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DEPARTMENT OF NATURAL RESOURCES

DIVISION OF GEOLOGICAL AND GEOPHYSICAL SURVEYS

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GROUND-WATER RESOURCES OF THE PALMER-BIG LAKE AREA, ALASKA: A CONCEPTUAL MODEL

By

J. Brett Jokela, James A. Munter, and

James G. Evans

STATE OF ALASKA
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GROUND-WATER RESOURCES OF THE PALMER-BIG LAKE AREA, ALASKA: A CONCEPTUAL MODEL

by
J.Brett Jokela,[1] James A. Munter,[2] and James G. Evans[1]

ABSTRACT

The Matanuska Susitna Borough in southcentral Alaska has witnessed rapid development for residential and recreational land use, particularly in the area between the communities of Big Lake and Palmer. Surface-water resources are an important attraction to the area. Ground-water resources are used almost exclusively for water supply in the area.

We provide a conceptual ground-water model for this area in order to provide a planning tool for water supply and waste disposal system design, to enhance understanding of ground-water resources, and to help protect ground-water supplies. The model consists of watershed delineations, a summary of geologic conditions in the area, a regional water-table map, representative cross sections for key areas, and descriptions of ground-water and surface-water interactions in the area. To demonstrate its utility, the model is applied to areas of particular concern.

The regional water table map used data from approximately 3,600 computerized water-well logs and hydrographic information from 1:25,000-scale topographic maps to show regional and local ground-water flow directions in 11 watersheds. Ground water is recharged from local precipitation and snowmelt throughout most of the study area. Ground water is an important contributor to base flow in area streams and discharges to most or all of the 439 lakes and ponds in the region. Although shallow ground-water divides were generally concordant with watershed boundaries, regional flow directions were somewhat discordant with regional stream orientations.

INTRODUCTION

This report presents a conceptual model of the ground-water resources of the Matanuska-Susitna Borough in the area between Big Lake and Palmer. The model is intended as a tool for planning and management of ground-water resources in the Borough. James M. Montgomery, Consulting Engineers, Inc. (JMM) prepared this report in cooperation with the State of Alaska, Department of Natural Resources, Division of Geological and Geophysical Surveys (DGGS) as part of a professional services agreement dated December 1989 between JMM and the Matanuska-Susitna Borough and a letter of agreement between JMM and DGGS dated January 12, 1990.

The Matanuska-Susitna Borough (MSB) is in southcentral Alaska, adjacent to and immediately north of the Municipality of Anchorage (fig. 1). The Borough is generally contained within the watersheds of the Matanuska and Susitna Rivers, which flow from glaciers in the Alaska Range, the Talkeetna Mountains, and the Chugach Mountains to tidewater in Knik Arm of Upper Cook Inlet. The lower reaches of the two glacial valleys converge, forming a low plain between Big Lake and the city of Palmer, an area known locally as the "Valley." The abundance of water-related recreational opportunities and the proximity to Anchorage have encouraged suburban development in the Valley.

The Borough has experienced rapid growth in the last two decades. Most of this development occurred in the valley as a result of the short driving distance to Anchorage. Surface-water resources of the Valley are heavily used for recreation, such as fishing and boating. Ground-water wells are the principal water source for both single-family and public water supplies, including large systems serving the heavily populated communities of Wasilla and Palmer. Only about one quarter of the Valley population of 30,000 or more has access to public water supplies.

Increased demand on water-resource quantity and quality throughout the Valley has resulted from several factors including:

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- Development of older subdivisions with smaller lots than would be permitted under existing regulations.
- Development of multifamily dwellings on small lots.
- Commercial water use.
- Solid waste landfills.
- Gravel pits.
- Land clearing.
- Wetland fill.
- Underground fuel tanks.
- Improperly installed and maintained septic systems.
- Inadequate drainage planning for impermeable paved areas.
- Increased recreational use of lakes.

Each of these factors potentially affects the quality and quantity of ground-water resources in the Valley.

A conceptual understanding (or model) of the distribution and characteristics of ground-water resources will help demonstrate the relationships between human activities and ground-water quality. Such a model can include descriptions of flow patterns, aquifer recharge areas, and discharge characteristics. Development of a model for the Borough will help identify the aquifers most commonly used and areas most likely to be affected by water supply withdrawals, wastewater disposal, or other sources of contamination.

The model is a planning tool for water-supply and waste-water system planning, for identifying hydrologically sensitive wetlands, and protecting ground-water supplies. Development of the model is a necessary prerequisite to providing ground-water management planning for the Valley. It will also help develop a ground-water monitoring network by helping planners understand the structure and dynamics of local ground-water flow systems. To illustrate uses of the model, this report provides examples of applications of particular concern to the Borough.

ACKNOWLEDGMENTS

Funding for this study was provided by Alaska Department of Environmental Conservation (ADEC) and the Matanuska-Susitna Borough (MSB). The study was conducted under the guidance of a technical advisory committee consisting of the authors of this report and Keith Anderson (JMM), William S. Ashton (ADEC), Gordon Nelson (USGS), William D. Pyle (JMM), and Rodney Schulling (MSB). JMM, project staff and personnel from DGGS and USGS assisted in the preparation of the report. Scott Ray, Richard D. Reger, and Larry L. Dearborn reviewed the manuscript.

DESCRIPTION OF THE STUDY AREA

STUDY AREA BOUNDARIES

We have developed a conceptual ground-water model for that portion of the Borough experiencing the most residential and recreational development. The study area generally includes the portion of the Borough south of the Little Susitna River from Big Lake to Palmer (fig. 1, sheets 1, 2, and 3). Study area boundaries were developed from a combination of hydrologic rationale and potential development activity.

GEOLOGIC SETTING

A conceptual description of ground-water resources requires an understanding of landforms and earth materials that influence the location and availability of ground water. This understanding should include knowledge of the depth and type of bedrock and the nature of the unconsolidated sediments that overlie bedrock. In the Valley, the terrain is dominated by distinctive landforms created by repeated glacial advances and retreats during the Pleistocene epoch (about 10,000 to 2 million years ago).

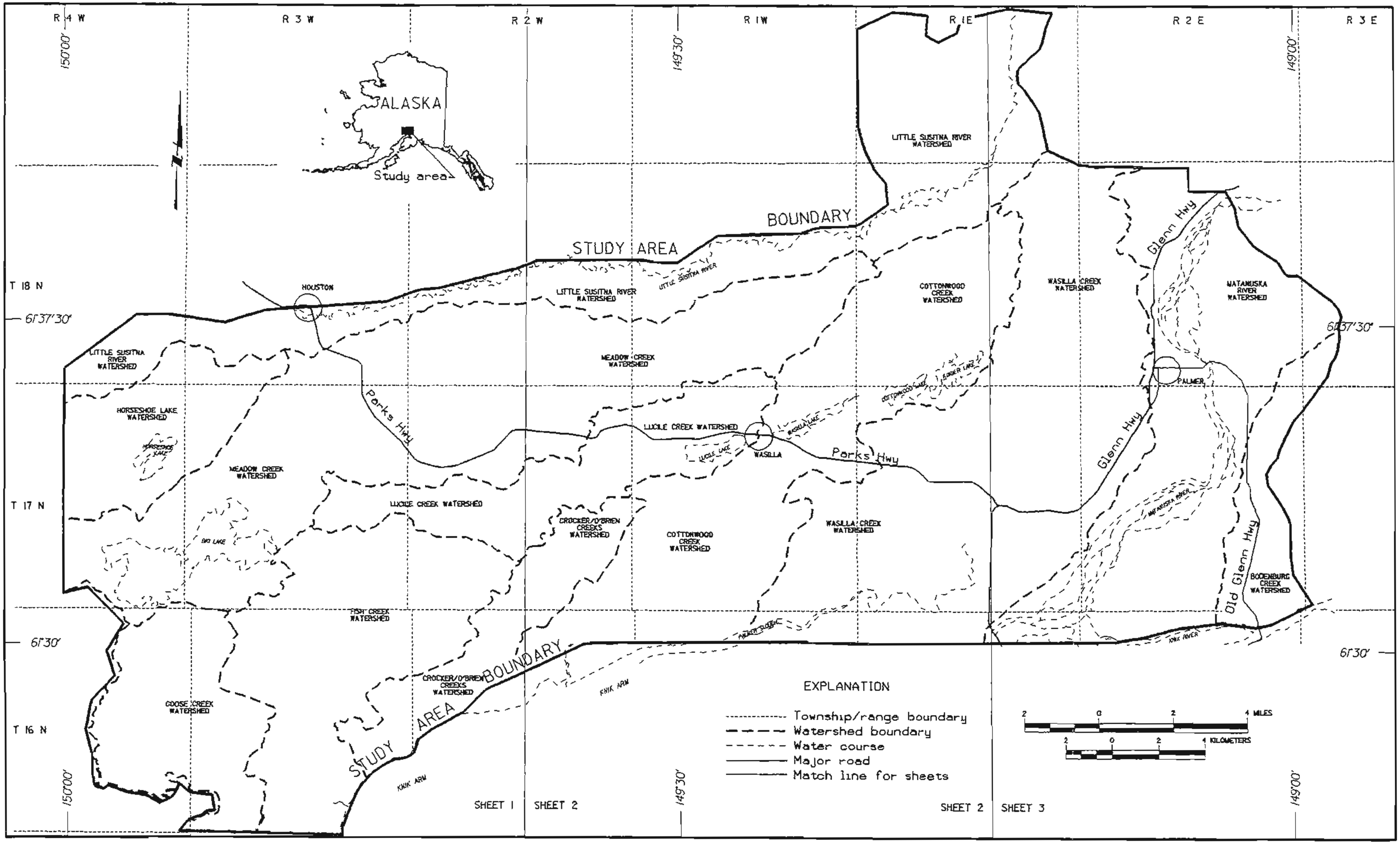


Figure 1. Index map showing locations of watersheds in Big Lake-Palmer area and coverage of sheets 1-3.

Several authors have discussed geological conditions as they relate to ground-water resources, notably Trainer(1960), Feulner (1971), and Freethey and Sculley (1980). The following brief summary describes earlier findings about the geology of the area.

BEDROCK

The term bedrock is used in this report to refer to all sedimentary, metamorphic and igneous rocks in the study area. Bedrock of the Chugach Mountains (including Bodenburg Butte) east of the study area is composed of mostly metasedimentary and intrusive igneous rocks of Mesozoic-age. The Talkeetna Mountains, located north of the study area, are composed mostly of intrusive igneous rocks of Tertiary age. A sequence of Tertiary-age sedimentary rocks (conglomerate, shale, sandstone and coal) are found on the southern flanks of the Talkeetna Mountains, along the Matanuska River northeast of the study area, and directly beneath the unconsolidated deposits in most of the study area. The Upper Cook Inlet region, which includes the study area, is bounded by faults along the foothills of the Talkeetna and Chugach Mountains.

Mapping by Freethey and Sculley (1980) shows that bedrock lies at or near the surface in the northern and eastern part of the study area, with the thickness of unconsolidated sediments increasing from north to south. The southern and western edges of the study area have depths to bedrock of more than 230 meters. Beyond the study area boundary to the west, the depth to bedrock is even greater, reaching a maximum of 1,300 meters in the Susitna River floodplain near the channel islands, approximately 30 kilometers west-southwest of Big Lake. A constriction of the Matanuska River floodplain near Palmer (sheet 3) is located in the vicinity of shallow bedrock.

UNCONSOLIDATED DEPOSITS

Quaternary-age unconsolidated deposits overlie bedrock in the Valley. Glacial drift was deposited on the valley floor when lobes of the Matanuska and Knik glaciers and earlier glaciers covered much of the Cook Inlet basin. Non-glacial processes are also responsible for a small portion of the materials that are found in the area. These materials include loess (windblown silt), alluvium in modern rivers and fans, talus, and marine and lacustrine deposits.

