Evaluation of Missing Gage-Height Record for Streams and Lakes in Kansas

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An evaluation of the occurrence and causes of missing gage-height record from stream- and lake-gaging stations in Kansas from 1987 through 1999 shows that there has been a 40-percent reduction in the amount of missing gage-height record during the past 13 years. Real-time gage-height and streamflow data are important to Kansas and the Nation for planning and decisions related to agriculture, industry, urban water supplies, navigation, riverine and riparian habitat, and flood-hazard identification. Long-term records from gaging stations are a cornerstone for national, regional, and local efforts to understand the Nation's water resources. Any gaps in those long-term records of streamflow and lake levels can mean a gap in the essential understanding and management of water resources. Reducing the amount of missing gage-height records, which are used to monitor and manage water resources in Kansas, is a major concern for the U.S. Geological Survey (USGS).

Introduction

Collection of flow data for streams and water-level data for lakes is a principal component of the USGS mission in providing reliable, impartial, and timely information needed to understand the Nation's water resources. Because gage-height data are used to compute daily streamflow and lake content, any missing gage-height data affects the quality of the computed record. As part of ongoing efforts to continually improve the quality and timeliness of streamflow and lake water-level data, the USGS evaluated the occurrence and causes of missing gage-height record in Kansas for 1987–99. This summary of the results of that evaluation was done in collaboration with the USGS Office of Surface Water in Reston, Virginia.

A previous evaluation of the occurrence and causes of missing gage-height record in Kansas for 1971–81 indicated that the stream- and lake-gaging stations had missing gage-height record an average of about 15 days per year (about 4 percent of the time) per station during the 11-year study period (Livingston, 1983). Faulty timers on digital recorders were the primary cause of missing gage-height record during this period, closely followed by silting and freezing of the orifice lines and well intakes.

Another evaluation of missing gage-height record (Wahl and Shields, 1989) analyzed data for USGS offices in Colorado, Iowa, Kansas, Missouri, Montana, Nebraska, New Mexico, North Dakota, Oklahoma, South Dakota, Texas, Utah, and Wyoming for 1982–86. This evaluation showed a substantial reduction from 1982 to 1983 in the amount of missing gage-height record caused by malfunctions of the digital recorder timers resulting from the replacement of the faulty timers with new solid-state timers beginning in 1982. The total amount of missing gage-height record, however, remained about the same as that of the 1971–81 evaluation (about 4 percent) due to increases in other problem categories.

Comparison of the occurrence and causes of missing gage-height record in Kansas from 1987 to 1999 with data from previous evaluations will help determine whether the occurrence of missing gage-height record in Kansas has changed with the use of advanced technology equipment such as electronic data recorders and pressure transducers.

Collection of Streamflow and Lake-Level Data in Kansas

The USGS currently (2001) collects gage-height data at approximately 160 continuous-record gaging stations in Kansas. Since the mid-1960's, gaging stations generally have been equipped with bubbler systems for the collection of gage-height record (fig. 1). In a bubbler system, an orifice is attached securely below the water surface and connected to a pressure-sensing device by a length of plastic tubing. Pressurized gas (usually nitrogen or air) is

