Ground-water Levels in Indiana[1]

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Introduction

Water has always been recognized as one of the necessities of life, and water from underground sources obtained through wells and springs has played a major part in the development of our modern world. The existence of the early nomads mentioned in the Bible was controlled largely by the sources of water supply and by the locations of existing wells and springs. In our modern world, however, because of the seeming ease with which the average citizen is supplied with water, with little or no effort on his part, the difficulties in obtaining adequate water supplies are often overlooked.

In 1935 the Indiana Department of Conservation, realizing the importance of ground-water supplies in the agricultural and industrial development of the State, began an observation-well program in cooperation with the United States Geological Survey. A number of wells were selected for observation and measurements of water level in the wells were made at regular intervals. This program has continued to date. Also, a small-scale study was made of the ground-water conditions in the heavily pumped Indianapolis area (5). In 1943 the Indiana State Legislature appropriated funds for expanding the cooperative water-resources investigations of the Department of Conservation and the U. S. Geological Survey. The observation-well program was enlarged and now includes 170 wells throughout the State.

Importance of Water Levels

The rocks and other surficial materials of the earth's crust nearly everywhere contain openings of one sort or another, in which water is stored. The type and size of these openings vary within wide limits, and therefore the rocks containing them vary widely in their capacities to store and to yield ground water. The zone in the earth's crust in which the openings in the rocks are filled with water is called the *zone of saturation*. The top of this zone, except where the top is formed by an impermeable formation, is the water table and its position is shown in a general way by the water levels in wells. In formations where the top of the *zone of saturation* is formed by an impermeable cover, the water levels in wells generally will rise above the bottom of the impermeable cover and the water in the formation is said to be under

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artesian pressure. Under artesian conditions, the surface represented by the water levels in wells is the pressure-indicating or *piezometric* surface.

The rock formations of the earth's crust are large underground reservoirs which are replenished by water from precipitation and, where the water table is below the level of lakes and streams, by seepage from those bodies. Water is removed from the reservoir by natural drainage through springs and into streams, by evaporation and transpiration or plant use, and by withdrawal from pumped or flowing wells. The stage to which the reservoir is full, under water-table conditions, is indicated by the water levels in wells.

The ways in which rainfall is dissipated is shown by the hydrologic cycle or water cycle. Water falls on the earth as rain, snow, or hail. Part of it evaporates as it falls, part is intercepted by plants and trees before it reaches the earth, and the remainder reaches the land surface. In turn, part runs off as surface flow into streams and lakes, part is evaporated from the land surface, and another part seeps into the ground. Of the portion that seeps into the ground, part is used by plants and is returned to the atmosphere, and part eventually reaches the zone of saturation, from which it drains naturally into surface streams and lakes or is recovered by wells. It is estimated that, of the total precipitation in Indiana, an average of 65 to 72 percent is lost through evaporation and transpiration, 8 to 20 percent runs off directly as surface runoff, and 10 to 20 percent is recharged to the ground-water reservoir, from which it is later discharged naturally or through wells.

Observation-well Program

The observation-well program which was started in 1935 included 46 wells, mainly in the northern half of the State. These wells were measured by personnel of the Indiana Department of Conservation, the Civilian Conservation Corps, the Soil Conservation Service, and various municipalities. The program has been expanded to include 170 wells at present, the majority of which are measured at weekly intervals and 35 of which are equipped with automatic recorders that give a continuous record of water-level changes. The locations of these wells are shown in figure 1.

The wells selected for observation purposes are unused wells that have been abandoned for one reason or another. They include wells of all types. They have been selected mainly on the basis of geographic distribution, considering, however, local geologic and topographic conditions. The main purpose of the observation-well program has been to determine the seasonal variations and general long-time trends in ground-water levels and to study the relation between rainfall and ground-water levels in different parts of the State.