Glacial drift in the Valley includes till, outwash stream deposits, and deposits formed in standing water. Till is fragmental, unconsolidated material deposited by or from glacial ice with little or no modification by running water. It is unsorted, consisting of rock fragments ranging in size from clay to boulders. End moraine, lateral moraine, and ground moraine deposits are predominantly composed of till.

Evidence of sorting by sizes, or evidence of weathering or smoothing of clasts is indicative of glacial outwash or glaciofluvial deposition. These deposits usually have very little fine material associated with them, as the running water carried away the fines while leaving behind the larger grain sizes. Some outwash deposits are pitted, where buried ice remained in the outwash channel and subsequently melted, leaving depressions in the otherwise flat terrain.

Still waters allow settling of fine materials, including fine silts and sands. The Knik Arm estuary was responsible for depositing silt layers along the southern boundary of the study area. Some well logs in the Valley report layers of silt and sand that may have been deposited in lakes created by glacial ice dams.

Most wells in the Valley obtain water from relatively well sorted sands and gravels within glacial drift. Where these sands and gravels occur near the land surface, they form a water table aquifer. Permeable deposits buried beneath silts and clays form confined aquifers. Both water-table and confined aquifers occur in the Valley.

SURFACE LANDFORMS

The advance and retreat of the glaciers has been inferred from geological evidence left behind on the ground surface in the Valley. Glacial melting and movement created a variety of depositional environments and an intricate pattern of material types and topographic features in the study area. Generally, the surface of the study area (fig. 2) exhibits a transition from glacial outwash and ice contact deposits in the east to morainal topography and more surface expressions of till materials in the west (Trainer, 1960; Reger and Updike, 1983; Daniels, 1981a and 1981b; and Reger, 1981a, 1981b, 1981c, and 1981d).

WATERSHED BOUNDARIES

The study areas include hundreds of ponds and lakes and a system of streams varying in size from small springs and rivulets in wetlands to the large, braided, glacier-fed Matanuska River. To provide a basis for discussion of ground-water resources at a local scale, principal topographic divides were identified from topographic maps and air photos to delineate watersheds. Eleven watersheds have been defined and are described in table 1 and figure 1. Some watersheds contain areas without integrated drainage networks. These areas of hummocky topography were not identified separately but were included with adjacent drainage networks in their watersheds.

Table 1. *Principal watersheds in the study area*

STUDY AREA WATERSHEDS

Watershed name	Drains to	Remarks
Little Susitna River	Knik Arm	The northern boundary of study area approximately follows the river channel. Watershed includes Government Peak winter sports area and south drainages to the river only.
Horseshoe Lake	Little Susitna River	Relatively flat, many lakes, interconnected by unnamed creek.
Meadow Creek	Fish Creek	Relatively flat, many lakes. Includes Big Lake. Area developing rapidly.
Lucile Creek	Meadow Creek	Headwaters in Wasilla area. Small stream runs parallel to Meadow Creek from Lucile Lake.
Goose Creek	Knik Arm	Southwest corner of study area. Headwaters near Big Lake. Large percentage of watershed is wetland.
Fish Creek	Knik Arm	Receives drainage from Lucile and Meadow Creek watersheds through Big Lake.
Crocker/O'Brien Creeks	Knik Arm	Watershed includes several small, contiguous drainages near Knik Arm.
Cottonwood Creek	Knik Arm	Numerous lakes, variable local relief.
Wasilla Creek	Knik Arm	Headwaters in mountains beyond study area boundary.
Matanuska River	Knik Arm	Glacial headwaters 80 miles upstream of study area boundary. Only local drainage considered.
Bodenburg Creek	Knik Arm	Narrow watershed with headwaters at Lazy Mountain. Includes community of Butte.

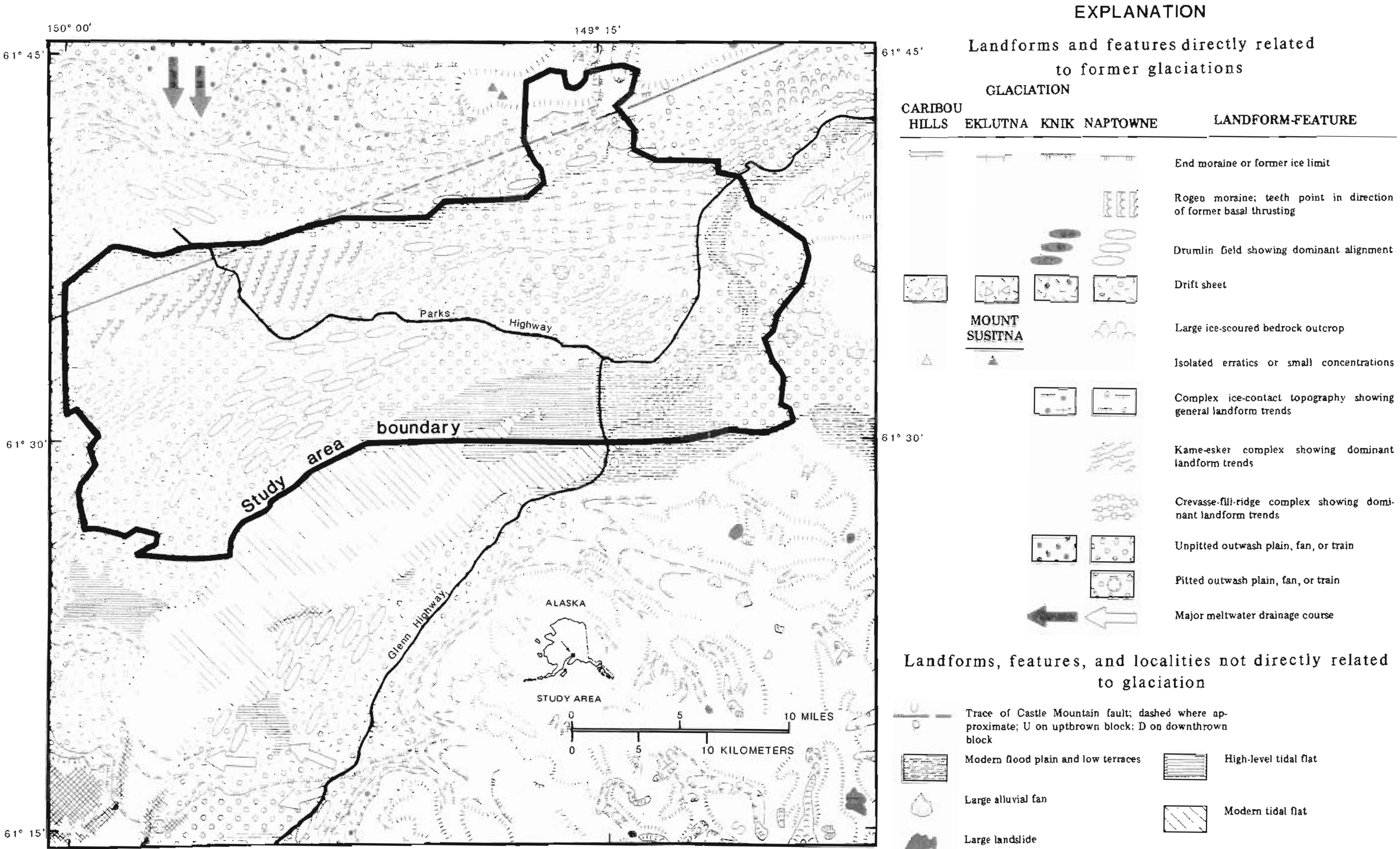


Figure 2. Landforms and geological features in study area (modified from Reger and Updike, 1983, plate 1).

AREAS OF PARTICULAR CONCERN

The Matanuska-Susitna Borough has identified several areas of particular concern (table 2) because of the potential for ground-water contamination or the possibility of inadequate or impaired public water supplies. Hydrogeologic cross-sections were constructed near these areas to identify local conditions and to show applications of the conceptual model. Available information for these areas is summarized in the section of this report under the heading "Study Area Observations and Inferences," page 29.

Table 2. *Areas of particular concern in the study area*

Area or facility	Location	Remarks
Houston Septage Facility	T17N R3W S11	Potential contamination from land disposal of effluent.
Big Lake Landfill	T17N R3W S22	Potential contamination from landfill leachate.
Airport Industrial Park	T17N R2W S13	Commercial water user. Potential industrial contamination.
Wasilla Leachfield	T17N R1W S13	Potential contamination from municipal wastewater.
Butte Landfill	T17N R2E S25	Potential contamination from landfill leachate. Landfill is closed.
Central Landfill	T17N R1E S1	Potential contamination from landfill leachate.
Colony School	T18N 1E S35	Water supply for school.
Government Peak winter sports area	T19N 1E S32	Water supply and wastewater disposal for possible resort development.

REGIONAL WATER TABLE

REGIONAL WATER TABLE MAP

The water table is defined as the level to which water will rise in a well that barely penetrates the water table. The regional water-table map is a generalized representation of the true water table on a regional scale. The regional water-table map, which is divided into three segments (sheets 1-3), can be used to infer regional and local flow directions of ground water. The maps show the study area boundary, watershed boundaries, water-table contours, regional and local ground-water flow directions (indicated by arrows), locations of cross sections, and individual well locations. Well identification numbers are shown for wells used in developing the hydrogeologic cross sections. The well identification numbers shown were arbitrarily assigned for this report only.

METHOD OF DEVELOPMENT

The regional water-table map was constructed using data from approximately 3,600 well logs in the USGS Ground-Water Site Inventory (GWSI) computer database. Approximately 100 other well logs were also obtained from DGGS files. Ground-water contours were manually drawn using water-level data from well logs and elevations of surface-water bodies. Approximate flow directions were interpreted as being perpendicular to the ground-water contours from higher elevations to lower elevations. Where no well log information was available in a region, contour lines were interpreted from surface expressions of the water table, such as lakes, ponds, streams, and wetlands. Although some wells in the study area tap confined or semiconfined aquifers, numerous wells appear to tap water-table aquifers. Dearborn and Allely (1983), for example, noted that the depth of about three-fourths of the known wells in the Big Lake area was 65 ft (20 m) or less. Approximately

10-20 percent of the water-level data appeared to be anomalous with the surrounding data. These anomalous data were not used to draw contours because of the likelihood that the data were erroneous or that the well tapped a confined aquifer rather than a water-table aquifer.

LIMITATIONS

The relatively low level of accuracy of the data available for constructing the region water-table map precludes its being used with confidence for exact site-specific definition of the water table or ground-water flow directions. The well-log data contained in the GWSI database, for example, were reported from many different drillers who recorded the information over many years. As a result, well data are commonly incomplete or of limited accuracy. Well locations and well-head elevations, as another example, are usually only approximately determined within the parcel of land on which the well is located.

The accuracy of the regional water-table map is limited also by the availability and distribution of data in the study area. Water-table contours are likely to be more accurate in areas with more closely spaced data.

The water table mapping also did not consider vertical ground-water flow components or local geologic heterogeneities. These factors can produce local ground-water flow patterns that are much more complex than shown. Local geologic variations occur in the study area because of the complex depositional environments that existed during glacial times.

RESULTS

The regional water-table slope in the central part of the study is from north to south. In the eastern part of the area the water table slopes toward the Matanuska River, and in the west the slope is predominantly northeast to southwest. Numerous local deviations from these trends occur, especially near streams.

The water-table gradient varies from greater than 0.2 meter/meter in the mountainous areas to as low as 0.0025 meter/meter in the western part of the study area. A comparison of local and regional flow-direction arrows on the water-table map shows that they commonly differ substantially in orientation. Several water-table mounds are also mapped, mostly straddling watershed boundaries. These water-table mounds provide direct evidence that percipitation and snowmelt recharge the shallow ground-water system throughout the study area. Precipitation falling on the foothills of the Talkeetna or Chugach mountains recharges water-table aquifers near the mountains and may also recharge deep aquifers in the lowlands.

