

IMPROVEMENTS IN DESIGN OF GRAVEL WALLED WATER WELLS

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Improvements in Design of Gravel Walled Water Wells

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ABSTRACT

Legislation and regulation at both the national and state level related to the protection and conservation of ground-water resources have received much attention over the past decade.

Laws were passed which provided for closer supervision of both the water well industry and the oil and gas industry with respect to protection and conservation of fresh and useable water and the collection of hydrogeologic information.

Minimum construction standards for water wells greatly improved standards of construction. Well records provided a wealth of hydrogeologic information. Gravel walled or gravel packed wells comprise a large proportion of the water wells drilled each year. A review of the water well records indicates most gravel packed wells are constructed with a continuous, highly permeable gravel pack from the bottom of the well to a point 10 or 15 feet below land surface. Although generally only the permeable zones are screened, the continuous gravel envelope around the casing allows continuous movement of water up or down the bore hole if there are head differences in different parts of the aquifer or aquifers penetrated by the bore hole.

Detrimental effects of this type of construction are demonstrated by examples from various parts of Kansas.

An improved design of gravel walled wells is suggested which would include clay or cement grout opposite the non-productive zones thus effectively preventing the flow of fluids up or down the bore hole in the gravel pack. Such construction would enhance the conservation and protection of ground-water resources and would simplify and reduce the cost of plugging upon abandonment.

Legislation and regulation at both the national and state level related to the protection and conservation of ground-water resources have received much attention over the past decade.

In Kansas, laws were passed which provided for closer supervision of both the water well industry and the oil and gas industry with respect to protection and conservation of fresh and useable waters and the collection of hydrogeologic information.

In Chapter 82a of the Kansas Statutes Annotated, Article 12 has been designated the Kansas Groundwater Exploration and Protection Act and its purpose includes "...to protect groundwater resources from waste and potential pollution...and to provide data on potential water supplies through well logs, well pumping tests and water quality tests..."

Section 7 of that article requires that qualifications of water well contractors include "...Knowledge of groundwater and subsurface geology in its relation to well construction."

Chapter 28, Article 30 of the Kansas Administrative Regulations relating to water wells requires that "...Confined waters shall be separated from each other and from unconfined waters encountered in the same borehole with grout or other approved materials in areas designated by the department [of Health and Environment]."

At the present time the only areas designated for water wells to be constructed in such a manner are in western and southeastern Kansas. In western Kansas this applies only to those wells that penetrate both the Ogallala and the Dakota aquifers, and in southeastern Kansas it applies to those that penetrate both Mississippian and Ordovician aquifers.

Minimum construction standards brought about by such legislation and regulation require: 1) at least 10 feet of surface grouting in the annular

space of the well---that area between the borehole and the well casing, 2) the use of approved grouting and casing materials, and 3) the submission of a WWC-5 water well record (Fig. 1).

Figure 2 illustrates some of the aforementioned terms and helps in their definition. Casing may be tubular steel or iron pipe or plastic pipe approved for use as casing, and its purpose is to maintain an open hole, protecting the borehole from caving and collapsing. Grout is defined as Portland cement, neat cement, or bentonite clay, and its purpose is to fill the annular space between the wall of the borehole and the casing to prevent the unwanted movements of fluids in the annular space and increase protection of the casing from corrosive fluids. The grout also prevents the entry into the well of water from the land surface or the soil zone which could carry bacteria or other potential contamination.

Also in Figure 2 one can see the use of a gravel pack around the screened portion of the casing. This gravel pack, in the annular space, provides support to the borehole and because of its permeability (ability to transmit fluid), allows water to flow into the screen and casing from the formation being tapped.

In Kansas, formations which usually produce adequate amounts of water to wells are unconsolidated sand and gravel, sandstone, and limestone.

Because of the way the wells are constructed in Figure 2, water only from the zone at the base of each well would rise to a certain level in the well. The elevation of this static water level is known as the pressure head or hydraulic head of the water-bearing zone being tapped. Measurements of the static water levels in these types of wells may be plotted with respect to time to form graphs known as well hydrographs.

1 LOCATION OF WATER WELL
 County: Butler Fraction $\frac{1}{4}$ $\frac{1}{4}$ $\frac{1}{4}$ Section Number Township Number Range Number
 T S R EW
 Distance and direction from nearest town or city? Street address of well if located within city?

2 WATER WELL OWNER:
 RR #, St. Address, Box # : Board of Agriculture, Division of Water Resource
 City, State, ZIP Code : Application Number:

3 DEPTH OF COMPLETED WELL 119 ft. Bore Hole Diameter 8.5 in. to 119 ft., and ... in. to ...
 Well Water to be used as:
 1 Domestic 3 Feedlot 5 Public water supply 8 Air conditioning 11 Injection well
 2 Irrigation 4 Industrial 6 Oil field water supply 9 Dewatering 12 Other (Specify below)
 7 Lawn and garden only 10 Observation well
 Well's static water level 85 ft. below land surface measured on 1 month 2 day 80 year
 Pump Test Data : Well water was ... ft. after ... hours pumping ... gpm
 Est. Yield gpm: Well water was ... ft. after ... hours pumping ... gpm

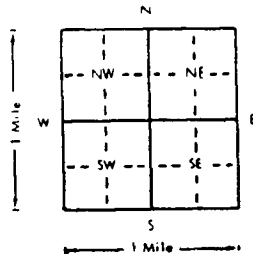
4 TYPE OF BLANK CASING USED:
 1 Steel 3 RMP (SR) 5 Wrought iron 8 Concrete tile Casing Joints: Glued Clamped ...
 2 PVC 4 ABS 6 Asbestos-Cement 9 Other (specify below) Welded ...
 7 Fiberglass Threaded ...
 Blank casing dia 5 in. to 99 ft., Dia in. to ... ft., Dia in. to ...
 Casing height above land surface 14 in., weight lbs./ft. Wall thickness or gauge No 14 inch

TYPE OF SCREEN OR PERFORATION MATERIAL:
 1 Steel 3 Stainless steel 5 Fiberglass 8 RMP (SR) 10 Asbestos-cement
 2 Brass 4 Galvanized steel 6 Concrete tile 9 ABS 11 Other (specify) ...
 12 None used (open hole)
Screen or Perforation Openings Are:
 1 Continuous slot 3 Mill slot 5 Gauzed wrapped 8 Saw cut 11 None (open hole)
 2 Louvered shutter 4 Key punched 6 Wire wrapped 9 Drilled holes
 7 Torch cut 10 Other (specify) ...
 Screen-Perforation Dia 5 in. to 119 ft., Dia in. to ... ft., Dia in. to ...
 Screen-Perforated Intervals: From 99 ft. to 119 ft. From ... ft. to ...
 Gravel Pack Intervals: From 119 ft. to 85 ft. From 55 ft. to 15 ft.

