

Association of Missouri Geologists



W. M. DRESSEL
307 Christy Drive
Rolla, Mo. 65401

FOURTH ANNUAL MEETING AND FIELD TRIP

SPONSORED BY EMPLOYEES OF THE

U. S. ARMY ENGINEER DISTRICT, KANSAS CITY
CORPS OF ENGINEERS

SEPTEMBER 1957

PROGRAM

Friday, September 20

12:00 Noon -- Kansas City District Laboratory
1532 Grand Avenue (NW corner 16th and Grand)

Tour of District Laboratory

Transportation via bus to Manhattan, Kansas
by way of the Kansas Turnpike and new U. S. 40

7:00 P.M. -- Wareham Hotel, Manhattan, Kansas

Annual Dinner

"Geological Design Aspects of Tuttle Creek Dam"
Mr. C. R. Golder, Head, Geology Section

"Soil Design Aspects of Tuttle Creek Dam"
Mr. R. G. Fehrman, Civil Engineer (Soils)

"Flood, Drought, and Fears"
Mr. C. R. Van Orman, Assistant Chief,
Engineering Division

Business Meeting

Saturday, September 21

7:30 A.M. -- Wareham Hotel, Manhattan, Kansas

Field Trip Departure

12:30 P.M. -- Lunch in Manhattan, Kansas

5:30 P.M. -- Arrival in Kansas City, Missouri

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ACKNOWLEDGMENTS

The Arrangements and Publication Committee appreciates the assistance of their fellow employees in the preparation of this report, particularly to members of the Geology Section and Dams and Foundations Section who read this report critically.

The committee also appreciates the Corps of Engineers granting permission to reproduce plates from office reports.

INTRODUCTION

In 1938 Congress authorized the construction of Tuttle Creek Dam, recognizing that it was the key flood-control project of the Kansas River Basin. However, due to lack of funds construction was not initiated until 1952. During 1953 the First Stage was completed and at this writing the Second and Third Stages of construction are progressing simultaneously. These stages include the completion of the left bank embankment, partial right bank embankment, and the control outlet works. The Fourth Stage plans and specifications will be released in the near future and entail the completion of the embankment, with closure planned in July of 1959. Construction of the overflow spillway will be under separate contract and will progress simultaneously with the Fourth Stage.

This report was compiled from office studies and covers the geological design aspects of Tuttle Creek Dam. Reports dealing with the construction of several test fills of compacted shale and limestone may be of particular interest to members of the Association in construction work and are on file in the District Office, Corps of Engineers, Kansas City, Missouri.

R.J.L.
C.R.G.

A. GEOLOGY OF TUTTLE CREEK DAM SITE AND RESERVOIR

1. Surface features.

a. General location and description.—Tuttle Creek Dam is located at mile 12.3 on the Big Blue River which forms the boundary between Riley and Pottowatomie counties and is 6 miles north of Manhattan, Kansas (see plate 1). The axis of the dam extends southwest-erly across the NW 1/4 of section 19, T. 9 S., R. 8 E., and across section 24, T. 9 S., R. 7 E. The proposed reservoir at full pool, elevation 1136 feet, m.s.l., would extend northward approximately 50 miles into Marshall County, the northernmost part being about 2.5 miles south of Marysville, Kansas. The embankment will be about 7,500 feet long at the crest with a maximum height of 157 feet. It is composed of rockfill, compacted earth, dredged sandfill, and shale-limestone fill totaling about 20,000,000 cubic yards. The outlet works on the right (west) bank include an intake structure, twin conduits, and a stilling basin which are founded essentially on the Long Creek limestone. The spillway, a gated chute type, is located on the left (east) abutment. Excavation for the spillway accounts for a major portion of the shale and limestone removed and used in the upstream embankment and berm fill. The base of the crest structure will rest on the Sallyards limestone and the chute slab on an excavated slope cutting several shales and limestones.

b. Topography.—The major topographic forms in the dam and reservoir area are the Big Blue River valley bottom land bordered by adjacent steep river bluffs and hills. Topographic relief is on the order of 250 feet to 350 feet, ranging from about elevation 1025 feet, m.s.l., immediately below the dam, to about 1250 feet, m.s.l., on hilltops adjacent to the river valley. A number of limestones, including Three Mile, Eiss, and Cottonwood, form conspicuous, almost horizontal benches along the slopes of the Flint Hills and Big Blue River valley walls.

c. Physiography.—The dam and the major part of the reservoir to about Randolph, Kansas, are in the physiographic section known as the Osage Plains; the portion of the reservoir north of Randolph lies in the Dissected Till Plains section.

(1) Osage Plains.—The Osage Plains section is typically a "scarped plains," an area in which the rock strata dipping gently to the west have been beveled by an ancient erosion plane sloping at a low angle to the east and in which the more resistant rock layers stand out as eastward-facing escarpments.

(2) Dissected Till Plains.—The Dissected Till Plains section of Kansas is that part of the northeast corner of the State that was glaciated during Pleistocene time and is now covered by glacial drift. The Osage Plains section, lying to the south and west of the Dissected Till Plains, was not glaciated; and, hence, the included topography is somewhat different and, in terms of geologic time, much older than that of the Dissected Till Plains.

(3) Flint Hills.--The Flint Hills are a range of low hills forming one of the eastward-facing escarpments in east-central Kansas, extending in a north-south direction through the Osage Plains and Dissected Till Plains Sections, from Marshall County to Cowley County, Kansas. Tuttle Creek Dam and Reservoir lie within the northern portion of the Flint Hills.

2. Subsurface explorations.--Subsurface explorations for Tuttle Creek Dam included 264 drive holes, 69 six-inch core holes, 28 two and one-eighth inch (NX) core holes, 13 "push" holes (for undisturbed overburden samples), 5 test pits, and 41 auger holes. In addition, 29 drive holes, 6 core holes, and 4 test pits were drilled at alternate sites which have been abandoned.

3. Unconsolidated surficial deposits.--The alluvial flood plain at the dam is about 5,000 feet wide. Surface elevations range from 1022 to 1027 feet, m.s.l. The alluvial deposits vary in thickness from 40 feet to about 100 feet and consist of silt (ML) and clay (CL, CH, and OH) in the upper 8 to 27 feet and of sand and gravelly sand (SM, SP, and SW) below. The sand and gravelly sand deposits range in thickness from about 25 to 80 feet. (See plate 2).

4. An alluvial terrace, composed principally of soft clay, 1,500 feet wide, is found on the right side of the valley between elevations 1025 and 1075 feet, m.s.l., rising gently landward on a colluvial slope to the higher elevation at the foot of the right abutment ridge. The riverward portion of the terrace is underlain by approximately 50 feet of alluvial deposits consisting of 40 feet of clay (CH, OH, and CL including a 6-foot thick intermittent peaty deposit) above about 10 feet of sand (SP, SW, and SM) at the base. The higher portion of the terrace is underlain by 10 to 20 feet of clay (CH and CL) with a small amount of discontinuous sands at its base.

5. A clay similar to that of the right bank terrace extends riverward from the foot of the left abutment ridge. This material is not expressed topographically and has neither the lateral nor vertical extent of the right terrace. The clay blanket averages about 20 feet in thickness and is 500 feet wide at the dam axis.

6. Description of geologic members.--Only those rock horizons which lie within areas of excavation or are critically involved in foundations are described, descending in order from younger to older rocks. The rocks described are all of the Permian age and belong to the Council Grove group. Beneath the Council Grove group are 100 feet of similar Permian rocks and over 2,000 feet of shales and limestones of the Pennsylvanian age. The geologic units described herein are either of formation or member rank and no differentiation has been made in their stratigraphic classification. Only in cases of formations composed of several members is the member name used for descriptive purposes. Generally, the limestones may be described as argillaceous and the shales as calcareous. All excavated bedrock will be utilized in the dam as shale and limestone fill, which is the

run of material from required excavations. Berm fill consists partly of surplus material from excavated bedrock, and rockfill and protective stone selected material from the Neva and Cottonwood limestones. Reference is made to plate 2 which shows the geologic section at the dam axis.

a. Middleburg limestone.--A 3-foot horizon of fine-grained, gray, medium-bedded, fossiliferous limestone, capped by a thin layer of greenish gray shale and light brownish gray limestone each of about one-half foot thickness. It is excavated in minor quantities in the spillway area and found just at the top elevation of the dam in the right abutment.

b. Hooser shale.--A 9-foot brownish green and brown shale, in layers from one to 2 feet thick which are generally massive and blocky; predominately a claystone. It is excavated in minor quantities in the spillway area and found just below the top of dam in the right abutment.

c. Eiss limestone.--A 9.5-foot horizon of light gray, fine-grained, medium hard limestone, with a 2-foot brownish green, sub-fissile shale just above the middle of the member. This member forms one of the prominent markers on the valley walls of the Big Blue River. It is excavated in minor quantities in the spillway area and found in the upper portion of the right abutment.

