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KANSAS ACADEMY OF SCIE
MULTIDISCIPLINARY GUIDEBOOK 4

Ecology and Hydrogeology of the Kansas Ecological Reserves and the Baker Wetlands

Fall Field Trip in Douglas, southeastern Jefferson, and southwestern Leavenworth counties, Kansas

October 5, 1991

Kansas Geological Survey Open-File Report 91-35

[Adapted from original document]

KANSAS ACADEMY OF SCIENCE

MULTIDISCIPLINARY GUIDEBOOK 4

Ecology and Hydrogeology of the Kansas Ecological Reserves and the Baker University Wetlands

Hosted by

EXPERIMENTAL AND APPLIED ECOLOGY PROGRAM, UNIVERSITY OF KANSAS

KANSAS GEOLOGICAL SURVEY

KANSAS BIOLOGICAL SURVEY

and

DEPARTMENT OF BIOLOGY, BAKER UNIVERSITY

Edited by W. Dean Kettle and Donald O. Whittemore

October 5, 1991

Kansas Geological Survey Open-File Report 91-35

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ITINERARY

The fourth annual fall field trip of the Kansas Academy of Science will begin from the Kansas Geological Survey and proceed to the Baldwin Woods portion of the Kansas Ecological Reserves (KER) in south-central Douglas County, followed by a visit to the Baker Wetlands on the southern edge of Lawrence (see Figure A). Participants can then eat their sack lunches in the area of the Geological and Biological surveys on West Campus. After lunch, the next stop is the Geohydrological and Experimental Monitoring Site at the Robinson Tract northeast of Lawrence. Afterwards, most of the afternoon involves visits to various educational and research locations in the 3 research natural areas of the KER tri-county tracts. The field trip is being held in conjunction with the Annual Field Day of the Experimental and Applied Ecology Program of The University of Kansas. There will be an informal outdoor supper held by the Program which the KAS participants are welcome to attend with a small donation to defray the cost of the extra food.

The following is the itinerary for the field trip:

<u>Morning</u>

9:00	Leave from Kansas Geological Survey south parking lot (by core building)
9:30-10:30	Baldwin Woods
10:50-11:50	Baker Wetlands

<u>Lunchtime</u>

12:00-12:50	Lunch around pond northwest of KGS (or inside KGS if raining)

<u>Afternoon</u>

1:15-1:45	Geohydrologic Experimental Monitoring Site (GEMS), Robinson Tract
2:00-3:00	Fitch Natural History Reservation
3:00-4:00	Rockefeller Experimental Tract
4:00-5:50	Nelson Environmental Study Area
6:00	Optional, informal outdoor supper with the KU Division of Systematics and Ecology

INTRODUCTION

The fourth annual fall field trip of the Kansas Academy of Science is being held in conjunction with the Annual Field Day of the Experimental and Applied Ecology Program at The University of Kansas (KU). The trip includes visits to the research natural areas of the Kansas Ecological Reserves of KU and the Baker University Wetlands (Figure A). The field trip is a coordinated effort of several groups in different disciplines at KU and the Biology Department of Baker University.

Habitats seen on the trip will include wetland, native tallgrass prairie, eastern deciduous forest, and land in various stages of ecological succession. Additionally, numerous ecological and environmental research projects on these natural areas will be discussed.

Production of the field guide and organization of the trip has brought together people from the Experimental and Applied Ecology Program, the Kansas Geological Survey, the Kansas Biological Survey, Baker University, and different departments at KU that are involved in research and education at the natural areas. The efforts have spawned a renewed recognition of the relationships of the biological communities to the interactions of climate, soils, geology, and hydrology.

Authors of chapters on the biota of the natural areas were provided with simple guidelines for developing their sections. Identifications of organisms in the checklists were often made to species. However, in other instances subspecies or variety could be determined but in other instances identifications were only made to genus or family. For these reasons the term "taxon" is frequently used to refer to the organism listed. Authors were asked to either provide author(ity) for each named species or to refer to a reference. Where possible common names were provided to make the lists more usable for a wider audience. Species are presented in the order most appropriate for the particular group. "Alphabetical", "phylogenetic", or "customary" were used to describe this arrangement. Authors were encouraged to provide general ecological information where appropriate. Occurrence data for species was taken to as precise a location (tract) as possible. Ecological and biological data included general information on habitat and abundance. Authors were also asked to identify any organisms (or assembleges) that were rare in the region and then to characterize the biota in relation to regional or continental distributions.

Chapters describing the biota of the natural areas provide a valuable baseline biotic inventory. It is hoped that, where appropriate, chapters of the guidebook will be refined and expanded in the future to provide data sets of even greater significance. Future plans include development of additional inventories and a synthesis of these studies with other ecological and environmental studies of the natural areas.

The editors wish to thank all contributors to the Guidebook for sharing their time and expertise. Special thanks go to Anna Kraxner, Kansas Geological Survey, for word processing, and to Vicky C. Varner and Galen L. Pittman, KU Experimental and Applied Ecology Program, for proof reading and miscellaneous tasks associated with the production of this document.

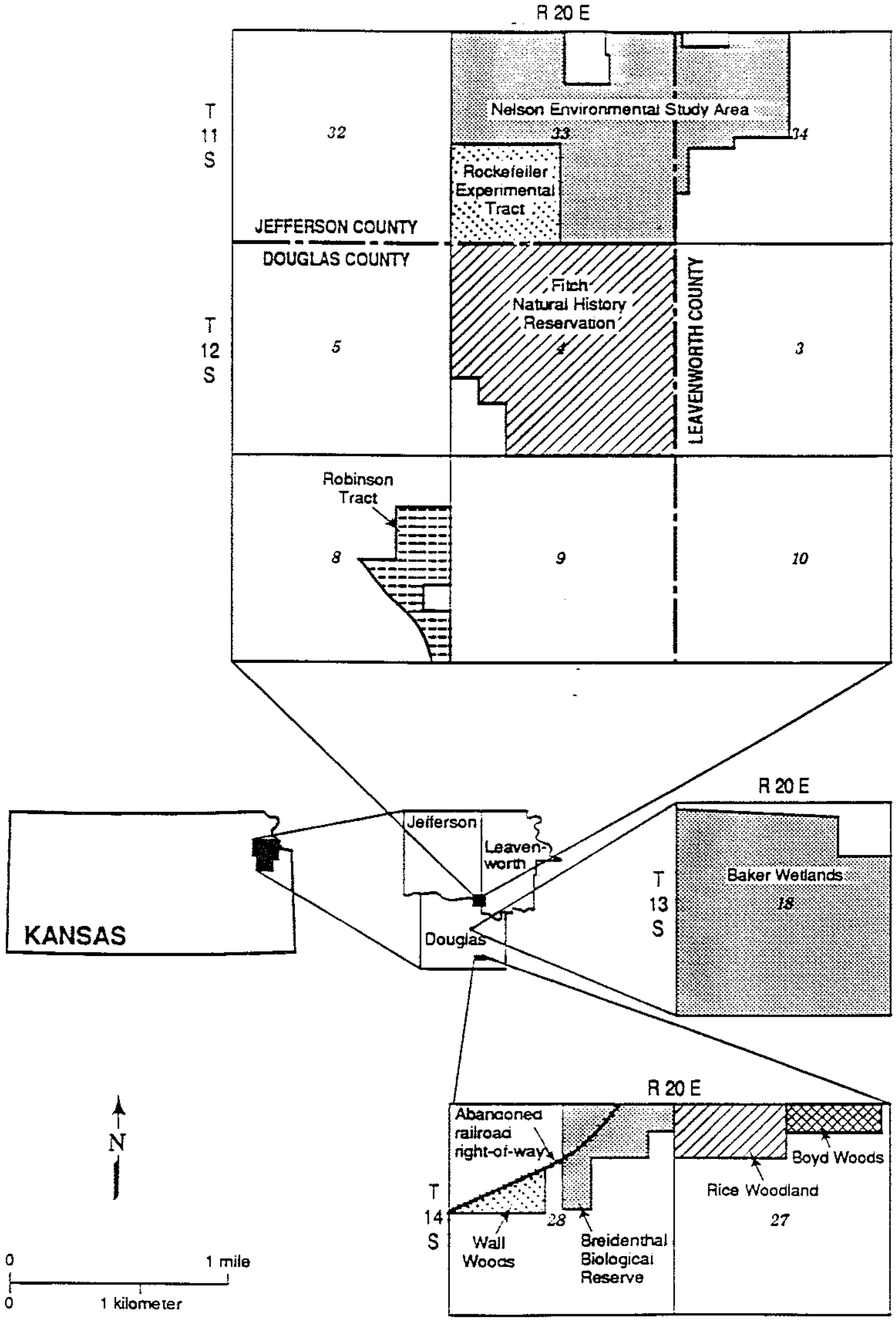

Figure A. Location of research natural areas in Douglas, Jefferson, and Leavenworth counties.

1930. Wet periods were generally longer and more severe than droughts from 1867 to 1930, while droughts were longer and more severe than wet periods from 1930 to 1957. In spite of severe droughts in the 1960's to 1980's, the severity and length of wet spells were approximately the same as the droughts. The severest wet spells since the 1950's drought occurred in 1961, 1973, the last half of 1977, and mid-1985 to mid-1987. A more moderate but extended wet spell was mid-1967 through much of 1969.

