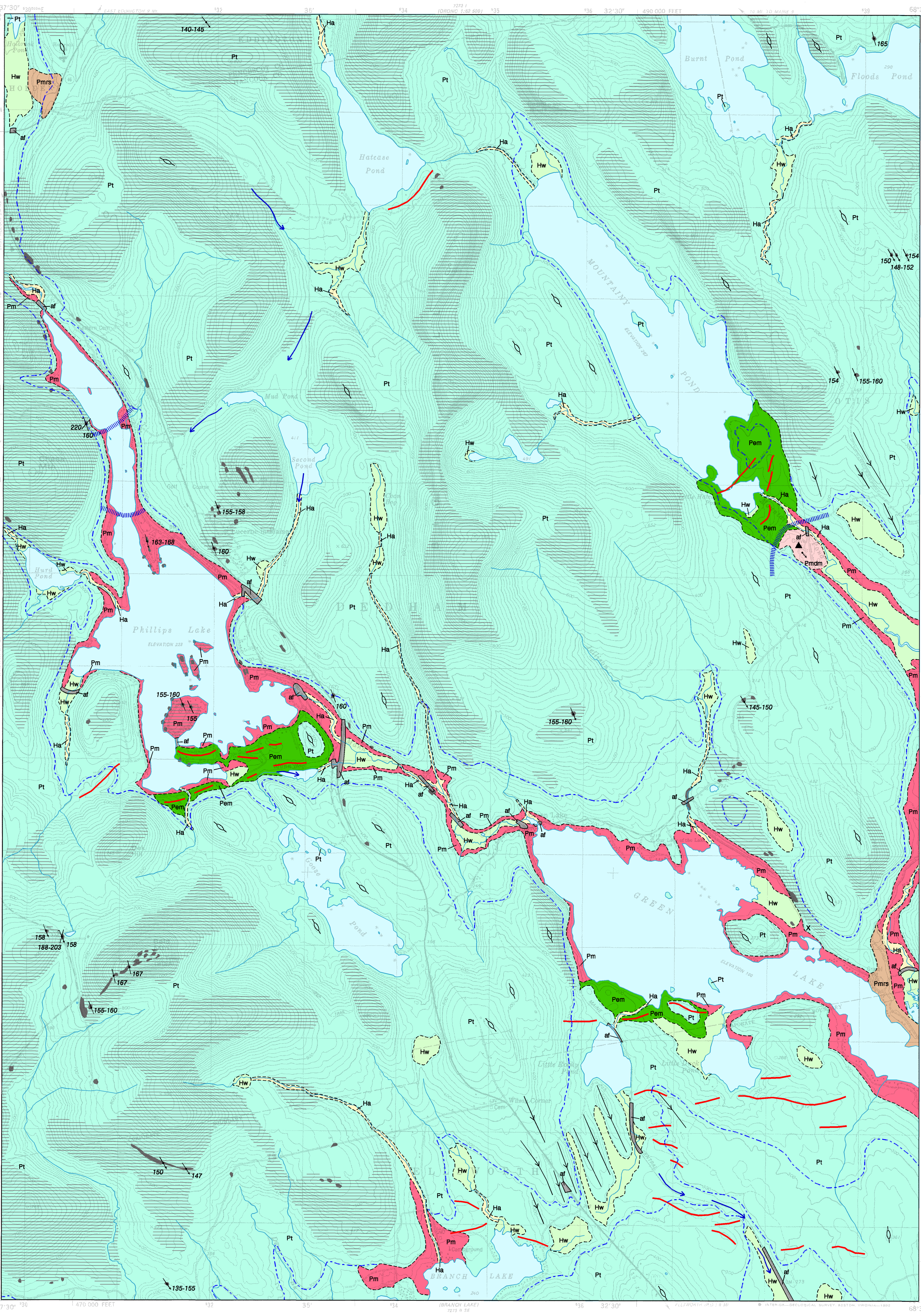
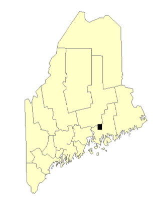
Surficial Geology



SOURCES OF INFORMATION

Surficial geologic mapping of the Green Lake quadrangle was conducted by Carol T. Hildreth during the 2010 field season. Funding for this work was provided by the U. S. Geological Survey STATEMAP program and the Maine Geological Survey, Department of Conservation.