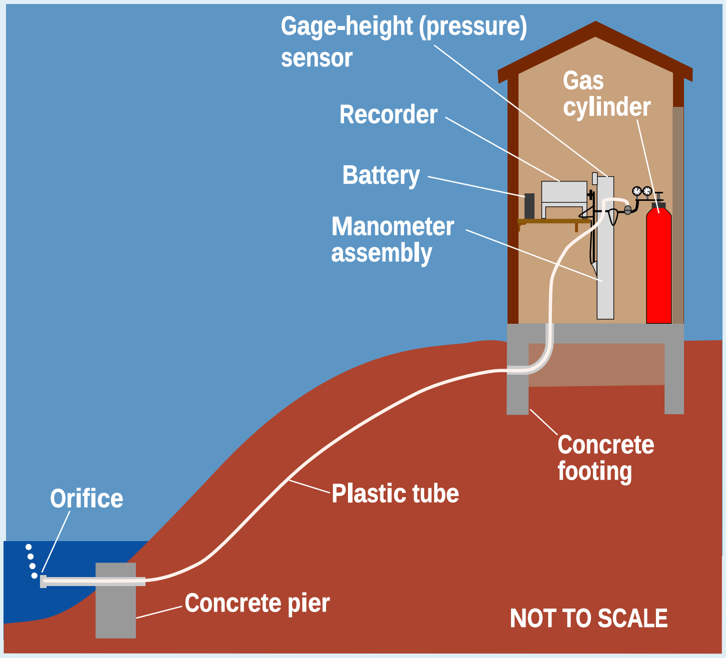

Figure 1. Typical bubble-gage installation, circa 1980.

forced through the tubing and out the orifice. Because the pressure in the tubing is a function of the depth of water above the orifice, a change in the water level of a stream or lake produces a corresponding change in the pressure in the tubing. Pressure sensors, such as mechanical manometers or electronic pressure transducers, convert the pressure in the tubing into height of water above a set datum level referred to as gage height. Graphic recorders, digital punch-tape recorders, or electronic data loggers record the gage height either continuously or at preset time intervals, usually 15 minutes. Solar-recharged batteries power the electrical equipment. Failure of any one of these components can cause missing gage-height record.

Gaging-station operation changed significantly in 1982 with the introduction of data-collection platforms (DCP's). The DCP collects gage-height data and transmits it to the Geostationary Operational Environmental Satellite (GOES) that relays the data to a ground station and then to USGS offices for dissemination (fig. 2). The data enters the computer system within a few seconds after satellite transmission. This information then is made available to the public on the USGS "Current Gage-Height and Streamflow Conditions" Internet site at URL:

http://ks.water.usgs.gov

Station descriptions, updated each year for each gaging station, include installation dates for new equipment. In 1987, nearly one-half of the gaging stations in Kansas were equipped with DCP's and by 1997, all of the gaging stations had DCP's (fig. 3). The new technology permits USGS offices to monitor the operation of the gaging stations continuously and allows them to time visits to gaging stations to coincide with those times when the need for data is greatest, such as during floods and to repair or service equipment at the gaging stations.

The introduction of the electronic pressure transducer also has reduced the gaps in gage-height data. Beginning in 1993, the pressure transducer replaced the mechanical manometer as the primary gage-height sensor (figs. 3 and 4). Installation and maintenance of the electronic pressure transducer takes less time

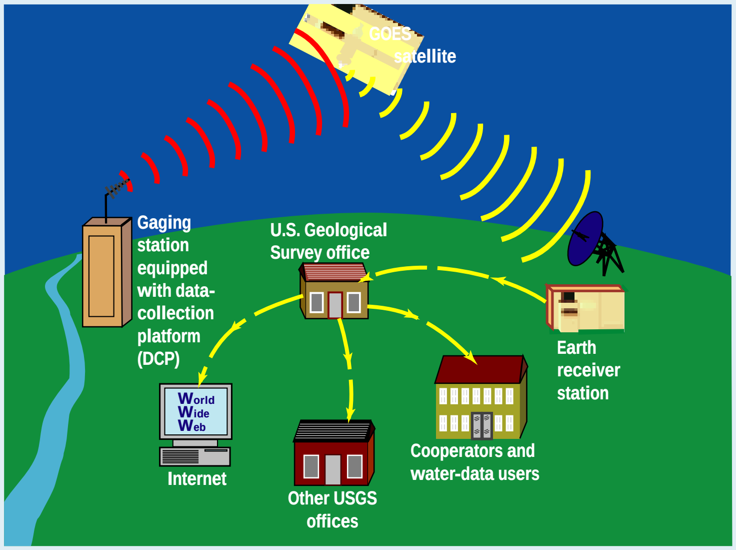

Figure 2. Transmission of gage-height or lake-level data from the gaging station to the data users.

than for manometers, and the transducers are more reliable, resulting in fewer days of missing data.