Table I-1. Mean monthly temperatures and precipitation for Lawrence (Atmospheric Science Library 1990)

	Temp. (°F)	Precip. (in)		Temp. (°F)	Precip. (in)
Jan	28.9	1.14	Jul	79.0	4.14
Feb	33.3	1.30	Aug	77.2	4.12
Mar	43.7	2.40	Sep	69.2	4.01
Apr	55.9	3.30	Oct	57.8	2.90
May	65.3	4.42	Nov	43.6	1.98
Jun	74.2	5.09	Dec	32.8	1.46

Physiography of the Natural Areas

The Baldwin Woods tracts are in an upland, predominantly hilly area within the Osage cuestas physiographic province (Figure I-1). The cuestas are formed by stream dissection and differential erosion of uplands underlain by limestone, sandstone, and shale (O'Connor 1960). The steepest slopes are limestone and sandstone escarpments near the headwater areas of small stream drainages. The Baldwin Woods lie along the southern limit of the valley of the Wakarusa and Kansas rivers. The woodlands in the area are on the northward facing slopes extending from the drainage divide between the Wakarusa and Kansas rivers to the north and the Marais des Cygnes River to the south. Elevations range from slightly greater than 1150 ft at the corner of one tract very near the top of the ridge forming the drainage divide, to less than 950 ft along the northern boundary of one of the tracts (based on the U.S. Geological Survey 7.5 minute topographic quadrangle for Baldwin City).

The Tri-County area is also generally hilly and, although lying in the glaciated region of Kansas, is essentially characterized as Osage cuestas affected by glaciation and glacial deposits of loess and till (Figure I-1). The floodplain of the Kansas River lies on the southwestern and southern strip of the Robinson Tract. Part of the tracts form the northern valley wall rising from the Kansas River floodplain. The tracts north of the Kansas River extend over a larger area than the Baldwin Woods and comprise primarily both hillslopes and more gentle topography of the remaining upland prairie along ridge tops. The elevations range from less than 840 ft in the Robinson Tract along the northern edge of the Kansas River floodplain to greater than 1090 ft on the hilltops of the Nelson Environmental Study Area (USGS Midland topographic quadrangle). The steepest slopes are generally wooded.

The Baker University Wetlands is a wetland prairie/marsh lying in the floodplain of the Wakarusa River. The physiographic location is along the southern border of the glaciated region (Figure I-1). The Wakarusa River channel meanders along the southern part of the wetlands. Most of the wetland area is nearly flat and generally lies within the elevation range of 821-814 ft (estimated from the USGS Lawrence East topographic quadrangle. The channel wall of the Wakarusa River is steep in comparison, dropping from about 820 ft to about 800 ft (the approximate elevation of the river water at low stage) within 100 ft of areal distance.

PART I. ATMOSPHERIC AND GEOLOGIC ENVIRONMENT

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Climate of the Douglas County Area

The climate of Douglas County and, therefore, of the natural areas, is humid continental. Both the temperature and precipitation maxima occur during the summer and the minima during the winter. The mean annual precipitation at Lawrence is 36.62 inches and the mean annual temperature 55.2° F based on the records from 1857 to 1990 (Atmospheric Science Library 1990). The mean monthly temperatures range from 28.9° F in January to 79.0° F in July, while the mean monthly precipitation range is 1.14 inches in January to 5.09 inches in June (Table 1).

The climatic extremes are wide with minimum temperatures as low as less than -20° F and maximum temperatures as high as above 110° F. The lowest mean monthly temperature was 5.0 for January, 1940, while the highest mean monthly value was 103.4° F for July, 1934. The average difference between the daily maximum and minimum temperatures is about 18-20° F during the winter and 21-23° F during the rest of the year. Months with no measurable precipitation have occurred a few times during the winter and the summer. The highest mean monthly precipitation was 16.62 inches in June, 1965. The wettest year was 1973 with 59.25 inches of precipitation, while the driest year was 1953 with 20.99 inches.

The changes in temperature and precipitation during the year are important to the growing season and fluctuations in plant growth and water supplies. The average date on which the last killing frost in the spring occurs at Lawrence is April 10 and the average date of the first killing frost in the fall is October 23, giving a mean annual growing season of about 196 days (Cardwell and Flora 1942). Killing frosts have occurred at appreciably later and earlier times to substantially decrease or increase the length of the growing season to about 170 days to above 220 days, respectively. Lake evaporation and potential evapotranspiration range widely from lows during the cold winter months to a high in July. The mean annual lake evaporation for the Douglas County area is about 45 inches (Todd 1970). The average annual potential evapotranspiration is approximately 32 inches (The Geographical Review 1948), which is less than the mean annual precipitation. The typical soil-moisture budget for Douglas County ranges from a surplus during the late winter through spring when the precipitation exceeds the potential evapotranspiration and the soil is at field capacity, to a deficiency during July and August when potential evapotranspiration exceeds the actual evaporation or soil-moisture utilization (as estimated for Lawrence based on relationships at Manhattan, Kansas described in Strahler and Strahler, 1973).

One of the greatest stresses on plant growth and water supplies is the occurrence of droughts. Although long periods of low precipitation generally reflect droughts well, the inclusion of evapotranspiration data, which is related largely to temperature, improves the indicator of the relative severity of droughts. The Palmer Drought Index (PDI) is a widely used measure of wet and dry conditions (Palmer 1965). It reflects antecedent soil moisture and is based on the difference between actual and potential evapotranspiration. The severest extended droughts in Douglas County as indicated by PDI values for the period 1867-1989 occurred during 1934-1939 and 1953-1956 (Atmospheric Science Library 1990). All of the mean monthly highs for temperature for June through September were set during the 1930's drought. The most extreme droughts other than those of the 1930's and 1950's were of shorter duration, from mid-1963 to mid-1964, mid-1976 to mid-1977, and mid-1988 through 1989. Droughts for the period from 1867-1930 were not as extreme or long as these since

Generalized physiographic map of Kansas

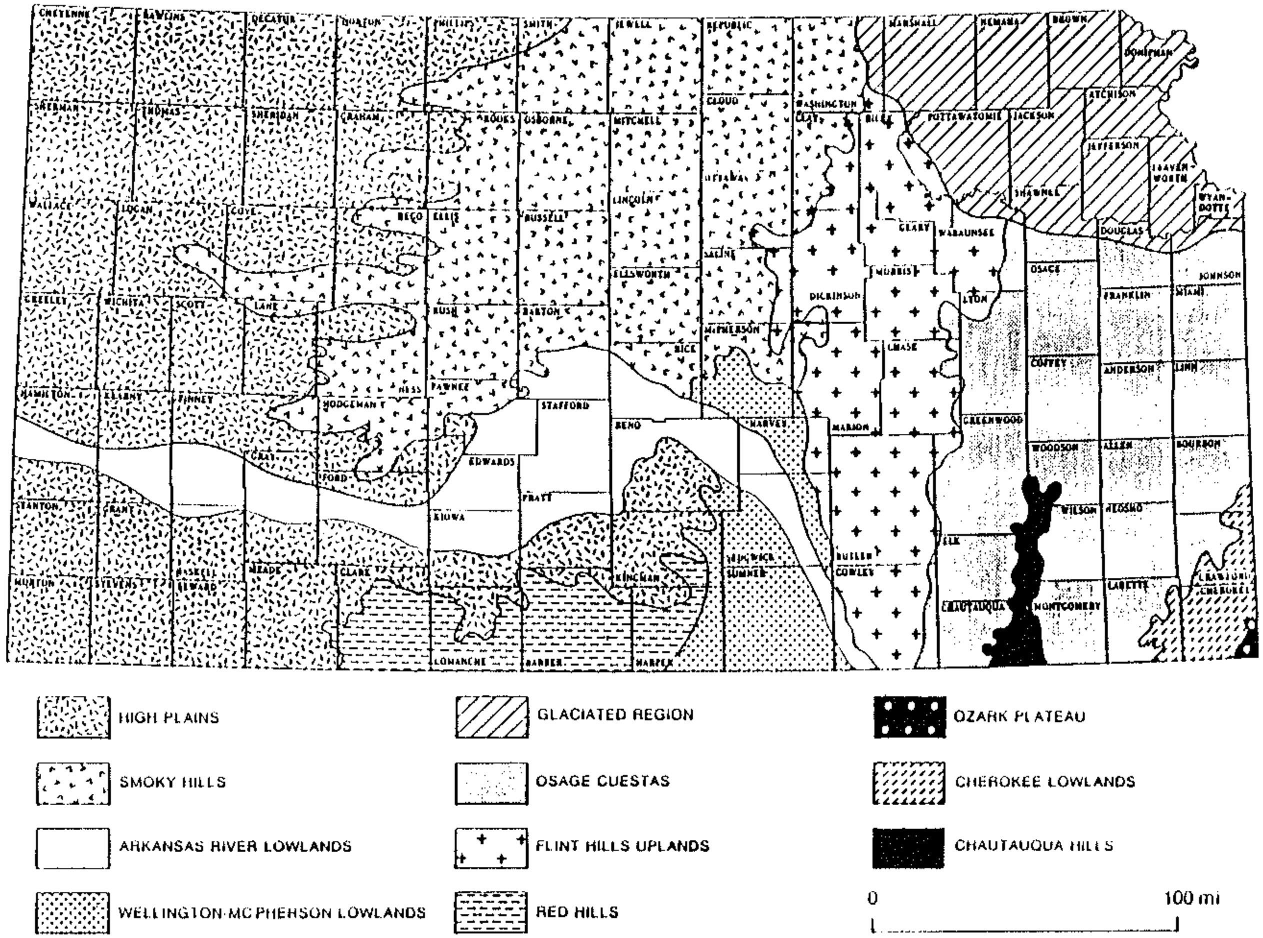

Figure I-1. Generalized physiographic map of Kansas. **Compare to Figure A and note that the southern boundary of the glaciated region passes approximately through the location of the Baker University Wetlands in Douglas County, such that the northern** tracts of the Kansas Ecological Reserves lie within and the Baldwin Woods lie to the south of the glaciated region.

