceeding 500 ppm is unpleasant to the taste of an Easterner who is accustomed to water of less than 50 ppm dissolved solids.

To the average individual user of water, one of the important factors in regard to chemical content pertains to its hardness. Hardness of water is caused mainly by the dissolved minerals of calcium and magnesium, usually in the form of bicarbonates or sulfates. The household user of water notices this hardness by the unpleasant taste, by the increased amount of soap required to produce a lather, and by the encrustation in hot-water tanks and water lines. Compounds of aluminum, iron, manganese, and free acid also may cause hardness, but these constituents usually are not found in appreciable quantities in either surface or ground waters of Oklahoma.

On a general nationwide comparative basis, water that has a total hardness of less than 50 ppm is usually rated as soft, and its treatment for removal of hardness is seldom justified for ordinary purposes.

Hardness between 50 and 150 ppm does not seriously interfere with the use of water for most household purposes, but its removal by softening processes may be profitable for laundries and other industries. When the hardness exceeds 150 ppm, treatment for its removal is usually desirable for most uses. The municipal water-supply study in 1951-52 showed that the hardness of 368 supplies ranged from 2 ppm for the City of Norman to 2,610 ppm for the City of Gotebo, and the hardness of 239 supplies exceeded 150 ppm. These figures emphasize that limits of hardness for water-supplies in Oklahoma and the Southwest are based more upon what the public is willing to accept rather than any generalized standards. For example the raw-water supply for Oklahoma City has a hardness of about 180 ppm, which through treatment processes is reduced to about 90 ppm before distribution; whereas the raw-water supply for Altus in southwestern Oklahoma has a hardness of about 600 ppm, none of which is removed by treatment before distribution. The use of detergents in recent years for dishwashers, home laundries, and even detergent soaps for bathroom use, has greatly minimized the importance of hardness as a major factor in determining suitability of waters for household purposes. Hardness of the Tulsa raw-water supply is about 90 ppm, which is sufficiently low to require no softening for most uses.

There are other minerals which affect the individual user of water by their presence or absence. The amount of sodium present in water used for drinking purposes by people with heart disorders is very important because such people usually are placed on a diet containing little or no sodium salts. For example the sodium concentration of the Norman water-supply is 207 ppm. A patient on a mild salt-free diet, not to exceed 200 milligrams of sodium per day, would consume that amount by drinking one quart of this water.

Other U. S. Public Health Service mandatory upper limits of chemical allowed in drining water include 0.1 ppm lead, 0.05 ppm arsenic, 0.05 ppm selenium, o.05 ppm hexavalent chromium, and 0.0001 ppm phenolic compounds in terms of phenol. Other recommended upper limits include 3.0 ppm copper and 15 ppm zinc. None of these consitute problems for most sources of surface and ground water-supplies in Oklahoma.

Quality standards for industrial use of water differ considerably, and it is not possible to specify average requirements. Much of the water used by industries is for cooling purposes, which has no particular tolerance specifications as far as chemical quality is concerned, so long as the water is not corrosive. At the other extreme, chemical-quality requirements for many plant processes are so exacting as to require preliminary treatment of any water used.

The use of water for irrigation has become an important factor to the agricultural economy of Oklahoma. The total amount of dissolved minerals that can be tolerated in an irrigation water varies considerably with the type of soil being irrigated, the crops grown, the drainage of the land, and the amount of rainfall. As the mineral content of an irrigation water increases, there is a greater tendency for the minerals to accumulate in the soil, making it necessary to increase the amount of water used because it has to serve the double purpose of supporting the crop and of leaching the accumulated salts from the soil. Of the various minerals usually present in natural waters, the concentration of sodium and its relative ratio to calcium and magnesium, commonly referred to as "sodium adsorption ratio", is the most critical because of the tendency of sodium to impair the soil's permeability to water.