A few gaging stations currently (2001) are equipped with a new, compact, air compressor-bubbler system that replaces the compressed-gas cylinder and conoflow (a mechanical device that regulates the orifice-line pressure and bubble rate). This new device also has the advantage of a programmable orifice-line purge that can periodically clear the orifice at gaging stations that have a persistent problem with the blocking of an orifice with silt or organic growth. The purging of the orifice line at these stations can greatly improve the accuracy of the gage-height data.

The advances in gaging-station equipment technology have helped to decrease the occurrence of missing gage-height record by reducing the amount of equipment that can malfunction and by allowing a quicker response time in repairing or replacing equipment. In addition, hydrologic technicians have fewer routine tasks to perform during visits to the station, and the maintenance of the equipment is less time consuming. Technicians no longer need to retrieve and process digital punch tapes and graphic strip charts. Now, all of the gage-height record is sent directly to USGS offices by satellite or downloaded onsite to a laptop computer, thus reducing the opportunity for mechanical malfunctions or human error that can lead to missing gage-height record.

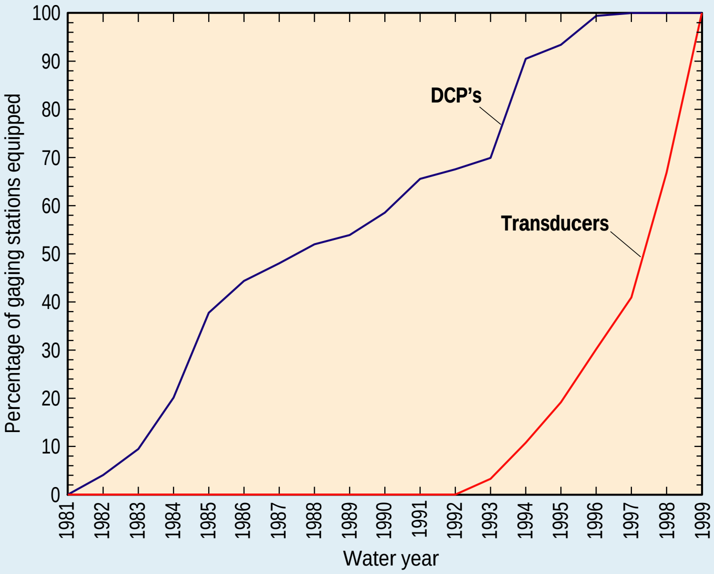

Figure 3. Cumulative percentage of data-collection platforms (DCP's) and electronic pressure transducers installed in U.S. Geological Survey gaging stations in Kansas, 1981–99. Water year is the 12-month period beginning October 1 and ending September 30. (The water year is designated by the calendar year in which it ends. For example, the period beginning October 1, 1998, and ending September 30, 1999, is called the 1999 water year.)

Evaluation of Missing Gage-Height Record, 1987–99

Station analyses written by the USGS at the end of the water year for each gaging station include information for determining the occurrence and causes of missing gage-height record for each year of operation. Any day having less than 12 hours of gage-height data that cannot be reasonably recovered was considered a day of missing gage-height record. The causes of missing gage-height record were divided into six problem categories:

Orifice—included problems associated with the orifice line or well-intake systems, including silted or frozen orifice lines and intakes.

Gage-Height Sensor—included manometer problems and pressure transducer problems excluding battery problems. Gas leaks were included in this category.

Power—included problems due to a weak or dead battery or power outage.

Recorder—included graphic, digital, electronic data recorder, and timer problems. DCP problems also were included in this category.

Vandalism and Animal Damage—included human destruction and animal damage.

Oversight—included technician errors such as leaving a graphic recorder pen off the chart, leaving a timer unplugged, leaving intake or gas valves closed, permitting a strip chart or digital tape to run out, or incorrectly programming electronic equipment.

These categories are slightly different from those used by Wahl and Shields (Sensor, Manometer, Timer, Power, Recorder, Vandalism, Oversight, and Other) in their 1989 report. In the 1987–99 evaluation, the orifice category replaced the sensor category of Wahl and Shields (1989), the gage-height sensor category replaced the manometer category, and the timer category was included in the recorder category. The vandalism and animal damage category included the "Other" category of Wahl and Shields (1989) because most of the other reasons for missing gage-height record for 1987–99 involved either human vandalism or animal damage of gaging equipment.