Geology and Soils of the Natural Area Region

Bedrock

The exposed and near surface bedrock in the areas of the Kansas Ecological Reserves (KER) is in the Upper Pennsylvanian Series. It consists of primarily limestones and shales in the Shawnee Group and predominantly shales and sandstones in the Douglas Group in the lower half of the Virgilian Stage, and chiefly limestones and shales in the Lansing Group in the top of the Missourian Stage. The sediments were deposited in cyclic sequences as a result of transgressions and regressions of shallow seas. The cycles comprise marine shales and limestones alternating with nonmarine beds including the sandstones. The rocks dip westward to northwestward about 20 ft per mile (O'Connor, 1960). Faulting during Pennsylvanian time, especially in southern Douglas County, resulted in erosion of some units and greater deposition of others thereby locally altering the thickness of selected rock units. Submarine slides and differential compaction also affected the thicknesses. Parts of two erosional valleys in the Upper Pennsylvanian rocks in Douglas County are filled with sandstones that vary greatly in thickness and character depending on proximity to the center of the channels. The stratigraphic section shown in Figure I-2 includes only the uppermost bedrock outcropping in the KER area and the lowermost units exposed in Douglas County and not the upper part of the Shawnee Group. The following descriptions are based largely on O'Connor (1960) with modifications for revised stratigraphic nomenclature in Zeller (1968). More emphasis is placed on those units that are of interest in the natural areas.

The thickness of the Oread Limestone averages about 60 ft in Douglas County. It consists of two massive limestone members, the Plattsmouth and Toronto limestones, and two thinner limestones, the Kereford and Leavenworth members. Natural exposures of the Kereford are uncommon because it is relatively thin (2.5-9 ft thick) and contains calcareous shale beds. The Toronto Limestone and especially the Plattsmouth Limestone form outcrop scarps and average 10 and 18 ft in thickness, respectively. The Plattsmouth is the thickest and most extensively quarried of the limestones in Douglas County. It is light-gray to nearly white, wavy bedded, and includes scattered chert nodules near the middle of the unit. The Toronto Limestone is light gray and massive when fresh, but becomes light to deep yellow brown and slabby upon weathering. Chert nodules are scattered in the upper part of the Toronto. The usual thickness range for the Leavenworth Limestone Member is 0.8-2 ft. Fossils in the limestone units include fusulinids, crinoids, bryozoans, corals, brachiopods, mollusks, and algae. The Heumader Shale, Heebner Shale, and Snyderville Shale members commonly have thicknesses of 2-4, 5-8, and 10-15 ft, respectively, although they may be locally substantially thinner or thicker. Some of the beds within the shales are unfossiliferous while others may contain brachiopod, mollusk, and conodont fossils.

The Lawrence Formation is commonly 140–180 ft thick. It is predominantly shale to silty and sandy shale in most of Douglas County, but includes the Ireland Sandstone Member in the southern part of the county. The upper part of the formation is usually shaley and contains two thin coal beds, the Upper and Lower Williamsburg coals. The lower of the coals was mined during the past. A discontinuous limestone, the Amazonia Limestone Member may be present below the upper shale. The nonmarine Ireland Sandstone ranges up to 150 ft thick and fills a west-southwest-trending erosional valley cut into the underlying Stranger Formation. The northern border of the valley was located just north of the Baldwin Woods. The Sandstone consists of very fine to medium sized quartz grains with a small amount of mica, pyrite, and clay minerals. The Robbins Shale Member is in the lower Lawrence Formation and is eroded and overlapped by the Ireland Sandstone. The thin Haskell Limestone Member is at the base of the Lawrence Formation. The Kansas Geological Survey buildings

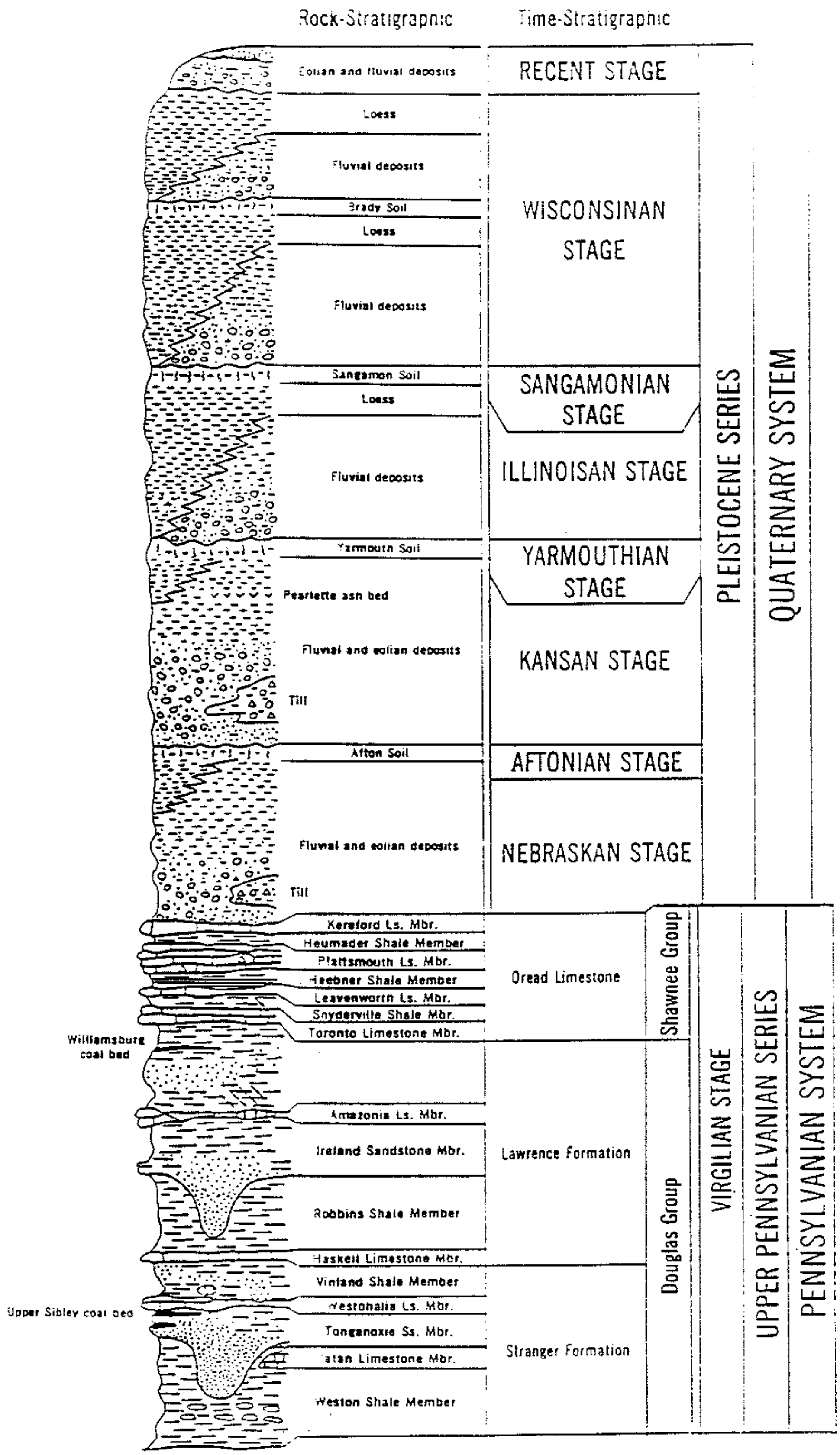

Figure I-2. Stratigraphic section for geologic materials underlying the natural areas (modified from Zeller 1968).

are on the Lawrence Formation. Plant fossils found in the shale are on display in the entrance of Moore Hall.