d. Stearns shale.--Approximately 11.5 feet of claystone and clay shale in layers from a few inches to several feet thick. Limy streaks and nodules are common. It is generally firm and dark gray to a dark greenish color. It is excavated in minor quantities in the spillway area and found in the upper portion of the right abutment.

e. Morrill limestone.--A three- to four-foot fine-grained, medium hard, gray to brownish gray limestone with a one-half foot greenish gray shale parting near the middle. It is excavated in the spillway area and found at the top of dam elevation in the left abutment and just below the lower limit of maximum pool elevation in the right abutment.

f. Florena shale.--Six feet of gray or greenish gray fossiliferous shale in one-foot layers, fissile and subfirm.

g. Cottonwood limestone.--A prominent bench-forming, water-bearing limestone, characterized by a growth of shrubs along the valley wall outcrops. The cottonwood limestone is a fine-grained, massive, medium hard, light gray, fossiliferous rock, averaging 7 feet in thickness with a parting near the middle of the member. The upper one-half contains small pits and chert nodules. In the left abutment, the Cottonwood limestone lies just below maximum pool elevation and is extensively present in the spillway excavation area. It is also found in the central portion of the right abutment. The Cottonwood limestone is the most durable rock present on the project and will be

used for riprap and rockfill. It is not of the desired quality for concrete aggregate due to the pitted nature and chert nodule content. This bed will require grouting.

h. Eskridge shale.—One of the most prominent shales encountered on the project, the Eskridge, is 24 feet thick, in one- to three-foot layers, and of a massive, blocky nature. It is generally hard, of a greenish gray color with prominent thick maroon bands and a foot or more of limestone near the top and bottom of the formation. It is excavated extensively in the spillway area and used in the embankment in shale and limestone fill and berm fill. The Eskridge shale is found in the upper part of the left abutment and in the central portion of the right abutment.

i. Neva limestone.—The Neva limestone is the thickest limestone found on the project. This 18-foot member is separated by two shales, and the characteristics of the upper and lower parts are somewhat different. The upper one-half is a light gray, fine-grained, thick-bedded limestone of quality almost equal to the Cottonwood limestone. A less than one-foot green shale seam separates the 9-foot upper bed from a 6-foot light brownish gray, thick-bedded, medium hard limestone with abundant solution cavities, which consistently take all the water during core drilling operations. A foot or more of shale and a similar thickness of limestone are found at the bottom of the member. It is extensively excavated in the spillway area, the upper part of which will be utilized in rockfill and the lower part, in addition, as downstream-slope surfacing. This member, located near the base of the spillway cut, the upper central portion of the left abutment, and in the lower part of the right abutment, will require extensive grouting.

j. Salem Point shale.—An 8-foot horizon of greenish gray, firm fissile shale, in layers from partings to several feet thick, with a massive 3-foot horizon at the bottom. A 1.5-foot light gray limestone lies near the middle of the member. It is extensively excavated in the spillway area and forms the foundation for a part of the spillway training walls. The Salem Point shale lies in the central part of the left abutment and in the lower portion of the right abutment.

k. Burr limestone.—Approximately four feet of light gray to brownish gray, fine- to medium-grained, soft to medium hard, thick-bedded limestone, which is found in the lower part of the right abutment and in the middle of the left abutment. It is excavated from the spillway cut and present at foundation elevation for the downstream portion of the spillway training walls. The Burr limestone is water-bearing and will require grouting.

l. Legion shale.—The Legion shale is a black, fissile, subfirm, waxy, clay shale, 1.5 feet thick. It is persistent, easily recognized in cores, and is a reliable marker bed. It is excavated

in the foundation cut for the spillway crest structure and found in the central part of the left abutment and lower part of the right abutment.

m. Sallyards limestone.--The 2.5-foot thick Sallyards limestone is a light to dark grey, medium hard to hard limestone and of similar occurrence as the Legion shale. The spillway structure will be founded on this limestone.

n. Roca shale.--A prominent shale, 23 feet in thickness, the Roca shale is massive, firm, and a greenish gray color with a reddish brown shale zone near the middle of the member. Four thin limestone zones, often dolomitic, are spaced throughout the member. It is excavated in the spillway pilot channel below the slab, and found near the center of the left abutment and in the lower part of the right abutment.

o. Howe limestone.--A 5-foot brownish gray, medium hard to hard limestone. It is one of the more pervious limestones and has an occurrence similar to that of the Roca shale.

p. Glenrock limestone.--The Glenrock limestone is a thin member, about two feet thick, light gray, fine-grained, well-jointed, thick-bedded, and hard. Minor amounts of Glenrock limestone will be excavated from the spillway outlet channel and a smaller amount from the outlet works area.

q. Johnson shale.--This is primarily a clay shale and occurs in a 23-foot section. Two persistent layers of argillaceous, medium hard limestone are usually present. Each layer is slightly less than one-foot thick; one is approximately six feet from the top of the section, the other about seven feet from the base.

r. Long Creek limestone.--The Long Creek limestone is an important member because it is used as the foundation stratum for the outlet works conduits, intake tower, and adjacent approach walls. Approximately seven feet of medium hard limestone is present in the area. Bedding ranges from three inches to a foot in thickness, sometimes discontinuous, with occasional thin, intermittent shaly partings. Small pits are abundant in a persistent porous zone one-half foot thick, about two feet from the top of the member. Joints are nearly vertical, spaced 2 to 10 feet apart, and orientated either nearly perpendicular to or paralleling the axis of the conduits. In the upper foot, there are frequent pink celestite encrustations, and narrow weathered zones of softened rock along most of the joints, more than half of which are open. Some are weathered and open to depths of one to three feet, but most are tight and healed with calcite, below a continuous free-parting bedding plane about one foot below the top of the formation. Some Long Creek limestone will be excavated in the spillway outlet channel area and treated as shale and limestone fill.

s. Hughes Creek shale.--The Hughes Creek shale is a member totaling 37 feet in thickness, and ranging from light gray to nearly black in color. Approximately 40 percent of the member consists of light gray, shaly limestone; fine- to medium-grained, fossiliferous, usually with numerous shaly partings, and ranges in hardness from very firm to hard. The remaining 60 percent of the member is dark gray to black, laminated, with some fissile shale which is generally firm to hard. The member shows considerable strength as a foundation shale. The larger portion of the Hughes Creek shale to be excavated will come from the outlet works stilling basin. A smaller amount will be excavated from the spillway outlet channel and will be used in the shale and limestone fill.

t. Americus limestone.--The Americus limestone is gray, fine- to medium-grained, shaly, medium-bedded, medium hard, and about four feet in thickness. A persistent black, fissile, subfirm to firm shale bed about 1.5 feet thick lies near the center of this member. The Americus limestone will not be involved in the excavation but is in contact with the flood-plain alluvium below the valley.

7. Geologic structure.--The rock strata in the area of the dam in general, have an average regional dip of about 30 feet per mile in a direction a little north of west. Local variations are common but of little magnitude and of no anticipated major importance with respect to design and construction of the dam structures. However, there is one important exception, a fault, tending eastward, in the upstream part of the spillway approach channel.

a. Fault.--The fault crosses the left abutment about 200 feet upstream from the left side of the chute spillway and enters the right abutment ridge about 4,000 feet upstream from the dam axis. (See plate 1 for location of the fault in the spillway.) The fault plane dips at about 72°; the downthrow is to the north, with a displacement of about 30 feet. The fault appears to be tight, and ground-water seepage through the fault will probably be restricted.

b. Jointing and weathering.--The joint pattern, spacing of joints, weathering along joints, and presence of open or closed joints in the shale and limestone members of the conduit area vary, but within any one zone the jointing, in general, is similar. This also appears to be the case in the left abutment and spillway area. The jointing in the bedrock of the dam site exhibits a wide range of characteristics; the joints may be closely to widely spread; some are open, others are tight or closed by mineral fillings; the rock surfaces may be relatively unweathered and durable; or, as in the case of the Long Creek limestone, exposed during construction of the conduit, parts of the rock were shown to be weathered to a depth of two to three feet and were several square feet in area. Shales are generally weathered to depths of 50 to 75 feet in the abutments, resulting in some softening, especially along bedding planes and joints. The upper 5 to 10 feet of the weathered zone may be partially altered to clay. The weathering of interbedded limestones is characterized by

iron stain along well developed joints and somewhat porous solution-formed honeycomb zones, some partially clay filled. The development of the solution channeling in the limestones may extend below the depth of general weathering for 50 to 100 feet, to about flood-plain elevation.

8. Excavation.—While the bedrock materials involved in required excavation are not to be classified with igneous rocks, such as granite, neither are they of the soft type as are poorly consolidated and cemented shales of some Tertiary sediments. The range of hardness, consolidation, and cementation, of the rocks in the Tuttle Creek Dam area is from fissile clay shales at one extreme to hard limestone at the other.