A comparison of the average number of days of missing gage height record for 1971–86 with the average number of days of missing record for 1987–99 shows an overall decrease of 40 percent. An average of about 15 days (about 4.1 percent) per year per station for 1971–86 was reduced to an average of about 9 days (about 2.5 percent) per year per station for 1987–99 (fig. 5). The average yearly number of days of missing gage-height record ranged from 6.5 to 26.1 days per station for 1971–81 and from 4.7 to 13.9 days per station for 1987–99.

The orifice system used by the USGS has not changed significantly since the 1960's, and orifice problems continue to be the major cause (46 percent) of missing gage-height record for 1987–99 (fig. 6). In 1999 alone, orifice problems were the cause of nearly 80 percent of the missing gage-height data in Kansas (fig. 7). The gage-height sensor caused 29 percent of the missing gage-height record for 1987–99 but was responsible for only 4 percent of the missing gage-height record in 1999 (fig. 8), mainly due to the replacement of manometers with electronic pressure transducers.

An increase in the number of DCP's located at gaging stations across the State from 1982 to 1999 most likely was responsible for most of the 40-percent decrease in missing gage-height record from 1987 to 1999. DCP's played a major role in decreasing the duration of problems that caused missing gage-height record. Problems were detected and corrected more quickly because of immediate access to real-time data from the gaging stations.

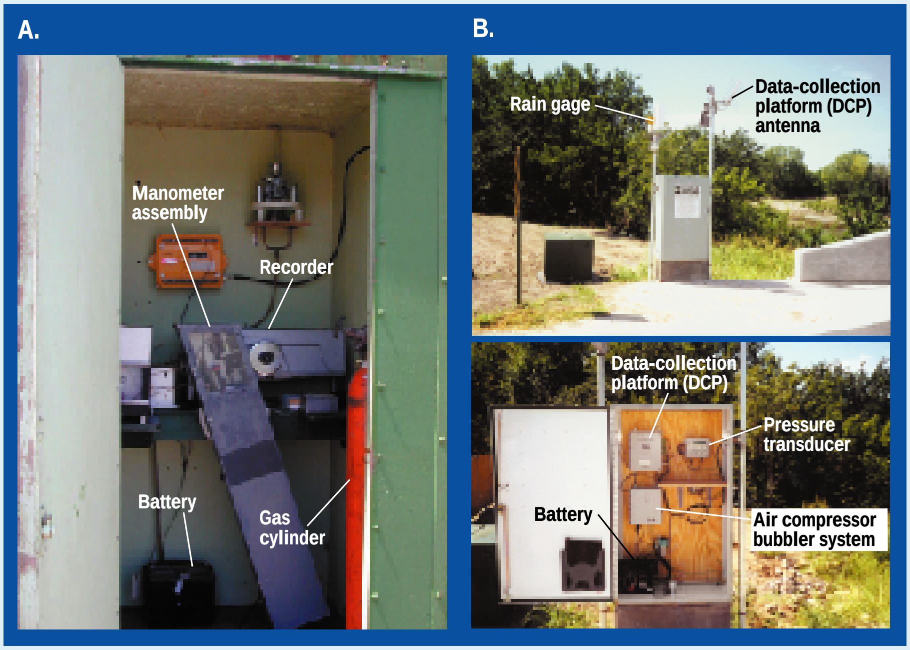

Figure 4. Typical stream-gage house installations in Kansas in (A) mid-1980's and in (B) 1999.