Figure 2 indicates a division of ten sub-basins for the Arkansas and Red River surface-water systems of Oklahoma. The black dots indicate locations at which daily samples for chemical analyses have been collected on a continuous basis for at least one year since 1946. Miscellaneous samples of surface waters for chemical analyses have been collected at numerous other locations over the State. These points are shown on Figure 3, along with the daily sampling stations to indicate areas of available chemical-quality data on surface-waters of Oklahoma.

The first sub-basin shown in figure 2, the Neosho (Grand) River basin probably is the best present and potential source of surface-water supply in the State. Every major stream, lake impoundment, and tributary stream with the exception of one small reach of Pryor Creek, is of sufficiently good quality for municipal, irrigation, and many industrial uses. There are some streams and lakes of equal or even better quality in other sub-basins of the State, but none have the consistent, overall good quality of the Neosho River system. The availability of good quality water in the Neosho River basin, along with related factors is the primary reason for the rapidly expanding industrial growth of such cities as Pryor, Muskogee, and even Tulsa, whose Lake Spavinaw supply lies within this basin. There have been some minor pollution problems in this basin recently as a result of industrial waste disposal, but through the cooperative efforts of industry and State pollution control agencies, these problems are being minimized, and there is no reason why this basin should not continue to be one of the best sources of good quality water in the State.

The second sub-basin shown in figure 2, the Verdigris River basin, contains water of rather wide variation in chemical quality. In general, waters of sufficiently good quality for municipal, agricultural, and many industrial uses can be found in the upper Caney River and Hulah Reservoir, upper Bird Creek, the upper two-thirds of the main stem Verdigris, and some of the smaller tributary streams such as Dog Creek, Candy Creek, Sand Creek, Pond Creek, and Buck Creek. The waters of Hominy Creek, lower Caney River, lower Bird Creek, lower Verdigris River and some of the smaller tributary streams such as Delaware Creek, Coon Creek, Possum Creek, Lightning Creek, and California Creek are too highly mineralized, mostly as a result of pollution from oil-field activities, to be suitable for consumptive uses. Water to be impounded in Oolagah Reservoir on the upper Verdigris River should meet all chemical quality standards for municipal, agricultural, and many industrial uses. Water samples for chemical analyses have been collected daily from the Verdigris River near Lenapah during the period October 1951 to the present. Based on weighted average mineral concentrations of the river at this location, the chemical content of water to be impounded in Oolagah should be about 300 ppm dissolved solids, 170 ppm hardness, 3 ppm nitrate, 40 ppm sulfate, and 60 ppm chloride. Corresponding figures for the Neosho (Grand) River water impounded in Lake Fort Gibson are 200 ppm dissolved solids, 150 ppm hardness, 2 ppm nitrate, 47 ppm sulfate, and 18 ppm chloride. In connection with use of Verdigris

River water for drinking purposes, there are taste and odor problems as a result of the presence of phenolic compounds from upstream pollution. If present upstream pollution control plans are successful, this problem will be eliminated.

The Upper Arkansas River basin, the third basin shown in figure 3, includes the main stem Arkansas River and tributaries from the Oklahoma-Kansas State Line to its junction with the Cimarron River above Tulsa. Very few surface waters in this area are of suitable quality for consumptive uses. The Arkansas River is rather poor in quality when it enters the State, and its principal tributary in this basin, the Salt Fork Arkansas River is extremely salty as a result of flowing through natural salt beds a few miles east of Alva. Thre has been some local development on tributary streams, but as a whole this basin shows little promise for any wide scale use of surface water for consumptive purposes.

The poor uality of water in the Arkansas River deteriorates further at Tulsa as the result of inflow from the Cimarron River, shown as sub-basin No. 5 in figure 2. In the extreme western part of the State, water from the Cimarron River is of sufficiently good quality to be used for irrigation. However there is a gradual downstream increase in salt concentration, and a very sharp increase as the river flows through natural salt deposits in the vicinity of Waynoka, where the water becomes about 200 times more salty than that in the extreme western part of the panhandle. As a result of inflow from the highly mineralized Cimarron River, water impounded in the Keystone Reservoir will not be suitable for any consumptive uses. The Cimarron River alone is not responsible for the poor quality of water in the Arkansas River at Tulsa, but it does contribute more than its share on the basis of volume of flows. During water year 1950, for example, the Cimarron River contributed 22 percent of the recorded streamflow at Tulsa, and during this same period it contributed 52 percent of the chloride load.