5 GROUT MATERIAL:
 1 Neat cement 2 Cement grout 3 Bentonite 4 Other
 Grouted Intervals: From 85 ft. to 55 ft. From 15 ft. to 4 ft.
 What is the nearest source of possible contamination:
 1 Septic tank 4 Cess pool 7 Sewage lagoon 10 Fuel storage 14 Abandoned water well
 2 Sewer lines 5 Seepage pit 8 Feed yard 11 Fertilizer storage 15 Oil well/Gas well
 3 Lateral lines 6 Pit privy 9 Livestock pens 12 Insecticide storage 16 Other (specify below)
 13 Watertight sewer lines
 Direction from well North How many feet 70' septic, 9' line ? Water Well Disinfected? Yes No
 Was a chemical/bacteriological sample submitted to Department? Yes No : If yes, date sample was submitted 1 month 2 day 80 year Pump Installed? Yes No
 If Yes: Pump Manufacturer's name Model No. HP Volts
 Depth of Pump Intake ft. Pumps Capacity rated at gal./min.
 Type of pump: 1 Submersible 2 Turbine 3 Jet 4 Centrifugal 5 Reciprocating 6 Other

6 CONTRACTOR'S OR LANDOWNER'S CERTIFICATION: This water well was (1) constructed, (2) reconstructed, or (3) plugged under my jurisdiction and was Completed on ... month ... day ... year and this record is true to the best of my knowledge and belief. Kansas Water Well Contractor's License No. This Water Well Record was completed on ... month ... day ... year under the business name of ... by (signature)

7 LOCATE WELL'S LOCATION WITH AN "X" IN SECTION BOX:



FROM	TO	LITHOLOGIC LOG	FROM	TO	LITHOLOGIC LOG
0	2	Fill Dirt			
2	3	Top soil			The water at 65 ft. has 4760 chloride and was cemented out for this reason.
3	5	Clay - brown			
5	11	Clay - redish brown			
11	20	Limestone - yellow			
20	40	Shale - yellow green			
40	82	Shale with limestone - yellow			
82	103	Shale - rusty red			
103	105	Limestone - light gray			
105	119	Shale - gray			

ELEVATION: Depth(s) Groundwater Encountered 1. 65 ft. 2. 104 ft. 3. ... ft. 4. ... ft. (Use a second sheet if needed)

INSTRUCTIONS: Use typewriter or b copies to Kansas Department of Health retain one for your records. Circle the correct answers. Send top three 0. Send one to WATER WELL OWNER and

Figure 1. WWC-5 water well record form.