9. Most of the shales, and all of the thicker limestones, have required systematic drilling and blasting, both to facilitate removal and obtain proper fragmentation. During the First Stage contract some of the shales and thin limestones were excavated with power shovels without blasting, but uniformity of break for use in the embankment and cost, both of the equipment repair and additional treatment required for processing on the fill, limited this method of excavation.

10. Structural excavation may require close tolerances and such can be obtained in shales (as long as too much "tailoring" of the rock is not required and cuts are limited to plane surfaces) by the use of chain type saws similar to those used in coal mines. Modifications of this equipment to suit the intended use and desired results may be necessary. Fresh, softer limestones may lend themselves to the above treatment, but line drilling will probably be the accepted practice.

11. Either shale or limestone may break back to the nearest well-developed joint regardless of the care or method used in excavation. This means that many lines and grades of the structure foundations will be finally determined in the field.

12. Slaking of shales.—Rock of the type termed shale may vary considerably within any one member. Shales, however, containing between 8 and 12 percent moisture will commence to dry out when exposed to the atmosphere, evidenced by cracking and ultimate breakdown of the rock, termed slaking. The severity and rapidity with which slaking will take place varies from one member to another, under any given conditions.

13. Excavated structural foundation surfaces should be protected from this moisture loss to preserve the firm shale surface in a satisfactory condition for the placement of concrete. Horizontal surfaces may be covered with a blanket of lean-mix-fill concrete immediately after excavation cleanup, treated with asphaltic or curing compounds, or a water mist spray used to maintain a damp shale surface. Where it is necessary that the surface also withstand construction traffic, the use of the fill concrete is indicated. Vertical or inclined surfaces are best treated with materials which are amenable to spray

application or the water mist. Care should be taken when water is used to see that the surface does not become overmoistened, resulting in extreme softening of certain shales. In no case have shale excavations remained open, even if treated, longer than was necessary, and construction work was planned with this in mind.

14. Reservoir leakage.--The sequence of rock strata in the reservoir area is similar to that found in the abutments at the dam. No breaks in the valley walls in the form of filled glacial channels have been recognized. (The regional dip is generally at right angles to the Big Blue River valley in a westerly direction at about 30 feet per mile.) Recharge of the exposed strata will have a tendency to raise the water table locally, but no far-reaching effect, either of a beneficial or adverse nature, is anticipated. The abutments of the dam will, however, receive grouting treatment which is discussed in paragraph 21.

B. STRUCTURE FOUNDATIONS AND ABUTMENTS

15. Outlet works.

a. Conduit foundation.--The upper 25 to 30 feet of bedrock strata at the outlet works site have been weathered and bedding planes and vertical joints are fairly well developed. The 5-foot Howe limestone is the upper member on the landward side of the outlet works area and is underlain by about 4 feet of subfirm, closely fractured Bennett shale. On the riverward side of the area, all of the Howe limestone and most of the Bennett shale have been removed by erosion. Below the Bennett shale, forming the natural bedrock surface in part of the area, is the 2-foot Glenrock limestone, a relatively hard but jointed rock. The Johnson shale, below the Glenrock limestone, is about 23 feet thick, composed of several types of shale with a few thin limestone layers. The shales range in strength from weak to firm. A weak zone, near the base of the Johnson shale, varies from a few inches to about 2 feet in thickness and is sometimes the consistency of clay. This zone was responsible for sliding during the conduit excavation under the Stage I construction. Joints in the Johnson shale are nearly vertical, generally smooth and regular, and rarely extended through more than one bed. The joint spacing varies from a few inches to several feet and the joint pattern shows trends nearly parallel and normal to the conduit axis.

b. The foundation elevation of the intake tower and conduits is based on top of firm Long Creek limestone. It was necessary, therefore, that this surface be determined, within reasonably close limits, for the entire area of the outlet works foundations by core drilling, before final design was accomplished.

c. Approach channel.--The approach channel is underlain by Long Creek limestone where its surface elevation ranges from 998 to 999 feet, m.s.l., for a distance of at least 300 feet upstream from

the control tower. Weathered Johnson shale will be excavated to form the lower 10 to 20 feet of sideslopes. Upstream, the channel is entirely in overburden - terrace clay and flood-plain alluvium.

d. Intake tower.--Results of test drilling indicated that the Long Creek limestone was present throughout the intake tower area approximately at elevations 997.5 to 999.0 feet, m.s.l., with a dip of about one percent landward and downstream. This surface, presented deviations of as much as one foot from indicated limits or the indicated slope. Hence, design for the intake tower assumed a firm foundation line one foot below the top of the Long Creek limestone.

e. Stilling basin and outlet channel.--The bottom of the stilling basin floor slab and walls are founded at elevation 977 feet, m.s.l., in the Hughes Creek shale member, a comparatively strong type of shale. It is considered to be adequate for the foundation but required protection from exposure to prevent surface slaking.

f. The Long Creek limestone forms a natural resistant still about 7 feet thick at the downstream end of the stilling basin. The natural surface of the limestone rises gradually downstream reaching approximately elevation 1002.5 feet, m.s.l., about 1,500 feet downstream from the dam axis. The limestone, presumably, continues to rise until cut off by erosion between 2,000 and 2,500 feet downstream but will be cut through beyond about 1,500 feet downstream as the bottom of the outlet channel is placed at elevation 995.0 feet, m.s.l.

g. The overlying Johnson shale will offer more resistance to erosion than would local unconsolidated sediments in the discharge channel but would doubtless undergo lateral erosion during periods of high water discharge. Protective measures have been considered for a distance of several hundred feet downstream from the stilling basin where the channel will probably not be excavated deeply enough into limestone to provide good sidewall protection.

16. Spillway.--Earlier investigations disclosed the large fault in the left abutment area and the spillway structures were moved downstream in order to be sufficiently removed from this anomaly. Spillway excavation involves the removal of the range of members as shown on plate 3. Other than the separate excavation of the Cottonwood and Neva limestones for special uses as riprap and rockfill, no special quarrying is required.

17. The overflow structure foundation is to penetrate the Salem Point-Burr-Legion sequence, the combined thickness of which is approximately 10 feet.

18. A sloping concrete slab extends downstream for 600 feet and crosses the Salem Point shale and Burr limestone which are also the foundation strata for the adjacent side walls of the spillway chute. Flip bucket excavation extends through the Sallyards limestone and upper few feet of Roca shale while the downstream scour protection

cutoff is to penetrate the Roca shale to the underlying Howe limestone. The upstream keywall of the flip bucket extends about 10 feet into the Roca shale. Lower rock members and overburden will be excavated in the spillway pilot channel through the Hughes Creek shale and possibly a little of the underlying Americus limestone.

19. Minor geologic structural and stratigraphic variations in the slab and cutoff area have been investigated by core borings to determine spillway chute side wall footing elevations. The degree of tolerance to lines and grades to which the contractor will develop these foundations depends upon specified results and field inspection. This may range from machine working of shale to line drilling and hand removal of limestone.

20. Other than tailoring the foundation rock for the chute side walls and protecting shales from surface drying and slaking during construction, no difficulties in the spillway area are anticipated.

21. Abutment grouting.

a. Pervious members.—The alternating sequence of limestones and shales as found in the Permian members at the dam site strongly suggests that flow of underground water through these rocks would be of a lateral nature. Further, the natural exposure along the valley walls are the more resistant limestone, certain ones marked by a growth of trees or shrubs, indicating the aqueous nature of the beds. Thus, in general, the shales are essentially impervious and the limestones are water bearing to a moderate degree.

b. Well-developed open, water-bearing channels are infrequent in these limestones. No cavities are indicated in outcrops or six-inch core samples with a vertical dimension of over one-half foot and with a similar lateral range, and these are of a limited length. The water-bearing zones, for example, in the Neva, Cottonwood, and Long Creek limestones are more of a honeycomb nature, with clayey material often partially filling the openings, which in turn are not continuously connected in any one direction. During core drilling operations, a 100 percent loss of drilling water was usually experienced in the lower Neva limestone.

c. General treatment.—A grout curtain is proposed in both abutments and the spillway area as shown on plate 6. In addition, an impervious upstream blanket will extend up both abutment slopes to contact the Eskridge shale. Grouting will be accomplished by the contractor after completion of the structure in the spillway and prior to placing the embankment fill on the abutments.

d. The full grouting program is scheduled to be performed under several contracts as shown on plate 6. Completion of the grout curtain across the spillway and adjacent areas is presently scheduled for a separate grouting contract. The Stage III contract grouted

riverward from the outlet works to the limit of the Long Creek limestone and on the left abutment to the top of the dam elevation. Right abutment grouting beneath the embankment will be done by the Stage IV contractor. The entire program will be flexible with appropriate changes being made, as required, from experience gained as construction progresses. No grouting is scheduled in the abutments above the elevation of the top of dam.

e. Extent of grout curtain.