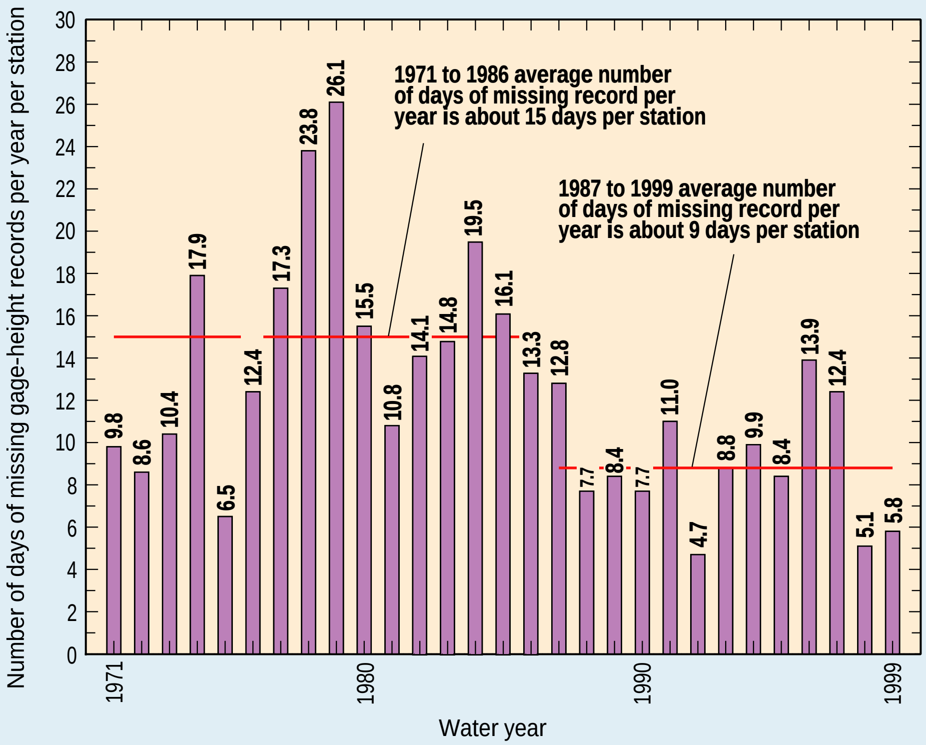

Figure 5. Average number of days of missing gage-height record per station in Kansas, 1971–99.

There was an increasing trend in missing gage-height record caused by the gage-height sensor from 1991 to 1994 (fig. 8). The manometer had been the preferred gage-height sensing instrument used by the USGS in Kansas since its introduction to stream-gaging stations in the early 1960's. Many of these units still had their original parts, and by the early to mid-1990's, they began failing. The replacement of manometers with electronic pressure transducers, beginning in 1993, greatly reduced the number of days of missing gage-height record due to problems with the gage-height sensor.

The pressure transducer requires less maintenance than the manometer, eventually resulting in a reduced risk of missing gage-height record due to human oversight. A relatively high percentage of missing gage-height record due to oversight during

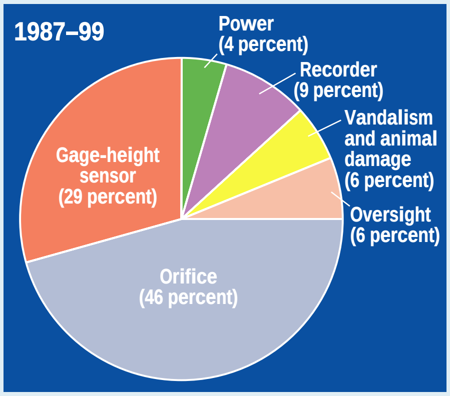

Figure 6. Average percentage of missing gage-height record in Kansas by problem category, 1987–99.

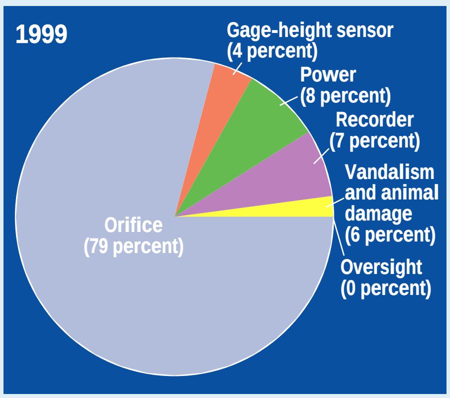

Figure 7. Average percentage of missing gage-height record in Kansas by problem category, 1999 water year.