Water-level Fluctuations

The water level in a well is nearly always changing in response to the effects of natural and artificial influences. It is affected by rainfall,

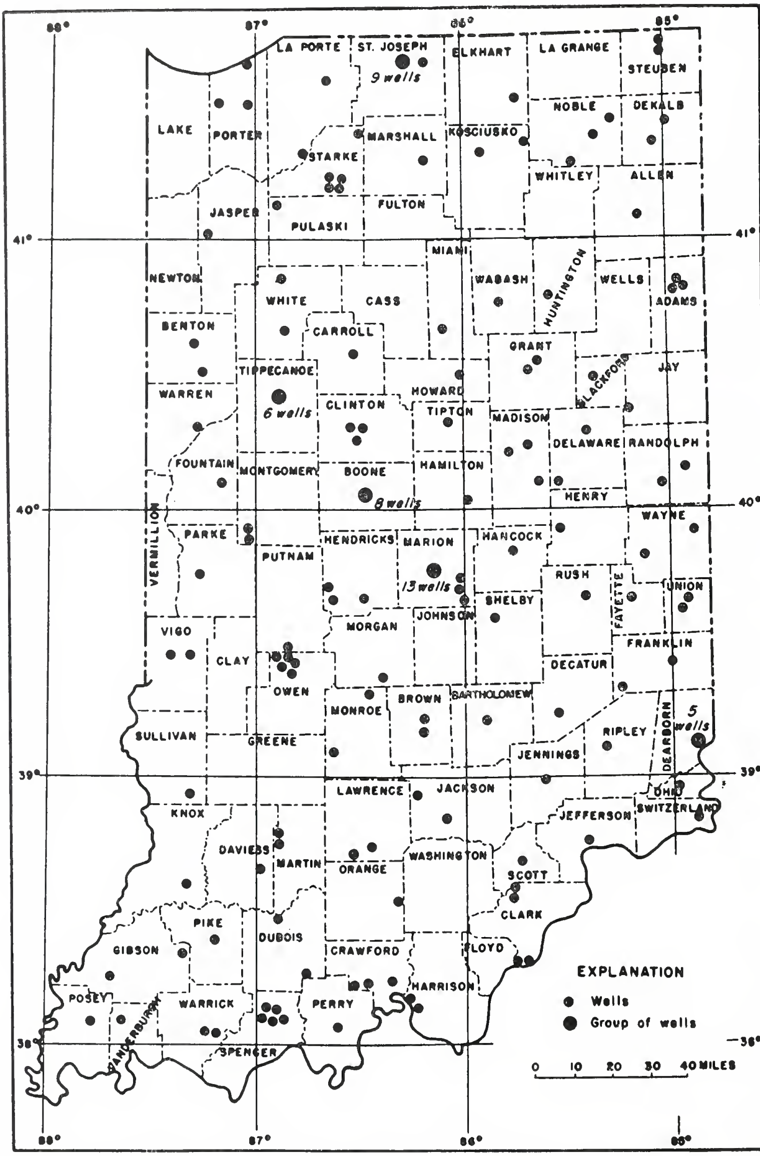

FIGURE I. OBSERVATION WELLS IN INDIANA - 1948.

and individual storms of several inches of precipitation may cause water levels to rise several feet in some wells. The relation between precipitation and ground-water levels in Indiana is much closer than is generally realized, and trends in ground-water levels follow closely the trends in precipitation.

Water levels in wells are also affected by recharge from nearby lakes and streams; by losses due to evaporation and transpiration, pumping from wells, and natural drainage into surface streams; and by minor factors such as changes in barometric pressure, passage of railroad trains, earthquakes, ocean tides, and earth tides. The potential effects of these various factors must be considered in the comparison of water levels measured at different times and in different wells.

In order to determine trends in precipitation for comparison with trends in water levels, a graph of the cumulative departure from normal precipitation was plotted, using the average annual precipitation data for the State as determined by the U. S. Weather Bureau. When precipitation is above normal the curve rises, and when precipitation is below normal the curve falls. The excesses and deficiencies in precipitation are added algebraically, giving the curve shown in figure 2.

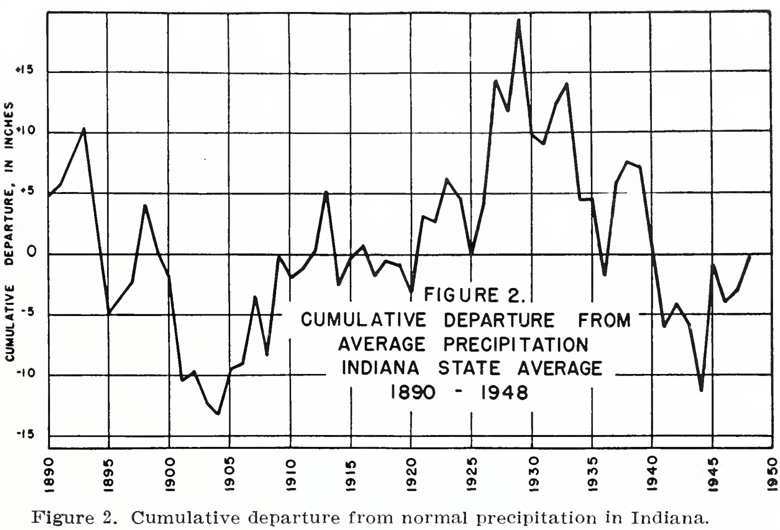

Figure 2. Cumulative departure from normal precipitation in Indiana.