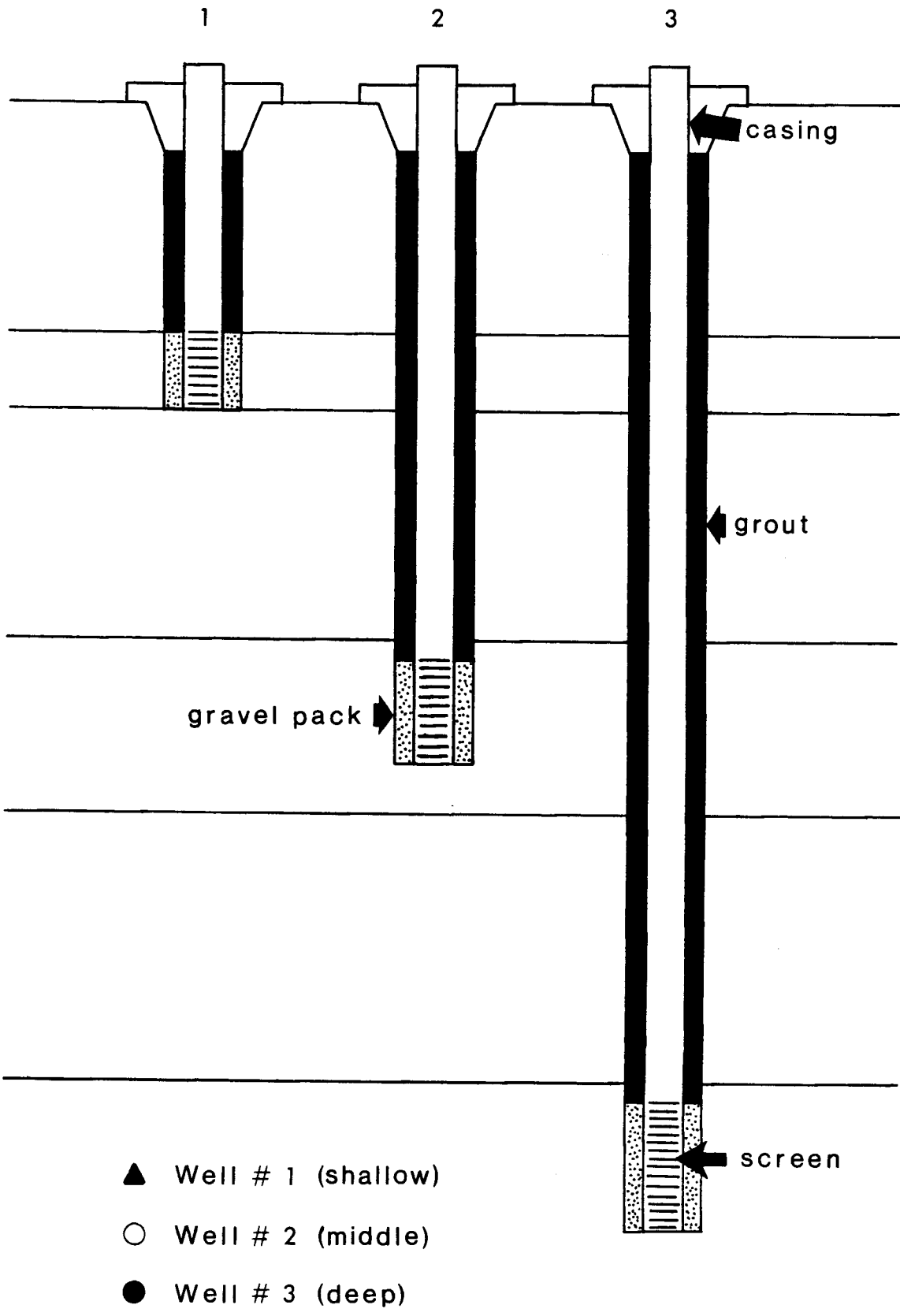


Figure 2. Water wells specially constructed for observation purposes.

Figure 3 represents such hydrographs at three different locations. At sites #3 and #11 the hydraulic head of the shallower zone is higher than the hydraulic head of the deeper zone. At site #5, however, the opposite is true, and the deeper zone has a higher hydraulic head than the shallower zones.

It is because of these hydraulic head differences of different water-bearing zones and the increasing use of the gravel walled or gravel packed construction in water wells that problems of waste and pollution of groundwaters are being recognized.

Gravel packed wells comprise a very large proportion of the more than 4,000 water wells completed each year in Kansas. A review of the water well records indicates that most gravel packed wells are constructed with a continuous highly permeable gravel pack from the bottom of the well to a point 10 or 15 feet below land surface at which point the remaining annular space is filled with grout, satisfying the minimum construction standards for water wells (Fig. 4). Although generally only the water-bearing zones are screened, the gravel envelope around the casing allows continuous movement of water up or down the borehole from zones of higher hydraulic head to zones of lower hydraulic head. Since in most cases the shallower zone has a higher head than the lower zone, the gravel pack acts as a continuous drain on the shallow water-bearing zone.

An example of this problem is illustrated (Fig. 5) in the Tatarax Hills subdivision in Manhattan, Kansas. Figure 6 illustrates a test hole that was drilled in two stages in the area of the proposed subdivision. Two water-bearing zones were encountered. The lower zone was known to have a hydraulic head approximately 20 feet below the head of the upper zone in the vicinity of the test hole. One year later, at the same location, two wells were completed in the lower zone for water supply to the subdivision (Fig. 7). A 24-hour

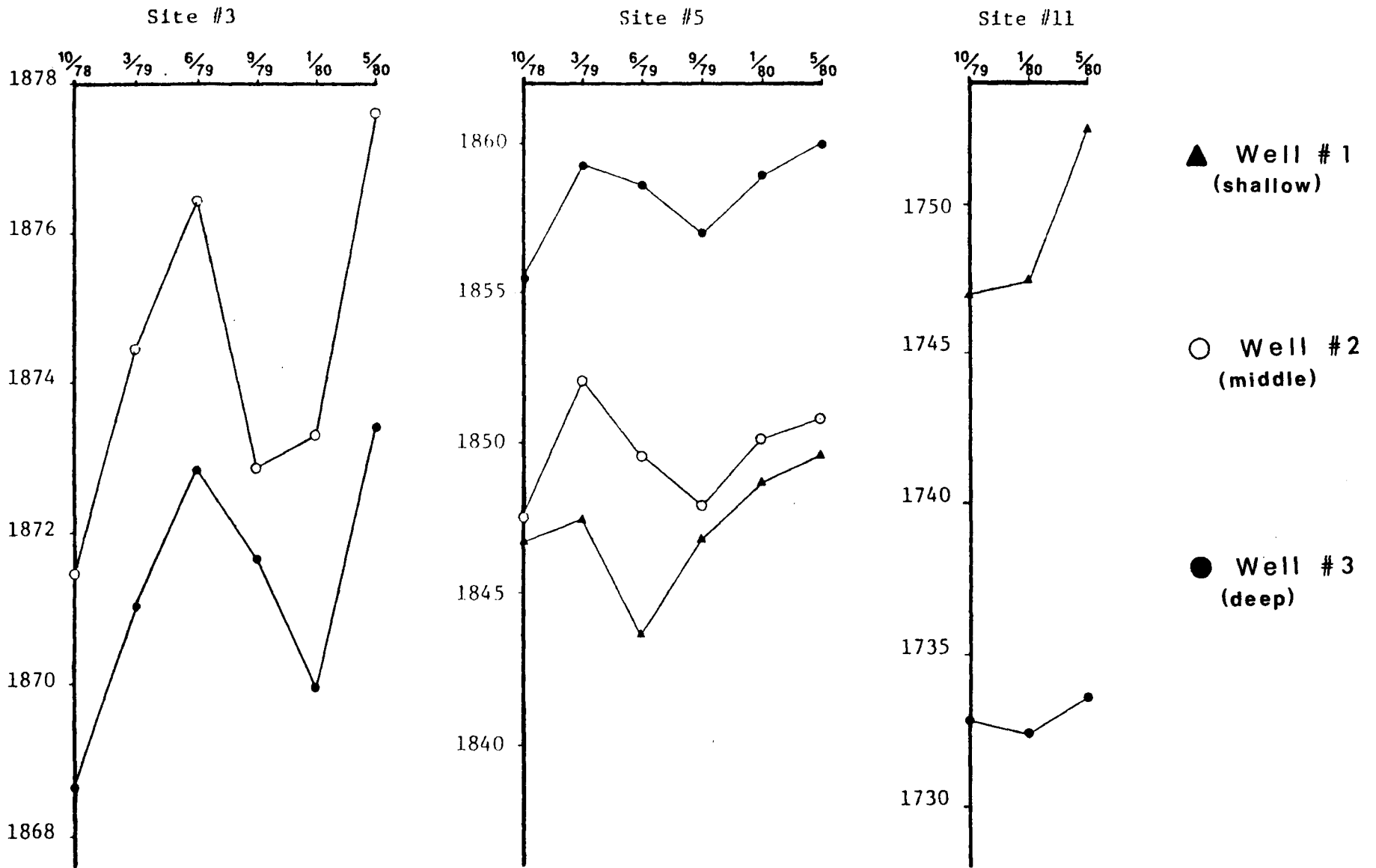


Figure 3. Well hydrographs.