The Stranger Formation comprises 4 members in Douglas County, the Vinland Shale, Westphalia Limestone, Tonganoxie Sandstone, and Weston Shale. The Vinland Shale consists of about 6 to 25 ft of chiefly marine clayey to sandy shale and calcite-cemented sandstone. It contains a persistent fossil zone of pelecypods. The Westphalia Limestone is only about 1.5 ft thick, is carbonaceous, and contains ostracod and tiny gastropod fossils and carbonized plant fragments. The nonmarine Tonganoxie Sandstone occupies an erosional valley cut into the Weston Shale Member and underlying Stanton Limestone. The ancient valley is 14 to 20 miles wide and trends in a northeasterly direction across Douglas County into southwestern Leavenworth County. The KER tracts north of the Kansas River lie on the northern edge of the valley, Lawrence approximately overlies the center of the valley, and the Baldwin Woods is south of the valley. The Tonganoxie Sandstone Member is chiefly composed of fine to very fine quartz grains slightly cemented with calcite and ranges up to 120 ft thick. Silty and shaley beds in the sandstone contain much mica. Thin coal beds are found in some parts of the Tonganoxie; the Blue Mound coal was mined in the past. The Weston Shale Member is a gray-blue and gray marine shale that weathers to mottled olive and gray or tan. It is slightly more than 100 ft thick where post-erosional channels have not cut into the shale. The Weston contains ironstone concretions that weather to a yellowish brown to reddish brown color. The concretions become larger and more numerous with depth.

The Lansing Group does not outcrop in the natural areas but exists in the subsurface. It consists of two limestone formations, the Stanton and Plattsburg limestones, separated by a shale formation, the Vilas Shale. The Stanton Limestone is about 44 ft thick and includes 3 limestone members. The South Bend Limestone Member has a thickness of 1-4 ft, the Stoner Limestone Member a thickness of 15-17 ft, and the Captain Creek Limestone Member a thickness of 6-7 ft. The two shale members separating the limestone members are the Rock Lake Shale and the Eudora Shale which commonly have thicknesses of about 10-15 ft and 7 ft, respectively. The Rock Lake Shale consists of both shale and marine sandstone. The Vilas Shale ranges from less than 10 ft up to 26 ft in thickness. The upper part is mainly silty shale and the middle and lower parts are chiefly sandy micaceous shale or silty sandstone. The underlying Plattsburg Limestone is about 13-32 ft in the subsurface and consists of 3 members: Spring Hill Limestone, Hickory Creek Shale, and Merriam Limestone. The Spring Hill Limestone Member comprises most of the unit, with a thickness of up to 22 ft.

Pleistocene deposits

Deposits of fluvial, lacustrine, eolian, and glacial sediments cover the bedrock in many areas of Douglas southeastern Jefferson, and southwestern Leavenworth counties. The fluvial deposits range widely in age, from glacial stages to the Recent Stage, and fill erosional valleys including the Kansas River and Wakarusa River floodplain and terrace areas. Glacial till and loess cover bedrock in some upland areas. The following descriptions of the deposits are from O'Connor (1960) and Zeller (1968).

Fluvial sediments in the floodplain areas of the Kansas and Wakarusa rivers and their tributaries range from clays to silts to sands and gravels. Recent alluvium covers somewhat more than half of the Kansas River floodplain, but only minor parts of the floodplains of the Wakarusa River and tributary streams. The alluvium is chiefly silt and sand with some clay similar to that presently carried by the rivers and occupies the lowest level of the floodplain in an irregularly shaped area on each side of the present river channel. Older terrace deposits comprise higher levels of the Kansas River floodplain and most of the floodplain areas of the Wakarusa River and tributaries. The sediments range from gravels deposited in the deep bedrock channels of the Kansas and Wakarusa rivers and generally grade upward to valley fill consisting of finer-grained sediments similar to the Recent alluvium. The valley fill ranges from river channel sands to silts and clays in overbank deposits and meander cutoff fill. The terraces in the floodplain areas were deposited during the retreat of the glaciers at the end of the Wisconsinan and Illinoisan glacial stages. Nearly all of Baker Wetlands is underlain by fluvial sediments of the Wisconsinan Stage. The elevation above the present river or stream surface and the erosional dissection of the terraces increases with increasing age of the stage. Remnants of fluvial sediments deposited as glacial outwash and valley fill during the Kansan Stage are also present along the edges of the Kansas River floodplain and on lower slopes of the valley walls of the Kansas and Wakarusa river valleys.

Deposits of glacial till cover portions of uplands in the Tri-County area of the KER, representing the southern advance of glacial ice during the Kansan Stage. The till is unstratified and unsorted and constitutes varying mixtures of clay, silt, sand, and gravel. Small deposits of stratified sand and gravel occur locally in some of the high upland tills. Chert gravels containing sparse erratics are present at several locations east and south of Lawrence and in the Eudora area. The leached and oxidized condition of the gravels and their stratigraphic position relative to Kansan deposits indicate that they are pre-Kansan. Thin layers of eolian silt (loess) were deposited over uplands and terraces during Pleistocene time. Much of the loess in Douglas County is probably of Wisconsinan age. The thickest loess deposits are located along bluffs of the Kansas River valley and range up to 5-10 ft thick at some locations.

Soils

Most of the following summary of the soils was extracted from information in the Soil Survey of Douglas County (Dickey et al. 1977a), one of the county soil series produced by the Soil Conservation Service. The reports for soils in Jefferson County (Dickey et al. 1977b) and Leavenworth County (Zavesky and Boatright 1977) indicate that the soils in the portions of the Tri-County area of the KER in these two counties are similar to those in Douglas County. The general soil map for Douglas County in Dickey et al. (1977) includes 5 different soil associations. Each soil association correlates well with the major bedrock groups, glacial-fluvial deposits, Recent alluvium, and glacial till mapped in O'Connor (1960).

The Martin-Sogn-Vinland association comprises "deep, moderately well drained, gently sloping to strongly sloping soils and shallow, sloping to moderately steep, somewhat excessively drained soils on uplands" according to Dickey et al. (1977a). The pattern of soils in this association is shown in Figure I-3. All of the tracts of the Tri-County area, and small areas in the southern portions of the Wall Woods and Breidenthal Biological Reserve are typified by this association. The soils formed mainly from the weathering products of interbedded limestones and shales of the Shawnee Group. The Martin soils are the deepest major soils of the association and occur mainly on the lower parts of the slopes and in the small drainages dissecting the hills. Sogn soils form on the limestones and thus, tend to be shallow and occur on moderate to steep slopes. The Vinland soils also are generally shallow, but are derived from the weathering of shales. The minor Oska soils are moderately deep, well drained, and occur on the limestones and shales generally along the more moderate slopes near the tops of hills. The minor Woodson soils are deep, somewhat poorly drained, and form on broad ridgetops where loess may be present.

The Sibleyville-Martin-Woodson association occurs mainly in the areas of exposed Douglas Group shales and sandstones. The association consists of "moderately deep, well drained, sloping to strongly sloping soils and deep, moderately well drained and somewhat poorly drained, nearly level to strongly sloping soils on uplands" (Dickey et al. 1977a). Most

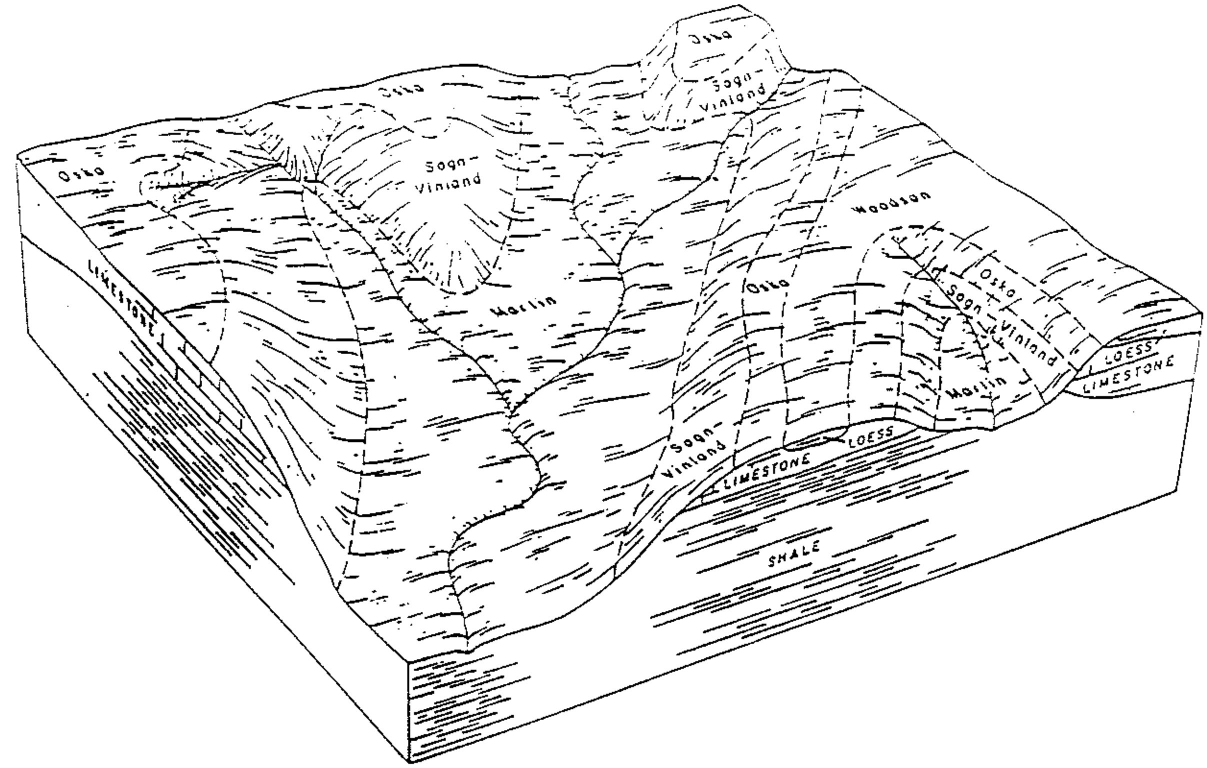

Figure I-3. Patterns of soils in Martin-Sogn-Vinland association (Dickey et al. 1977a).