In the 62 years of record, the general trend in precipitation was downward from 1893 through 1903, predominantly upward from 1904 through 1929, generally downward from 1930 through 1944, and has been somewhat upward since 1944. It is interesting to note that the cumulative deficiency in precipitation was greater in 1904 than in 1944. It should be noted also that the cumulative-departure curve from 1929 through 1944 dropped from an excess of 19.48 inches to a deficiency of 11.40 inches, a total of 30.88 inches, nearly 80 percent of a year's precipitation.

General Trends in Ground-Water Levels

Before discussing in detail the trends in ground-water levels in Indiana, several general facts must be considered. When water is pumped from a well, the water level in the well must be lowered in order to cause additional water to move into the wells to replace that which is pumped out. The water level in the formation around the well is also lowered, causing a depression in the water table that is shaped more or less like an inverted cone. This lowering is called the *cone of depression.* When many wells in a given area are pumped, the individual cones of depression often merge and a regional cone of depression is developed. The size and shape of the regional cone of depression are determined by many factors, the most important of which are the thickness, permeability, and storage capacity of the water-bearing material and the quantity of water being pumped. The cone of depression normally will continue to expand until the quantity of recharge occurring within it is equal to the quantity of water being pumped. In most areas, both the recharge and the pumpage vary from day to day, and thus the cone of depression seldom remains constant in size or shape. A decline in ground-water levels does not necessarily indicate overdevelopment of the available ground-water supplies of a given area, but may indicate merely the normal expansion of the cone of depression necessary to cause the required quantities of water to flow to the wells from which it is pumped.

The increased efficiency of pumps and the widespread use of electricity have greatly increased the use of water. Because it is easier to pump larger quantities of water now than it was 20 years ago, many new uses have been found for water and the average requirements for water have been steadily increasing. The increased use of water for industrial processes and for air conditioning and cooling, and the increasingly widespread use of water in rural areas for sanitary plumbing facilities, washing, and cooling, have placed a much greater demand on our sources of water. It has been estimated that an average of about 20 billion gallons of ground water a day was pumped in the United States during 1945, nearly twice the quantity pumped during 1935 (2).

The increased use of water is something that many people fail to appreciate. It is easy to turn on a faucet or press a button to turn on a pump, and as long as the water is there, why worry about it? Yet, many of the wells supplying these increased demands were never originally developed to yield as much water as they do now. A well that supplied 10 gallons a minute 15 years ago may have provided all the water that could be used, particularly if it was pumped by hand, and there is no reason why it should be expected to produce 25 or 50 gallons per minute at the present time after 15 years of use.

Water levels throughout the State fluctuate seasonally, and the amount of seasonal change is greater than many people realize. Ground-water levels generally reach their highest stage in the spring, usually decline through the summer months, and reach a low stage sometime between October and January. During the late winter and spring, they usually rise again. The seasonal variations in ground-water levels in

Indiana are as much as 20 or 30 feet in some wells. The comparison of a water level measured at one season of the year with that measured during a different season of an earlier year often gives misleading results.

In 1912, W. J. McGee (4), of the United States Bureau of Soils, obtained information on changes in ground-water levels on a nation-wide basis by sending out questionnaires. The records of nearly 29,000 wells throughout the United States were tabulated by counties. On the basis of his study he found that "the total lowering (in ground-water levels), since settlement . . . was 14 feet or over in Indiana . . ." This statement has often been used in discussion of general trends of ground-water levels. The validity of McGee's conclusion has been questioned by O. E. Meinzer (6), late Chief of the Ground Water Division (now Ground Water Branch) of the U. S. Geological Survey, on the basis that McGee's detailed facts do not support his major conclusion, that his questionnaires were sent out and were returned largely in September, a month in which water levels are normally at a low stage, and that 1910 was an unusually dry year throughout the United States. Although in Indiana the rainfall during 1910 was only 2.58 inches below the average, the water levels were probably lower than normal because of deficient precipitation during the spring months when recharge usually occurs.