(1) Right abutment.--At the right abutment the embankment slopes are relatively steep to minimize length of the conduits and embankment stability considerations contemplate controlling seepage to reduce uplift pressure in the foundation. In the vicinity of the conduits, this is accomplished by extending the grout curtain through the Long Creek limestone and by drainage of this bed behind the stilling basin sidewalls. Beyond the conduit, the bottom of the curtain steps progressively up the slope. Depth at the end of the embankment will include at least the particularly pervious lower part of the Neva limestone and will be deepened slightly to also include the relatively pervious Burr and Sallyards limestones in order to equal the probable depth of any future extension of the grout curtain into the abutment. It is expected that the need for any such extension of the curtain will be determined principally by leakage experienced from the outcrops or near outcrops of these three limestone beds in the tributary valley lying immediately west of the dam (see plate 1).

(2) Left abutment.--At the left abutment, the narrow ridge left between the embankment and spillway excavation results in a somewhat greater seepage problem. Beneath the abutment slope, the grout curtain extends downward to include the Long Creek limestone and it is contemplated that drainage near the downstream toe of the dam will be obtained by tapping this bed, most probably by a local deepening of the relief well drainage ditch. Beneath the spillway structure, the depth of the curtain includes the Howe and Glenrock limestones and was so established for controlling uplift beneath the crest structure and downstream chute slab. Design of the spillway is arranged for addition of a stilling basin should experience show this necessary, and in such event, grouting across the spillway would need to be extended through the Long Creek limestones to control uplift beneath the stilling basin slab. Considering this possibility, and more importantly the improved control of seepage around the end of the embankment, the curtain between the spillway and end of the embankment has been deepened slightly to include the Long Creek bed. The curtain is terminated about 300 feet beyond the spillway structure by its intersection with the major fault which is considered relatively impervious and thus likely to obviate the need for any future lateral extension of the curtain into the abutment. Some special grouting may be necessary at each end of the spillway crest structure.

f. Grouting method.--Since the principal objective is to grout the limestone beds, the intervening shale beds being relatively tight, it is planned to use the stop grouting method. This involves drilling grout holes to their full depth and beginning with the lowest horizon, grout each named limestone horizon in turn, with a packer set immediately above it. Any shale beds or thin limestones within the shale which will take grout, are also grouted in conjunction with the named limestone bed immediately above. For these conditions, the stop method was chosen, since it is understood the Fort Worth District has had good success with it in reasonably comparable shale-limestone formations and because it is cheaper than the stage grouting method.

g. One line of grout holes will be located along the axis of the dam in the abutments and immediately upstream of the spillway crest structure, (see Sections L-L and M-M, plate 6) initially drilled to full depth with primary holes spaced on 10-foot centers and additional holes determined by the split-spacing method. Grout pressures will be carefully limited and controlled. Grout holes will be drilled 30 degrees from the vertical in a landward direction in each abutment in order to increase the possibility of intersection with the nearly vertical joints present in the bedrock. Maximum vertical depth of the grout curtain will be 150 feet.

FIELD TRIP GUIDE

Eastern Kansas

1957

(From Kansas City to Manhattan,
Kansas via the Kansas Turnpike, US
Highway 40, and Kansas Highway 13.)

prepared for the
MISSOURI ASSOCIATION OF GEOLOGISTS

by the
STATE GEOLOGICAL SURVEY OF KANSAS,
UNIVERSITY OF KANSAS, LAWRENCE

Road log by
John M. Jewett and Daniel F. Merriam

ROAD LOG

Cumulative Mileage Mileage

		Welcome to the Sunflower state; population: 1,905,299 (1950); area: 82,276 square miles; capital: Topeka. Enter Kansas Turnpike at 18th Street Interchange, Kansas City, Kansas.
0.00	0.00	Off ramp onto Turnpike.
0.1	0.1	Drum limestone (above) underlain by Cherryvale shale (Quivira shale and Westerville limestone members).
0.3	0.2	Drum and Cherryvale on right (north) and Kansas River valley on left. Base of Westerville limestone member not exposed.
0.9	0.6	Overpass.
1.0	0.1	Exit - West Kansas City.
1.1	0.1	Loess exposures on both sides of road.
1.7	0.6	Chanute shale overlain by Iola limestone.
2.2	0.5	Lane shale overlain by Wyandotte limestone (Frisbie to Argentine members).
2.6	0.4	View of Kansas River on left (south).
2.8	0.2	Iola limestone exposure.
3.1	0.3	Overpass.
3.5	0.4	Loess on both sides of road. Note slump.
3.7	0.2	Underpass - 61st Street, Kansas City.
4.2	0.5	Underpass - 65th Street, Kansas City.
4.4	0.2	Loess on both sides of road.
4.75	0.35	Underpass - Bridge 300 A.
5.0	0.25	Wyandotte limestone exposures.

5.1	0.1	Underpass - 72nd Street, Kansas City.
5.5	0.4	Toll station - Kansas City.
5.9	0.4	Overpass.
6.8	0.9	Underpass - 86th Street, Kansas City. Small outcrop of Farley limestone (Wyandotte) on right.
7.7	0.9	Bonner Springs shale - Plattsburg limestone (above) on both sides of road.
7.9	0.2	Overpass.
8.0	0.1	Bonner Springs - Plattsburg.
8.2	0.2	Farley (Wyandotte) - Bonner Springs - Plattsburg.
8.25	0.05	Farley (Wyandotte).
8.4	0.15	Overpass.
8.9	0.5	Bonner Springs - Plattsburg.
9.9	1.0	Underpass - 110th Street (K 107), Kansas City.
10.6	0.7	Stranger formation (Tonganoxie sandstone).
10.9	0.3	Overpass.
11.3	0.4	Tonganoxie sandstone.
11.5	0.2	Underpass - Riverview Road.
12.1	0.6	Exit - Bonner Springs and K 7.
12.2	0.1	Underpass - Bonner Springs Interchange.
12.5	0.3	Underpass - K 7.
13.0	0.5	Overpass.
13.4	0.4	Top of Stanton limestone.
13.9	0.5	Bonner Springs shale.
14.0	0.1	Underpass - 142nd Street, Kansas City.
14.4	0.4	Overpass over Santa Fe Railroad.
14.55	0.15	Overpass.
14.8	0.25	Underpass - Kansas Avenue.
14.9	0.1	Bonner Springs and Plattsburg limestone.
15.3	0.4	Stanton formation, all members exposed.
15.6	0.3	Tonganoxie sandstone.
16.1	0.5	Underpass - De Soto Road.
17.1	1.0	Underpass - Bridge 289.
18.1	1.0	Underpass - Bridge 282.
19.1	1.0	Underpass - Bridge 281.
19.9	0.8	Underpass - Bridge 279.
20.4	0.5	Stranger Creek Bridge. Note wide valley and flood plain.
21.4	1.0	Stanton limestone exposures on both sides of road.
22.3	0.9	Underpass - Bridge 277.
22.9	0.6	Sand and silt filled channel in Stranger formation.
23.25	0.35	Haskell limestone member (Stranger formation) on right (poor exposure).
23.4	0.15	Underpass.
23.5	0.1	Stranger formation.
24.5	1.0	Underpass - Eudora Road.
24.7	0.2	Tonganoxie sandstone.
25.6	0.9	Bridge.
26.5	0.9	Tonganoxie sandstone.

26.95	0.45	Underpass.
27.0	0.05	Lawrence Service area - water supply from well in Tonganoxie sandstone.
27.8	0.8	Underpass - Bridge 272.
29.2	1.4	Stranger formation exposures.
29.7	0.5	View of Lawrence and Kansas River valley.
29.9	0.2	Underpass - K 32.
30.2	0.3	Bridge.
30.5	0.3	Overpass - Union Pacific Railroad.
30.8	0.3	Bridge. Oread limestone scarp ahead. Note meander scars on terrace.
31.5	0.7	Overpass - Westvaco Chemical Company, gravel and sand pit to left.
31.9	0.4	Overpass. Airport to right.
32.5	0.6	Overpass.
32.7	0.2	Exit - East Lawrence. Lawrence is the home of the University of Kansas and Haskell Indian Institute. The State Geological Survey is located on the University Campus in Lindley Hall (Mineral Resources Building). Visitors are always welcome.
32.95	0.25	Overpass - US 40 and US 24.
33.1	0.15	Bridge over Kansas River.
33.7	0.6	Overpass.
33.8	0.1	Cut in low terrace on right.
33.9	0.1	Underpass - Michigan Street, Lawrence.
33.95	0.05	Exit - West Lawrence.
34.3	0.35	Underpass - West Lawrence Interchange.
34.45	0.15	Underpass - Country Club Road.
34.9	0.45	Road on terrace. Oread limestone scarp to left and ahead.
35.5	0.6	Underpass - Lake View Alternate Road.
36.5	1.0	Bridge over Baldwin Creek.
37.2	0.7	Complete Oread limestone exposure from the Toronto (and upper Lawrence shale) to Kereford limestone.
37.5	0.3	Underpass - Harrison Well Road. Lecompton scarp ahead.
38.0	0.5	Plattsmouth limestone and underlying Heebner shale members of the Oread limestone on both sides of road.
39.3	1.3	Lecompton limestone exposure (Spring Branch to King Hill members).
39.55	0.25	Underpass - Kanwaka Road - Biel limestone member of the Lecompton exposed.
39.85	0.3	Lecompton (Biel down to Spring Branch and coal bed in underlying Stull shale).
40.2	0.35	Lecompton complete (Spring Branch to Avoka members).
40.5	0.3	Lecompton limestone exposure on both sides. Deer Creek limestone ahead.
41.1	0.6	Tecumseh shale and lower part of the Deer Creek limestone.
41.6	0.5	Overpass - Lecompton Road.
42.2	0.6	Deer Creek limestone (complete) and upper Tecumseh shale.
42.55	0.35	Overpass.