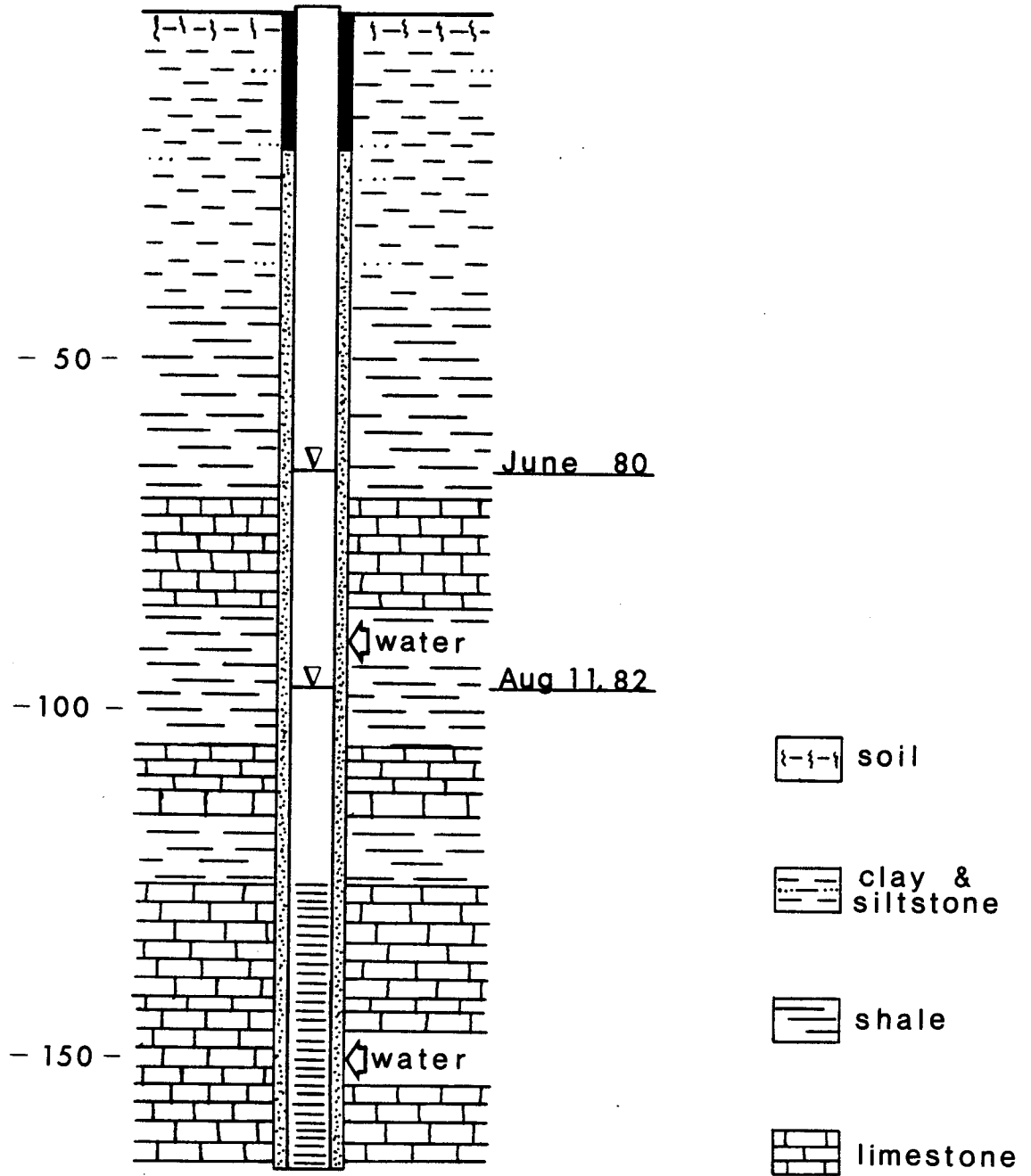


Figure 4. Gravel walled water well in Marion County, Kansas.