Even though water from Keystone will not be suitable for consumptive uses, storage alone will greatly improve the Arkansas River quality downstream, with its tendency to decrease the large variations in daily mineral concentrations. Maximum chloride concentrations exceeding 5,000 ppm have been observed for the Arkansas River at Tulsa, during the period of chemical quality studies from October 1946 to the present. However these excessively high concentrations normally occurred on days of relatively low streamflow, and they would have had a comparatively small effect on the concentration of water stored in the proposed reservoir. The maximum concentrations and fluctuations in concentration of the Keystone water will depend to a great extent on the amount of stored water, reservoir operation, evaporation, and physical features of the reservoir, but based on previous studies the chloride concentrations of the stored water probably will not be much higher or lower than 600 ppm.

Downstream improvement of stored water in Keystone Reservoir would result from inflow of both the Verdigris and Neosho Rivers, and in addition, every tributary stream in the lower Arkansas River basin, shown as sub-basin No. 4 in figure 2, is of sufficiently good quality for all consumptive uses. For instance the mineral content of waters from Tenkiller Reservoir on the Illinois River and Wister Reservoir on the Poteau River is only about one-half of that for water from Fort Gibson Reservoir.

In the reach of the Arkansas River from Tulsa to the Arkansas State Line, the Canadian River is the only stream which does not have a dilution effect or cause an improvement in the quality of Arkansas River water. Water from the Canadian River, shown as sub-basin No. 7 on figure 2, is highly mineralized, due mostly to salt from oil-field operations. Under present conditions, water impounded in the Eufaula Reservoir will not be suitable for consumptive uses. Much of the Canadian River water flowing into Oklahoma from Texas is highly mineralized, and two of the principal tributaries in Oklahoma, Little River and North Canadian River, carry large amounts of oil-field brines.

The quality of water in the upper reaches of the Little River in the vicinity of Norman is suitable for municipal, irrigation and many industrial uses. However, oil-field brines discharged into the lower reaches of the river are such that water being discharged into the Canadian River is so concentrated at times as to exceed that of sea water. During water year 1956 the Little River drainage basin contributed only 5 percent of the streamflow for the Canadian River near Whitefield (near Eufaula Reservoir site), but it contributed 43 percent of the chloride load. For the same water year, and assuming the average chloride concentration of the polluting brine to be about 90,000 ppm, approximately 25.7 million barrels (42-gallon barrels) of brine were discharged into Little River between the two sampling sites of Norman and Sasakwa, a distance of 72 river miles. Using this same comparision, 9 percent of the flow of Little River near Sasakwa during water year 1956 was contributed by oil-field brines.

The North Canadian River, principal tributary stream to the Canadian River and shown as sub-basin No. 6 on figure 2, is of sufficiently good quality west of Oklahoma City for most consumptive uses. Water from this stream, impounded in two off-channel reservoirs is the principal source of water-supply for Oklahoma City; yet a few miles downstream from the intake of the Oklahoma City water-supply, the river has chloride concentrations exceeding 10,000 ppm. This combination of oil-field brine pollution in the North Canadian River and Little River tributaries, and the Canadian River itself in the Texas Panhandle eliminates any possibility of consumptive uses of Eufaula Reservoir water under present-day conditions.