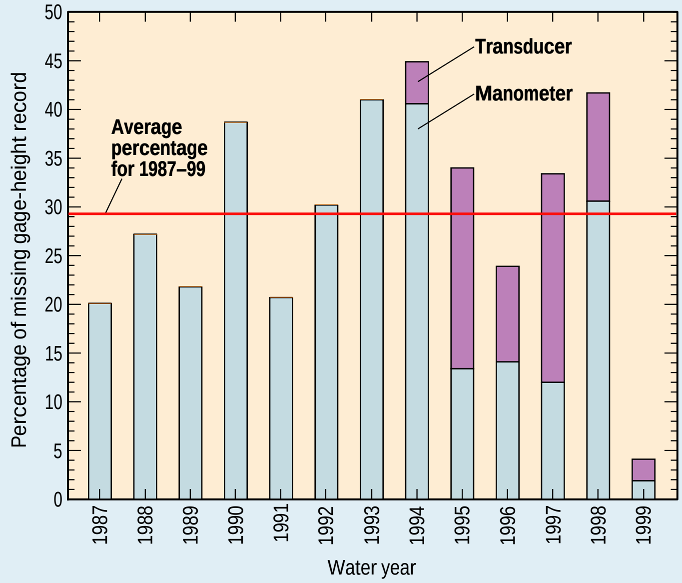

Figure 8. Percentage of missing gage-height record in Kansas due to problems with the gage-height sensor, 1987–99.

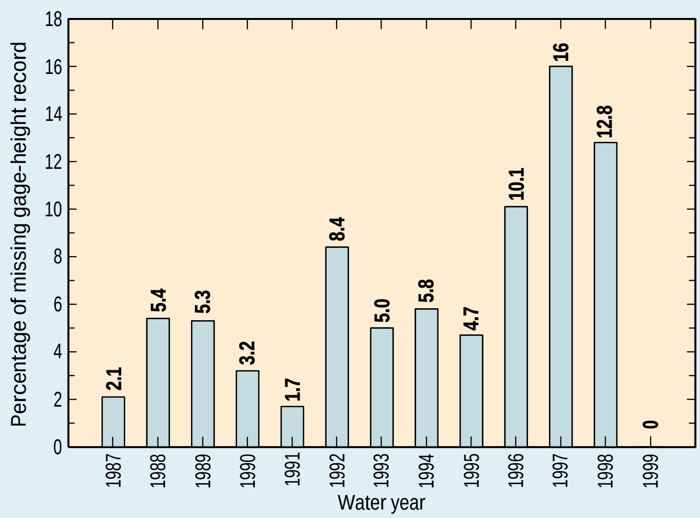

Figure 9. Percentage of missing gage-height record in Kansas due to oversight by technicians, 1987–99.

1996–98 (fig. 9) coincides with the period of the installation of electronic pressure transducers. However, a part of the higher percentage of missing gage-height record caused by gage-height sensor problems during 1997–98 (fig. 9) can be attributed to technicians learning the operation of the electronic pressure transducers. By 1999, the amount of missing gage-height data due to oversight was reduced to 0 percent.

The orifice continues to be the largest contributor to missing gage-height record. The occurrence of missing gage-height record could be reduced considerably with the development of a viable replacement for the bubbler system. Currently (2001), the development of radar, laser, and acoustic-doppler devices that can sense gage height or measure discharge directly without direct contact with the water show some promise.

Conclusions

Continuing evaluation shows the importance of tracking the occurrence and causes of missing gage-height record to help minimize the loss of valuable information from USGS gaging stations and to evaluate the effectiveness of improved equipment technology. An annual evaluation of the data can indicate the need for operational changes, additional training, and research and development of advanced sensing and recording equipment for the continued reduction of missing gage-height record. The USGS will continue to evaluate its record of providing high-quality, impartial environmental data and to seek improvements in data-collection techniques and equipment for the Nation's benefit.

References

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