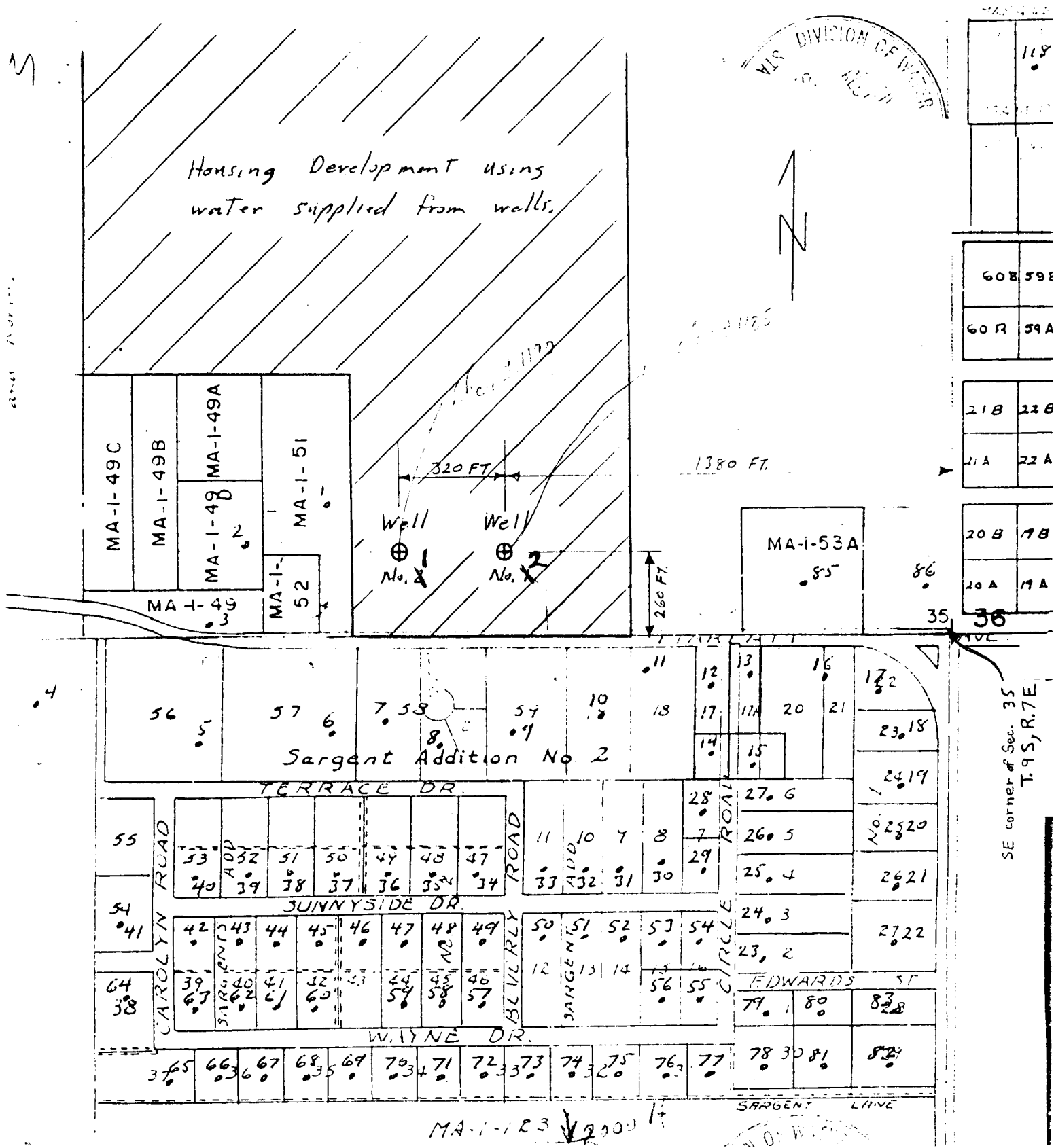


Figure 5. Map of housing developments near Manhattan, Kansas.

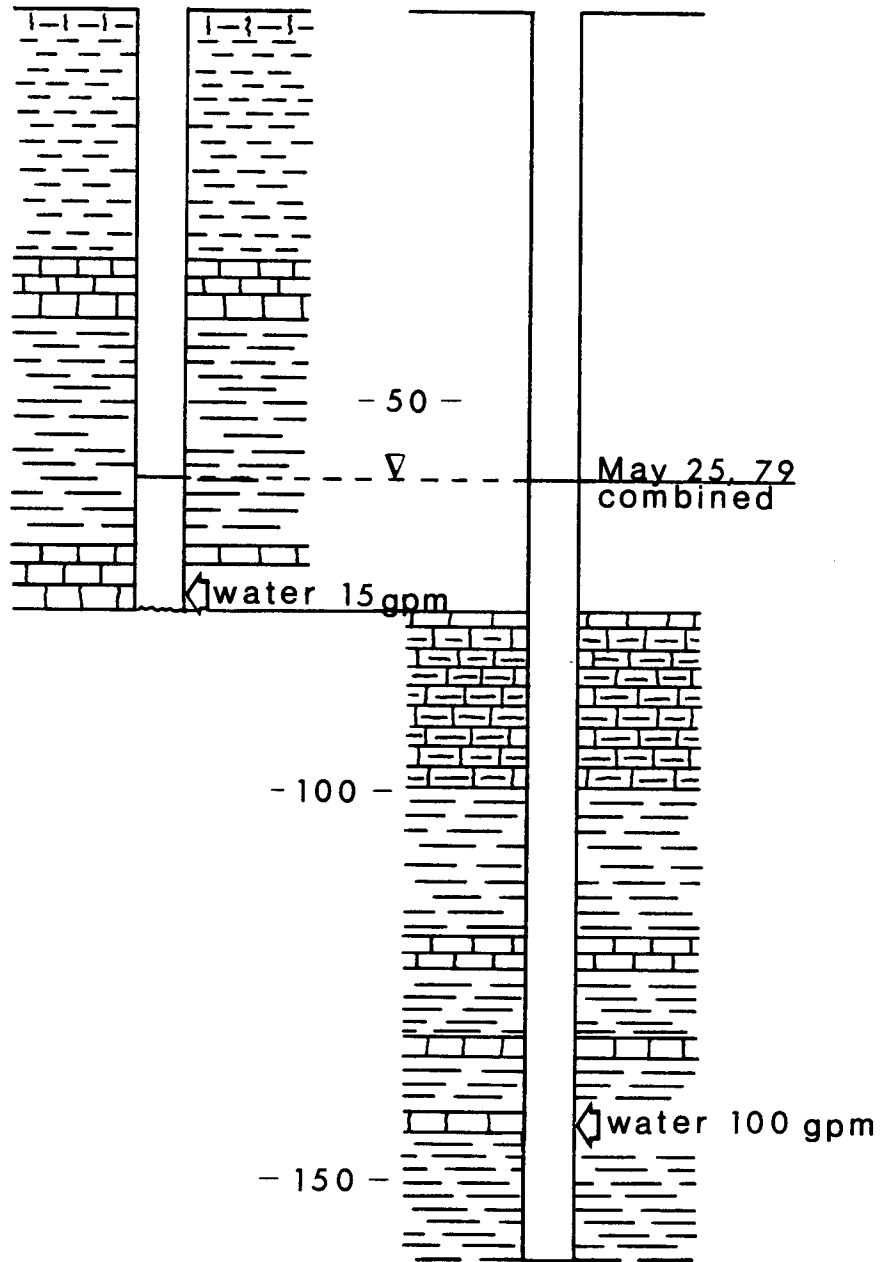


Figure 6. Test hole drilled for Tatarax Hills subdivision, Manhattan, Kansas.