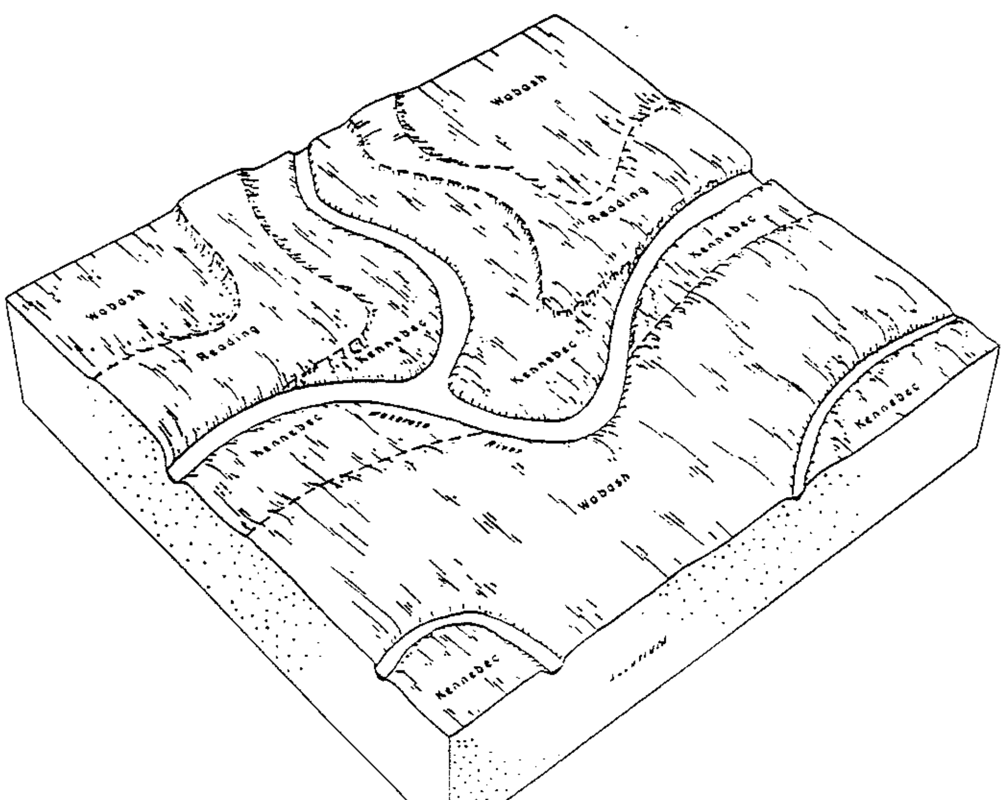

Figure I-4. Patterns of soils in Wabash-Kennebec-Reading association (Dickey et al. 1977a).

of the Baldwin Woods area includes this association. Sibleyville soils are moderately deep, well drained, and generally occur on side slopes of hills. Their counterpart in Figure I-3 would be the Sogn-Vinland soils. In the Baldwin Woods area, Basehor soils also occur on slopes in this position. The Basehor soils are shallow, well drained soils that formed from fine-grained sandstone. The Martin and Woodson soils are described above and occur in the same relative positions as in Figure I-3. Minor Pawnee soils are present in somewhat the same relative position as the Oska soil in Figure I-3 as well as on ridgetops.

The Wabash-Kennebec-Reading association formed chiefly over fluvial sediments deposited during the Wisconsinan Stage of glaciation, but also includes areas of fluvial deposits of Illinoisan age. This association comprises "deep, nearly level, well drained to very poorly drained soils on bottom lands" of flood plains and terraces of the rivers and larger streams (Dickey et al. 1977a). Essentially all of the soils in the Baker University Wetlands and the southwestern and southern parts of the Robinson Tract are included in this association. Figure I-4 shows the pattern of the major soils in the association. The Wabash soils occur in backwater areas on high bottoms and low terraces adjacent to the bottom of the valley walls of the floodplain. The silty clay nature of the soils reflects the overbank type of fluvial deposits and results in poor to very poor drainage. The soil in the northern two-thirds of the Baker University Wetlands is Wabash silty clay. The Kennebec soils are on the first bottoms adjacent to streams and are subject to common flooding. The silt loam and silty clay loam that constitutes these soils reflects the coarser-grained character of the sediments deposited on the floodplain near the streams in comparison with those on the higher bottoms and low terraces where the Wabash soils occur. Kennebec silt loam is present in strips adjacent to the Wakarusa River channel. Thus, the Kennebec soils are well to moderately well drained. Both Kennebec and Wabash soils cover the strip of the Robinson Tract in the Kansas River floodplain. The Reading soils formed on high bottoms and terraces. The soils are well drained and consist of silt loam and silty clay loam. Reading silt loam occurs in the southern part of the Wetlands as a wide band just north of and paralleling the Wakarusa River and to the south of the Wakarusa River within the area between the meander that encroaches farthest into the Wetlands.

Soils of the Eudora-Kimo association are on the Recent alluvial sediments of the lower levels of the Kansas River floodplain. The association includes "deep, nearly level to gently undulating, well drained and somewhat poorly drained soils on bottom lands" (Dickey et al. 1977a). Eudora soils occur in the higher areas of the gently undulating flood plain of the Kansas River but below the higher Wisconsinan terrace deposits. They are well drained silt loam. Kimo soils are nearly level and are located in low areas of the Kansas River floodplain where finer surface sediments have accumulated. Thus, the surface layer of the Kimo soils consists of silty clay loam to silty clay and the soils are somewhat poorly drained.

The Pawnee-Woodson-Morrill association formed on the thicker deposits of glacial till deposited during the Kansas Stage of glaciation, and also are present on some glaciofluvial and old alluvial clayey sediment. The association is in locations with broad and moderately wide ridgetops and long, sloping side slopes such as occur in parts of the Lawrence area and from Eudora to the south for about 7 miles. "Deep, nearly level to strongly sloping, well drained to somewhat poorly drained soils on uplands" comprise the association (Dickey et al., 1977). Pawnee soils are well drained and occur on hill sides that are have gentle to moderate slopes, but can also be on ridgetops where Woodson soils are not locally present. Woodson soils form on broad ridgetops where loess may be present and are deep and somewhat poorly drained. Morrill soils occur on moderately to strongly sloping sides of hills below Pawnee and Woodson soils and are well drained. The Thurman complex that covers most of the sloping area of the Robinson Tract is a group of minor soils in the Pawnee-Woodson-Morrill association. Thurman soils range from loamy fine sand to sandy loam to clay loam, reflecting the composition of the glaciofluvial sediments on which they formed.

Hydrogeology of the Natural Areas

Baldwin Woods

Most of the Baldwin Woods is underlain by shales and sandstones of the Douglas Group (Figures I-2 and I-5). The Toronto Limestone Member of the Oread Limestone overlies the top of the Lawrence Formation in the southwest and northwest corners of the Breidenthal Biological Reserve and the extreme southeast corner of the Wall Woods. The base of the Toronto is estimated at an elevation of 1100 ft based on the geologic map of O'Connor (1960) and the U.S. Geological Survey topographic map for the area. The quarries just to the south of the Breidenthal Biological Reserve and to the north of the Wall Woods removed blocks of the Toronto Limestone. The water present in the quarry pits occurs because the underlying shale of the top of the Lawrence Formation is relatively impermeable. There is a possibility that moist soils could exist at the base of the Toronto Limestone as a result of small amounts subsurface flow through fractures in the limestone above the underlying shale.

The Ireland Sandstone Member of the Lawrence Formation is an important aquifer in southern Douglas county (O'Connor, 1960). The aquifer yields small to moderate quantities of water to wells (usually 5-50 gpm, but up to 100 gpm possible in some areas). Baldwin City obtains municipal water supplies from the Ireland Sandstone. The ground-water is unconfined (water-table conditions) in the outcrop areas of the Ireland Sandstone such as at the Baldwin Woods. At the Baldwin City well field, the base of the Ireland Sandstone rests on the Weston Shale Member in the lower part of the Stranger Formation. However, the Ireland Sandstone is thinner and finer grained at the Baldwin Woods than at the location of the Baldwin City wells because the Woods lie farther from the center of the ancient Ireland valley. The geologic map (Figure I-5) drawn using the 7.5 minute topographic quadrangle for Baldwin City and the geologic map in O'Connor (1960) indicates that the Ireland overlies the upper part of the Stranger Formation in the Baldwin Woods area.