HYDROGEOLOGIC CROSS SECTIONS

METHODOLOGY

Seven cross sections were developed to show typical ground-water conditions in areas of particular concern where sufficient well-log data were available. The sections are drawn at various horizontal scales; the vertical scales are all identical. Thus, vertical exaggeration in the cross sections varies from 125x to 312.5x.

Cross sections show the land surface topography, the interpreted water table, the location of surface water, important cultural features such as roads and airports, and the surface landforms along the sections as mapped by Reger (1981a; 1981b; 1981c; 1981d) and Daniels (1981a; 1981b). A regional landform map by Reger and Updike (1983) supplied landform information for areas not covered by other maps.

The data used in the development of the cross sections were taken from well log data stored in the GWSI database. The database contains information about water levels and geologic units observed by drillers during well installation. These observations were converted into standard terminology by USGS prior to computer entry (figs. 3-9).

To enhance visualization of hydrogeologic conditions in the study area, geologic units were categorized as permeable or less permeable units, depending on the degree of sorting and the grain size of the materials described. Well sorted and relatively coarse-grained materials were classified as permeable units (for example, gravel, sand, alluvium) and poorly sorted and relatively fine-grained materials are classified as less permeable units (for example, clay, silt, till). Permeable units are patterned and less permeable units are unpatterned on all cross sections.

The line of each cross section is drawn from well to well in plan view so that each of the wells used for the cross section lies directly on a cross section line, and the line bends at every well. The deflection of the cross section lines between wells is generally limited to less than 45 degrees. The inferred water table position between wells on the sections is shown to illustrate regional trends and local variations of the water table.

The subsurface deposits shown on the sections are somewhat disordered and generally not continuous from well to well. As a result, subsurface geologic correlations were not made, and individual water-bearing units were not specifically identified as part of this study. Rather, the data demonstrate that the regional water table shown on sheets 1-3 is a generalized representation of a complex flow system where local geologic conditions control the depth and yield of ground-water resources and local directions of ground-water flow.

BIG LAKE CROSS SECTION

The Big Lake cross section (fig. 3) is the longest in the study area. It extends from Big Lake in the southwest to Pittman Road to the northeast (sheet 1). This section was developed to show ground-water conditions near the Big Lake Landfill and within the western lakes region of the study area. The section is drawn at a smaller horizontal scale than the other sections (1:50,000) to provide a view of ground-water conditions over a region at least twice the size of those shown by the other sections.

The water-table trend in the cross section is downslope from north to south except at topographic divides where local ground-water divides can also be observed. This may indicate that both local and regional ground-water flow systems occur in this area. The Big Lake section also clearly illustrates the heterogeneity of the glacial deposits. Four different surface landform types are shown on the cross section (Reger, 1981a) with numerous individual segments of each type. This irregular composition of the surface deposits also characterizes subsurface deposits.

LUCILE CROSS SECTION

The Lucile cross section line (fig. 4) extends from the southwestern shore of Lucile Lake northeast to the northern boundary of the Lucile watershed (sheet 2). The cross section allows close study of the Wasilla vicinity including the existing Wasilla Municipal Airport. The trend of the water table slope is from north to south. The cross section illustrates how topographically high areas can have a relatively thick (over 30 meters) unsaturated zone above the regional water table.

LUCILE LAKE DETAILED CROSS SECTION

A detailed cross section (fig. 5) through Lucile Lake and the area immediately south of the lake (sheet 2) illustrates typical ground-water and surface water interactions in the study area.

This section gives a detailed view of the local water table configuration near Lucile Lake. The significance of the water-table mound located immediately to the south of the lake is discussed under the heading "Lucile Creek watershed" (page 31). The regional water-table slopes approximately north to south.

COTTONWOOD CROSS SECTION

The Cottonwood Creek cross section (fig. 6) is located in the northern part of the Cottonwood watershed (sheet 2). This area contains several lakes, including Wasilla, Cottonwood, and Mud Lakes and is in close proximity to the Wasilla community septic tank effluent leachfield. This area has an abundance of available well data. The water table on this section shows a marked drop in elevation from north to south. Two deep wells on the north end of the cross section appear to have penetrated Tertiary sedimentary rocks (sandstone and coal) to obtain water.

COLONY CROSS SECTION

The Colony cross section (fig. 7) is located close to the Colony Jr./Sr. High School and the Central Landfill (sheet 3). It was drawn to determine the water table configuration in the vicinity of these two sites. The Colony section is short due to a lack of available data north of the school and south of the landfill. The trend of the water table is downward from north to south. Nine of the twelve wells in this section show sandy gravel underlain by gravelly clay. Seven of these wells penetrate gravel or sandy gravel below the gravelly clay. The gravelly clay may be a continuous till layer confining a deeper gravelly aquifer. Three of the wells that do not conform to this pattern are all on the northern portion of the section.

The surface landform data used in this and the following sections are from a regional landform map by Reger and Updike (1983) and use different terminology than that used on the preceding sections.

PALMER CROSS SECTION

The Palmer cross section (fig. 8) extends from immediately east of Palmer through the municipal airport, south to the Matanuska River (sheet 3).

The flatness of the floodplain terrain is distinctly different from the gently sloping outwash plain to the north. This is the one watershed of the study area in which continuous confining units are clearly identifiable above permeable units. The findings in this area match the findings of Trainer (1960), who documented the existence of a confining layer in the area north and west of Palmer. Thick alluvial deposits beneath the confining layer and the location of the section in a major river valley indicate that a large and productive aquifer may exist. The water table trends downward from north to south in the outwash plain segment of the cross section but rises slightly near the river.

BUTTE CROSS SECTION

The Butte cross section (fig. 9), which is located in the Bodenburg Creek watershed, allows study of the ground-water conditions near the community of Butte and the Butte Landfill. The cross section closely follows Bodenburg Creek from the Matanuska/Bodenburg hydrologic boundary to the Butte Airport area (sheet 3). Numerous bends in the section cause the section line to cross the creek several times, although detailed topographic depressions are not shown at the crossings.

The topographic relief along the section is less than five meters which complicates interpretations of ground-water conditions. The water table shows a low area in the middle of the section. This low area may be a result of map inaccuracies caused by local topographic relief not incorporated in the database, seasonal variations in the water table, or fluctuations in water levels caused by rising or falling stages of the Matanuska or Knik Rivers. The existing data are insufficiently detailed to discern specific ground-water and surface- water interactions in this area.

INTERACTIONS OF GROUND WATER AND SURFACE WATER

The Valley area contains abundant and diverse types of surface water. In addition to the two largest rivers, the Matanuska and the Little Susitna, there are approximately 439 lakes and ponds and 10 streams or rivers. Surface water also is found in wetlands located throughout the study area. Some wetlands are closely associated with lakes, ponds, streams, or rivers, and others are geographically isolated, usually in closed upland depressions. Tidal sloughs of Knik Arm border the study area to the south.

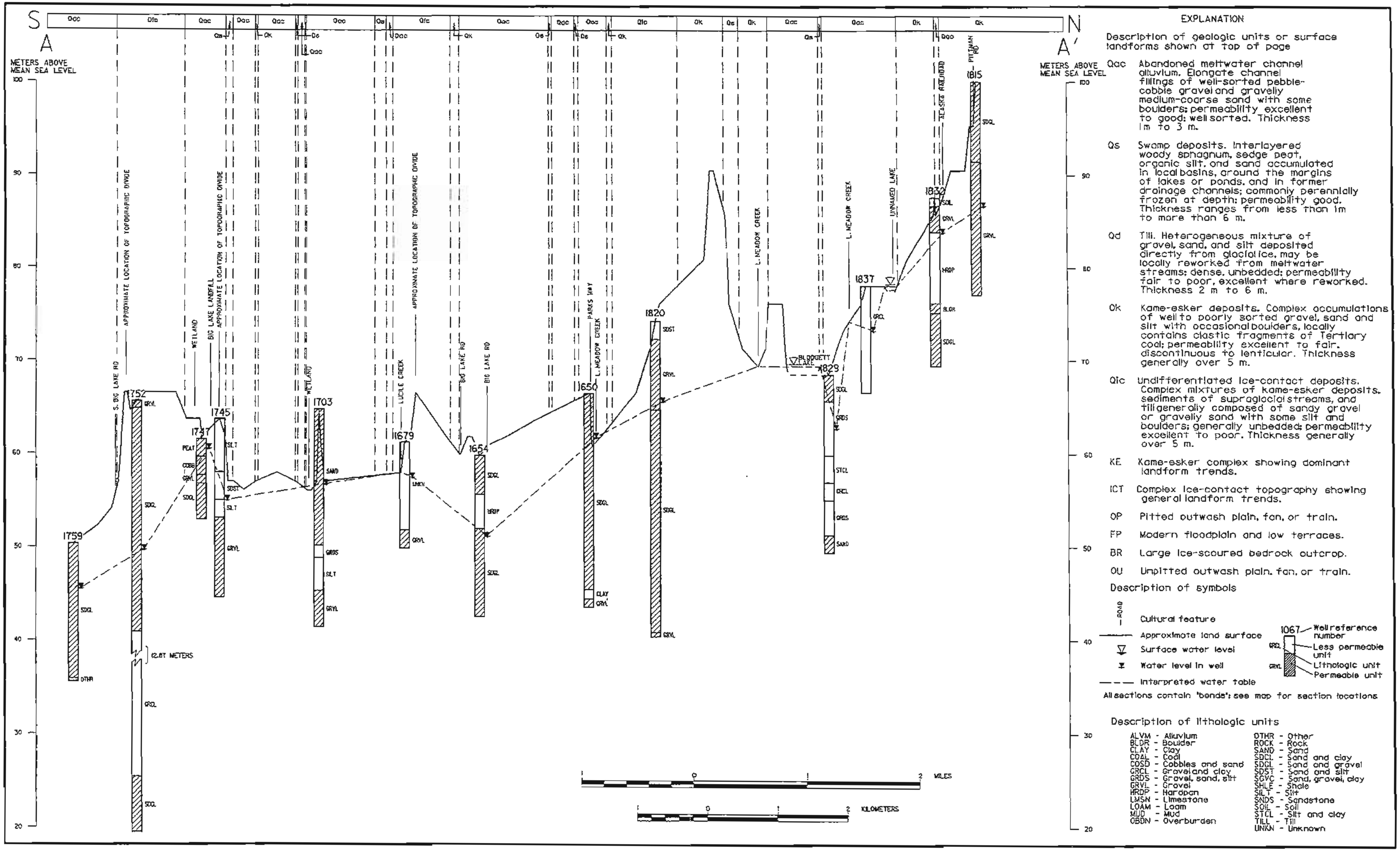
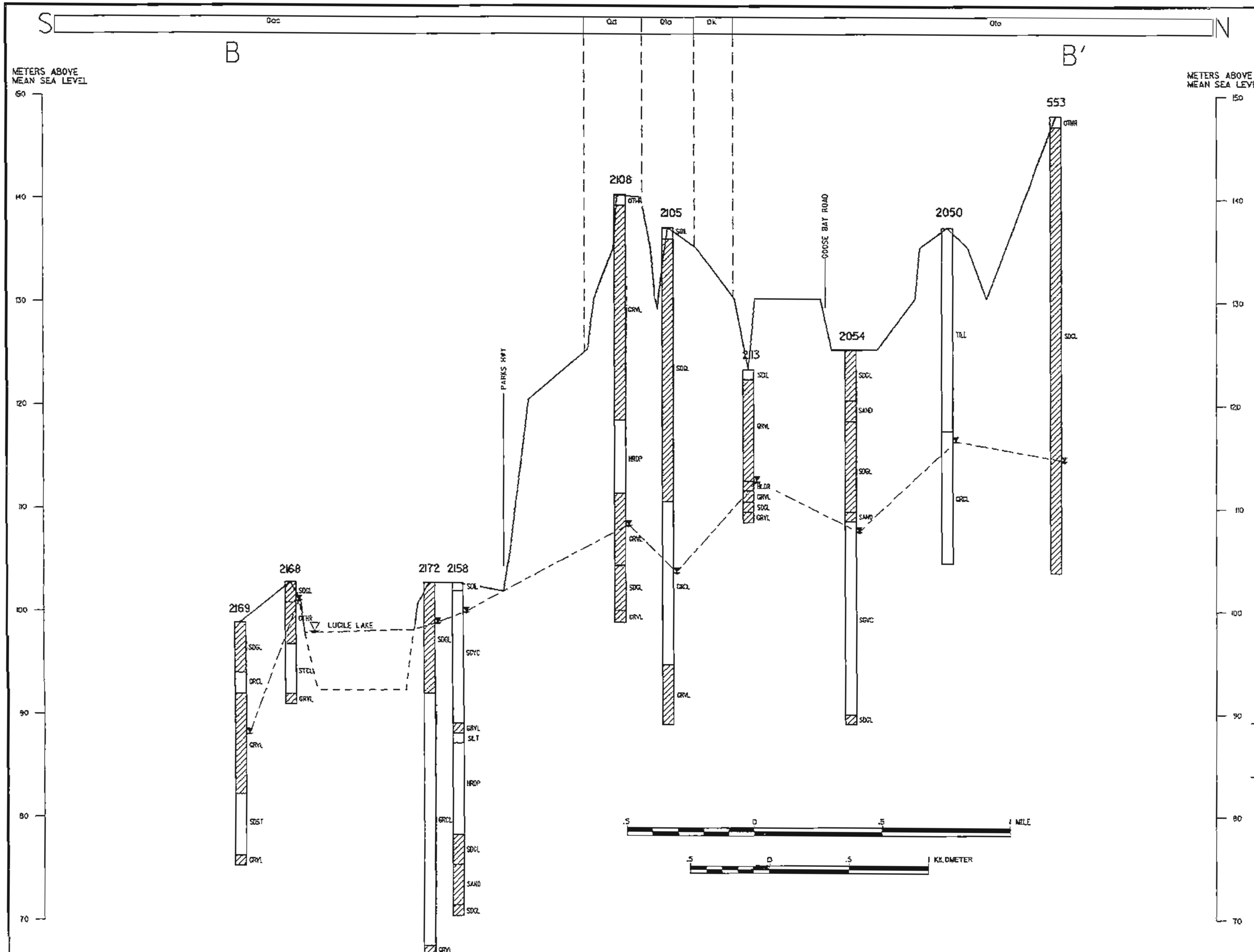


