Geohydrology and Water Quality of Stratified-Drift Aquifers in the Lower Merrimack and Coastal River Basins, Southeastern New Hampshire

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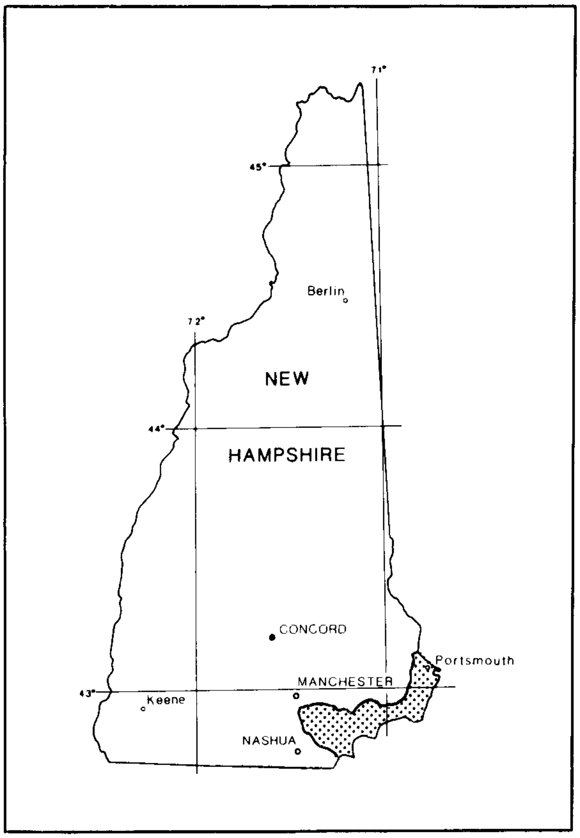

Prepared in cooperation with the

NEW HAMPSHIRE DEPARTMENT OF ENVIRONMENTAL SERVICES
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whose wells were contaminated or threatened by contamination from this site.

The Ottati and Goss/Great Lakes Container Corporation hazardous-waste site is on land west of State Route 125 in Kingston. The site was used for the storage and reconditioning of drums from 1955 through 1980. By 1980, the site contained an estimated 4,300 drums of unknown chemical waste (Goldberg-Zoino and Associates, 1986). Most of these drums were stored outdoors with no protection from the weather. Clean-up activities began in 1981, and drum-removal operations were completed by the summer of 1982. A preliminary hydrogeologic investigation, by a private consulting firm (Ecology and Environment, Inc., 1982) has indicated an extensive ground-water-contaminant plume that extends from the site towards Country Pond to the southeast. Another private consulting firm is completing a final RI/FS that will define the nature and extent of site contamination and identify the remedial action needed to complete clean-up activities at the site.

The Coakley landfill covers 20 acres in a residential area in North Hampton. The landfill borders the towns of Greenland to the northwest and Rye to the northeast. Originally a sand and gravel quarry, the site was converted to a landfill in 1971. Thirteen residential wells, to the north, east, and south of the site, have been closed because of contamination by VOCs from the landfill (New Hampshire Water Supply and Pollution Control Division, 1985a). A private consultant completed a draft RI/FS in 1988 that defined the nature and extent of site contamination and remedial action needed to clean up the site (Roy F. Weston, Inc., 1988-1989). As of 1990, no remedial action has been taken at the site except to cap the landfill and install catchment drains around its perimeter.

The Holton Circle site is in a residential cul-de-sac off Pillsbury Road in the town of Londonderry. Small concentrations of VOCs were detected in water samples from the unconsolidated and bedrock aquifers in 1988.

Pease Air Force Base is on a peninsula between Great Bay and the Piscataqua River in the towns of Portsmouth and Newington. A private consultant, under contract to the U.S. Air Force, did an Installation Restoration Program, Phase II Stage 1 Confirmation/Quantification Study at Pease Air Force Base during 1986. In this study, 20 sites were investigated for possible contamination. Past activities at Pease Air Force Base in support of aircraft maintenance has resulted in the generation of small quantities of hazardous wastes, including spent degreasers, solvents, paint strippers, and contaminated jet fuels (Roy F. Weston, Inc., 1986).

The Duston Road site is near the intersections of Duston Road, Eyssi Drive, and Atkinson Road in Salem. Ground water near the Duston Road site was determined to be contaminated with VOCs in October 1983 (New Hampshire Water Supply and Pollution Control Division, 1985b). The source of contamination proved to be drums buried in the overburden layer. In August 1984, more than 63 barrels, as well as debris and contaminated soil, were removed. Contamination at the site extends into the thin, sandy aquifer and the crystalline bedrock aquifer (New Hampshire Water Supply and Pollution Control Division, 1985b). In addition, some contaminants were found in Dietal Pond and Providence Hill Brook. Because ground water was contaminated in many nearby domestic wells, including wells finished in unconsolidated deposits and bedrock, a town water line was extended to the affected area in October 1984 to provide potable water.

Ten facilities (fig. 24 and pls. 1-3) are on the New Hampshire Water Supply and Pollution Control Division and New Hampshire Waste Management Divisions's RCRA Regulated Facilities List (New Hampshire Department of Environmental Services, 1987). Three of these sites are in Seabrook, two are in Derry, two are in Newington, one is in Salem, one is in Hampton, and one is in Londonderry.

SUMMARY AND CONCLUSIONS

The lower Merrimack and coastal river basins in southeastern New Hampshire encompass 327 mi^2, of which 24 percent is covered by stratified-drift deposits. About 79 percent of the water pumped by high-capacity wells is derived from wells screened in coarse-grained stratified drift. Population for the 25 communities of the study area was 228,495 in 1987, and is projected to increase at an average annual rate of 3.32 percent to the end of the century. The quantity and quality of ground-water resources are generally sufficient for immediate water needs, however, stresses from a rapid population increase have caused local deterioration in quality and shortages that have forced some communities to seek water from increasingly distant sources.

At present, the maximum yield of all community water-supply systems that withdraw water from the stratified drift is estimated to be 6 Mgal/d. Towns served by high-yielding gravel-packed wells include

Hampton, North Hampton, Portsmouth, Rye, and Seabrook. Many of the shallow aquifers within these towns are developed at or near their full potential yields and, as a result, additional sources are sought from the bedrock aquifer or from aquifer areas outside of town boundaries. Maximum well yield averaged 328 gal/min for 8 municipal wells tapping crystalline bedrock and 377 gal/min for 19 municipal wells tapping stratified drift.

Two types of topography define the stratified-drift deposits found in the study area. West of and including the Spicket River drainage basin are low, rounded hills and ridges with local topographic relief of 100 to 200 ft between interstream divides and stream bottoms. The most extensive stratified-drift aquifers are confined within well-defined valley walls and consist of valley trains, deltas, and kame terraces.

East of the Spicket River basin, topographic relief is less than 100 ft with sluggish streams flowing in broad valleys cut into predominantly sand, silt, and clay units. The most productive aquifers are outwash plains and kame plains that are often underlain by fine-grained marine deposits. In some areas, a small confining layer composed of clay and silt is interbedded with stratified drift and separates the aquifer into an upper unconfined part and a lower confined part.

Total thickness of sand and gravel sediments ranges from 0 at the boundary of till or marine deposits and stratified drift to more than 120 ft at one location in Kingston. The average seasonal water-table fluctuation is 3 to 5 ft. Hydraulic conductivity generally ranges from 3 to 300 ft/d. Transmissivity ranges from near 0 to greater than 4,000 ft^2/d.