Quadrangle Location

SCALE 1 : 24,000

1 MILE

7000 FEET

1 KILOMETER

CONTOUR INTERVAL 20 FEET

TRUE NORTH

Topographic base from U.S. Geological Survey Green Lake quadrangle, scale 1:24,000 using standard U.S. Geological Survey topographic map symbols.

The use of industry, firm, or local government names on this map is for location purposes only and does not impute responsibility for any present or potential effects on the natural resources.

Green Lake Quadrangle, Maine

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SURFICIAL GEOLOGY OF MAINE

Continental glaciers like the ice sheet now covering Antarctica probably extended across Maine several times during the Pleistocene Epoch, between about 1.5 million and 10,000 years ago. The slow-moving ice superficially changed the landscape as it scraped over mountains and valleys (**Figure 1**), eroding and transporting boulders and other rock debris for miles (**Figure 2**). The sediments that cover much of Maine are largely the product of glaciation. Glacial ice deposited some of these materials, while others washed into the sea or accumulated in meltwater streams and lakes as the ice receded. Earlier stream patterns were disrupted, creating hundreds of ponds and lakes across the state. The map at left shows the pattern of glacial sediments in the Green Lake quadrangle.

The most recent "Ice Age" in Maine began about 30,000 years ago, when an ice sheet spread southward over New England (Stone and Borns, 1986). During its peak, the ice was several thousand feet thick and covered the highest mountains in the state. The weight of this huge glacier actually caused the land surface to sink hundreds of feet. Rock debris frozen into the base of the glacier abraded the bedrock surface over which the ice flowed. The grooves and fine scratches (striations) resulting from this scraping process are often seen on freshly exposed bedrock, and they are important indicators of the direction of ice movement (**Figure 3**). Erosion and sediment deposition by the ice sheet combined to give a streamlined shape to many hills, with their long dimension parallel to the direction of ice flow. Some of these hills (drumlins) are composed of dense glacial sediment (till) plastered under great pressure beneath the ice.

A warming climate forced the ice sheet to start receding as early as 21,000 calendar years ago, soon after it reached its southernmost position on Long Island (Ridge, 2004). The edge of the glacier withdrew from the continental shelf east of Long Island and reached the present position of the Maine coast by about 16,000 years ago (Borns and others, 2004). Even though the weight of the ice was removed from the land surface, the Earth's crust did not immediately spring back to its normal level. As a result, the sea flooded much of southern Maine as the glacier retreated to the northwest. Ocean waters extended far up the Kennebec and Penobscot valleys, reaching present elevations of up to 420 feet in the central part of the state.

Great quantities of sediment washed out of the melting ice and into the sea, which was in contact with the receding glacier margin. Sand and gravel accumulated as deltas (**Figure 4**) and submarine fans where streams discharged along the ice front, while the finer silt and clay dispersed across the ocean floor. The shells of clams, mussels, and other invertebrates are found in the glacial-marine clay that blankets lowland areas of southern Maine. Ages of these fossils tell us that ocean waters covered parts of Maine until about 13,000 years ago. The land rebounded as the weight of the ice sheet was removed, forcing the sea to retreat.

Meltwater streams deposited sand and gravel in tunnels within the ice. These deposits remained as ridges (eskers) when the surrounding ice disappeared (**Figure 5**). Maine's esker systems can be traced for up to 100 miles, and are among the longest in the country.