42.8	0.25	Upper part of the Tecumseh and lower part of the Deer Creek.
44.6	1.8	Underpass - Lecompton Alternate Road.
45.9	1.3	Basal part of the Topeka limestone.
46.1	0.2	Underpass - Big Springs Road.
46.6	0.5	Overpass.
46.7	0.1	Top of Calhoun shale (note crossbedding), and basal Topeka limestone.
47.5	0.8	Basal Topeka limestone exposures on both sides of road.
47.6	0.1	Overpass - US 40.
48.2	0.6	Lower part of the Topeka limestone.
48.6	0.4	Underpass - Miliken Road.
48.8	0.2	Topeka limestone (Hartford - Curzon) on both sides of road.
49.0	0.2	View of the city of Topeka.
49.8	0.8	Ervine Creek limestone (above), Larsh - Burroak shale, and Rock Bluff limestone (members of the Deer Creek limestone).
50.3	0.5	Ervine Creek to Rock Bluff.
50.55	0.25	Calhoun shale and lower Topeka limestone (above).
50.7	0.15	Underpass - Earl Hall Road.
51.1	0.4	Deer Creek limestone (Rock Bluff to Ervine Creek).
51.55	0.45	Deer Creek limestone (Rock Bluff to Ervine Creek).
51.7	0.15	Calhoun shale.
52.1	0.4	Topeka limestone (Hartford limestone member).
52.3	0.2	Underpass - Tecumseh Road.
52.9	0.6	Topeka service area entrance.
53.25	0.35	Topeka limestone (Hartford to Dubois limestone well exposed).
53.8	0.55	Underpass - Croco Road.
54.2	0.4	Exit - East Topeka.
54.4	0.2	Underpass - East Topeka Interchange. Exposure of basal Topeka limestone.
54.9	0.5	Underpass Wittenberg Road.
55.6	0.7	Underpass - 29th Street.
55.7	0.1	Basal Topeka limestone and upper Calhoun shale.
55.9	0.2	Lower Topeka limestone.
56.4	0.5	Overpass - California Street, Topeka.
57.0	0.6	Overpass.
57.5	0.5	Sandstone in Severy shale.
57.7	0.2	Overpass.
58.05	0.35	Howard limestone - Nodaway coal and overlying Church limestone.
58.4	0.35	Nodaway coal and Church limestone.
58.5	0.1	Overpass - Santa Fe, Missouri Pacific Railroads, and US 75.
58.8	0.3	Exit - South Topeka. Slow - keep right - enter ramp.
59.05	0.25	Toll Station - South Topeka.
59.2	0.15	Over cloverleaf - straight ahead - overpass over US 75.
59.6	0.4	Enter US 75. You are now going north toward downtown Topeka.
60.6	1.0	Highway Commission Building on right.
60.9	0.3	Stoplight at 29th Street.
61.35	0.45	Kansas National Guard Armory.
61.95	0.6	Stoplight. Turn left (west) on 21st Street.

62.05	0.1	Bridge across Shunganunga Creek. Kansas Free Fairgrounds on right.
62.5	0.45	Stop (4 way) - 21st and Buchanannan Streets.
62.7	0.2	Washburn University Campus on right.
63.7	1.0	Stop - 21st and Oakley Streets. Winters Veterans Administration Hospital on left.
64.2	0.5	Stop 21st and Gage Streets. Turn right on Gage (north).
64.7	0.5	Stoplight at 17th and Gage Streets. Continue north on Gage.
65.7	1.0	Stop - (4 way) 10th and Gage Streets. Turn left (west) on 10th. Gage Park on right.
65.9	0.2	Gage Park zoo on right.
67.7	1.8	Turn right (north) on Wannamaker Road - Straight ahead for west on US 40 - use cloverleaf - curve right on ramp.
68.1	0.4	Enter US 40 and go under Interchange underpass. You are now heading west on US 40 which is a limited access highway.
68.7	0.6	Bridge.
68.8	1.1	Silver Lake shale overlain by Burlingame limestone*.
70.8	1.0	Overpass.
71.1	0.3	Exit - Auburn Road and overpass.
71.4	0.3	Auburn shale.
72.05	0.65	Emporia limestone (Reading limestone member).
72.4	0.35	Reading limestone overlying Auburn shale.
72.8	0.4	Bridge.
73.0	0.2	Auburn shale and overlying Emporia limestone.
73.4	0.4	Bridge.
74.2	0.8	Valencia Road.
74.7	0.5	Willard shale.
75.05	0.35	Tarkio limestone and Wamego shale (above) members of the Zeandale limestone and Willard shale (below).
75.4	0.35	Tarkio limestone outcrops both sides of road.
75.7	0.3	Tarkio underlain by Willard shale.
76.0	0.3	Upper part of the Emporia formation.
76.1	0.1	Emporia and Auburn on left.
76.5	0.4	Exit - Vassor Road.
76.7	0.2	Overpass.
76.8	0.1	Willard overlain by Tarkio.
77.5	0.7	Buffalo Mound ahead on skyline.
78.0	0.5	Exit - Willard - Dover Road.
78.2	0.2	Overpass.
78.5	0.3	Maple Hill limestone member of the Zeandale limestone.
78.7	0.2	Tarkio limestone.
79.1	0.4	Dover limestone (member of the Stotler limestone), on right.
79.3	0.2	Dover limestone underlain by Pillsbury shale.

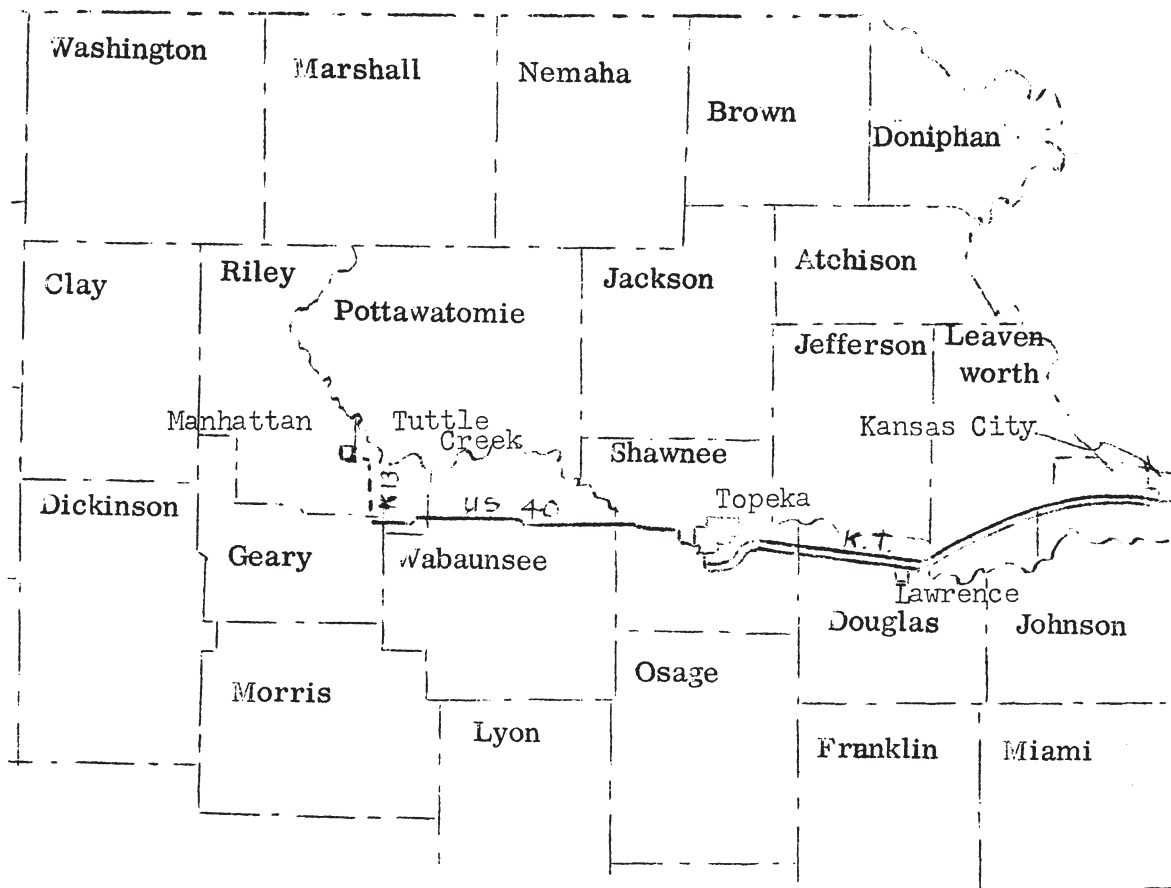
*The Wabaunsee and Admire groups (upper Pennsylvanian and lower Permian) have been recently reclassified by Moore and Mudge (See A. A. P. G. Bull., vol. 40, no. 9, p. 2271-2278, 1956.).