A total of 19 aquifers have transmissivities greater than 1,000 ft^2/d. Of these, 8 are currently used for public water supply and 11 are unused. Because the aquifers of the eastern report area are contained by fine-grained marine sediments that isolate them from surface-water bodies, long-term ground-water-supply potential is limited.

Aquifers that have the greatest potential for supplying additional amounts of water include the Kingston outwash plain in the Powwow River valley, the Windham valley-train deposit south of Cobbetts Pond, the delta at Island Pond in Derry, and the kame deltas in central Greenland and in central North Hampton.

Two aquifers that are currently undeveloped and of potential importance were selected for a detailed hydrologic analysis. The yield and contributing recharge areas to hypothetical wells in the Windham-Cobbetts Pond and Kingston-Powwow River aquifers were evaluated by use of a computer model that simulates ground-water flow. These hypothetical wells were simulated at sites considered favorable for future pumping centers. The principle of superposition was used to superimpose drawdowns, computed by the flow model, on the mapped water-table surface. Total well yields, representing maximum development at the Windham-Cobbetts Pond and Kingston-Powwow River aquifers, were estimated to be 0.6 and 4.0 Mgal/d. Potential yields derived from an analytical procedure based on surficial geology agree with the computer-model estimates for these aquifers.

Simulations of the Windham-Cobbetts Pond model indicate that, at maximum development, the contributing area approaches the full extent of the aquifer and far exceeds the area affected by drawdown in the Kingston-Powwow River model.

Sensitivity analyses of the models indicate that the Kingston-Powwow River model was most sensitive to changes in river- and pond-bottom conductance and the Windham-Cobbetts Pond model to changes in specific yield. These findings emphasize the importance of accurately determining bottom conductance for aquifer systems for which induced infiltration is the primary source of water (Kingston-Powwow River model) and specific yields for aquifers where ground-water storage is the primary source (Windham-Cobbetts Pond model).

The ground-water quality from 30 well sites is suitable for drinking and other domestic uses except at a few sites where natural aquifer composition or human activities have degraded water quality. Ground water in the region is generally soft, slightly acidic, and low in total dissolved solids. Ground-water-quality samples meet the USEPA's primary drinking-water regulations except for an elevated level of trichloroethylene in water from one supply well that has ongoing treatment for this constituent.

Inorganic constituents that exceed New Hampshire Water Supply Engineering Bureau's (written commun., 1988) secondary drinking-water standards and the USEPA's (1989) secondary drinking-water regulations are iron, manganese, and aluminum. Seven samples had iron concentrations greater than 300 μg/L, 19 samples had manganese concentrations greater than 50 μg/L, and 4 samples had aluminum concentrations greater than 50 μg/L. Most ground water in the area contains enough dissolved manganese to cause stains on plumbing fixtures and laundry, thus restricting its use without treatment. Concentrations of iron in some ground water is high enough to cause similar problems. Treatment can reduce manganese and iron concentrations.

Water samples were also analyzed for 36 volatile organic compounds. Of 25 wells sampled, water samples from four wells had trace concentrations and water samples from a fifth well had small concentrations of volatile organic compounds. Trichloroethylene in water samples from well PXW-2 was the only constituent whose concentration exceeds New Hampshire Water Supply Engineering Bureau's (1990) drinking-water standards for volatile organic compounds.

Extensive ground-water contamination at seven hazardous-waste sites has seriously decreased the amount of reliable, safe withdrawals from selected aquifers in some areas.

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GLOSSARY

Ablation till: Loosely consolidated rock debris, formerly carried by glacial ice, that accumulated in places as the surface ice was removed by ablation.

Aquifer: A geologic formation, group of formations, or part of a formation that contains sufficient saturated permeable materials to yield significant quantities of water to wells and springs. Where water only partly fills an aquifer, the upper surface of the saturated zone is free to rise and decline (Heath, 1983).

Aquifer boundary: A feature that limits the extent of an aquifer.

Basal till: A firm, compact clay-rich till deposited beneath a moving glacier, containing abraided stones oriented, in general, with their long axes parallel to the direction of ice movement.

Bedrock: Solid rock, locally called "ledge," that forms the Earth's crust. It may be exposed at the surface but more commonly is buried beneath a few inches to more than 100 feet of unconsolidated deposits.

Cone of depression: A depression produced in a water table or other potentiometric surface by the withdrawal of water from an aquifer; in cross section, shaped like an inverted cone with its apex at the pumped well.

Confined aquifer: An aquifer saturated with water and bounded above and below by material having a distinctly lower hydraulic conductivity than that of the aquifer itself.

Contact: A plane or irregular surface between two different types or ages of rocks or unconsolidated sediments.

Cubic foot per second (ft^3/s): A unit expressing rate of discharge. One cubic foot per second is equal to the discharge of a stream 1 foot wide and 1 foot deep flowing at an average velocity of 1 foot per second.

Cubic feet per second per square mile [$(ft^3/s)/mi^2$]: A unit expressing average number of cubic feet of water flowing per second from each square mile of area drained.

Deposit: Earth material that has accumulated by some natural process.

Dissolved solids: The residue from a clear sample of water after evaporation and drying for 1 hour at 180 degrees Celsius; consists primarily of dissolved mineral constituents, but may also contain organic matter and water of crystallization.

Drainage area: The area or tract of land, measured in a horizontal plane, that gathers water and contributes it ultimately to some point on a stream channel, lake, reservoir, or other water body.

Drawdown: The lowering of the water table or potentiometric surface caused by the withdrawal of water from an aquifer by pumping; equal to the difference between the static water level and the pumping water level.

Drumlin: A low, smoothly rounded, elongated oval shaped hill of glacial till, built under the margin of glacial ice and shaped by its flow; its longer axis is parallel to the direction of movement of the ice.

Effective size: The grain size at which 10 percent of the sample consists of smaller grains and 90 percent consists of larger grains.

Esker: A long ridge of sand and gravel that was deposited by water flowing in tunnels within or beneath glacial ice.

First quartile: For a set of measurements arranged in order of magnitude, that value at which 25 percent of the measurements are lower in magnitude and 75 percent are higher.

Flow duration (of a stream): The percentage of time during which specified daily discharges are equaled or exceeded within a given time period.

Fracture: A break, crack, or opening in bedrock along which water may move.

Gneiss: A coarse-grained metamorphic rock with alternating bands of granular and micaceous minerals.

Granite: A coarse-grained, light colored, igneous rock.

Granodiorite: A coarse-grained igneous rock that contains quartz, plagioclase, potassium feldspar, biotite, and hornblende.

Gravel: Unconsolidated rock debris composed principally of particles larger than 2 millimeter in diameter.

Ground water: Water beneath the water table in soils or geologic formations that are fully saturated.

Ground-water discharge: The discharge of water from the saturated zone by (1) natural processes such as ground-water seepage into stream channels and ground-water evapotranspiration and (2) discharge through wells and other man-made structures.

Ground-water divide: A hypothetical line on a water table on each side of which the water table slopes downward in a direction away from the line. In the vertical dimension, a plane across which there is no ground-water flow.

Ground-water evapotranspiration: Ground water discharged into the atmosphere in the gaseous state either by direct evaporation from the water table or by the transpiration of plants.