Other sand and gravel deposits formed as mounds (kames) and terraces adjacent to melting ice, or as outwash in valleys in front of the glacier. Many of these water-laid deposits are well layered, in contrast to the chaotic mixture of boulders and sediment of all sizes (till) that was released from dirty ice without subsequent reworking. Ridges consisting of till or washed sediments (moraines) were constructed along the ice margin in places where the glacier was still actively flowing and conveying rock debris to its terminus. Moraine ridges are abundant in the zone of former marine submergence, where they are useful indicators of the pattern of ice retreat (**Figure 6**).

The last remnants of glacial ice probably were gone from Maine by 12,000 years ago. Large sand dunes accumulated in late-glacial time as winds picked up outwash sand and blew it onto the east sides of river valleys, such as the Androscoggin and Saco valleys (**Figure 7**). The modern stream network became established soon after deglaciation, and organic deposits began to form in peat bogs, marshes, and swamps. Tundra vegetation bordering the ice sheet was replaced by changing forest communities as the climate warmed (Davis and Jacobson, 1985). Geologic processes are by no means dormant today, however, since rivers and wave action modify the land (**Figure 8**), and worldwide sea level is gradually rising against Maine's coast.

References Cited

Borns, H. W., Jr., Doner, L. A., Dorion, C. C., Jacobson, G. L., Jr., Kaplan, M. R., Kreutz, K. J., Lowell, T. V., Thompson, W. B., and Weddle, T. K., 2004, The deglaciation of Maine, U.S.A., *in* Ehlers, J., and Gibbard, P. L., eds., Quaternary Glaciations – Extent and Chronology, Part II: North America: Amsterdam, Elsevier, p. 89-109.

Davis, R. B., and Jacobson, G. L., Jr., 1985, Late-glacial and early Holocene landscapes in northern New England and adjacent areas of Canada: Quaternary Research, v. 23, p. 341-368.

Ridge, J. C., 2004, The Quaternary glaciation of western New England with correlations to surrounding areas, *in* Ehlers, J., and Gibbard, P. L., eds., Quaternary Glaciations – Extent and Chronology, Part II: North America: Amsterdam, Elsevier, p. 169-199.

Stone, B. D., and Borns, H. W., Jr., 1986, Pleistocene glacial and interglacial stratigraphy of New England, Long Island, and adjacent Georges Bank and Gulf of Maine, *in* Sibrava, V., Bowen, D. Q., and Richmond, G. M. (editors), Quaternary glaciations in the northern hemisphere: Quaternary Science Reviews, v. 5, p. 39-52.

Figure 1: "The Bubbles" and Jordan Pond in Acadia National Park. These hills and valleys were sculpted by glacial erosion. The pond was dammed behind a moraine ridge during retreat of the ice sheet.

Figure 2: Daggett's Rock in Phillips. This is the largest known glacially transported boulder in Maine. It is about 100 feet long and estimated to weigh 8,000 tons.

Figure 3: Granite ledge in Westbrook, showing polished and grooved surface resulting from glacial abrasion. The grooves and shape of the ledge indicate ice flow toward the southeast.

Figure 4: Glaciomarine delta in Franklin, formed by sand and gravel washing into the ocean from the glacier margin. The flat delta top marks approximate former sea level. Kettle hole in foreground was left by melting of ice.

Figure 5: Esker cutting across Kezar Five Ponds, Waterford. The ridge consists of sand and gravel deposited by meltwater flowing in a tunnel beneath glacial ice.

Figure 6: Aerial view of moraine ridges in blueberry field, Sedgwick (note dirt road in upper right for scale). Each bouldery ridge marks a position of the retreating glacier margin. The ice receded from right to left.

Figure 7: Sand dune in Wayne. This and other "deserts" in Maine formed as windstorms in late-glacial time blew sand out of valleys, often depositing it as dune fields on hillsides downwind. Some dunes were reactivated in historical time when grazing animals stripped the vegetation cover.

Figure 8: Songo River delta and Songo Beach, Sebago Lake State Park, Naples. These deposits are typical of geological features formed in Maine since the Ice Age.