Oklahoma City, Oklahoma
July 15, 1957

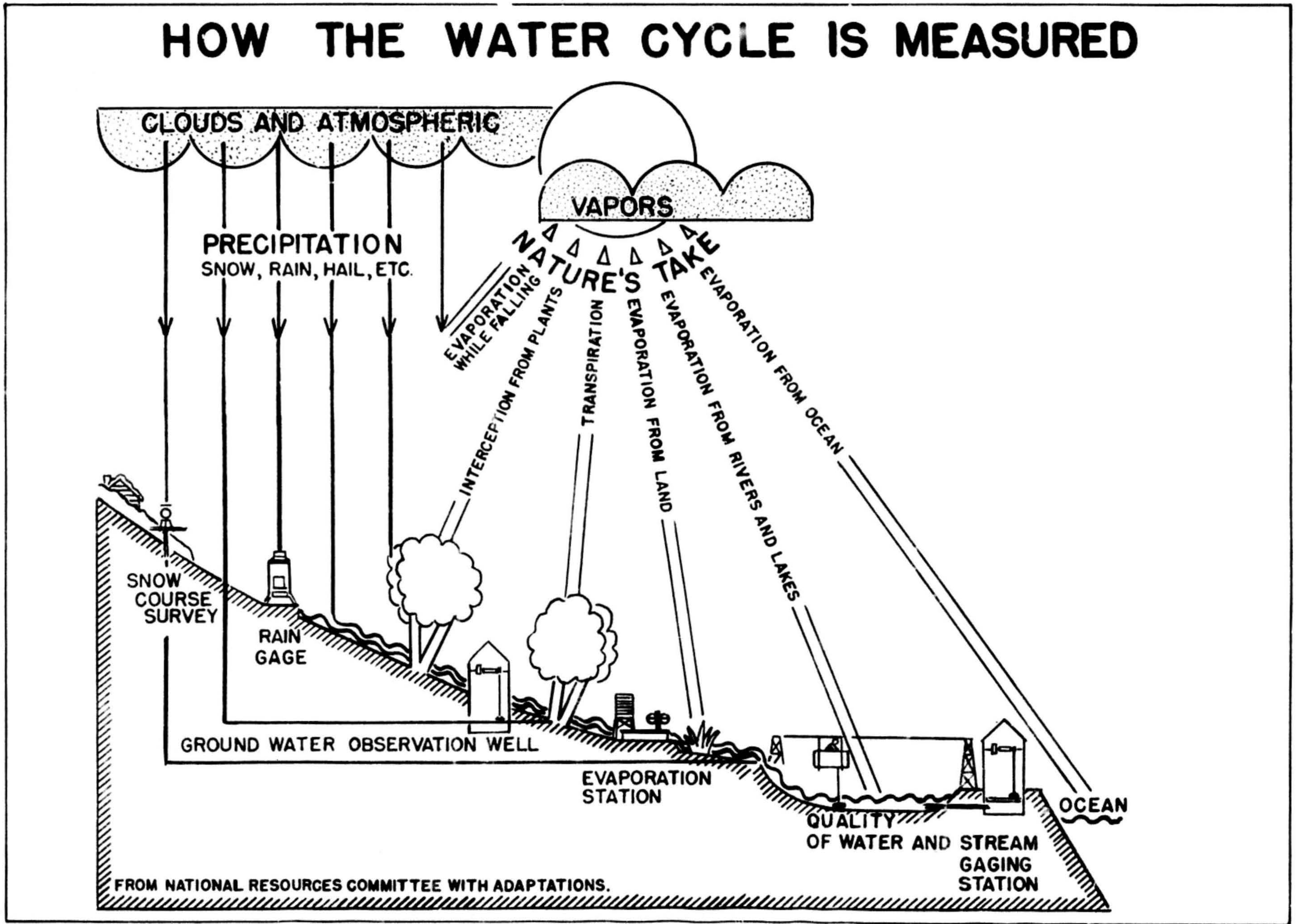

Figure 1- Graphic representation of the hydrologic cycle.