Ground-water recharge: Water that is added to the saturated zone of an aquifer.

Ground-Water Site Inventory (GWSI): A computerized file maintained by the U.S. Geological Survey that contains information about wells and springs throughout the United States.

Head, static: The height of the surface of a water column above a standard datum that can be supported by the static pressure of a given point.

Hydraulic conductivity (K): A measure of the ability of a porous medium to transmit a fluid, expressed in unit length per unit time. A material has a hydraulic conductivity of 1 foot per day if it will transmit in 1 day, 1 cubic foot of water at the prevailing kinematic viscosity through a 1-foot-square cross section of aquifer, measured at right angles to the direction of flow, under a hydraulic gradient, of 1-foot change in head over 1-foot length of flow path.

Hydraulic gradient: The change in static head per unit of distance in a given direction. If not specified, the direction is generally understood to be that of the maximum rate of decrease in head.

Hydrograph: A graph showing stage (height), flow velocity, or other property of water with respect to time.

Ice-contact deposits: Stratified drift deposited in contact with melting glacial ice. Landforms include eskers, kames, kame terraces, and grounding-line deltas.

Igneous: Descriptive term for rocks or minerals solidified from molten or partially molten material--that is, from a magma, such as basalt or granite.

Induced infiltration: The process by which water infiltrates an aquifer from an adjacent surface-water body in response to pumping.

Kame: A low mound, knob, hummock, or short irregular ridge composed of stratified sand and gravel deposited by glacial meltwater; the precise mode of formation is uncertain.

Kame plain: Moderately flat-topped hills of sand and gravel; surrounded or nearly surrounded by ice-contact slopes.

Kame terrace: A terrace-like ridge consisting of stratified sand and gravel formed as a glaciofluvial deposit between a melting glacier or stagnant ice lobe and a higher valley wall, and left standing after the disappearance of the ice.

Kettle: A steep-sided, basin- or bowl-shaped hole or depression, commonly without surface drainage, in stratified-drift deposits; formed by the melting of a large, detached block of stagnant ice left behind by a retreating glacier.

Lodgement till: A firm, compact clay-rich till deposited beneath a moving glacier, containing abraded stones oriented, in general, with their long axes parallel to the direction of ice movement; also called basal till.

Marine limit: The former limit of the sea. The highest shoreline during a period of late-glacial submergence.

Mean (arithmetic): The sum of the individual values of a set, divided by their total number; also referred to as the "average."

Median: The middle value of a set of measurements that are ordered from lowest to highest; 50 percent of the measurements are lower than the median and 50 percent are higher.

Metamorphic: Descriptive term for rocks such as gneiss and schist which have formed, in the solid state, from other rocks.

Micrograms per liter (μg/L): A unit expressing the concentration of chemical constituents in solution as the mass (micrograms) of a constituent per unit volume (liter) of water. One thousand micrograms per liter is equivalent to one milligram per liter.

Milligrams per liter (mg/L): A unit for expressing the concentration of chemical constituents in solution as the mass (milligrams) of a constituent per unit volume (liter) of water.

Outwash: Stratified deposits chiefly of sand and gravel removed or "washed out" from a glacier by meltwater streams and deposited beyond the margin of a glacier, usually occurring in flat or gently sloping outwash plains.

Outwash deltas: Deltas formed beyond the margin of the glacier where glacial meltwater entered a water body.

Outwash plain: A broad, gently sloping sheet of outwash deposited by meltwater streams flowing in front of or beyond a glacier.

pH: The negative logarithm of the hydrogen-ion concentration. A pH of 7.0 indicates neutrality; values below 7.0 denote acidity, and those above 7.0 denote alkalinity.

Phi grade scale: A logarithmic transformation of the Wentworth grade scale based on the negative logarithm to the base 2 of the particle diameter, in millimeters. (4 mm = -2 phi, 2mm = -1 phi, 1 mm = 0 phi, 0.5 mm = 1 phi, and so on)

Phyllite: A fine-grained metamorphic rock, similar to schist, often having a silky luster.

Porosity: The property of a rock or unconsolidated deposit that is a measure of the size and number of internal voids or open spaces; it may be expressed quantitatively as the ratio of the volume of its open spaces to its total volume.

Potential yield: The potential yield, defined for the purposes of this report, is the rate at which water can be withdrawn from a basin by pumping for 180 days without recharge without producing an undesirable result. An undesired result is an adverse situation such as progressive lowering of the water table resulting in depletion of the ground-water reserves, excessive lowering of pond levels and streamflow by induced infiltration such that water resources are adversely affected, the intrusion of water of undesirable quality, the deterioration of the economic advantages of pumping, and land subsidence caused by lowered ground-water levels. Any prolonged water withdrawals in excess of the potential yield will result in the mining of the water resource and have negative impacts on environmental, social, or economic conditions.

Precipitation: The discharge of water from the atmosphere, either in a liquid or solid state.

Primary porosity: Porosity that is intrinsic to the sediment or rock matrix; that is, the spaces naturally occurring between the grains or particles of which the rock or sediment is formed. See secondary porosity.

Runoff: That part of the precipitation that appears in streams. It is the same as streamflow unaffected by artificial diversions, storage, or other human activities in or on the stream channels.

Saturated thickness (of stratified drift): Thickness of stratified drift extending down from the water table to the till or bedrock surface.

Saturated zone: The subsurface zone in which all open (interconnected) spaces are filled with water. Water below the water table, the upper limit of the saturated zone, is under pressure greater than atmospheric.

Schist: A metamorphic rock with subparallel orientation of the visible micaceous minerals, which dominate its composition.

Secondary porosity: Porosity created by altering the original condition of a rock or sediment by such phenomena as solution, fracturing, or faulting.

Sediment: Fragmental material that originates from weathering of rocks. It can be transported by, suspended in, or deposited by water.

Specific capacity (of a well): The rate of discharge of water divided by the corresponding drawdown of the water level in the well, stated in this report in gallons per minute per foot.

Specific yield: The ratio of the volume of water that a rock or soil will yield, by gravity drainage, after being saturated to the total volume of the rock or soil.

Standard deviation: A measure of the amount of variability within a sample; it is the square root of the average of the squares of the deviations about the arithmetic mean of a set of data.

Storage coefficient: The volume of water an aquifer releases from or takes into storage per unit surface area of the aquifer per unit change in head. In an unconfined aquifer, the storage coefficient is essentially equal to the specific yield.

Stratified drift: Sorted and layered unconsolidated material deposited in meltwater streams flowing from glaciers or settled from suspension in quiet-water bodies fed by meltwater streams.

Surficial geology: The study of or distribution of unconsolidated deposits at or near the land surface.

Superposition: A principle that states--for linear systems--that the solution to a problem involving multiple inputs (or stresses) is equal to the sum of the solutions to a set of simpler individual problems that form the composite problem.

Third quartile: For a set of measurements arranged in order of magnitude, the value at which 75 percent of the measurements are lower in magnitude and 25 percent are higher.

Till: A predominantly nonsorted, nonstratified sediment deposited directly by a glacier and composed of boulders, gravel, sand, silt and clay mixed in various proportions.

Transmissivity: The rate at which water is transmitted through a unit width of aquifer under a unit hydraulic gradient. Equal to the average hydraulic conductivity times the saturated thickness.

Unconfined aquifer (water-table aquifer): An aquifer only partly filled with water. In such aquifers the water is unconfined in that the water table or upper surface of the saturated zone is at atmospheric pressure and is free to rise and fall.