In Indiana, where the period of detailed water-level records is short, generally not exceeding 14 years, it has not been possible to estimate the average change in the State since settlement began. In 1907 a field investigation of the ground-water resources of north-central Indiana was made by F. G. Clapp and S. R. Capps (1). During the investigation water levels were measured in many wells, some of which have been measured again in recent years, particularly in the Indianapolis and South Bend areas. Although little is known about the wells measured in 1907, and point from which the well was measured, and whether nearby wells were being pumped, a comparison of water levels in 1907 with those measured in recent years will show that water levels have declined to some extent, mainly in the areas of heavy ground-water pumping.

In the Indianapolis area, McGuinness (5, p. 43), has shown that "in 11 wells in limestone, mostly outside the downtown district, the declines in water level from 1907 to 1940 ranged from less than 1 foot to about 35 feet and averaged about 15 feet. Two wells in limestone showed net rises during the same period, largely because of decreased pumpage from limestone in 1940. In one gravel well in the north-central part of the city, the water level in 1941 was 9 feet lower than that in 1907 and in another gravel well in the southern part of the city, the water level was about the same in 1940 as in 1907. According to these and other available data, the decline in water levels that has accompanied the development of the ground-water resources of the Indianapolis area has ranged in different parts of the area from a few feet to more than 50 feet. The largest declines have occurred in the downtown district where during the summer of 1941 the water levels in wells in both gravel and limestone were more than 50 feet lower than the reported original levels." Similar declines are reported in other industrial districts within the Indianapolis area.

Fragmentary information on water levels in South Bend indicates that water levels have declined an average of about half a foot per year over a period of nearly 50 years (6). It is concluded that this decline has been necessary in order to develop the ground-water resources of the South Bend area. Other industrial areas in the State where records show that water levels have apparently declined include Frankfort, Lebanon, and Marion, and similar declines have doubtless occurred in many others, for which information is not now available.

The graphs of three wells in different parts of Indiana have been plotted for the period of record to show typical examples of natural water-level fluctuations (Fig. 3). Well Steuben 1 is in the northeastern corner of the State, in an area of glacial moraines of rolling topography.

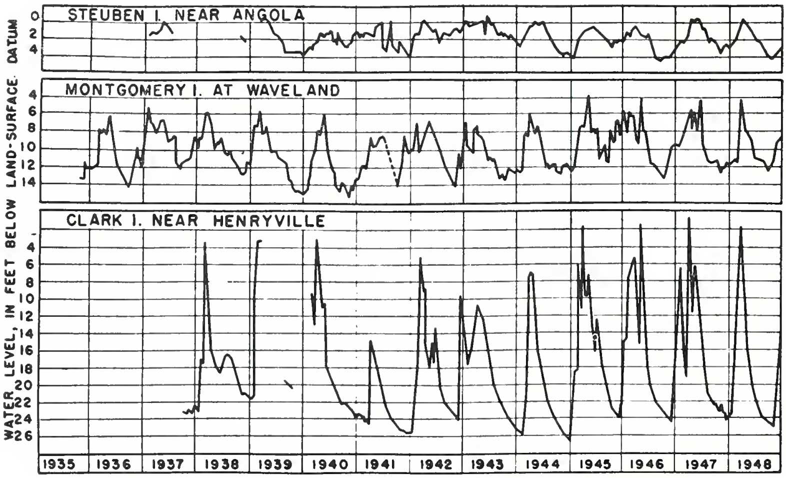

FIGURE 3. GRAPHS OF WATER LEVELS IN OBSERVATION WELLS IN INDIANA.

Figure 3. Graphs of water level in Steuben 1, Montgomery 1, and Clark 1, Indiana.

The seasonal fluctuation is about 4 feet and no serious decline in water level has occurred during the past 10 years. Well Montgomery 1 is in west-central Indiana in an area of gently rolling topography. The seasonal variation in water level is 8 to 10 feet and the general trend since 1940 appears to be upward. Well Clark 1 is in the southern part of the State in a wooded area of gently rolling topography. The seasonal fluctuation in water level is 20 to 24 feet and the general trend has been slightly upward since 1941. None of these wells are affected by pumping and the water-level fluctuations are rather typical of those in wells in rural areas where a relatively small quantity of water is pumped from the ground. The main causes for the differences in seasonal range are differences in precipitation and in storage capacity of the water-bearing materials.

Graphs of water level in areas of heavy pumping from wells show similar seasonal changes, although the changes are usually greater and occur at a slightly different time in the year, largely because of seasonal pumping. These water levels generally start to rise at or shortly after the end of the air-conditioning or cooling season and reach their highest stage in March or April.