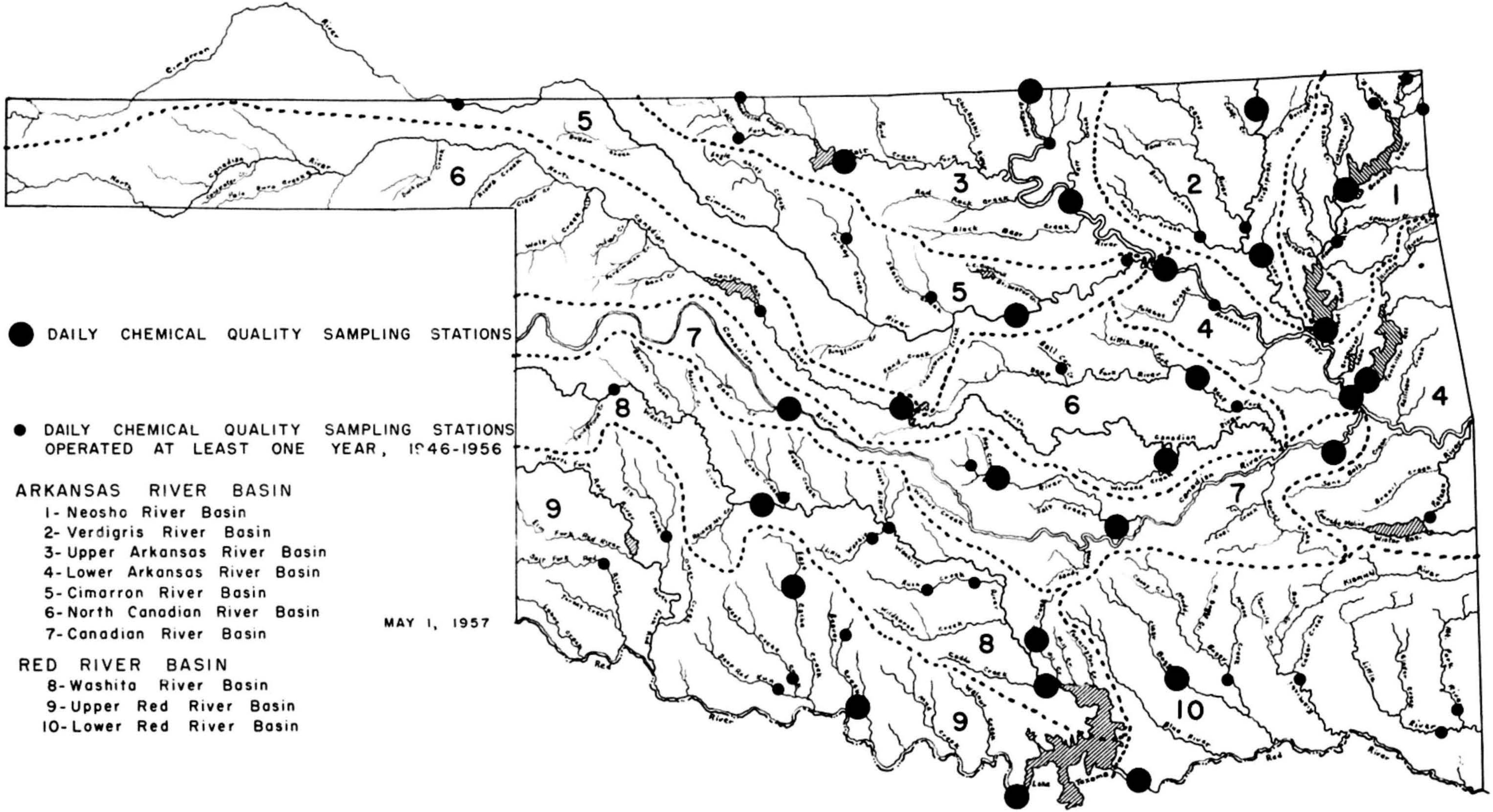

Figure 2 - Daily Chemical Quality Sampling Stations for Oklahoma Surface Waters