Figure 3. Hydrogeologic cross section A-A′ in Big Lake area (sheet 1). Landforms from Reger (1981c, d).



EXPLANATION

Description of geologic units or surface landforms shown at top of page

Qac Abandoned meltwater channel alluvium. Elongate channel fillings of well-sorted pebble-cobble gravel and gravelly medium-coarse sand with some boulders; permeability excellent to good; well sorted. Thickness 1 m to 3 m.

Qs Swamp deposits. Interlayered woody sphagnum, sedge peat, organic silt, and sand accumulated in local basins, around the margins of lakes or ponds, and in former drainage channels; commonly perennially frozen at depth; permeability good. Thickness ranges from less than 1 m to more than 6 m.

Qd Till. Heterogeneous mixture of gravel, sand, and silt deposited directly from glacial ice, may be locally reworked from meltwater streams; dense, unbedded; permeability fair to poor, excellent where reworked. Thickness 2 m to 6 m.

Qk Kame-esker deposits. Complex accumulations of well to poorly sorted gravel, sand and silt with occasional boulders, locally contains clastic fragments of Tertiary coal; permeability excellent to fair, discontinuous to lenticular. Thickness generally over 5 m.

Qic Undifferentiated ice-contact deposits. Complex mixtures of kame-esker deposits, sediments of supraglacial streams, and till generally composed of sandy gravel or gravelly sand with some silt and boulders; generally unbedded; permeability excellent to poor. Thickness generally over 5 m.

KE Kame-esker complex showing dominant landform trends.

ICT Complex ice-contact topography showing general landform trends.

OP Pitted outwash plain, fan, or train.

FP Modern floodplain and low terraces.

BR Large ice-scoured bedrock outcrop.

OU Unpitted outwash plain, fan, or train.

Description of symbols

ROAD — Cultural feature

—— Approximate land surface

Surface water level

Water level in well

— — — Interpreted water table

1067 — Well reference number

Less permeable unit

GRCL, GRVL — Lithologic unit

Permeable unit

All sections contain 'bends'; see map for section locations

Description of lithologic units

ALVM - Alluvium	OTHR - Other
BLDR - Boulder	ROCK - Rock
CLAY - Clay	SAND - Sand
COAL - Coal	SDCL - Sand and clay
CBSD - Cobbles and sand	SDGL - Sand and gravel
GRCL - Gravel and clay	SDST - Sand and silt
GRDS - Gravel, sand, silt	SGVC - Sand, gravel, clay
GRVL - Gravel	SHLE - Shale
HRDP - Hardpan	SILT - Silt
LMSN - Limestone	SNDS - Sandstone
LOAM - Loam	SOIL - Soil
MUD - Mud	STCL - Silt and clay
OBDN - Overburden	TILL - Till
	UNKN - Unknown

Figure 4. Hydrogeologic cross section B-B′ in Lucile Creek watershed (sheet 2). Landforms from Daniels (1981a, b).

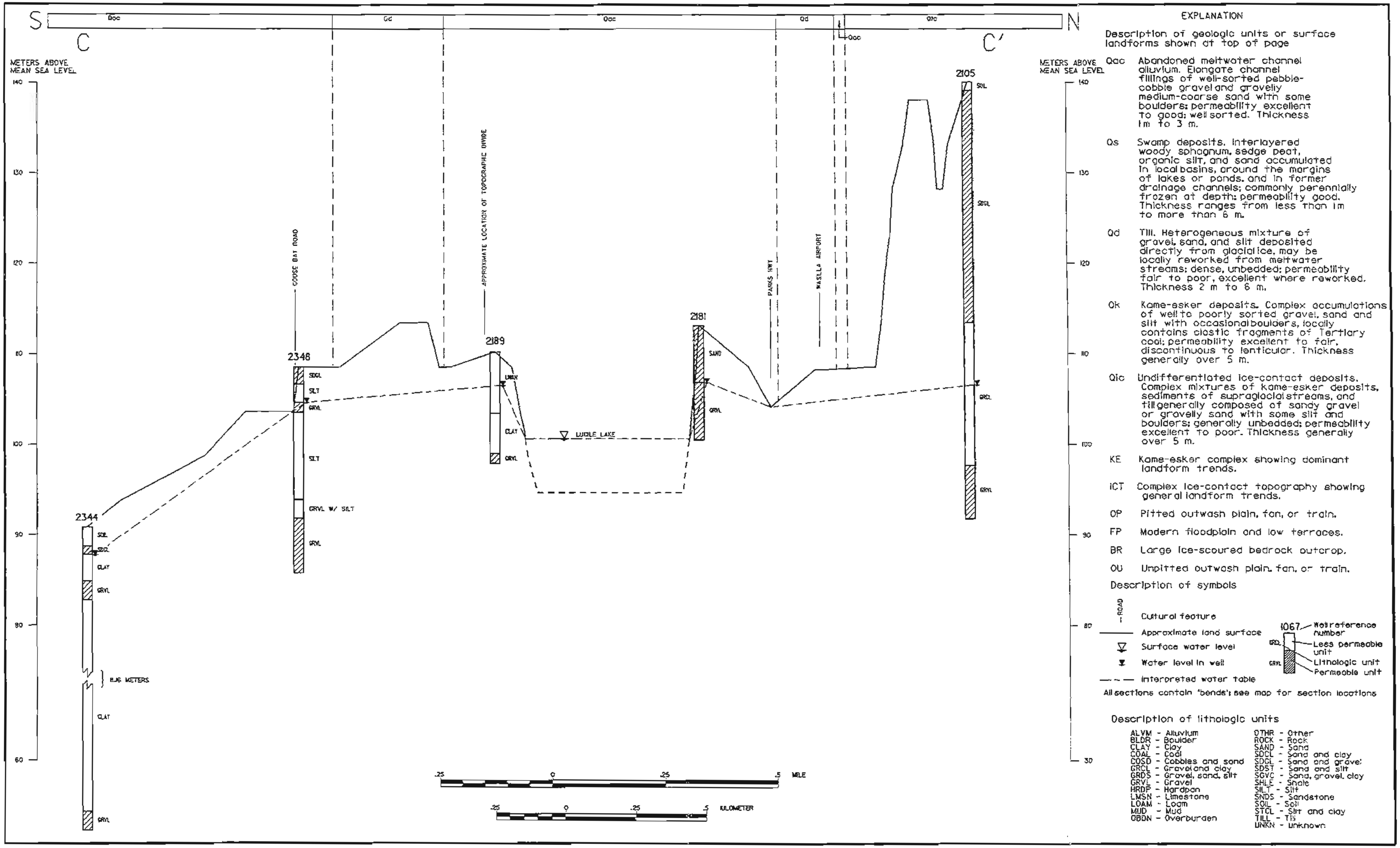


Figure 5. Detailed hydrogeologic cross section C-C′ in Lucile Lake area (sheet 2). Landforms from Daniels (1981 a, b).

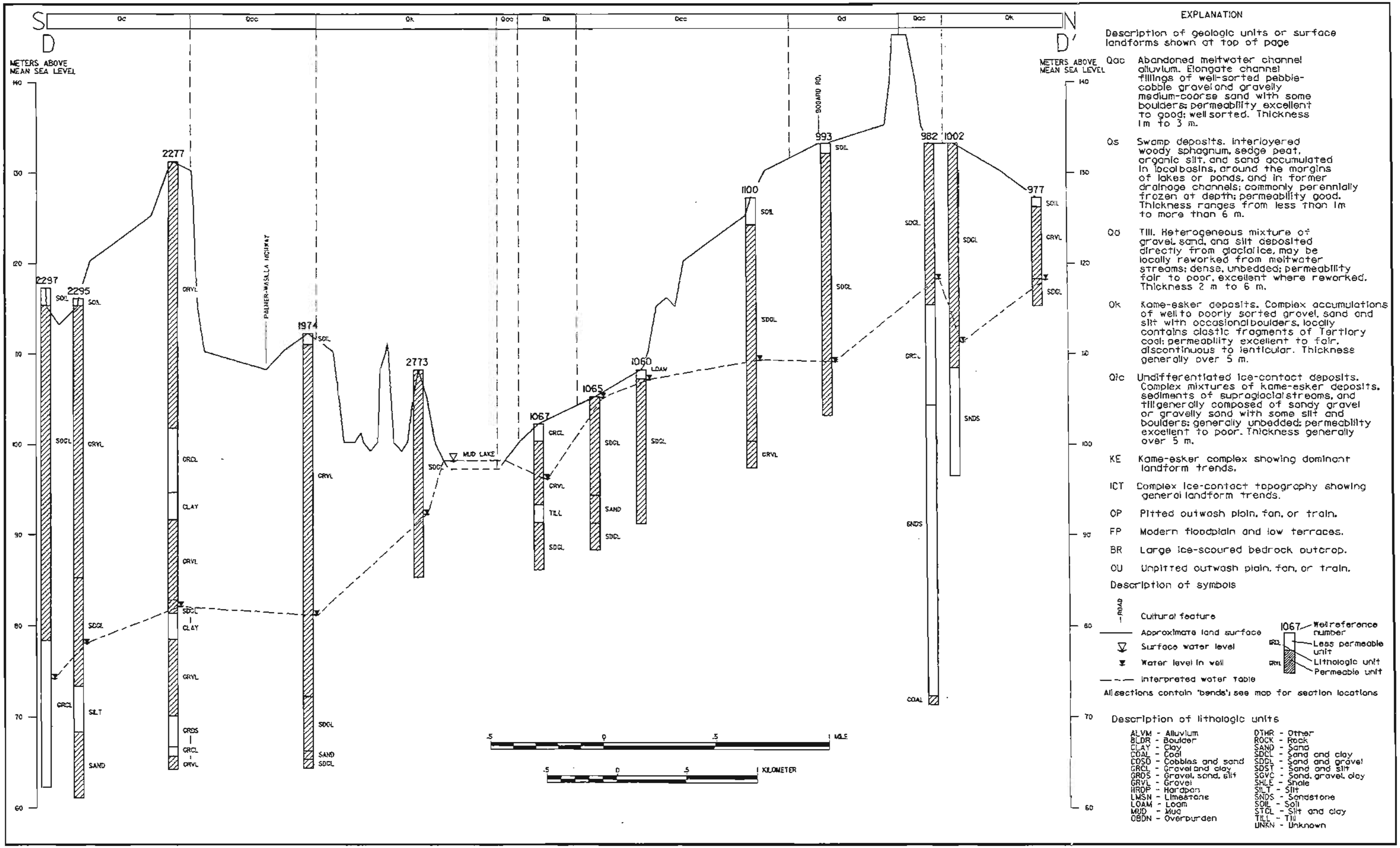


Figure 6. Hydrogeologic cross section D-D′ in Cottonwood watershed (sheet 2). Landforms from Daniels (1981 a, b).