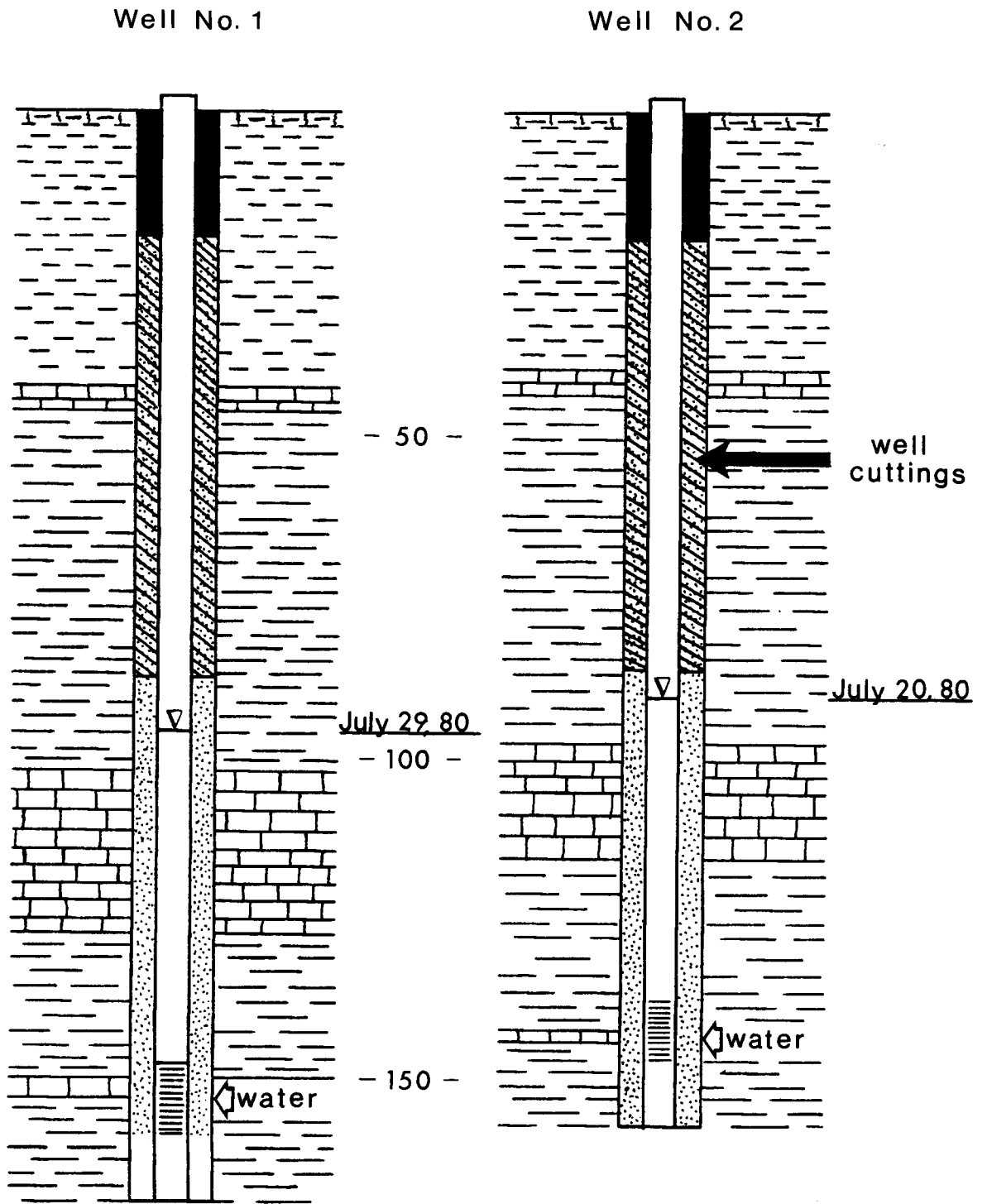


Figure 7. Water supply wells for Tatarrax Hills subdivision, Manhattan, Kansas.

pump test was performed on these two wells and the results showed substantial recharge to the lower zone after 13 feet of drawdown had occurred. In trying to explain this recharge to the aquifer, an investigation revealed that there were about 120 existing individual home water wells within one-half mile of the two Tatarrax wells. Reviewing available water well records in this area showed that many of the 120 wells had been completed in the lower aquifer with extensive gravel packs and were allowing water to enter the annular space of the wells from the shallow zone and drain to the lower zone. This caused water supply problems to homeowners with wells completed in the shallow zone.

Another problem from gravel packed well construction is contamination of a good quality aquifer by hydraulic interconnection with an aquifer of poorer quality.

Based on information from U.S. Geological Survey Water Supply Paper 1891, Figure 8 illustrates this problem in Finney County, Kansas. The figure shows that the Arkansas River Alluvium contains groundwater much higher in total dissolved solids than groundwater in the underlying undifferentiated Tertiary and Quaternary deposits.

A water well constructed in Garden City, Kansas, very near the Arkansas River is shown in Figure 9. The well construction in the figure is based on its WWC-5 record. The well has a 26-inch diameter borehole, 16-inch diameter casing, and a gravel pack from 10 to 205 feet. This depth would put the base of the well in the undifferentiated Tertiary and Quaternary deposits.

Depending on the hydraulic heads of the water-bearing zones penetrated and hydraulically interconnected by this well construction, a large amount of water could move either upward, constituting a waste of better quality water