Note: The first letter of each map unit indicates the general age of the unit:
H = Holocene (postglacial deposit formed during the last 10,000 years).
Q = Quaternary (deposit of uncertain age, but usually late-glacial and/or postglacial).
P = Pleistocene (deposit formed during glacial to late-glacial time, prior to 10,000 years B.P. [years before present]).

af — **Artificial fill** - Variable mixtures of surficial sediments, rock fragments, and artificial materials that were transported and dumped to build up roads, lowlands, etc.

Ha — **Stream alluvium** - Sand, gravel, silt, and organic sediment. Deposited on flood plains of modern streams. Unit may include some wetland areas (Hw). Generally corresponds to the lower terrace levels and current flood plain of the major streams in the quadrangle.

Hw — **Freshwater wetland deposits** - Peat, muck, silt, clay, and sand. Deposited in poorly drained areas. Unit may include some stream alluvium areas (Ha).

Pm — **Glaciomarine undifferentiated deposits.** Massive to stratified and cross-stratified sand, silt, clay, and minor gravel. Consists partly of undifferentiated late-glacial sea-floor sediments (Presumpscot Formation), small glaciomarine fan deposits (particularly in Mountainy Pond Brook and Great Brook valleys), and partly of beach and nearshore deposits formed in relatively shallow water. In places, material may be reworked as sea level fell, by wave and tidal current action. Locally may contain boulders and gravel. Found as a blanket deposit over bedrock and older glacial sediments.

Pmrs — **Glaciomarine deltaic, beach, and spit deposits** laid down in the marine environment as sea level fell after the maximum marine invasion. These deposits were identified in the Great Brook valley and on Scotts Neck in Green Lake at the eastern edge and near Holbrook Pond in the northwest corner of the map. Probable beach deposits were found in pits along the road west of Great Brook. The stratified deposits of Scotts Neck are minimally exposed but interpreted herein as those of a spit, and the gravel pit area immediately north of Scotts Neck is abandoned and slumped but interpreted herein as a recessional delta or fan deposit; alternatively, these deposits may be the result of wave and current reworking of original esker deposits.

Pmd — **Glaciomarine delta deposits.** Sand and gravel and minor silt deposited in contact with or beyond the ice front by glacial meltwater issuing into the late-glacial sea from within the ice. One small ice-contact marine delta is found in the area. The Mountainy Pond delta (Pmdm) in the east has a surface elevation between 280-300 feet (85.3-91.4 m) with an estimated observed topset-foreset contact elevation of 270-290 feet (82.3-88.4 m), about the same elevation (279 ft [85 m]) of a topset-foreset contact measured in a delta east of Beech Hill Pond in the next quadrangle to the east (Thompson and others, 1989), which indicates sea level at about the time of deposition of this landform. The top layers of deltas in the area tend to be gravelly and the foreset beds tend to be sandy.

Pem — **End moraine deposits.** Complex association of glacial till and coarse-grained ice-contact stratified sand and gravel deposits in a broad ridge that has an undulating surface with scattered abundant large boulders, and a relatively steep northern side interpreted to be the contact slope with the ice front at the time of deposition. Identified in parts of Branch Lake, Green Lake, Phillips Lake, and Mountainy Pond. In places, these deposits are draped over with 2 or more feet of glaciomarine deposits (Pm).

Pt — **Till** - Light- to dark-gray, nonsorted to poorly sorted mixture of clay, silt, sand, pebbles, cobbles, and boulders. A predominantly sandy to silty diamicton containing some gravel. Till may underlie most other surficial deposits in the map area.

Bedrock exposures - Not all outcrops are shown on the map. Gray dots indicate individual outcrops; ruled pattern indicates areas of abundant exposures and areas where surficial deposits are generally less than 3 m (10 ft) thick.

Contact - Boundary between map units. Dashed where approximately located.

Glacially streamlined hill - Symbol shows trend of long axis, which is parallel to former glacial ice-flow direction. Some are drumlins and some are bedrock-cored hills.

135 135 180 180 — **Glacial striation locality** - Arrow shows ice-flow direction inferred from striations on bedrock. Absent an arrow indicates absence of inference of direction. Dot marks point of observation. Number is azimuth (in degrees) of flow direction. At sites where two or more sets of striations are present and relative ages determined, the flagged arrows indicate the older flow directions.