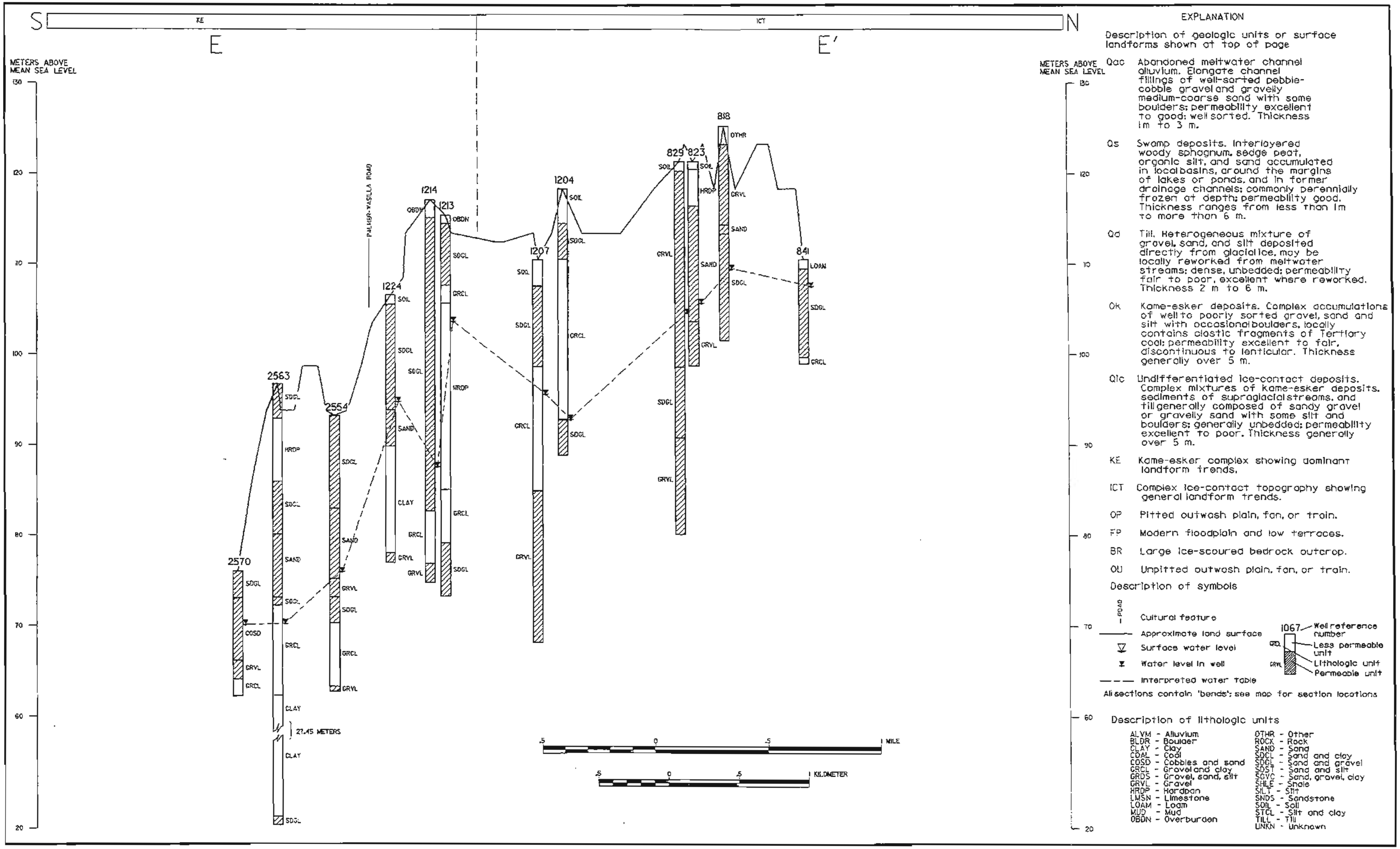


Figure 7. Hydrogeologic cross section E-E′ in Wasilla Creek watershed (sheet 3). Landforms from Reger and Updike (1983).

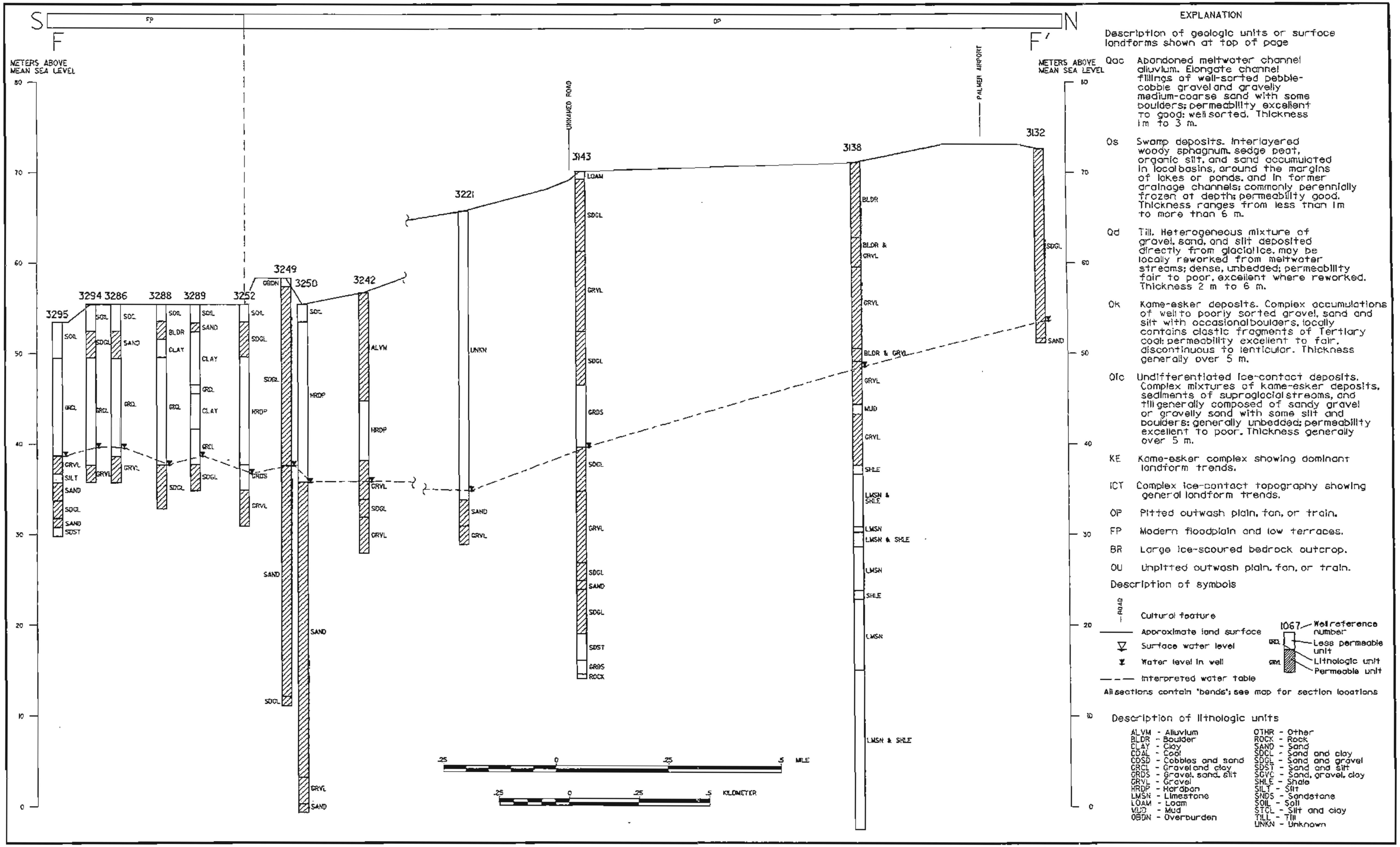


Figure 8. Hydrogeologic cross section F-F′ in Matanuska watershed (sheet 3). Landforms from Reger and Updike (1983).

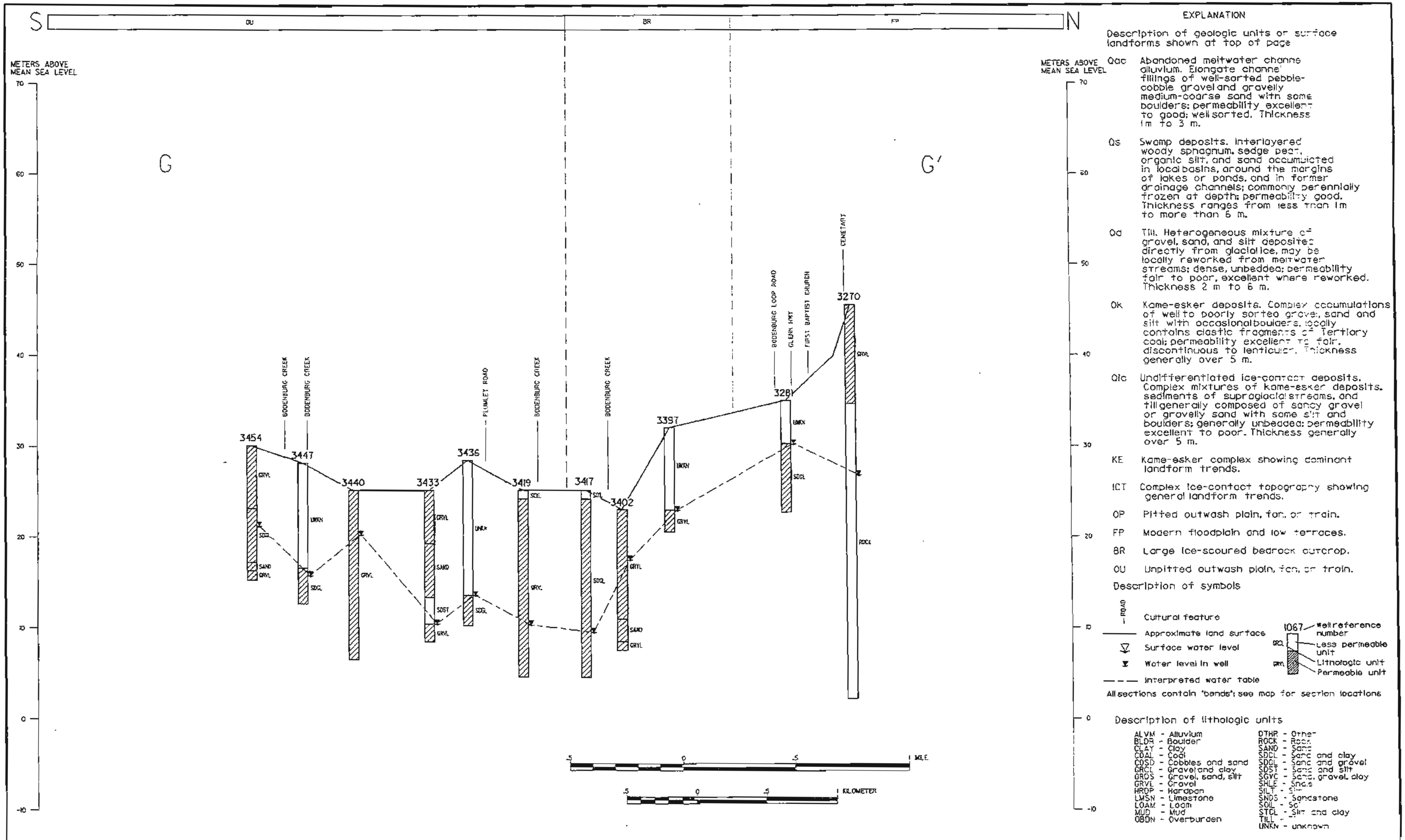


Figure 9. Hydrogeologic cross section G-G′ in Bodenburg watershed (sheet 3). Landforms from Reger and Updike (1983).