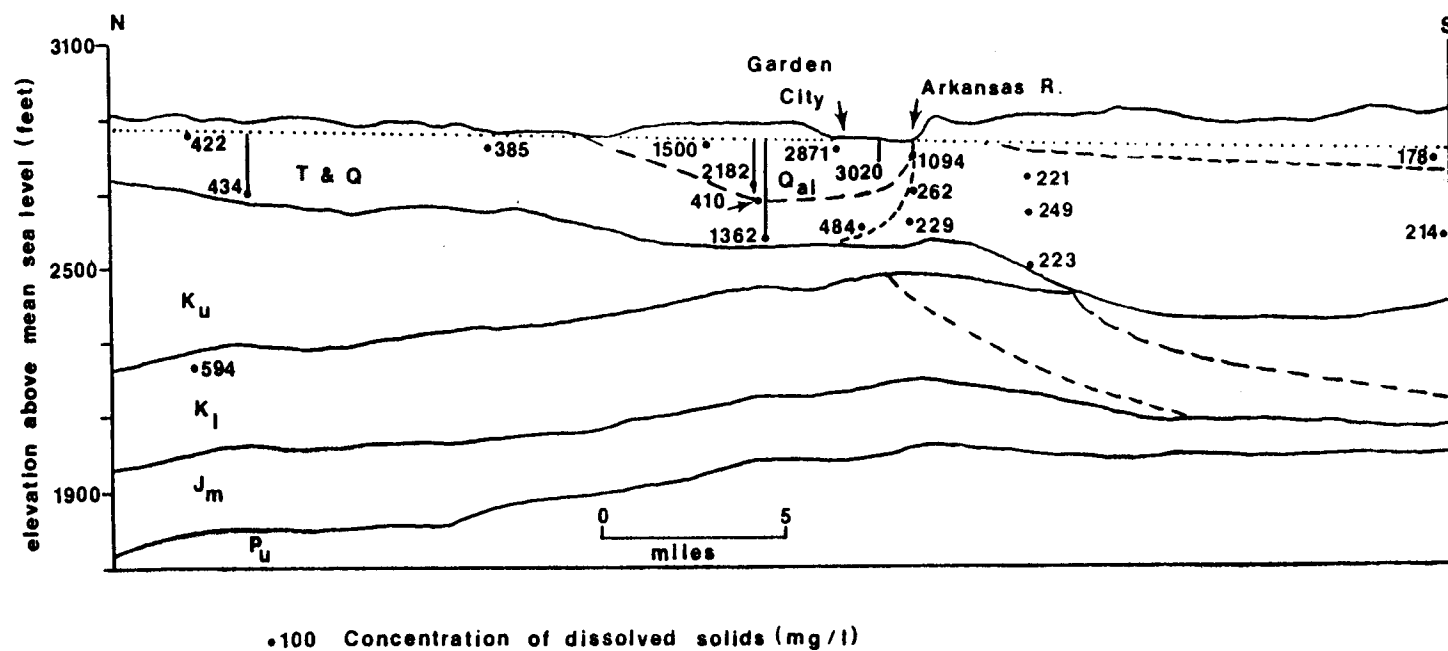


Figure 8. North-south section, showing total dissolved solids in groundwater, Finney County, Kansas.

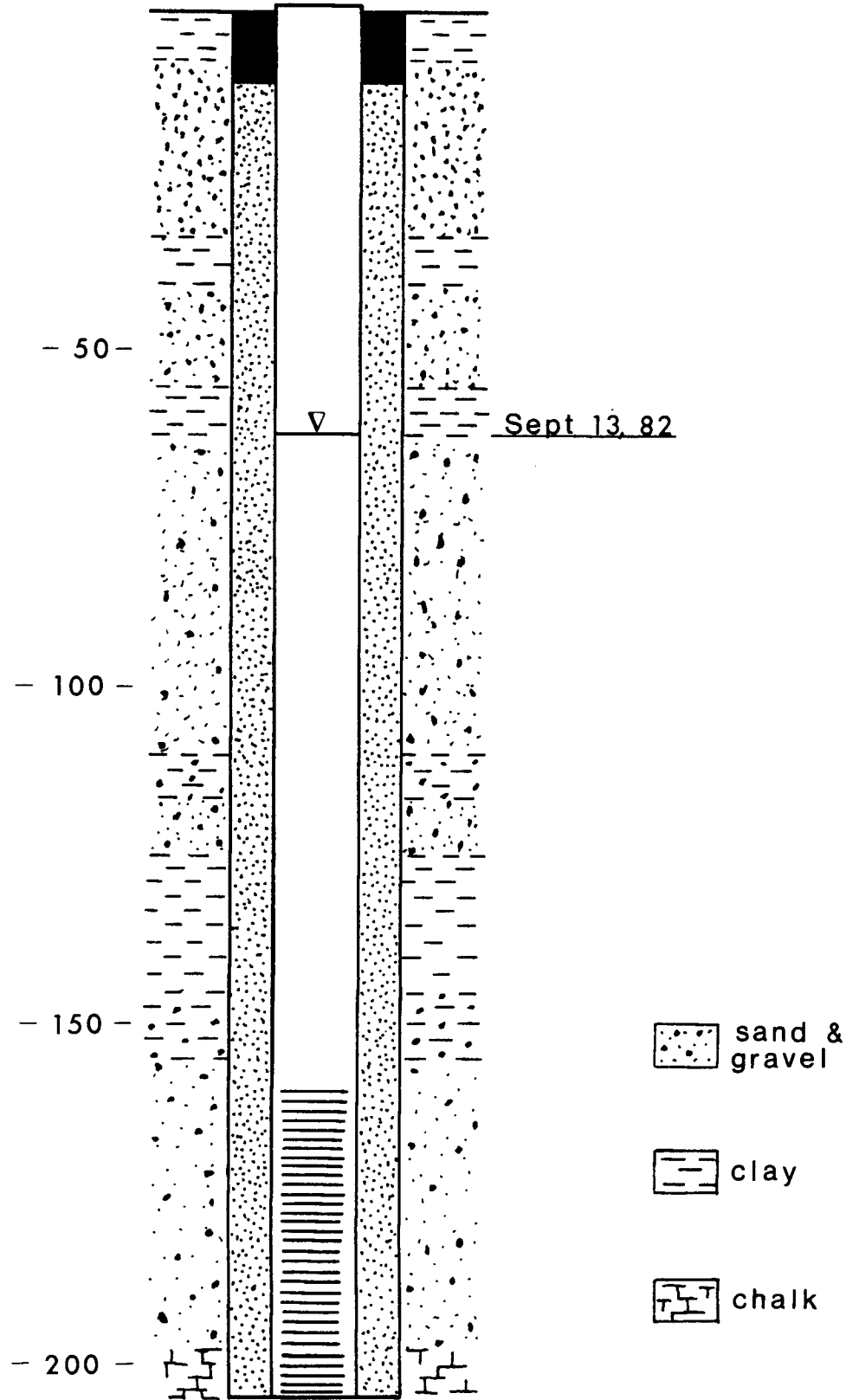


Figure 9. Gravel walled water well in Garden City, Kansas.

to a zone of poorer quality, or downward which would allow poorer quality water from the Arkansas River Alluvium to contaminate fresher water in the underlying deposits.