Springs and seeps could be expected to occur at the base of the Ireland where it overlies shale such as the Robbins Shale Member of the Lawrence Formation or shales of the underlying Stranger Formation. The springs and seeps would be expected to vary appreciably in flow dependent on the amount of antecedent recharge. During and just after wet periods flows would be appreciably greater than during droughts. Springs or seeps at the base of the Ireland could be a major contributor to maintenance of water during dry periods to the very small pond in the eastern portion of the Breidenthal Biological Reserve. A band of moist soils along the outcrop base of the Ireland Sandstone could exist which might affect the distribution of floral and faunal species in the Baldwin Woods. The elevation of the base of the Ireland based on the geologic and topographic maps is estimated as 970 ft. The quality of water in the sandstone is probably similar to that for a well located about 0.2 mile to the west of the western corner of the Wall Woods (Table I-2). The water is very hard as a result of the solution of carbonate minerals, but otherwise would be considered good for domestic use.

The Stranger Formation found farther down the hillslopes in the Breidenthal Biological Reserve, Rice Woodland, and Boyd Woods is predominantly sandy shale to shale. Very small amounts of ground water could be possibly obtained from thin sandstone beds in the Vinland Shale Member, but no thick sandstones of the Tonganoxie Sandstone Member should be present because the ancient Tonganoxie valley lay appreciably to the north and northwest of the Baldwin Woods. Thus, the lower part of the Stranger Formation at the Woods is the Weston Shale Member. Weston Shale outcrops in the extreme northeast corner of the Breidenthal Biological Reserve, the north-central portion of the Rice Woodland, and the northwest part of the Boyd Woods. The elevation of the top of the Weston Shale is estimated as 950 ft. If the Vinland Shale is sandy in the area, there is a possibility that another moist band of soils could

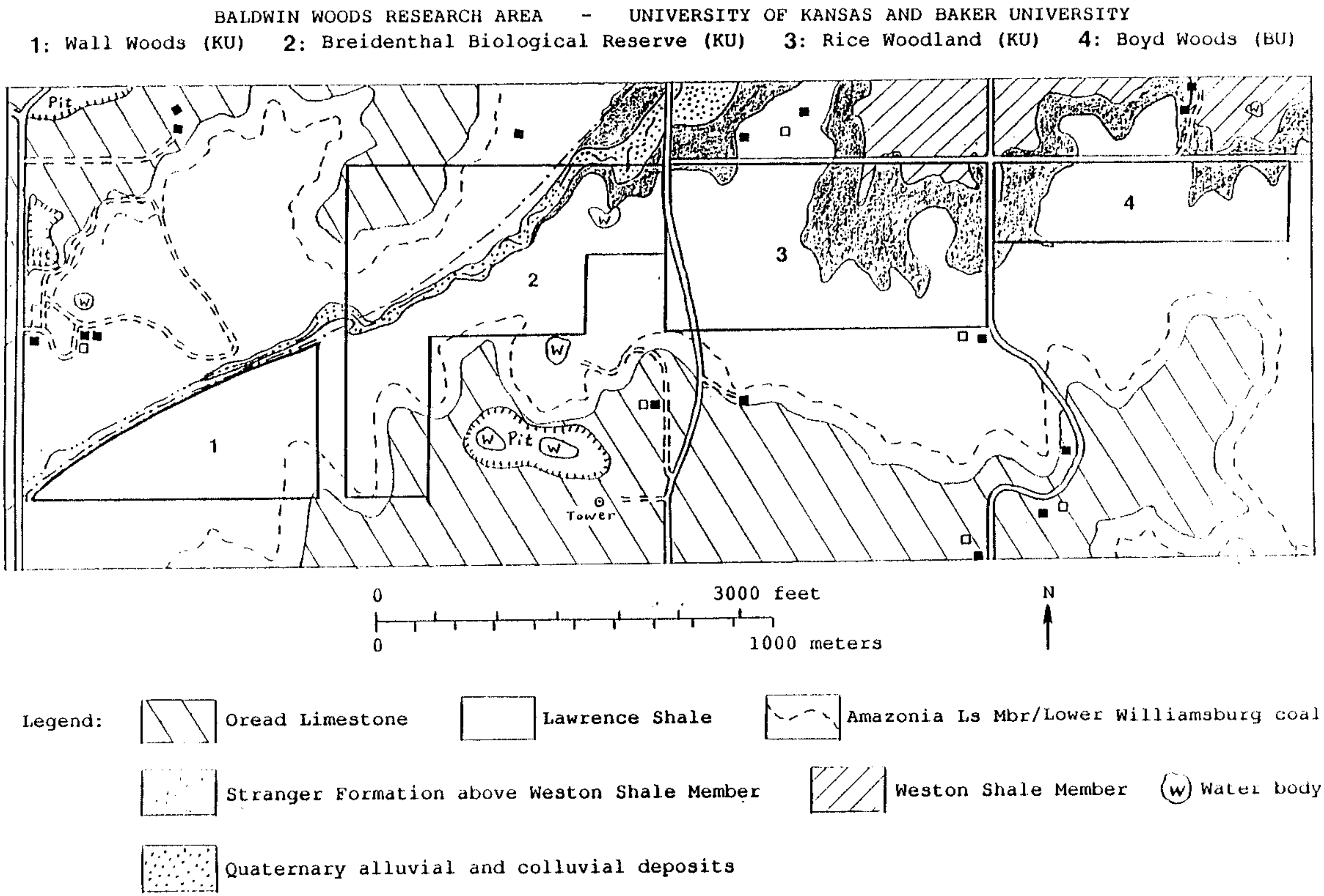

Figure I-5. Preliminary geologic map for the Baldwin Woods area. The map was produced using the U.S. Geological 7.5 minute topographic quadrangle for Baldwin City and estimates of elevations for stratigraphic boundaries in O'Connor (1960).

occur along the slopes just below this elevation. Recent colluvium and alluvium and Wisconsinan fluvial deposits are present in a narrow band along the tributary to Coal Creek in the Breidenthal Biological Reserve. Ground-water flow could continue to occur in these deposits during periods of no stream flow to help maintain subsurface soil moisture along the tributary channel.

Baker Wetlands

The Baker University Wetlands is on Wisconsinan fluvial sediments underlying the Wakarusa River floodplain. Some Illinoisan fluvial deposits could also form part of the alluvium under the Wetlands. Based on logs of test holes and wells in the Wakarusa River valley south of Lawrence (O'Connor 1960), the maximum depth of the alluvial sediments below the Wetlands and above the bedrock is probably 65-70 ft. The expected character of the sediments would be clay to silty clay to sandy clay in the upper 30 ft, to sandy clay and silt from 30 to 50 ft depth, to silty sand from 50-55 ft, with the last 5-10 ft silty sand or silty sand and gravel. The sediments differ markedly from those underlying the Kansas River floodplain, where much greater thicknesses of sands and gravels are present. A cross section (Figure I-6) from O'Connor (1960) that crosses the Wakarusa valley two miles west of the Baker Wetlands shows the shape and character of the bedrock valley in comparison with that of the Kansas River valley to the north.

Moderate amounts of ground water could be obtained from wells screened in the basal sands and gravels underlying the Wetlands. However, the presence of silt and very fine sand and the thin zone of the basal sands and gravels (1-7 ft) mean that wells drilled into the aquifer are difficult to screen and develop. The quality of water in the sediments underlying the area would probably be similar to that for well water listed in Table I-2 for the Wakarusa River floodplain. The nitrate concentration for the well water in the table is relatively high indicating local contamination. Nitrate concentrations in the basal sands and gravels underlying the Wetlands would be expected to be substantially lower, but the chloride content could be higher as a result of the intrusion of saline water from the underlying Stranger Formation. The clayey nature of most of the sediments under the Wetlands indicates that there would be only slow hydraulic communication between the surface and the basal unit. The clayey sediments under the soils would also help to perch surface water to maintain the wetland character of the area.

Robinson Tract

The Robinson Tract extends from the northern part of the Kansas River floodplain to partway up the valley wall. The valley wall in the vicinity has relatively moderate slopes in comparison with other portions of the Kansas River valley. Based on a test hole in the square portion of non-reserve land on the east side of the Robinson tract, the slopes in the tract above the floodplain are underlain by Kansas glaciofluvial deposits (O'Connor 1960). The test hole was near the junction of the road to the home and the north-south county road in the NE 1/4 of the SE 1/4 of Sec. 8, based on its location on Plate 1 in O'Connor (1960) and land surface elevation of 894 ft. Clay to sandy clay extends from the surface to 23 ft, clay and very fine sand from 23 to 52 ft, coarse sand and fine gravel at 52-58 ft, and fine to medium gravel at 58-62.5 ft, which rest on a limestone that could be the Haskell Limestone Member at the base of the Lawrence Formation. The base of the fluvial deposits is at an elevation of about 832 ft at this location, about the same elevation as the break in slope at the edge of the floodplain. A well screened in the 10 ft of basal sands and gravels at the location of the test hole could be expected to yield moderate amounts of water if the water level in the sediments were at least several feet above the top of the sands and gravels. Such a water level might occur there but probably would fluctuate appreciably from severe wet to severe dry periods.