Ground water, though not as readily observable as surface water, is closely linked to surface water throughout the valley. Most surface-water bodies can be thought of as outcrops of ground water and represent areas where the water table is at or above the land surface. Before examining specific ground-water and surface-water relationships in the study area, it is useful to review some of the principal concepts that have been developed to understand ground-water and surface-water interactions in similar geologic settings elsewhere.

CONCEPTUAL MODELS OF INTERACTIONS OF GROUND WATER AND SURFACE WATER

Interactions between ground water and surface water are aspects of the hydrologic cycle that are rarely understood with certainty for particular locations. However, an understanding of the possible types of interaction is important for interpreting the ground-water and surface-water observations in the study area. The concepts discussed below are broad enough to apply to all types of surface water in the study area. The conceptual model is easily modified to allow for local variations that result from the size of the surface-water body, or topographic or geologic irregularities.

GROUND-WATER DISCHARGE

Ground-water discharge to surface water occurs as a result of gravitational forces acting on ground water that is at a higher elevation than that of the surface-water body. Figure 10 illustrates a ground-water discharge setting where water, originating as rainfall, percolates to the water table, flows through the ground-water system, and discharges to the lake or stream. Ground water in fairly uniform geologic settings has been shown to enter lakes at relatively high rates in near-shore areas, compared with off-shore areas. Although ground water has a downward component of flow in recharge areas, ground water discharging to surface water usually flows upward near the surface-water body. Ground-water discharge to a stream is the main component of the stream's base flow during times without significant rainfall, snowmelt, or runoff (such as winter or early spring conditions).

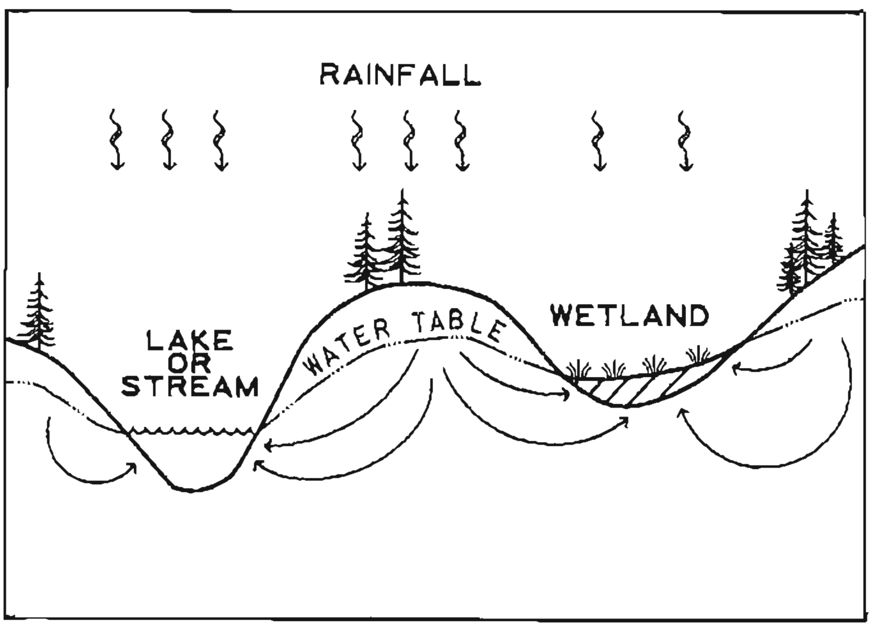


Figure 10. Diagram showing ground-water discharge to surface water.

GROUND-WATER RECHARGE

In some instances water in a surface-water body can recharge the ground-water system. This occurs where the surface-water body is at a higher elevation than the nearby water table. Figure 11 shows a recharge lake or stream. A wetland can also provide ground-water recharge.

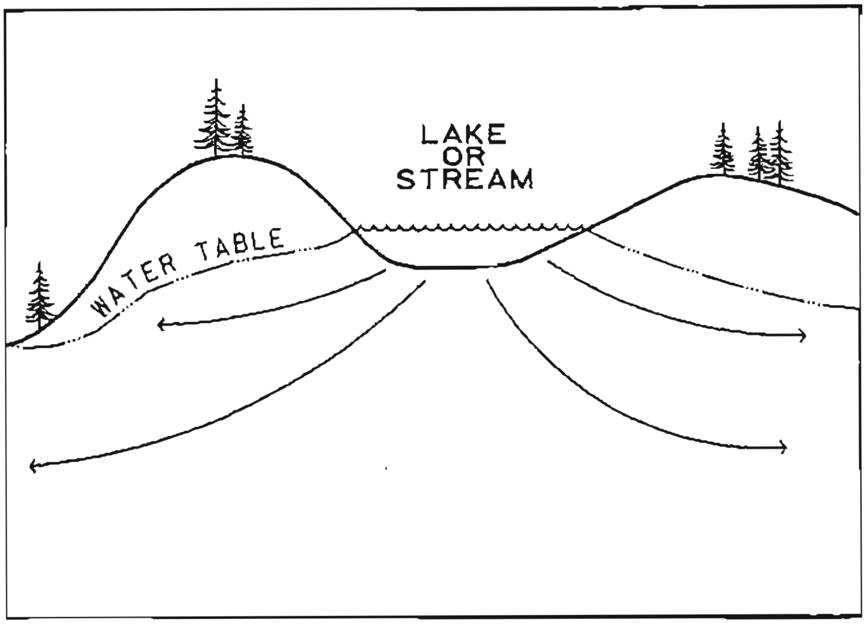


Figure 11. Diagram showing ground-water recharge from surface water.

MIXED RECHARGE AND DISCHARGE

Different sections of a surface-water body can exhibit different relationships to local ground water. Deep lakes for example, can intercept a deep ground-water flow system that is not the same system as one occurring near shore. However, such flow systems are difficult to identify and are not important to this study.

Lakes known as ground-water flow-through lakes receive ground-water discharge on one side and lose water to the ground-water system on the other (fig. 12). These lakes are common where the long axis of the lake is parallel to the direction of the regional water-table slope. Ground-water flow-through lakes can have a significant portion of their annual water budget composed of ground-water inflow and outflow, even though the net addition or loss of ground water might be small.

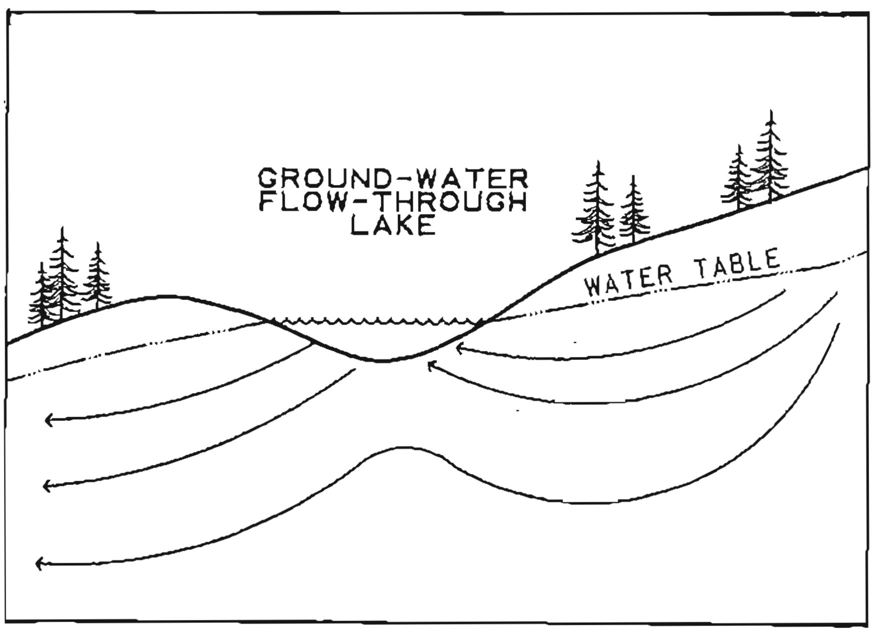


Figure 12. Diagram of a ground-water flow-through lake.

Streams can exhibit varied recharge-discharge relationships at different points along their course. For example, streams commonly lose water to ground water as they exit mountain valleys and gain water from ground water in their lower reaches.

PERCHED WATER

Water separated from the local ground-water system by an unsaturated zone is called perched water (fig. 13). A low-permeability layer such as clay or silt must lie under the perched water body (pond or wetland). True perched-water bodies are difficult to distinguish from ground-water recharge water bodies because it is difficult to identify truly unsaturated conditions in the low-permeability materials beneath the water body. Perched water leaks to some extent to the local ground-water bodies either through or around the edges of the low-permeability layer.

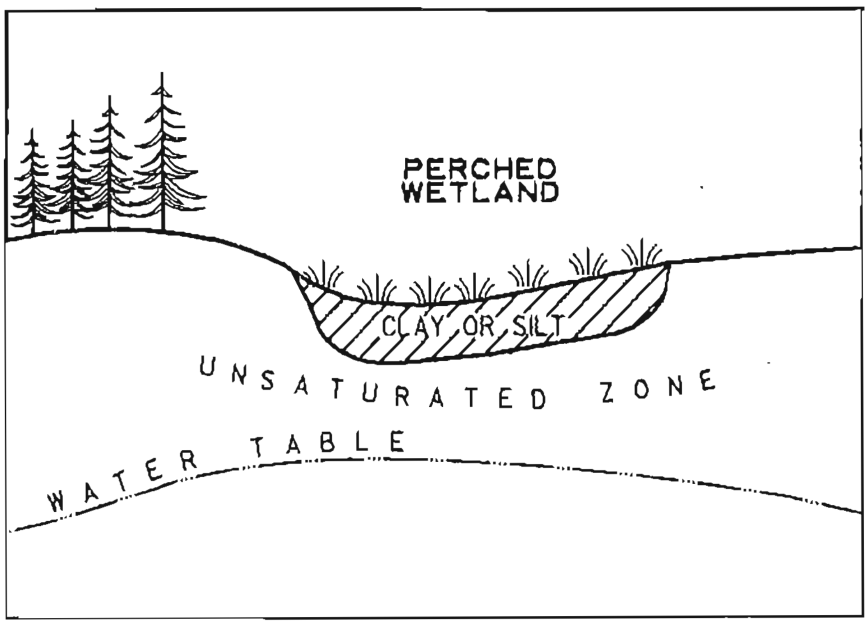


Figure 13. Diagram showing wetland perched on soils of low permeability.