The improved design suggested for gravel walled wells can be illustrated in Figure 10(a) which is based on the WWC-5 water well record in Figure 1 from Butler County, Kansas. The improved design includes grouting the annular space opposite non-water-bearing zones, thus preventing movement and mixing of waters in the gravel pack and therefore enhancing the conservation and protection of groundwater resources.

Figures 1 and 10(a) show that the shallow water-bearing zone was grouted out and separated from the lower water-bearing zone because it contained 4,760 milligrams per liter of chloride constituting a very poor quality water.

Figure 10(b) shows a well approximately one-half mile from the well in 10(a). The shallower water-bearing zone in 10(b) was also grouted out in the annular space, possibly for the same reason of poor water quality. However, two other water-bearing zones were encountered in the lower portion of the well and they were hydraulically interconnected by the gravel pack.

This improved design would also facilitate the effective plugging of water wells after they have been abandoned. Two references previously cited (K.S.A. Chapter 82a, Article 12, and K.A.R. Chapter 28, Article 30) further require that all water wells and water-supply test holes that have been abandoned be properly plugged. After abandonment the casing would merely need to be filled with approved and properly positioned plugging materials with no fear of any movement or mixing of waters in the annular space of the well. Effective plugging would also be less expensive in this design as opposed to a gravel walled well that hydraulically interconnected two or more water-bearing zones.

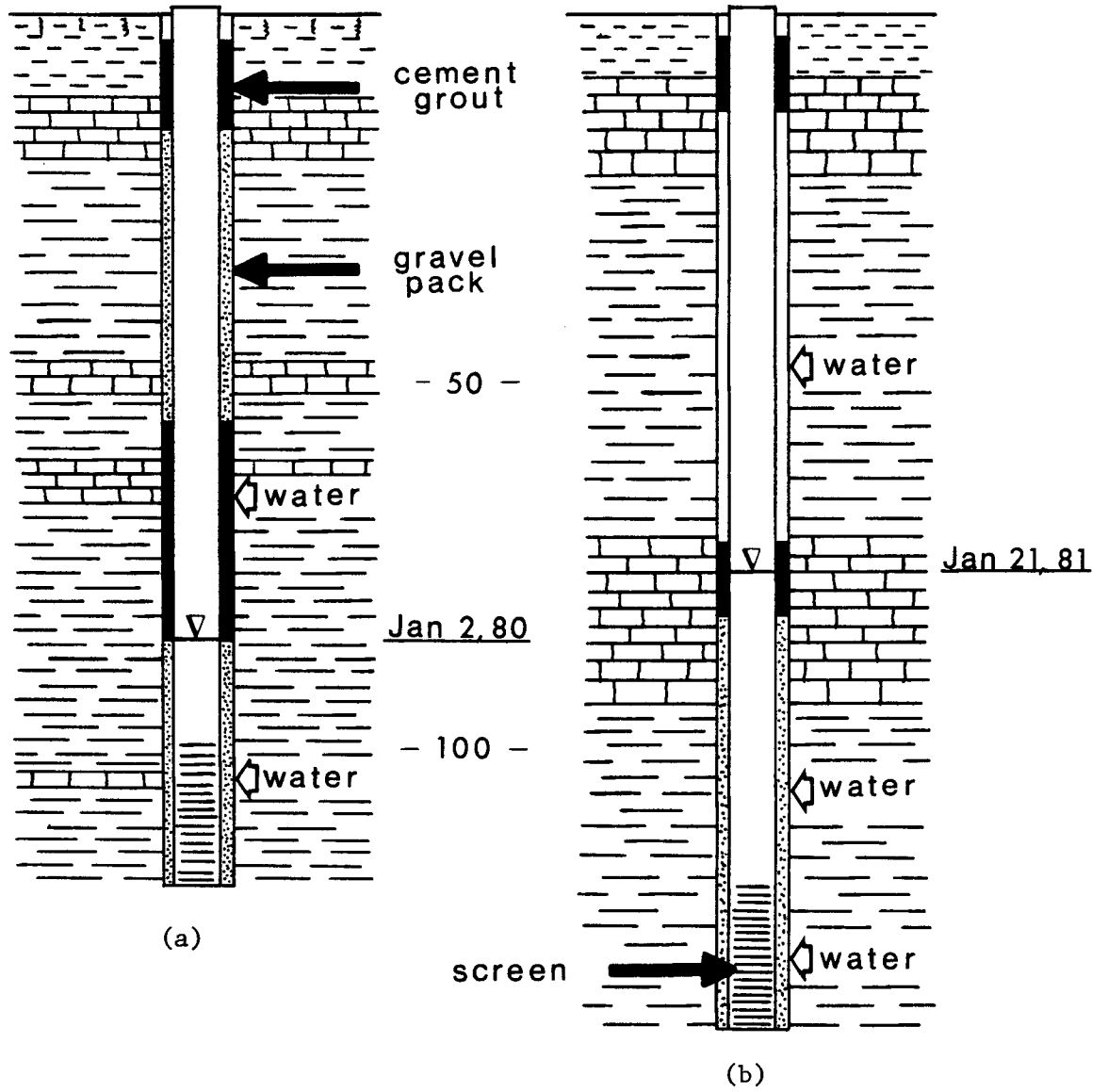


Figure 10. Examples of well construction in Butler County, Kansas.

In conclusion, it has been shown that waste and contamination of our groundwater resources is occurring in many parts of the state and that there is great potential for this continued occurrence owing to the increased use of gravel walled water wells. This waste and contamination occurs despite laws and regulations designed and administered to prevent it. More research is needed to strengthen these laws and regulations and help delineate other areas where these problems are critical.

By breaking up the interval of gravel pack in a water well with grout in the annular space between water-bearing zones, movement and mixing of waters will be prevented, thus enhancing conservation and protection of our groundwater resources. Also, effective plugging of abandoned water wells constructed with the improved design will be simple and inexpensive.

REFERENCES

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- Kansas Geological Survey, Public File of WWC-5 Water Well Records.
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