Unconsolidated deposit: A sediment in which the particles are not firmly cemented together, such as sand in contrast to sandstone.

Unsaturated zone: The zone between the water table and the land surface in which the open spaces are not completely filled with water.

Valley train: A long, narrow body of sand and gravel deposited by meltwater streams far beyond the margin of an active glacier and confined in the walls of a valley below the glacier; it may or may not emerge from the mouth of the valley to join an outwash plain.

Water table: The upper surface of the saturated zone. Water at the water table is at atmospheric pressure.

APPENDIX

Geohydrologic sections based on seismic-refraction data

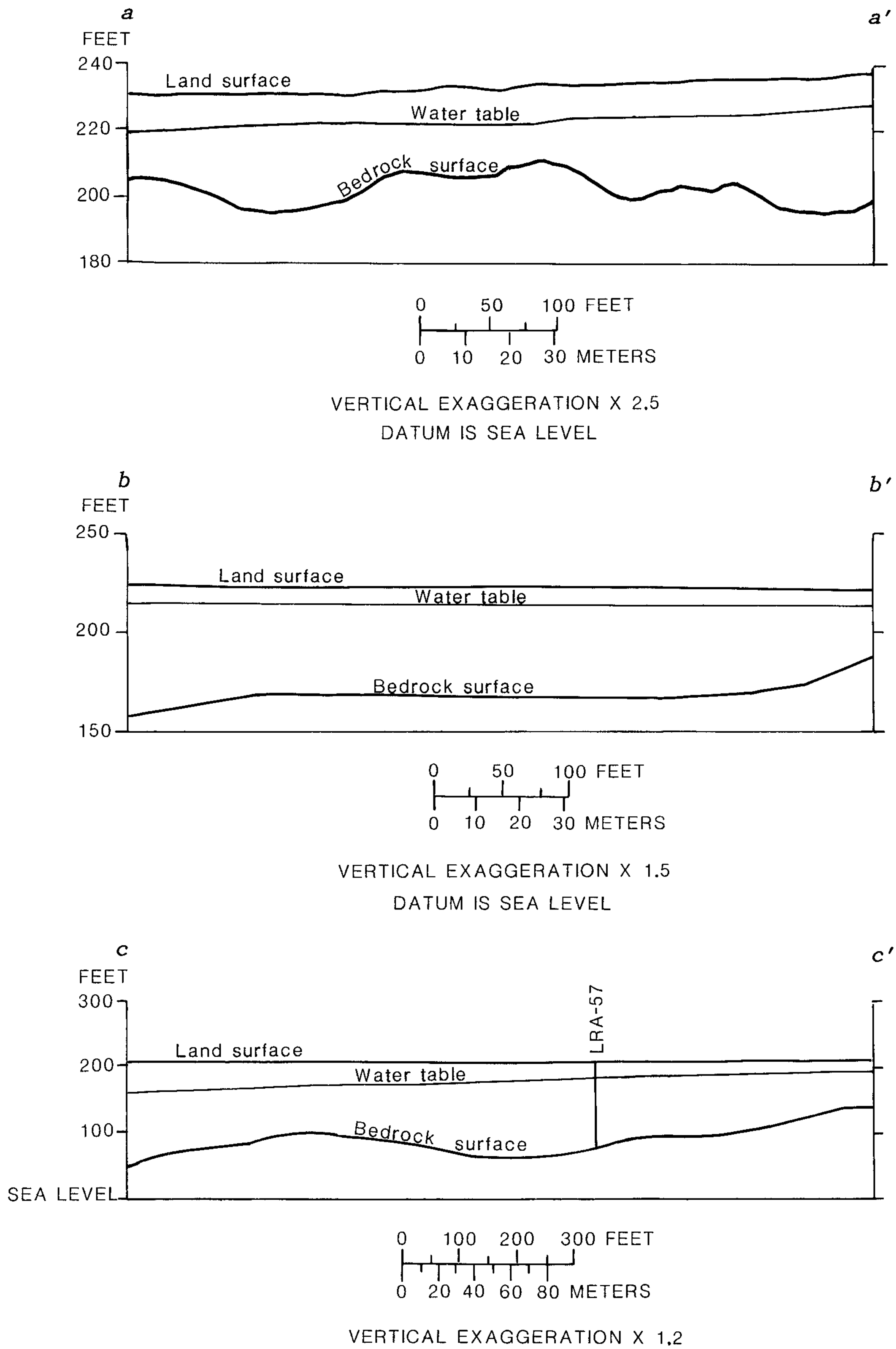

Figure A1.--Geohydrologic sections based on seismic-refraction data for Londonderry a-a′, b-b′, and c-c′. Lines of section are shown on plate 1.