79.6	0.3	Dover limestone on both sides of road.
79.8	0.2	Dover limestone outcrop on both sides of road.
81.3	1.5	Dry shale and Grandhaven limestone (members of Stotler limestone).
81.9	0.6	Dry shale and Grandhaven limestone.
82.0	0.1	Dover limestone on both sides of road.
82.35	0.35	Bridge.
83.1	0.75	Junction with K 30, continue west on US 40.
83.3	0.2	Bridge.
83.7	0.4	Brownville limestone (Wood Siding formation, Pennsylvanian) overlain by Towle shale (Onaga shale, Permian).
84.95	1.25	Falls City limestone overlain by West Branch shale (Janesville shale). Haxby (below).
85.9	0.95	Aspinwall limestone.
86.2	0.3	Vera Road.
86.7	0.5	Cut ahead is mostly in Hughes Creek shale with Long Creek limestone at very top of hill (members of the Foraker limestone).
89.0	2.3	Bridge.
89.6	0.6	Roadside Park.
90.4	0.8	Hughes Creek shale exposure with Long Creek limestone at top.
90.6	0.2	Hamlin shale overlain by Foraker limestone.
90.85	0.25	Bridge over Mill Creek.
91.1	0.25	Overpass - Rock Island Railroad.
91.3	0.2	Junction of K 138 and US 40. Continue ahead on US 40.
91.75	0.45	Bridge.
92.0	0.25	Chert gravel hills (buried Pleistocene valley) on right.
93.95	1.95	Bridge.
94.15	0.2	Junction of K 135 and US 40. Continue ahead on US 40.
95.4	1.25	Overpass - Rock Island Railroad.
95.6	0.2	Bridge.
96.1	0.5	Grenola limestone to Cottonwood limestone (lower member of Beattie limestone) exposures.
96.45	0.35	Cottonwood limestone.
96.65	0.2	Junction of K 99 and US 40. Continue ahead on US 40. Florena shale and Morrill limestone (members of the Beattie limestone).
97.05	0.4	Picnic table on left.
97.5	0.45	Bader limestone.
98.0	0.5	Threemile limestone (Wreford formation) and underlying Speiser shale.
98.4	0.4	Threemile - Havensville shale (Wreford formation) and underlying Speiser shale.
98.6	0.2	Funston limestone on left side of road.
98.9	0.3	Funston at top, Blue Rapid shale, Crouse limestone, and Easley Creek shale (below).
99.2	0.3	Crouse limestone on both sides of road.
99.4	0.2	Bader limestone.
99.6	0.2	Beattie limestone.







99.9	0.3	Cottonwood limestone.
100.4	0.5	Bridge.
102.15	1.75	Riley County line.
102.4	0.25	Funston limestone on left.
102.6	0.2	Wreford limestone (Threemile member).
103.0	0.4	Schroyer limestone (Wreford formation). You now are in the Flint Hills, one of the most beautiful parts of Kansas.
104.4	1.4	"Reef" in Havensville shale above Threemile limestone (members of Wreford).
105.0	0.6	Bader limestone.
105.7	0.7	Eskridge shale.
106.0	0.3	Bridge. Neva limestone (Grenola limestone).
106.3	0.3	Roadside Park on left.
107.1	0.8	Eskridge shale overlain by the Beattie limestone.
107.65	0.55	Eskridge shale to Bader limestone.
107.9	0.25	Bridge.
108.1	0.2	Bader limestone.
108.4	0.3	Funston limestone, Speiser shale, and lower part of Wreford (in ascending order).
108.55	0.15	Havensville and Schroyer (Wreford formation).
108.75	0.2	Schroyer limestone (note chert).
108.9	0.15	Schroyer limestone.
109.4	0.5	Florence limestone (of the Barneston limestone) overlying Matfield shale.
109.8	0.4	Florence limestone.
110.1	0.3	Junction K 13 and US 40. Turn right (north) on K 13.
110.2	0.1	Quarry in Florence limestone on left.
110.5	0.3	Cut in Florence limestone.
110.8	0.3	Florence limestone.
111.05	0.25	Kinney limestone (member of the Matfield shale).
111.3	0.25	Schroyer limestone.
111.65	0.35	Threemile limestone and underlying Speiser shale.
111.8	0.15	Havensville and Schroyer.
112.1	0.3	Schroyer limestone.
112.5	0.4	Kinney limestone.
113.15	0.65	Schroyer limestone.
115.4	2.25	Funston limestone and lower beds exposed up to the Wreford. View of Kansas River valley ahead.
115.8	0.4	Eiss limestone on left side of road.
116.2	0.4	Grenola limestone exposures on both sides of road.
116.7	0.5	Lower part of Grenola formation.
117.6	0.9	K - Hill on left (section from Foraker to Cottonwood).
118.2	0.6	Bridge over the Kansas River.
118.3	0.1	City limits of Manhattan. Home of Kansas State College.
118.6	0.3	Turn right (north) on K 13 and K 18.
118.75	0.15	Stoplight at Junction with US 24. Continue straight ahead (north).

- 119.7 0.95 "Blumont" section on left Hughes Creek shale up to Cottonwood limestone.
- 120.0 0.3 Hughes Creek shale - Big Blue floodplain to right.
- 120.5 0.5 Hughes Creek shale.
- 121.2 0.7 Johnson shale and Red Eagle formation on left of road.
- 122.8 1.6 Grenola limestone on left - Cottonwood limestone on hill above.
- 123.5 0.7 **Tuttle Creek Dam on right.**
- 123.7 0.2 Bridge over Phiel Creek.
- 123.8 0.1 Leave K 13 continue straight ahead on secondary road.
- 124.0 0.2 Headquarters of Tuttle Creek Dam on left.