Marine delta topset-foreset contact locality. Delta formed at the ice front during late-glacial marine submergence. Arrow points in general direction of dip of foreset beds.

Moraine ridge - Line shows inferred crest of moraine ridge composed of mostly till and/or minor water-laid sediments (sand and gravel) interpreted to have formed in the marginal zone of the glacier, perpendicular to the ice-flow direction.

Grooved till surface. The long axes of SE-trending parallel ridges and grooves in till are inferred to have been carved into the till surface by the ice as it flowed over the area. Symbol is on the ridge parts of the landform complex.

Direction of meltwater flow.

X — **Large boulder.** Huge (house-sized) boulder.

Ice-margin position - Shows an approximate position of the glacier margin during ice retreat, based on meltwater deposits, moraines, and/or positions of meltwater channels.

Upper limit of marine submergence - Shows highest elevation of sea level immediately following recession of the last glacial ice sheet from the quadrangle.

USES OF SURFICIAL GEOLOGY MAPS

A surficial geology map shows all the loose materials such as till (commonly called hardpan), sand and gravel, or clay, which overlie solid ledge (bedrock). Bedrock outcrops and areas of abundant bedrock outcrops are shown on the map, but varieties of the bedrock are not distinguished (refer to bedrock geology map). Most of the surficial materials are deposits formed by glacial and deglacial processes during the last stage of continental glaciation, which began about 25,000 years ago. The remainder of the surficial deposits are the products of postglacial geologic processes, such as river floodplains, or are attributed to human activity, such as fill or other land-modifying features.

The map shows the areal distribution of the different types of glacial features, deposits, and landforms as described in the map explanation. Features such as striations and moraines can be used to reconstruct the movement and position of the glacier and its margin, especially as the ice sheet melted. Other ancient features include shorelines and deposits of glacial lakes or the glacial sea, now long gone from the state. This glacial geologic history of the quadrangle is useful to the larger understanding of past earth climate, and how our region of the world underwent recent geologically significant climatic and environmental changes. We may then be able to use this knowledge in anticipation of future similar changes for long-term planning efforts, such as coastal development or waste disposal.

Surficial geology maps are often best used in conjunction with related maps such as surficial materials maps or significant sand and gravel aquifer maps for anyone wanting to know what lies beneath the land surface. For example, these maps may aid in the search for water supplies, or economically important deposits such as sand and gravel for aggregate or clay for bricks or pottery. Environmental issues such as the location of a suitable landfill site or the possible spread of contaminants are directly related to surficial geology. Construction projects such as locating new roads, excavating foundations, or siting new homes may be better planned with a good knowledge of the surficial geology of the site. Refer to the list of related publications below.

OTHER SOURCES OF INFORMATION

1. Hildreth, C. T., and Doughty, D. F., 2011, Surficial materials of the Green Lake quadrangle, Maine: Maine Geological Survey, Open-File Map 11-19, scale 1:24,000.
2. Foster, L. E., and Smith, T. T. (compilers), 2011, Significant sand and gravel aquifers in the Green Lake quadrangle, Maine: Maine Geological Survey, Open-File Map 11-29, scale 1:24,000.
3. Thompson, W. B., 1979, Surficial geology handbook for coastal Maine: Maine Geological Survey, 68 p. (out of print).
4. Thompson, W. B., and Borns, H. W., Jr., 1985, Surficial geologic map of Maine: Maine Geological Survey, scale 1:500,000.
5. Thompson, W. B., Crossen, K. J., Borns, H. W., Jr., and Andersen, B. G., 1989, Glaciomarine deltas of Maine and their relation to late Pleistocene-Holocene crustal movements, *in* Anderson, W. A., and Borns, H. W., Jr. (editors), Neotectonics of Maine: studies in seismicity, crustal warping, and sea level change: Maine Geological Survey, Bulletin 40, p. 43-67.