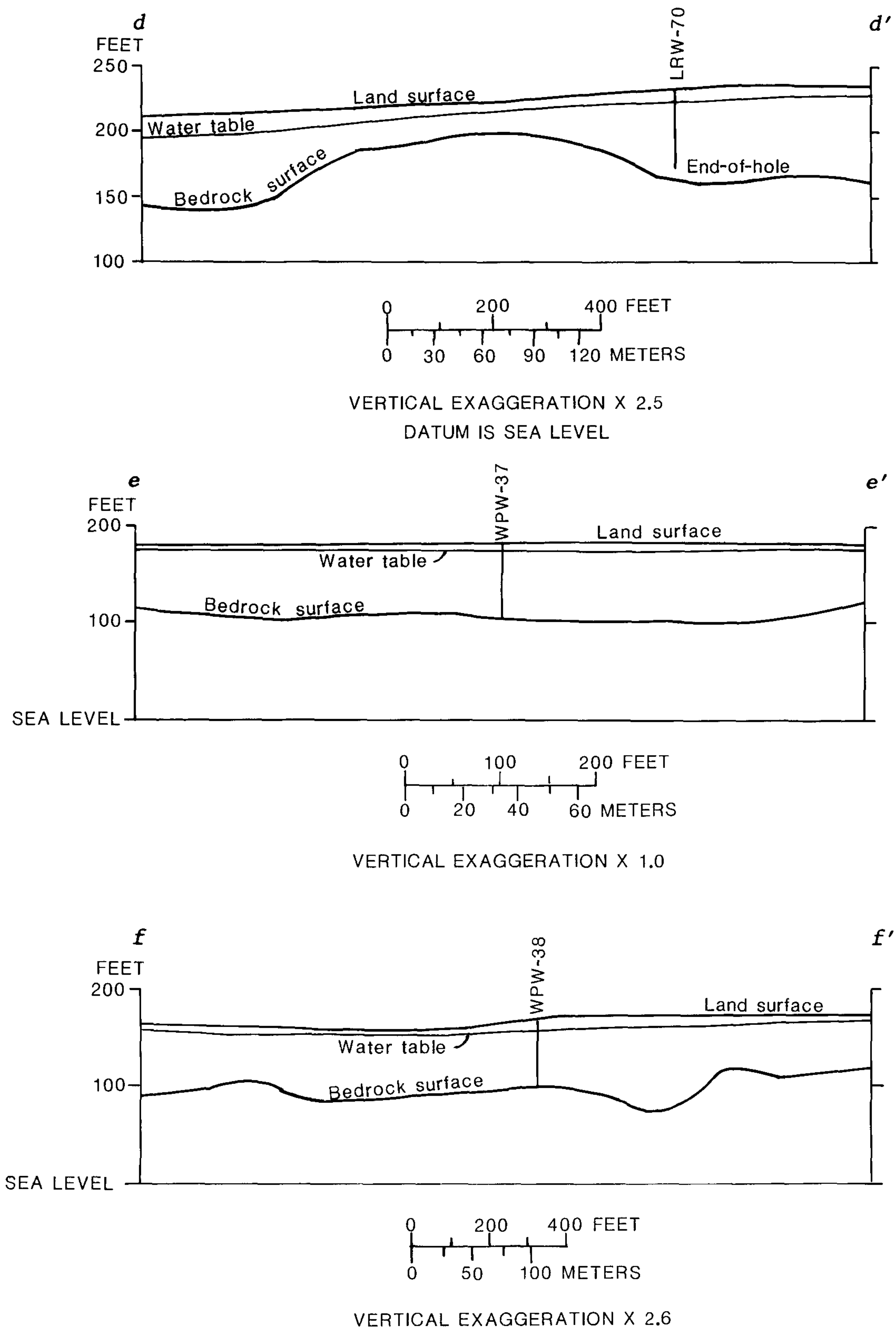

Figure A2.--Geohydrologic sections based on seismic-refraction data for Londonderry d-d', Windham e-e', and f-f'. Lines of section are shown on plate 1.

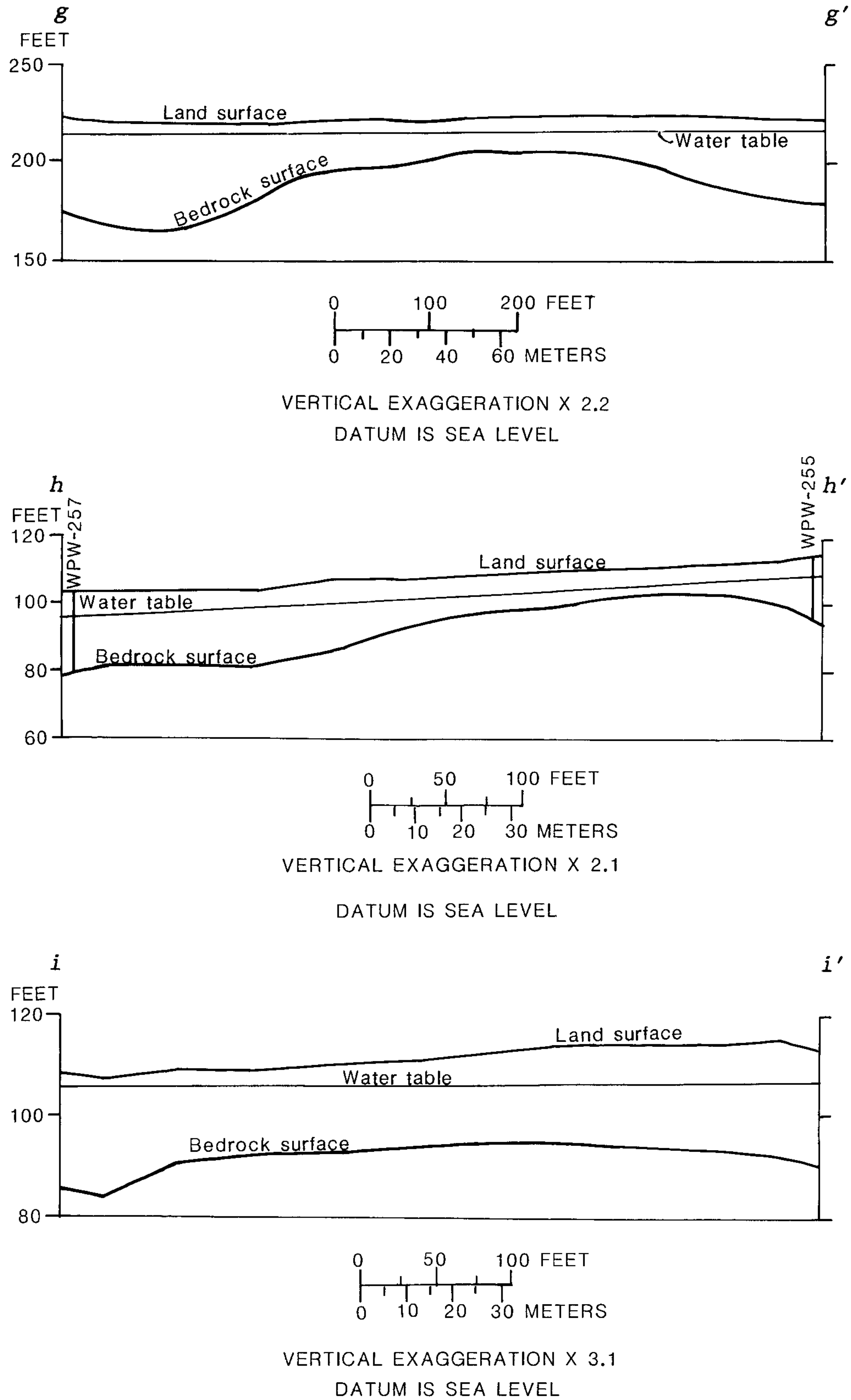

Figure A3.--Geohydrologic sections based on seismic-refraction data for Windham g-g′, h-h′, and i-i′. Lines of section are shown on plate 1.