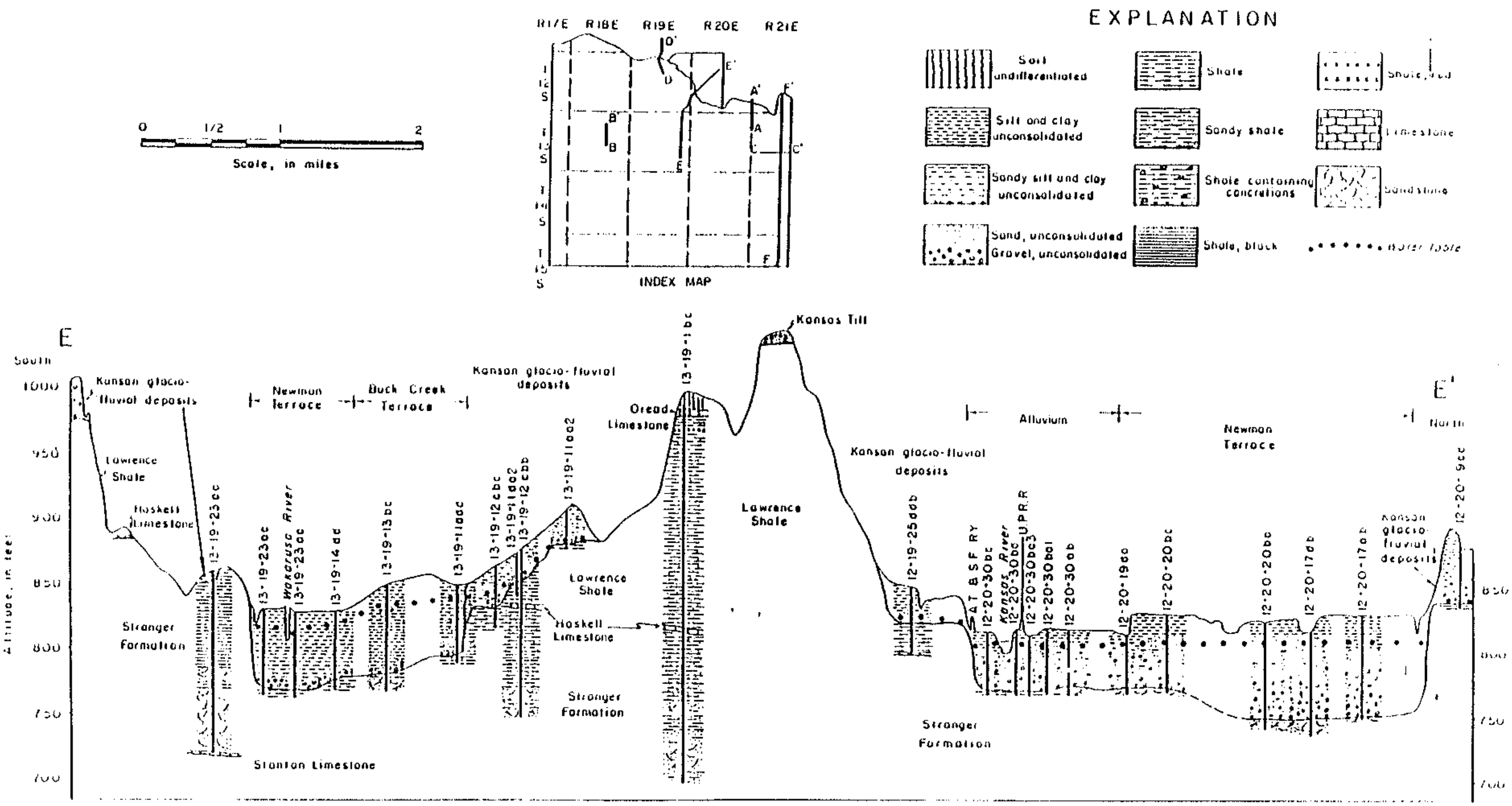

Figure I-6. Geologic cross section for the Wakarusa River and Kansas River floodplains (from O'Connor 1960). Note the coarser sediments filling the bedrock cut under the floodplain and terrace areas in the Kansas River valley on the right (north) side of the figure in comparison with the Wakarusa River valley on the left (south).

Table I-2. Chemical composition of ground waters from different geologic strata representative of units underlying the natural areas.

Concentration units are in mg/L. Nitrate concentrations greater than 10 mg/L probably represent contamination from the surface. Concentrations for dissolved Sr, PO4, Fe, and Mn in the water sample from the Robinson Tract well 12-20-8ddd were 0.44, 0.25, 0.018, and 0.028 mg/L, respectively, the field pH was 6.7 units and the specific conductance 721 uS (umho/cm). Values for the fluvial deposits underlying the Kansas River floodplain (the KER water-supply well in the Robinson Tract) are from D. Whittemore (unpublished), the others are from O'Connor (1960). Location is given as township S, range E, section, large to small quarters.

Location	14-19-15db	14-20-29da	13-19-12aad	12-20-8ddd	13-19-18dd
Geologic source	Oread Limestone	Ireland Sandstone Member	Tonganoxie Sandstone Member	Wisconsinan fluvial deposits	Wisconsinan fluvial deposits
Type area	upland	upland	Wakarusa R. valley	Kansas R. floodplain	Wakarusa R. floodplain
Well type	dug	drilled	drilled	drilled	dug, drilled
Depth, ft	28.7	92	78-127	71	37
T.D.S[a]	515	560	2,980	442	318
Total hardness[b]	305	332	384	348	218
SiO_2	2.6	13	9.6	25	5.2
Ca	63	95	103	124	71
Mg	36	23	31	9.4	10
Na + K	80	86	1,020	16.8[c]	27
K				1.0	
HCO_3	417	495	434	379	205
SO_4	32	83	58	49.5	67
Cl	43	17	1,540	11.0	13
F	0.2	0.3	0.3	0.19	0.2
NO_3	53	1.1	4.9	18	35

a. Total dissolved solids; b. Total hardness as mg/l $CaCO_3$; c. Na concentration

The south and southwest portions of the Robinson Tract lie on upper terraces of the floodplain of the Kansas River. A test hole was drilled by the KGS and USGS in 1971 at the extreme southeast corner of the Robinson Tract (100 ft west and 50 ft north of the center of the intersection) where the land surface elevation is 828 ft. A total of 73 ft of Wisconsinan fluvial deposits were drilled before encountering gray shale of the Stranger Formation. Clayey sediments extend from the soil to a depth of 24 ft, fine to medium-grained sand at 24-28 ft, clay at 28-38 ft (with sand streaks 34-38 ft), sand and fine to medium gravel at 38-58 ft, fine to medium gravel at 58-64 ft, and fine to coarse gravel in the bottom 9 ft. The zone containing gravel from a depth of 38-73 ft is the main portion of the aquifer. Other wells drilled more recently in the area have encountered bedrock at a depth of about 70-71 ft. The deepest part of the bedrock channel underlying the Kansas River floodplain in the Lawrence area is just to the southwest of the southern part of the Robinson Tract based on the cross section shown in Figure I-6. The bottom of the bedrock channel is only several feet deeper than at the southeastern corner of the Tract, indicating that the deep ancient channel of the river was against the northern part of the valley. Figure I-6 shows the broader extent and coarser nature of fluvial sediments in the Kansas River valley in comparison with the Wakarusa River valley.

The bedrock underlying the alluvium is a silty sandstone in the upper portion of the Tonganoxie Sandstone Member of the Stranger Formation. Field measurements of specific conductance during a pumping test using the KER supply well in the southeastern corner of the Robinson Tract showed very little increase, indicating that significant amounts of saline water that could be present in the deeper parts of the Tonganoxie Sandstone at this location are not being drawn up. Ground-water flow from the uplands may be slower through the shales and limestones than through the top of the Tonganoxie laterally to the wall of the subsurface bedrock valley resulting in the flushing of saline water from the top of the Tonganoxie Sandstone.

The sands and gravels of the alluvial aquifer of the Kansas River in the Lawrence area provide large quantities of water for municipal, industrial, and irrigation use. Yields of large capacity wells are generally in the 500-1,000 gpm range. The KER water-supply well drilled in 1976 pumps water at a rate of about 100 gpm to the experimental pond facility at the Nelson Environmental Study Area. The chemical composition of the well water on October 23, 1990 is listed in Table I-2. The water is very hard, but would be considered very good for domestic and agricultural purposes. The nitrate concentration is high enough that some local contamination of the aquifer is suspected such as from human or animal waste, fertilizer, or oxidation of soil organic matter from farm disturbance of soils. Monitoring wells of the Geohydrologic Experimental and Monitoring Site (GEMS) of the Kansas Geological Survey are located in the vicinity of the supply well. Additional information on the GEMS studies are in Part II of this field guide.

Tri-County Area

The subsurface material of the Fitch Natural History Reservation(FNHR), Rockefeller Experimental Tract, and the Nelson Environmental Study Area (NESA) consists of glacial till and loess on the broad to narrow ridgetops, shales and limestones of the Oread Limestone along the upper hillslopes, primarily shales of the Lawrence Formation along the lower parts of the slopes, and glaciofluvial deposits at the base of the slopes along the stream drainages. None of these materials within the Tri-County area is capable of yielding more than a few gpm to a conventional shallow well.