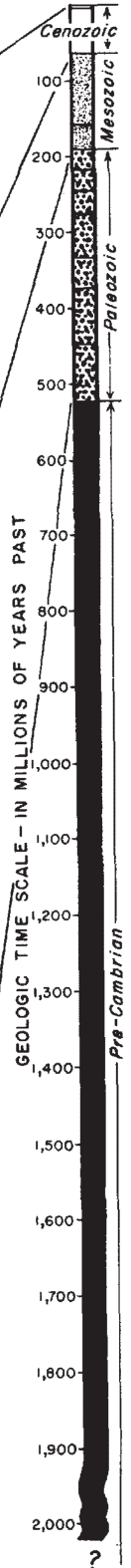
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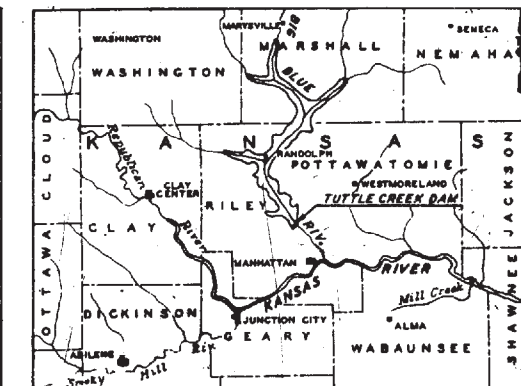
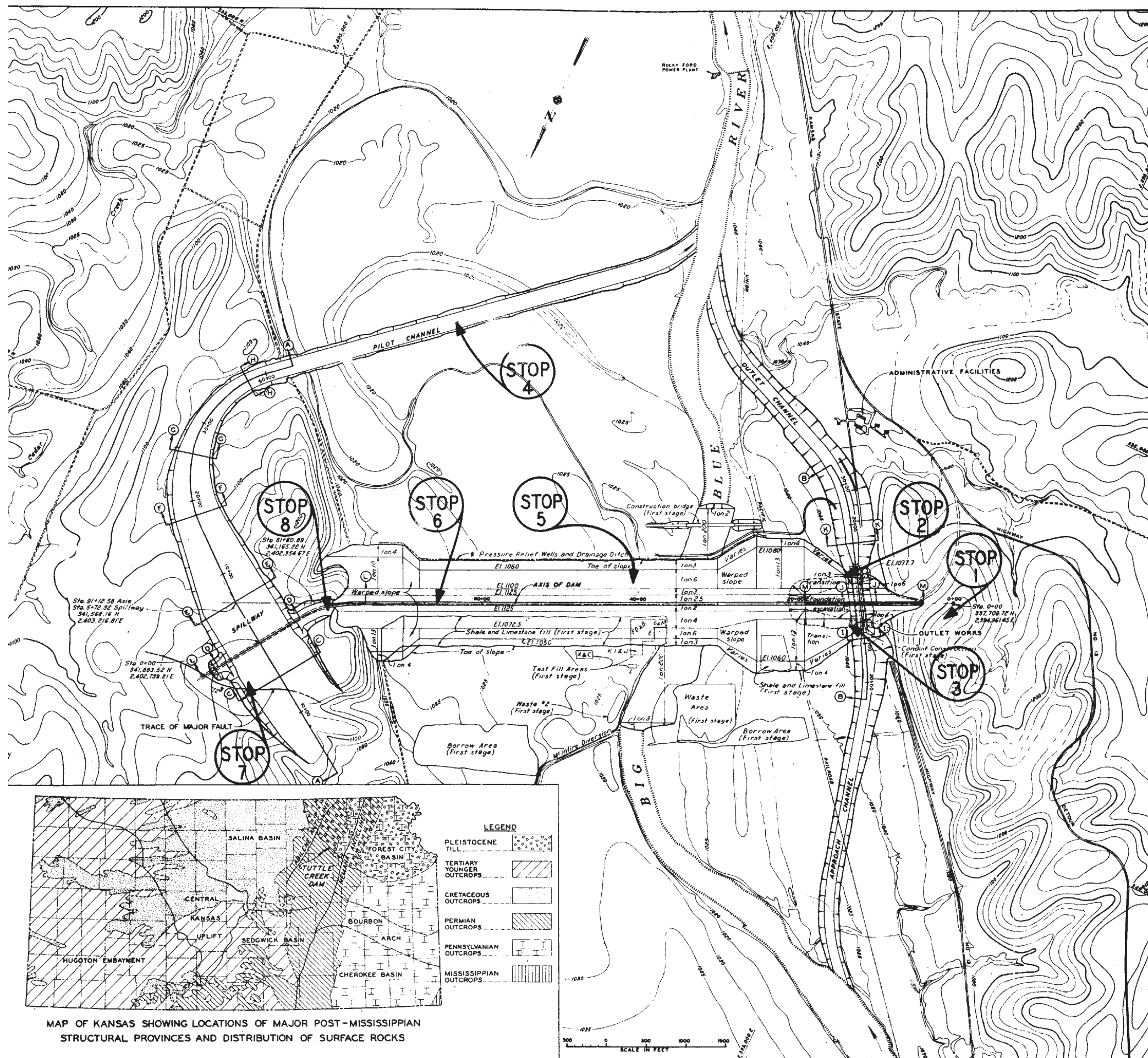
GEOLOGIC TIMETABLE AND KANSAS ROCK CHART

ERAS	PERIODS	ESTIMATED LENGTH IN YEARS*	TYPE OF ROCK IN KANSAS	PRINCIPAL MINERAL RESOURCES
CENOZOIC	QUATERNARY (PLEISTOCENE) 	1,000,000	<i>Glacial drift; river silt, sand, and gravel; dune sand; wind-blown silt (loess); volcanic ash.</i>	Water, agricultural soils, sand and gravel, volcanic ash.
	TERTIARY	59,000,000	<i>River silt, sand, and gravel; fresh-water limestone; volcanic ash; bentonite; diatomaceous marl; opaline sandstone.</i>	Water, sand and gravel, volcanic ash, diatomaceous marl.
MESOZOIC	CRETACEOUS 	70,000,000	<i>Chalk, chalky shale, dark shale, varicolored clay, sandstone, conglomerate. Outcropping igneous rock.</i>	Ceramic materials; building stone, concrete aggregate, and other construction rock; water.
	JURASSIC	25,000,000	<i>Sandstones and shales, chiefly subsurface.</i>	
	TRIASSIC	30,000,000		
PALEOZOIC	PERMIAN 	25,000,000	<i>Limestone; shale; evaporites (salt, gypsum, anhydrite); red sandstone and siltstone; chert; some dolomite.</i>	Natural gas; salt; gypsum; building stone, concrete aggregate, and other construction materials; water.
	PENNSYLVANIAN 	25,000,000	<i>Alternating marine and non-marine shale, limestone, and sandstone; coal; chert.</i>	Oil, coal, limestone and shale for cement manufacture, ceramic materials, construction rock, agricultural lime, gas, water.
	MISSISSIPPIAN 	30,000,000	<i>Mostly limestone, predominantly cherty.</i>	Oil, zinc, lead, gas, chat and other construction materials.
	DEVONIAN	55,000,000	<i>Subsurface only. Limestone, black shale.</i>	Oil
	SILURIAN	40,000,000	<i>Subsurface only. Limestone.</i>	Oil
	ORDOVICIAN 	80,000,000	<i>Subsurface only. Limestone, dolomite, sandstone, shale.</i>	Oil, gas, water.
	CAMBRIAN	80,000,000	<i>Subsurface only. Dolomite, sandstone.</i>	Oil
PRE-CAMBRIAN (Including PROTEROZOIC and ARCHEOZOIC ERAS)		1,600,000,000 +	<i>Subsurface only. Granite, other igneous rocks, and metamorphic rocks.</i>	Oil and gas.

*Not scaled for geologic time or thickness of deposits.



*Committee on Measurement of Geologic Time, National Research Council

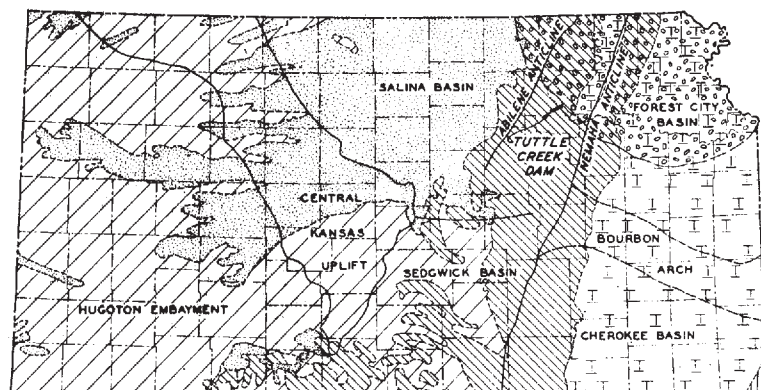


LOCATION
SCALE IN MILES

INDEX

FILE NO.	TITLE	PLATE NO.
A-9-7-561	General Plan, Location and Index	1
A-9-7-562	Geological Section Along Axis of Dam	2
A-9-7-563	Plan of Underground Explorations	3
A-9-7-564	Generalized Geologic Column and Summary of Test Results	4
A-9-7-565	Geologic Profiles-Spillway and Outlet Works	5
A-9-7-566	Geologic Sections-Spillway	6
A-9-7-567	Geologic Sections-Spillway and Outlet Works	7
A-9-7-568	Grouting	8

NOTES
 (A)-(A) - Indicates geologic sections or profiles.
 For geologic profiles (A)-(A) and (B)-(B) see Dwg. File No. A-9-7-565.
 For geologic sections (C)-(C), (D)-(D) and (E)-(E) see Dwg. File No. A-9-7-566.
 For geologic sections (F)-(F), (G)-(G), (H)-(H), (I)-(I), (J)-(J) and (K)-(K) see Dwg. File No. A-9-7-567.
 For grouting sections (L)-(L) and (M)-(M) see Dwg. File No. A-9-7-568.



MAP OF KANSAS SHOWING LOCATIONS OF MAJOR POST-MISSISSIPPIAN STRUCTURAL PROVINCES AND DISTRIBUTION OF SURFACE ROCKS

LEGEND

PLEISTOCENE TILL	(Stippled pattern)
TERTIARY YOUNGER OUTCROPS	(Diagonal lines, top-left to bottom-right)
CRETACEOUS OUTCROPS	(Diagonal lines, bottom-left to top-right)
PERMIAN OUTCROPS	(Horizontal lines)
PENNSYLVANIAN OUTCROPS	(Vertical lines)
MISSISSIPPIAN OUTCROPS	(Dotted pattern)