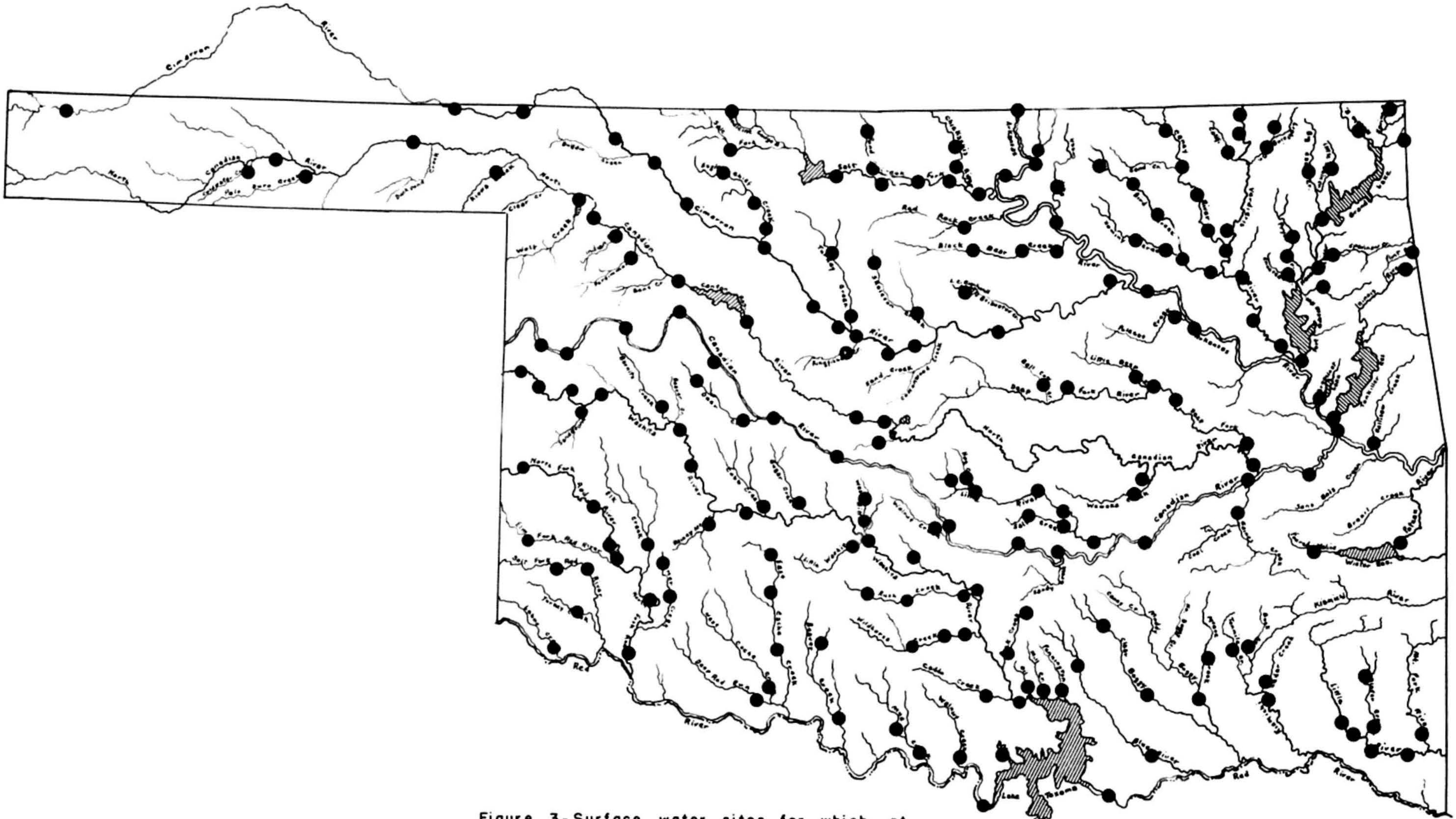

Figure 3 - Surface water sites for which at at least one chemical analysis is available.