STUDY AREA OBSERVATIONS AND INFERENCES

We developed a lake classification scheme for this study to understand the relative abundance of different types of lakes in the study area. Lakes and ponds (except oxbow lakes and ponds near the Little Susitna River) were classified according to their position in the local surface water drainage system. For simplicity in this report, the term lake refers to both lakes and ponds. Lakes with both inlets and outlets are *drainage lakes*, lakes with no inlet or outlet are *seepage lakes*, and lakes with inlets or outlets only are *inlet lakes* or *outlet lakes*, respectively. This classification scheme clarifies the relative importance of surface water and ground water in a lake's water budget. Outlet lakes, for example, can form only when water coming into a lake exceeds water lost from the lake by evaporation, pumping, or ground-water outflow.

The study area contains about 56 drainage lakes. Not surprisingly, they are typically found in the central areas of topographic basins where one of the main streams or a tributary flows through the lake. About 31 outlet lakes are distributed widely throughout the study area. The abundance of these lakes indicates that the water inputs to area lakes by precipitation, surface runoff, and ground-water inflow are typically greater than water losses by evaporation and ground-water outflow. Only one inlet lake was identified in the study area.

The most common (351) lakes in the area are seepage lakes. These lakes typically form in closed topographic depressions left by melting ice masses during the waning phase of the most recent glaciation of the area. They are present throughout the study area, vary widely in size and configuration, and are not usually associated with stream systems.

Wetlands, in general, are much more abundant and widespread in the western part of the study area than in other areas. This coincides with the area where water-table gradients are relatively flat. The flat water table and the low gradient of local streams are responsible for the large areas of poor drainage that occur in this region.

Examination of the regional water-table map shown on sheets 1-3 indicates that ground-water basins are generally concordant with topographic basins described previously. This concept, however, may apply only to shallow ground-water systems defined by available well and surface data. A deeper, regional flow system may underlie the shallow ground-water basins, with recharge occurring near the Talkeetna Mountains and discharge occurring near Knik Arm. Although the existence of such a system is hypothesized, data to confirm its presence is currently lacking.

Local relationships are described below by watershed. Using previously identified watersheds, the descriptions are based on the shape and position of water-table contours relative to surface-water bodies.

As previously described, most of the study area is underlain by unconsolidated glacial, alluvial, and glaciofluvial deposits that are up to 230 meters thick. Well-log descriptions show sand and gravel deposits are relatively common both at the land surface and in shallow aquifers. As a result, in many localities throughout the study area, ground-water flow systems are likely to contribute significantly to surface-water flows of lakes and streams. This theory is consistent with Feulner (1971) who noted that Cottonwood Creek, Lucile Creek, and Fish Creek all have well sustained base flows. Ground water is probably a significant component of the annual water budget of most of the 351 seepage lakes identified in the Valley.

BODENBURG CREEK WATERSHED

Bodenburg Creek drains a nearly flat alluvial terrace underlain by a nearly flat water table (sheet 3, fig. 9). The creek probably gains water during most of the year from the ground-water system throughout its length. There are several small closed-depression kettle lakes that are probably closely linked to the local ground-water system.

MATANUSKA RIVER WATERSHED

Small mountain streams located in the eastern part of the Matanuska River Basin disappear as they descend the mountain front. These streams provide recharge to the ground-water flow system in the foothills area. The predominant feature of this basin however, is the Matanuska River (sheet 3), which drains a large area northeast of the study area. The river is braided and closely tied to local ground-water systems near active and seasonally active channels and sloughs. Large short-term and seasonal changes in Matanuska River levels cause fluctuations in local ground-water levels and an alternating recharge and discharge relationship with ground water. The flat terrain near the Matanuska River results in a relatively uniform water-table gradient (fig. 8).

WASILLA CREEK WATERSHED

Wasilla Creek and its tributaries appear to receive ground-water discharge throughout most or all of their lengths (sheets 2, 3). However, the creek does not cause significant deflections in the regional water-table contours, and, therefore, the amount of discharge may be small. A large portion of the Wasilla Creek Basin is not drained by an integrated surface drainage network. This area, known as the Bradley/Kepler Lakes area, contains numerous closed-depression lakes that appear to receive ground-water discharge. Ground water in the Wasilla Creek watershed is present both under water-table conditions and in confined or semi-confined aquifers beneath till (fig. 7).

COTTONWOOD CREEK WATERSHED

Cottonwood Creek and the chain of lakes that it drains are probably all fed by ground water along their lengths (sheet 2, fig. 6). Finger Lake was the subject of special studies reported by Edmondson and others (1989), who suggested that eutrophication and algae blooms are related to local ground-water seepage. The water table slopes toward Wasilla Lake from the north, and the lake has a discernable water-table mound on the south side, indicating ground-water inflow from both sides. Incision of the creek valley below the surrounding terrain near Knik Arm causes the water table to be depressed in this area.

LITTLE SUSITNA RIVER WATERSHED

Little Susitna River probably receives ground-water discharge along most of its length in the study area (sheets 1-3). Although inflow from the north side of the stream may be significant, inflow from the south may be relatively low because of the small size of the drainage basin south of the river.

The mean annual runoff of Little Susitna River Basin above the stream gauge near Palmer is 3.41 cubic feet per second per square mile (cfsm) (Vaill and others, 1987) compared with average values of 0.5 to 1 cfsm across most of the rest of the study area (Freethey and Scully, 1980). The difference is attributable to the higher elevation and precipitation in the Little Susitna basin north of the study area.

CROCKER AND O'BRIEN CREEK WATERSHEDS

Crocker and O'Brien Creeks appear to receive discharge from local and regional ground-water flow systems (sheets 1, 2) because of their location near Knik Arm. The water table gradient is highest near the creeks, indicating a high potential for ground-water inflow to the creeks.

LUCILE CREEK WATERSHED

The long axis of Lucile Lake trends perpendicular to the regional water-table gradient (sheets 1, 2), and the lake appears to receive ground-water inflow from both the north and south sides (fig. 5). Local precipitation and snowmelt infiltrate and form a ground-water mound on the south side of the lake, providing for ground-water discharge to the lake from that side. Lucile Creek headwaters form in Lucile Lake which suggests that the lake may receive significant ground-water inflows. Numerous small, closed depressions, both lakes and wetlands, are located in the Lucile Creek Basin. The nature of the local ground-water flow systems around these depressions is not clear from available well-log and geologic data.

MEADOW CREEK WATERSHED

The Meadow Creek watershed contains 115 lakes, including the largest lake in the region, Big Lake (sheets 1, 2). Most of these lakes are either seepage lakes or outflow lakes; Big Lake is a drainage lake. Water-table contours indicate that local ground-water discharges to Meadow Creek and its principle tributaries (fig. 3). Numerous lakes north of Meadow Creek and Little Meadow Creek are oriented with their long axis parallel to the regional water-table slope. These are probably ground-water flow-through lakes. Local flow systems probably exist around several closed-depression seepage lakes near Big Lake, but are not discernable with existing data.

HORSESHOE LAKE WATERSHED

Horseshoe Lake watershed is a poorly drained basin with a relatively high percentage of lake and wetland surface area (sheet 1). The land surface and water-table gradients are low. The lakes are oriented similarly to lakes in the adjacent Meadow Creek Basin, and are probably flow-through lakes.

FISH CREEK WATERSHED

The eastern part of Fish Creek watershed contains numerous closed-depression lakes and wetlands. Although data are sparse, these features appear to be higher than the water table in upland areas. If so, most of these surface water bodies would be recharging ground water in this area. Conversely, Fish Creek and its primary tributaries and lowland wetlands function as drains on the local ground-water flow system.

GOOSE CREEK WATERSHED

Much of the land surface of the Goose Creek watershed is either lake or wetland. The basin has a low water-table slope and poor drainage. Ground-water inflow to the lakes and wetlands is probably minimal because of the proximity of the lakes and wetlands to basin divides and the prevalent low gradients in the area.

GROUND WATER QUALITY

DATA FROM USGS SOURCES

Records of surface-water and ground-water quality for the Valley are available from various sources. USGS has records of ground-water quality from approximately 150 wells in its QW database (fig. 14). Additionally, USGS (Still and Cosby, 1989) has occasional surface-water quality records for:

Little Susitna River (near Palmer: 1948-52, 1967-68, 1971-72; near Houston: 1972, 1978, 1983)
Wasilla Creek (near Palmer: 1949, 1951-52, 1982-83; near Wasilla: 1951, 1982-1983)
Cottonwood Creek (near Wasilla: 1948-52, 1981-83; at Loop Road: 1983)
Lucile Creek (1982-83)
Little Meadow Creek (1974-75, 1982-83)
Fish Creek (at the outlet of Big Lake: 1974-75; 1982-83)

Feulner (1971) summarized the quality of surface and ground water as follows:

> Generally, surface water is of good quality and, except for isolated instances, contains less than 0.3 mg/l (milligrams per liter) of iron (the suggested maximum of the U.S. Public Health Service, 1962). All the surface waters have a hardness of less than 150 mg/l and are of the calcium magnesium bicarbonate type. The Matanuska River near Palmer contains more sulfate than the other streams. . . .
>
> Ground water in the study area has a greater chemical-quality variation than the surface water. It generally is harder than surface water, except in areas adjacent to streams where the water quality of both is similar. Much of the ground water obtained from shallow wells drilled in the alluvium contains objectionable concentrations of iron, most of which could be easily removed by aeration and filtration of the water prior to storage or use. Ground water ranges from about 50 to more than 200 mg/l in hardness and is of the calcium bicarbonate type. Water from city well 3 at Palmer is of the sodium bicarbonate type and contains a higher concentration of sulfate than does water from most other wells in the area. This well is probably drilled in a former channel of the Matanuska River. The water level in the well appears to fluctuate with river level and the higher sulfate content is evidently related to the higher sulfate level of water in the river.

Feulner (1971) noted occasional findings of elevated levels of boron in some Palmer area wells, which may have significance for agricultural water supply. These levels of boron provide no threat to public health.

Feulner (1971) also reported several wells with high nitrate concentration, including one Palmer well with up to 270 mg/l nitrate as NO_3 (61 mg/l nitrate as N). This is approximately six times greater than the suggested maximum concentration for drinking water supply.