The most probable source of water for a well drilled on the ridgetops within the natural areas would be from within fractures, joints, and bedding planes of the Plattsmouth Limestone Member of the Oread Limestone. The log of a test hole drilled April 26, 1971 (Table I-3) in the northwest part of the NESA indicates that the Plattsmouth Limestone is 17 ft thick and somewhat weathered. The depth to water in the test hole on May 13, 1971 was 13.4 ft below the surface, a level just above the top of the Plattsmouth. The water level for this location could be expected to decline markedly during dry spells because ground-water flow to seeps and springs along the hillslopes and slow flow to underlying units would drain the limestone without substantial recharge. The Palmer Drought Index for Lawrence in April-May, 1971 was approximately -1 (Atmospheric Science Laboratory 1990), a value near the average climatic conditions. Thus, the depth to water at the test hole location could be expected to be greater during appreciably wetter periods and lower during droughts. The test hole was drilled on a relatively narrow ridgetop in the natural areas. If a well were drilled in the broader and somewhat higher portions of the ridgetops in the central portion of the NESA, the water level would probably not drop as much into the limestone during droughts, but still could drop enough to appreciably decrease the amount of water available. The quality of the water from the Oread Limestone would be very hard from the dissolution of carbonate minerals in the limestones and shales, but should be good for drinking if not contaminated in the past by leaching of nitrate from human or animal wastes, fertilizer, or the oxidation of soil organic matter during agricultural disturbance. The water analysis in Table I-2 is probably representative of water for the Oread, except for the high nitrate content which is above the 45 mg/L standard for drinking use. Uncontaminated ground waters in the upland areas of the northern tracts would have a lower nitrate content, and a somewhat lower sodium and chloride concentration because these latter two constituents are associated with animal and human waste thought to be the main source of the nitrate in the analysis in Table I-2.

Drainage of water through the Plattsmouth, Leavenworth, and Toronto limestones to the slopes of the natural areas would produce springs and seeps along the base of the limestones at the top of the underlying shales. The locations of the springs and seeps would probably be more irregular than bands of wet soils in the Baldwin Woods because the ground-water flow would be more through joints and fractures of varying sizes in different areas, in contrast with both fracture and matrix permeability in the sandstone in the Baldwin Woods. Upper Pennsylvanian rocks dip about 20 ft per mile to the west-northwest in north-central Douglas County (O'Connor 1960). The test hole described in Table I-3 drilled in the northwestern part of the NESA includes the Lower Williamsburg coal at a subsurface elevation of 959-960 ft. Barnett, Stuart, and Associates (1988) encountered a thin coal seam at an elevation of 985.2-985.4 ft in boring D-1 and at 982.3-982.9 ft in boring D-5 in the SW 1/4 of the SW 1/4 of Sec. 34, the portion of the NESA in Leavenworth County. If the coal is the Lower Williamsburg seam, then the dip of the Lawrence Shale is about 20-25 ft per mile. However, an unpublished geologic map by T. McClain for the NESA indicates that the dip is only about 15 ft per mile. McClain's map shows that the elevation of the base of the Plattsmouth Limestone ranges from about 1040 ft in the NW 1/4 of Sec. 33 to 1052 ft in the SE 1/4 of the same section in the Jefferson County portion of the NESA. The base of the Toronto Limestone ranges from an elevation of about 1008 ft to 1020 ft in the same respective quarter-sections on his map. Borings (Barnett, Stuart, and Associates 1988) in the SE 1/4 of Sec. 33 in the vicinity of the experimental pond facility passed through clays before encountering the top of some limestone at a subsurface elevation of about 1060-1061 ft. This should be somewhere in the middle of the Plattsmouth Limestone Member, based on the dip of the rocks. The borings at higher locations to a maximum depth of 20 ft found only clays and no shale or limestone. The top of the rock column is at an elevation of 1062 at the location of the test hole described in Table I-3. This suggests that the Kansas glacier stripped the bedrock to an elevation of approximately 1060-1062 ft in the NESA, followed by deposition of till, and later, loess, that now comprise the unconsolidated mantle.

Glaciofluvial deposits and colluvium are present in the two more gently sloped valleys in the west-central and south-central portions of the FNHR. These deposits can supply water to shallow wells. A well was dug in the fluvial deposits near the residence in the valley in the northwest part of the FNHR in November 1955. The well has a casing of concrete and brick, diameter of from 72 to 36 inches, and a depth of 27 ft. The measured water level on November 6, 1975, was 20.7 ft below land surface. The level dropped to a depth of 22.7 ft on November 7, 1955, after pumping at 3–4 gpm for 6 hours (V. Fitch, personal communication). The water level on November 11, 1955 was 20.5 ft below land surface

Table I-3. Log of a test hole in the northwest portion of the Nelson Environmental Study Area, T. 11 S., R. 20E-, Sec. 33bc, drilled April 26, 1971.

The elevation of the land surface was 1070 ft. (McClain, unpublished).

Geologic description	Thickness/ft	Depth/ft	Elevation of base/ft
Soil, brownish black	1	1	1069
Quaternary - Pleistocene Series			
Clay, brownish gray	7	8	1062
Pennsylvanian - Upper Pennsylvanian Series			
Virgilian Stage			
Shawnee Group			
Oread Limestone			
Heumader Shale Member			
Shale, clayey, gray, weathered to tan	6	14	1056
Plattsmouth Limestone Member			
Limestone, cherty, weathered tan to brown; contains 2" gray shale layers at 15, 16, and 17 ft	5	19	1051
Limestone, gray, white and tannish brown; contains gray shale layer from 21 to 21.5 ft	12	31	1039
Heebner Shale Member			
Shale, clayey, dark gray to black	2	33	1037
Shale, laminated, black	3	36	1034
Leavenworth Limestone Member			
Limestone, gray, hard	2	38	1032
Snyderville Shale Member			
Shale, clayey, gray; harder streaks of tan sandy or limy shale in upper 5 ft; lower 6 ft are sparsely sandy	11	49	1021
Toronto Limestone Member			
Limestone, gray, hard; layers of gray shale from 54 to 54.2 ft, 56.2 to 56.5 ft, and 56.8 to 57.1 ft	13	62	1008
Douglas Group			
Lawrence Shale			
Shale, clayey, light greenish gray	11	73	997
Upper Williamsburg coal			
Coal, black, soft	1.5	74.5	995.5
Shale, clayey, light greenish gray; contains laminated dark gray layers	5.5	80	990
Amazonia Limestone Member			
Limestone, gray; thin shale partings from 81 to 83 ft	2.5	82.5	987.5
Shale, clayey, light gray	27.5	110	960
Lower Williamsburg coal			
Coal, black, soft	1	111	959
Shale, platy, light gray	24	135	935
Shale, very fine sandy, gray	30	165	905

according to O'Connor (1960). The period of level measurements was during the severe drought period of the 1950's, thus the usual water level is expected to be higher. Although the dug well is about 600 ft west-southwest of the residence, it became contaminated from near surface seepage. Use of the water for household purposes was discontinued at the end of 1983 and the well was capped. The residence was connected to the rural water system in the fall 1984. The quality of water in the fluvial deposits is probably similar to that for the ground water from the Oread Limestone in Table I-2 because drainage through the limestones and calcareous shales of the Oread and the Lawrence Formation would comprise an appreciable portion of the water at the FNHR location. Whether the nitrate was as high as that in the table would depend on the location of the septic field and any past activities in the area that could have introduced nitrate to the subsurface.

If a deep well were drilled near the FNHR residence, it would encounter the coarser sediments of the Tonganoxie Sandstone Member of the Stranger Formation at a depth of 200-250 ft. The well would probably yield small to moderate amounts of water to a well. However, the water may be saline and not suitable for domestic use because the sandstone aquifer is confined underlying this location. An analysis of the water from a well in the Tonganoxie Sandstone that was located in south Lawrence (Table I-2) suggests what the water quality might be like in the lower part of the sandstone underlying the FNHR residence. A test hole next to Foley Hall (the former Geohydrology Center of the KGS and location of the present offices of the KBS) was drilled an additional 24 ft past the Tonganoxie Sandstone down to the Stoner Limestone Member of the Stanton Limestone. The chloride content of the borehole water was 2,160 mg/L. The geologic environment of the south Lawrence well (Table I-2) and the Foley borehole is somewhat equivalent to that of the FNHR residence home based on the presence of the overlying Lawrence Formation and the position relative to the Kansas River valley and to the north-northeast strike of the rocks. The water quality in the Tonganoxie Sandstone is relatively good where the sandstone is unconfined in Douglas and Leavenworth Counties and also good in some confined areas such as southwestern Douglas County. The water in the sandstone generally improves updip, thus, the best quality for the northern tracts area would be expected in the southeast corner of the FNHR. As indicated in the geohydrologic description for the Robinson Tract, the water in the upper part of the Tonganoxie Sandstone is probably of better quality due to the flushing effect of water moving laterally to the subsurface wall of the bedrock valley of the Kansas River. Thus, a well drilled to a depth of about 170 ft at the FNHR residence might yield small quantities of water of usable quality in the upper part of the Tonganoxie. Prior to the shallow well dug in the fluvial sediments near the residence, a well was drilled about 200 ft deep into the Tonganoxie Sandstone (H. O'Connor, personal communication) in 1948 or 1949, about 50 ft east-northeast of the residence. The drilled well provided water of acceptable quality for a few years until it was abandoned and filled due to a combination of low yield (H. O'Connor) and contamination from surface material (V. Fitch).

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