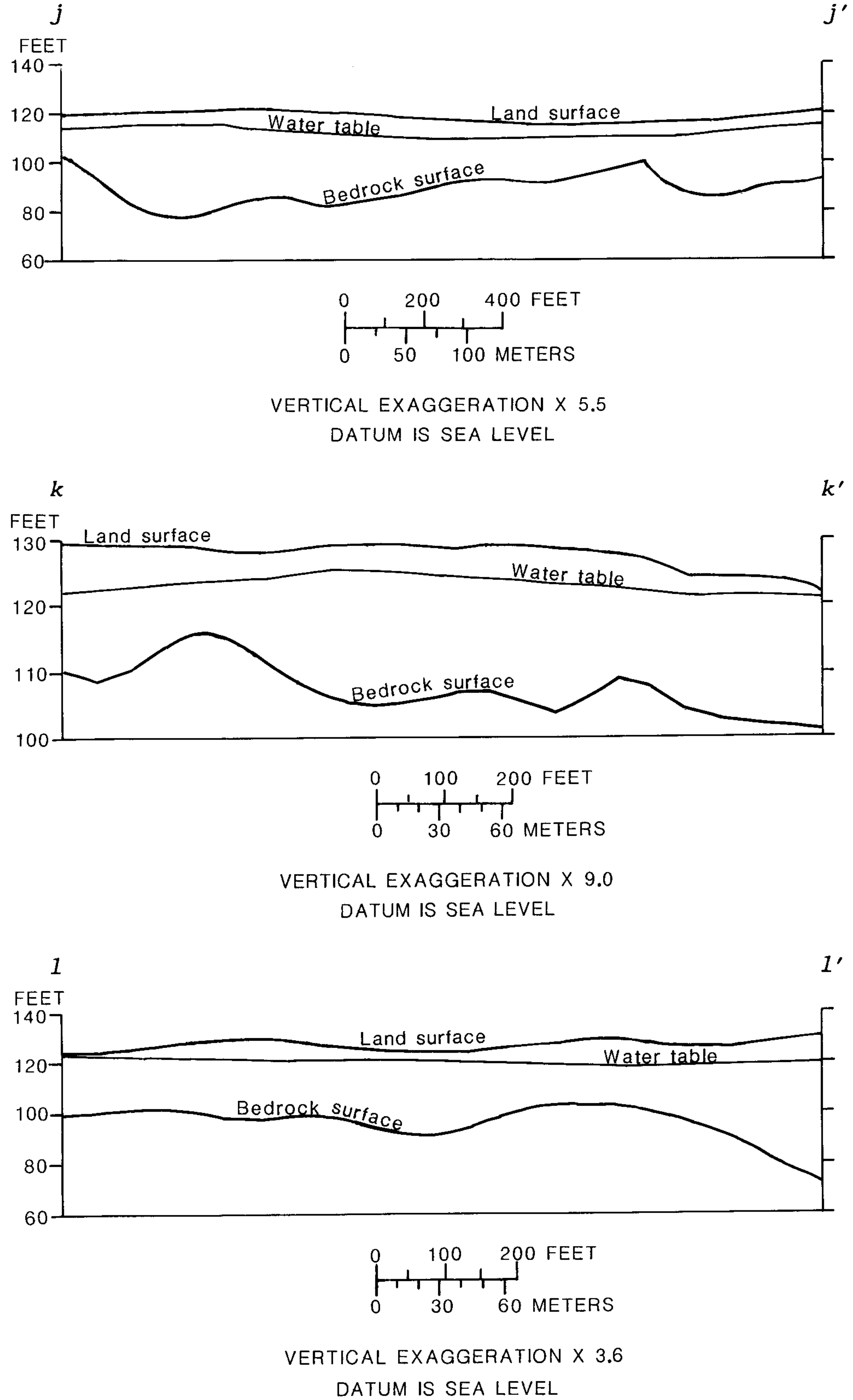

Figure A4.--Geohydrologic sections based on seismic-refraction data for East Kingston j-j' and Kingston k-k' and l-l'. Lines of section are shown on plate 2.

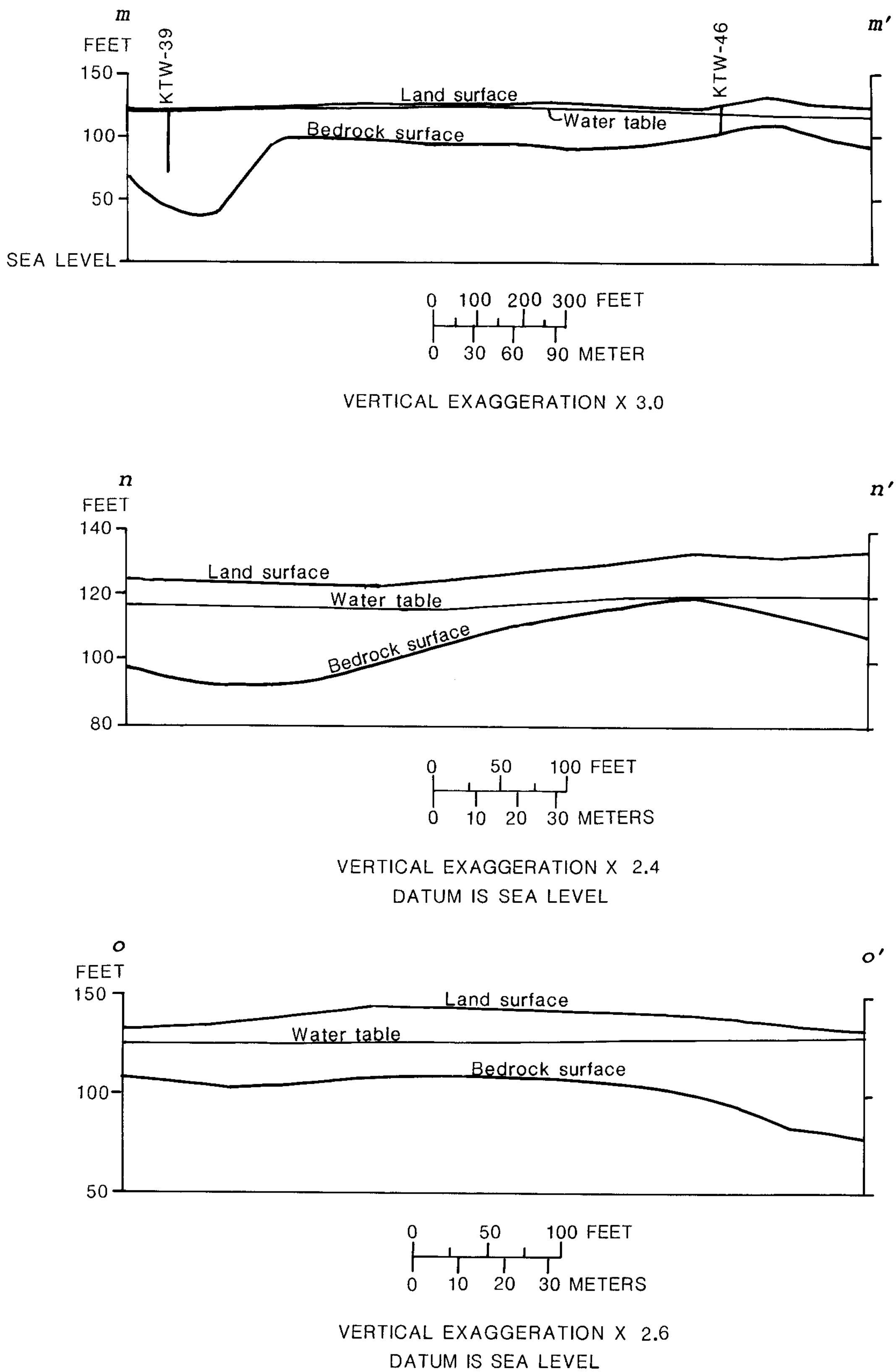

Figure A5.--Geohydrologic sections based on seismic-refraction data for Kingston m-m′, n-n′, and o-o′. Lines of section are shown on plate 2.