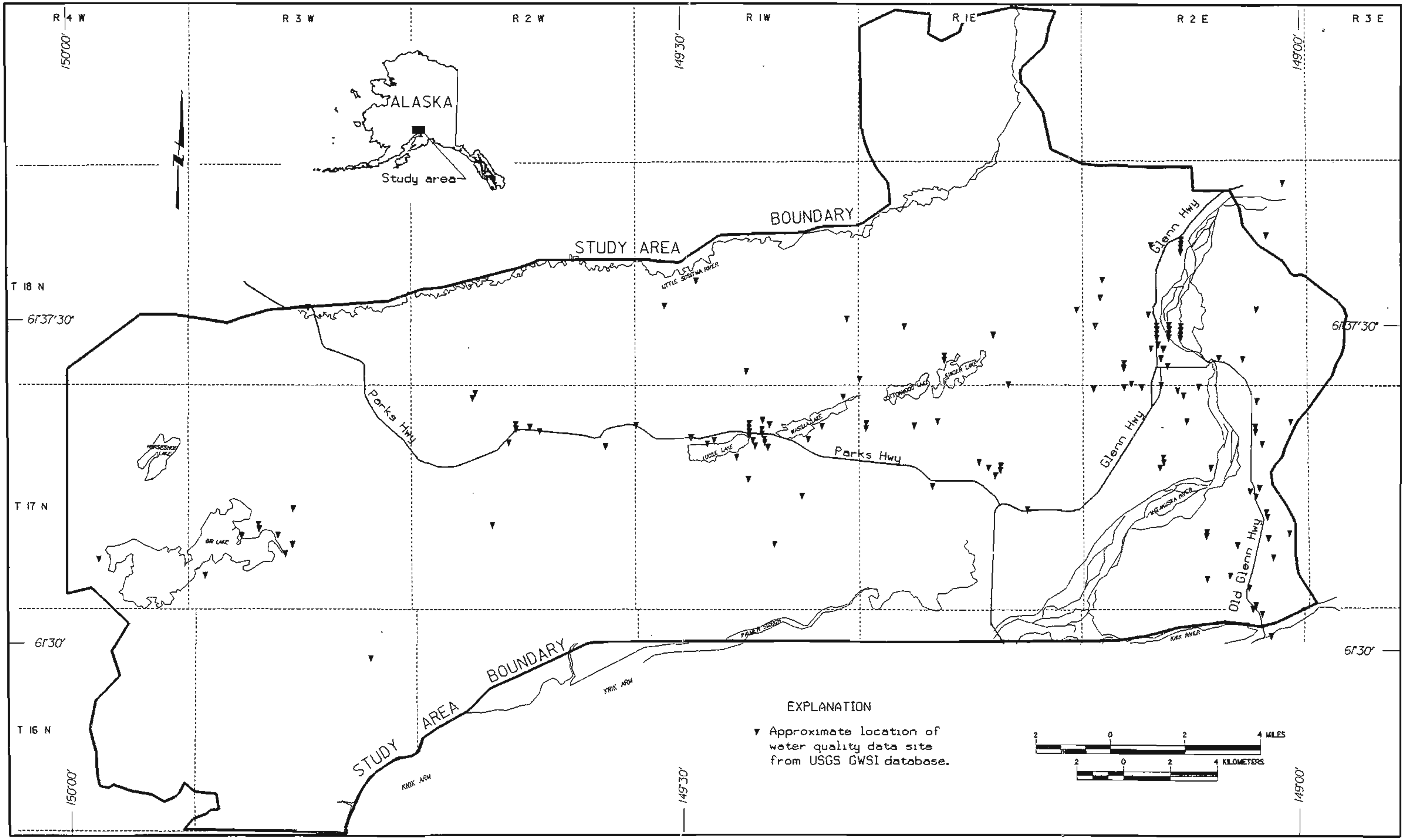


Figure 14. Map of water-quality stations in USGS QW database for Big Lake-Palmer Area.

DATA FROM STATE OF ALASKA SOURCES

The Alaska Department of Environmental Conservation (ADEC) has authority to require water quality analyses from public water supply systems and from monitoring wells at landfills, wastewater disposal sites, and sites of possible ground-water contamination. These records are on file at the department's Matanuska-Susitna district office in Wasilla or Anchorage.

Maurer and Woods (1987) inventoried water quality data obtained from area lakes. They provide references to morphometric, biological, water column profile, sediment, general chemistry, and other data.

Munter and Maynard (1987) reported several other instances of ground-water contamination in the valley. Three water supply wells showed bacteriological contamination (Fishhook West Subdivision, Knik Bay, and Ship Ahoy Bar). Where contamination was confirmed, system owners corrected the problem by constructing new water systems (ADEC, 1988). Butte Landfill is a fourth site identified by Munter and Maynard (1987) as a source of ground-water contamination. This site is being monitored as part of a cooperative agreement between the Matanuska-Susitna Borough and the U.S. Geological Survey.

REPORTS TO LOCAL AGENCIES

Gilfilian Engineering, Inc. (1989) reported results of monitoring discharges from the Houston Septage Facility to ground water. In October 1989 ground-water mounding that resulted from a slug discharge was observed at the site. This short duration discharge was high in conductivity and nitrates. Monitoring the unconfined sandy gravel aquifer downgradient from the site showed that significant dilution took place from ground-water flow. Several on-site wells contained background nitrate levels of less than 1 mg/l. Eighty percent reduction from peak nitrate levels was observed within 800 feet of the discharge point.

Gilfilian (1989) investigated ground-water quality near the Wasilla community leachfield. Comparing his findings to background levels, he reported increased levels of chloride, conductivity, COD, nitrogen, purgeable aromatic hydrocarbon, and inorganic chemicals in the shallow unconfined aquifer near the leachfield. A deeper, confined aquifer was not apparently affected by the discharge. Gilfilian drew no conclusions about the rate of contaminant movement or extent of the contaminant plume from the leachfield discharge.

APPLICATIONS OF THE CONCEPTUAL MODEL

The conceptual model described in this report can be used to attain a general understanding of ground-water conditions throughout the Valley and to make informed decisions about ground-water issues. These issues may include protecting recharge areas, developing monitoring networks, developing land-use policies, managing data, and managing waste-disposal problems.

A brief review of eight areas of particular concern (table 2) are given below, with examples of how the conceptual model can be applied to better understand and solve problems at each area. This section also describes how to apply the conceptual model to development of a regional water quality monitoring network.

HOUSTON SEPTAGE FACILITY

Gilfilian Engineering, Inc. (1989) mapped plumes of contaminated ground water from the Houston Septage Facility from the point of discharge to the facility boundary. As a result of high permeability and steep hydraulic gradients, the ground water moves about 10 meters per day. Compared with concentrations in the effluent, contaminant concentrations in the plumes appear to be diluted in the ground water.

Contamination from the septage facility may be causing slightly elevated levels of nitrates in the ground water between the facility and Little Meadow Creek. The facility will probably be required to limit effluent discharges to maintain low levels of nitrate contamination of these waters. By coordinating periodic sampling of

Little Meadow Creek with septic discharge events, data could show what effect, if any, the facility's have discharges have on the water quality of Little Meadow Creek.

BIG LAKE LANDFILL

The Big Lake Landfill is located in alluvial deposits in a natural topographic depression between ice-contact deposits near the surface-water divide between the Lucile Creek and Fish Creek watersheds. The landfill is more than 1 kilometer from the nearest stream, although wetland areas lie to the north and southwest within 0.5 kilometers of the site. A relatively high ground-water table in the area and permeable materials suggest that local ground-water recharge is taking place near the landfill. As a result of the landfill's location near a ground-water divide, local water table gradients are low and are not clearly defined with available data. Additional data collection efforts could include ongoing monitoring of ground-water quality and improved definition of local aquifers and water-table gradients.

AIRPORT AND INDUSTRIAL PARK

Approximately 1 mile west of Lucile Lake in glaciofluvial and till deposits the Matanuska Susitna Borough has identified an area under consideration for propose the development of an airport and industrial park. Well-log data are not available for this particular area, therefore it is difficult to describe ground-water conditions and aquifers. Aquifer yields for commercial water wells are likely to be highest in glaciofluvial material, especially downgradient from Lucile Lake. Depth and thickness of glaciofluvial material is not documented.

Runoff from impervious pavement in areas of commercial and airport development may alter the local hydrologic regime and water quality. Since the area near Lucile Creek is principally discharging ground water to the creek, potential ground-water contamination problems are likely to be localized. Lucile Creek water quality may be adversely affected by stormwater and wastewater discharge into the creek.

Background water-quality monitoring of the creek downgradient from the proposed development is important for facility planning.

WASILLA LEACHFIELD

The Wasilla community leachfield is situated in gravelly alluvium on the flank of an abandoned meltwater channel. The water table beneath the site is similar to the elevation of the water surface in wetland downgradient from the facility. Ground-water contamination has been documented in on-site wells and is inferred from elevated levels of chlorides and conductivity above natural background conditions in the surface water of the wetland. The abandoned meltwater channel results in a highly irregular water table configuration within a few kilometers of the site. Improved local definition of the water table would be necessary to delineate probable ground-water flow paths.

The extent of contamination could also be defined further, along with the potential for increased contamination from the system. Wells in the meltwater alluvium downgradient from the leachfield within 3 kilometers may be candidates for monitoring to insure safe drinking water.

BUTTE LANDFILL

Butte landfill is located on the edge of the study area near the topographic divide between Bodenburg Creek and the McRoberts Creek/Jim Creek watershed. The landfill appears to be in an area where the water-table gradient is low and the glaciofluvial soils are relatively permeable. Because of the local aquifer permeability, potential is high for transport of leachate from the landfill.

To define ground-water flow directions, a local ground-water table map would need to be prepared from synchronous monitoring of water levels in local wells. Regional water-table fluctuations in the area may have important effects on contaminant migration directions and rates.

CENTRAL LANDFILL

The Central landfill is located in ice-contact deposits, including kames. Most wells along the nearby Colony cross section are developed in a gravelly aquifer beneath a confining unit that is as much as 20 meters or more thick. The confining unit may act to limit downward migration of contaminants from the landfill. Complex topography and geology of the region may make it difficult to define the exact configuration of any leachate plumes that may exist.

COLONY JUNIOR/SENIOR HIGH SCHOOL

Colony Junior/Senior High School is located in ice-contact deposits with sandy gravel water-table aquifers. Local recharge might be taking place from Walby and Gooding Lakes upgradient from the high school. Water quality in these lakes could have an influence on water quality at the school. Additional study of recharge areas near the school and lake water quality would further define these relationships.

GOVERNMENT PEAK WINTER SPORTS AREA

Steep gradients and thin till soils near the site complicate proposed developments for the ski area. Ground-water supplies for the site are probably not abundant, which suggests that surface-water supplies may be necessary for development. The location of the development in a recharge area suggests that consideration should be given to incorporating ground-water protection measures into design, construction, and operation practices.

DEVELOPMENT OF A WATER QUALITY MONITORING NETWORK

Maynard (1988) presented a methodology to design a ground-water monitoring network for the Valley. It could be used in conjunction with the conceptual model presented in this report . Ground-water basins and geologic information described in this report could be used with information about potential sources of contamination to establish areas that are at a serious risk of contamination and should be assigned a high priority for inclusion in the monitoring network. Specific network design could be done after identifying network goals and establishing a budget.

CONCLUSIONS

Ground water is widely used for water supply throughout the Valley area. Ground water exists in a variety of settings in the valley. These include a major alluvial aquifer near the Matanuska River, glacial drift aquifers in much of the lowland area, and bedrock aquifers in mountain foothills environments. Both local and regional ground-water flow systems can be generally described with existing map and well-log data throughout the Valley. Existing data are insufficient for local delineation of ground-water flow directions.

Ground water and surface water are closely interconnected in the Valley. Ground water discharges into most lakes, streams, and wetlands, although the reverse relationship sometimes occurs. Ground water is fed by streams infiltrating into foothills slopes and by direct infiltration of precipitation and snowmelt throughout the study area.

Ground water throughout most of the Valley is of suitable quality for general domestic, agricultural, and commercial or industrial use. Localized water quality impairment has occurred as a result of a few specific waste-disposal operations. Potential sources of ground-water contamination include fuel storage tanks, septic systems, road-salt storage areas, agricultural chemicals, and urban runoff. The hydrogeologic conditions of the Valley suggest shallow water-table aquifers are susceptible to contamination from these sources.

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Sheets 2-3 *For* WATER-TABLE CONTOUR INTERVAL 20 METERS

read WATER-TABLE CONTOUR INTERVALS 20 AND 100 METERS

Sheets 2-3 *For* BASE MAP CONTOUR INTERVALS 5 AND 10 METERS

read BASE MAP CONTOUR INTERVALS 5, AND 20 METERS

Sheet 1: *Delete* BIG LAKE WATERSHED

Sheet 2: *For* ANCHORAGE C-8 NW,NE,SW,SE
B-8 NW,NE

read ANCHORAGE C-7 NW,NE,SW,SE

Sheet 3: *For* ANCHORAGE C-8 NW,NE,SW,SE
B-8 NW,NE

read ANCHORAGE C-6 NW,NE,SW,SE