The graphs of water levels in downtown Indianapolis show typical seasonal changes in ground-water levels in areas of heavy commercial and industrial pumpage (Fig. 4). Well Marion 2 is a gravel well near the center of the downtown area, and Marion 10 is a limestone well somewhat farther from the center of pumping. The sharply declining trend prior to 1941 was caused largely by deficient precipitation and relatively high rates of pumping. The rising trend since 1941 is doubtless due to normal precipitation and to somewhat decreased industrial pumping.

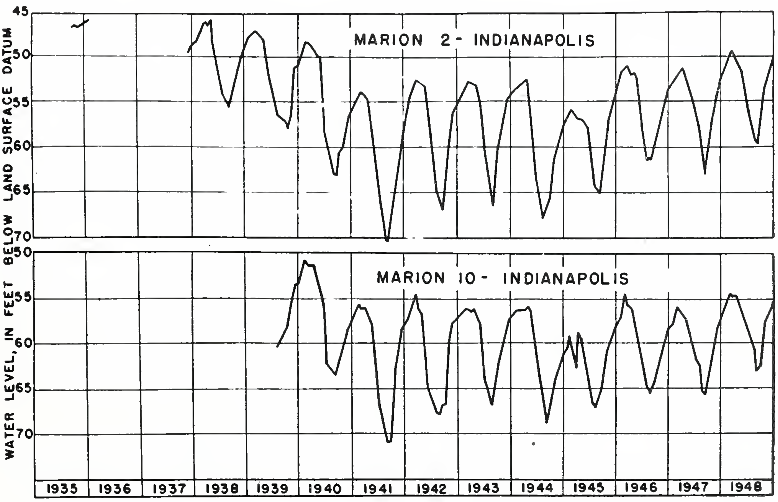

FIGURE 4. GRAPHS OF WATER LEVELS IN OBSERVATION WELLS IN INDIANAPOLIS, INDIANA.

Figure 4. Graphs of water levels in Marion 2 and Marion 10, Indianapolis, Indiana.

Conclusions

It has been shown that ground-water levels are affected by many factors, the most important of which are precipitation and pumping from wells. The seasonal change in water levels generally exceeds the change from year to year, and comparison of water levels in a well at different seasons of the year may lead to erroneous conclusions. The use of water from wells has increased tremendously, much more than is generally realized, and a large increase in pumpage must necessarily result in a lowering of water levels.

We have often been asked "Have the ground-water levels in Indiana fallen seriously?" The answer to this question must be qualified. Since settlement of the State began, ground-water levels doubtless have been lowered in many areas, especially where large quantities of water are pumped from wells. In rural areas, generally speaking, the water levels have also declined to some degree because of land drainage, but the decline does not appear to be nearly as great except where formations have been drained by mining or quarrying operations. Where no artificial drainage has been done and where little or no water is pumped, there is no reason to expect that the ground-water levels are any lower now than in the past. Some decline in ground-water levels may be beneficial, as natural losses from ground-water storage through drainage into streams and by evaporation and transpiration are diminished.

In urban and industrial areas, where large quantities of water are pumped from wells, the decline in water levels has been more pronounced, although it is now serious in few places, if any. In the South Bend area, where water levels have declined from 10 to 25 feet during the past 50 years, wells still flow in certain parts of this city.

During the period 1930 through 1944, rainfall in Indiana was generally below normal and ground-water levels declined to probably their lowest stage in history. There has been a general rise in water levels from 1945 to the present time, but when another prolonged period of deficient rainfall occurs, ground-water levels will fall to the low stages once more. It is essential, therefore, to continue our records of water levels in order to be forewarned of possible overdevelopment in areas of heavy pumping or areas of generally scanty supplies.

Studies to date indicate that the ground-water resources of Indiana in general are not being exhausted and additional ground-water supplies may be developed in many areas. Over-all replenishment of the ground-water reservoir is believed to be greater than the withdrawals of water from wells, and large quantities of water are draining naturally into streams. Some of the natural drainage could be salvaged by properly spaced wells.

In heavily developed areas much of the apparent shortage of ground-water supplies is due to the close spacing of wells and their mutual interference, and to incrustation of well screens and of the formations surrounding wells.

The demand for water will continue to increase and ground water will become increasingly important in our daily lives. The inventory of the ground-water resources of the State must be continued to prevent over-development of our present sources and to assist in the development of new sources of supply.

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