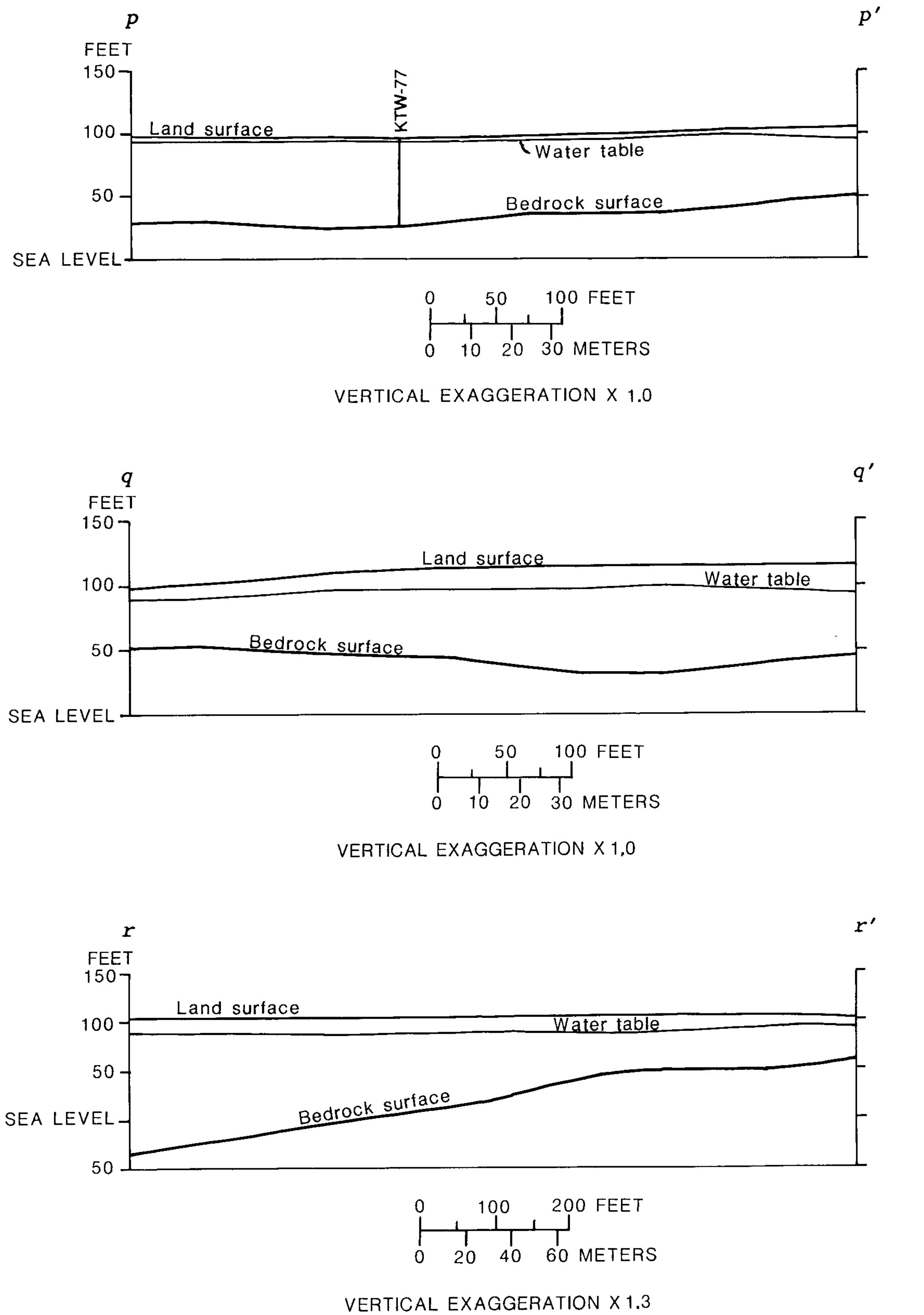

Figure A6.--Geohydrologic sections based on seismic-refraction data for Kingston p-p′, q-q′, and r-r′. Lines of section are shown on plate 2.

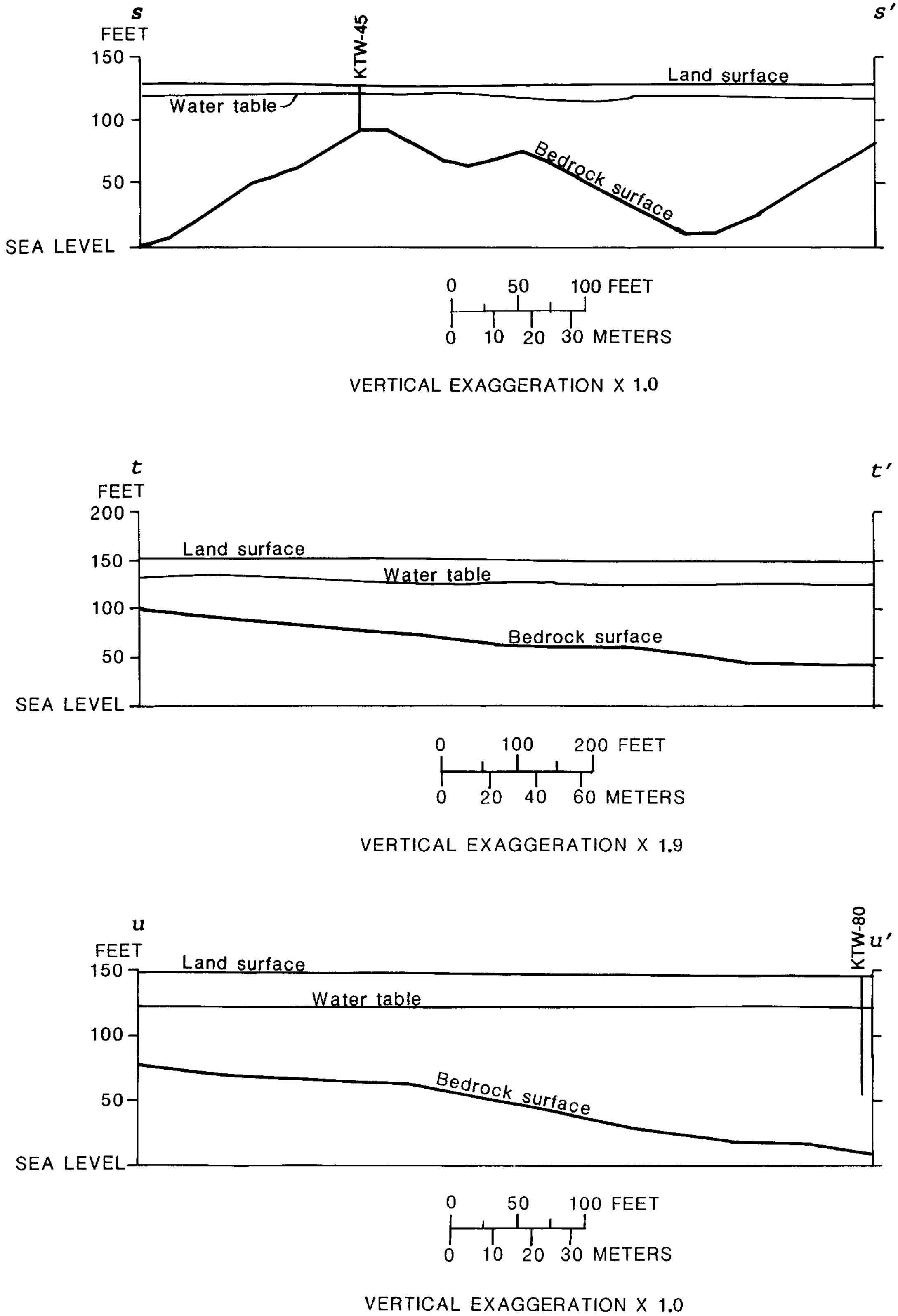

Figure A7.--Geohydrologic sections based on seismic-refraction data for Kingston s-s', t-t', and u-u'. Lines of section are shown on plate 2.