BIG BLUE RIVER, KANSAS
TUTTLE CREEK DAM

GENERAL PLAN, LOCATION AND INDEX

Sheet 1 of 1

Scale: as shown

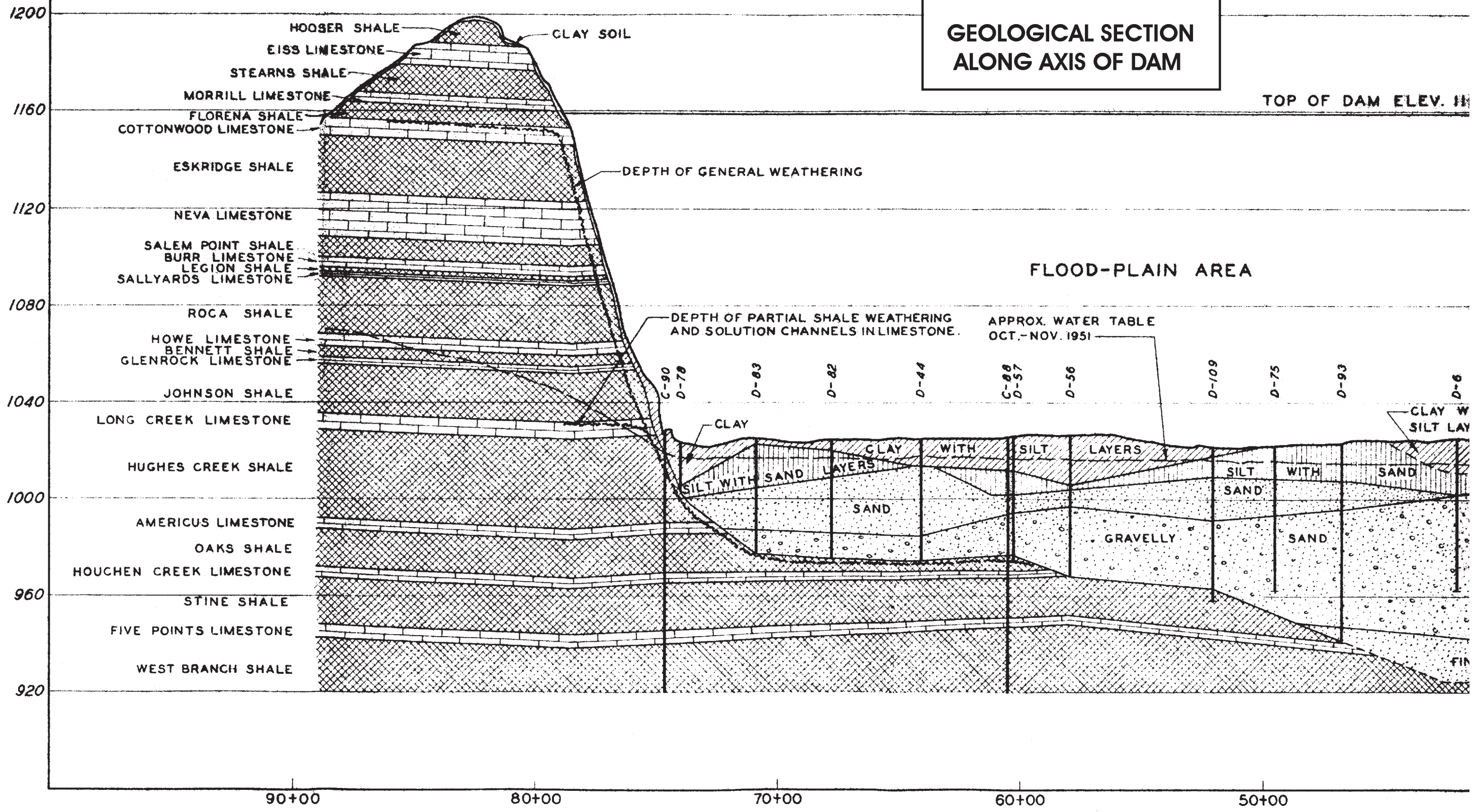
KANSAS CITY DISTRICT
 FILE NO. A-9-7-561

To accompany Design Memorandum No. 6 dated December 1955

TUTTLE CREEK DAM

GEOLOGICAL SECTION ALONG AXIS OF DAM

ELEVATION IN FEET ABOVE MEAN SEA LEVEL



TOP OF DAM ELEV. 1160

FLOOD-PLAIN AREA

DEPTH OF PARTIAL SHALE WEATHERING AND SOLUTION CHANNELS IN LIMESTONE.

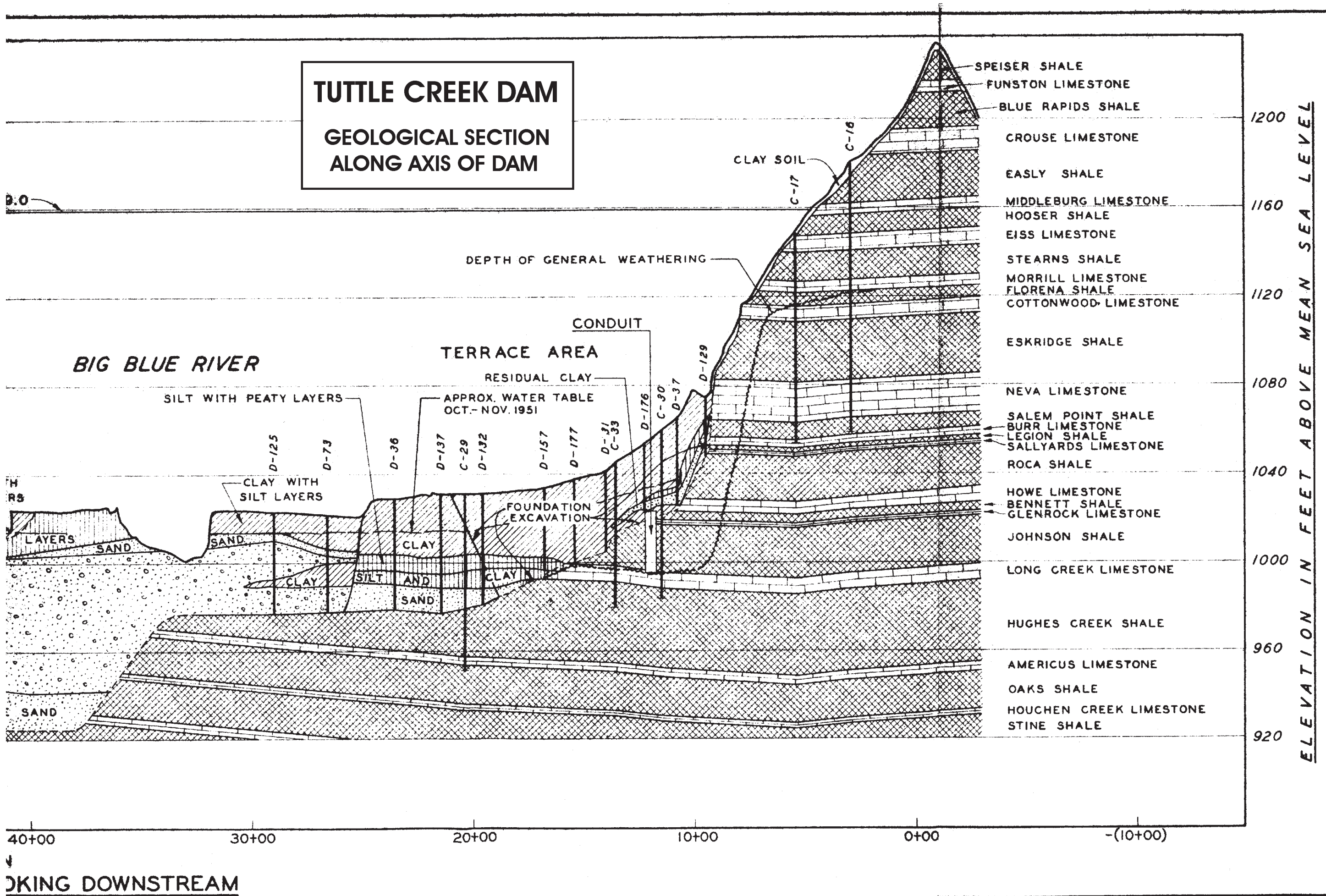
APPROX. WATER TABLE OCT.-NOV. 1951

STATION

GEOLOGICAL SECTION ALONG AXIS OF DAM

TUTTLE CREEK DAM

GEOLOGICAL SECTION ALONG AXIS OF DAM



- SPEISER SHALE
- FUNSTON LIMESTONE
- BLUE RAPIDS SHALE
- CROUSE LIMESTONE
- EASLY SHALE
- MIDDLEBURG LIMESTONE
- HOOSER SHALE
- EISS LIMESTONE
- STEARNS SHALE
- MORRILL LIMESTONE
- FLORENA SHALE
- COTTONWOOD LIMESTONE
- ESKRIDGE SHALE
- NEVA LIMESTONE
- SALEM POINT SHALE
- BURR LIMESTONE
- LEGION SHALE
- SALLYARDS LIMESTONE
- ROCA SHALE
- HOWE LIMESTONE
- BENNETT SHALE
- GLENROCK LIMESTONE
- JOHNSON SHALE
- LONG CREEK LIMESTONE
- HUGHES CREEK SHALE
- AMERICUS LIMESTONE
- OAKS SHALE
- HOUCHEN CREEK LIMESTONE
- STINE SHALE

ELEVATION IN FEET ABOVE MEAN SEA LEVEL

40+00 30+00 20+00 10+00 0+00 -(10+00)

↓
DOWNSTREAM