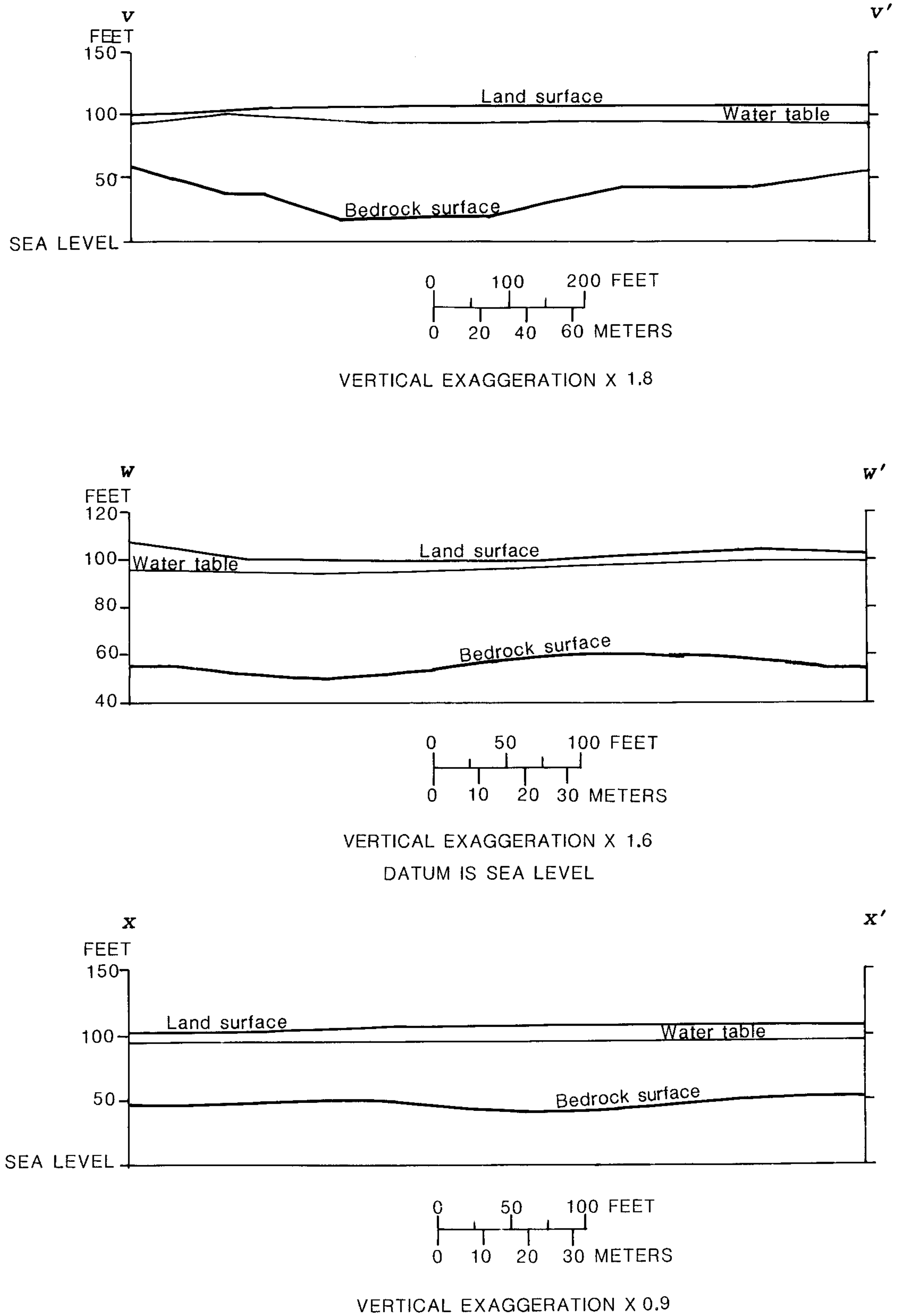

Figure A8.--Geohydrologic sections based on seismic-refraction data for Kingston v-v′, w-w′, and x-x′. Lines of section are shown on plate 2.

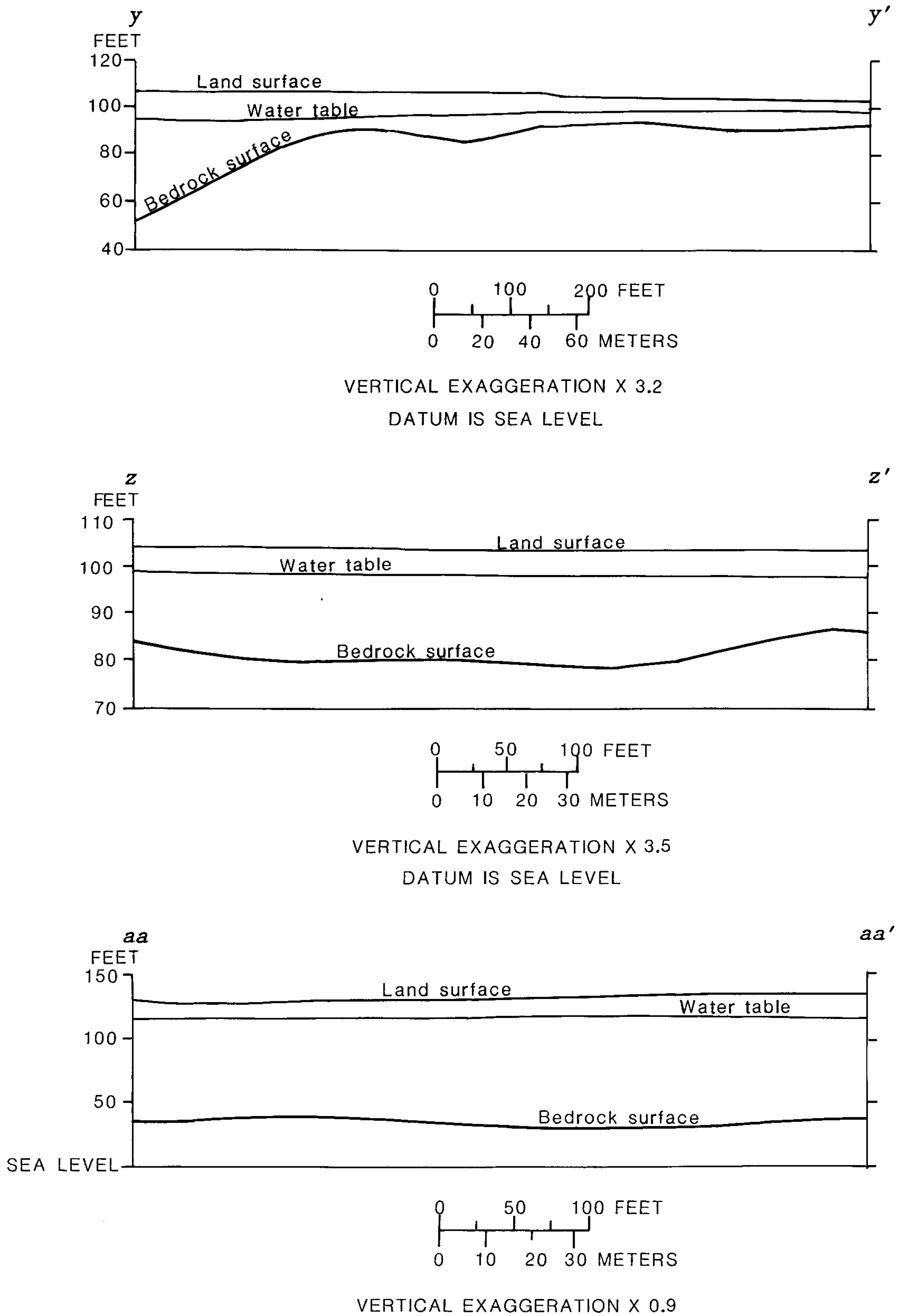

Figure A9.--Geohydrologic sections based on seismic-refraction data for Kingston y-y', z-z', and aa-aa'. Lines of section are shown on plate 2.

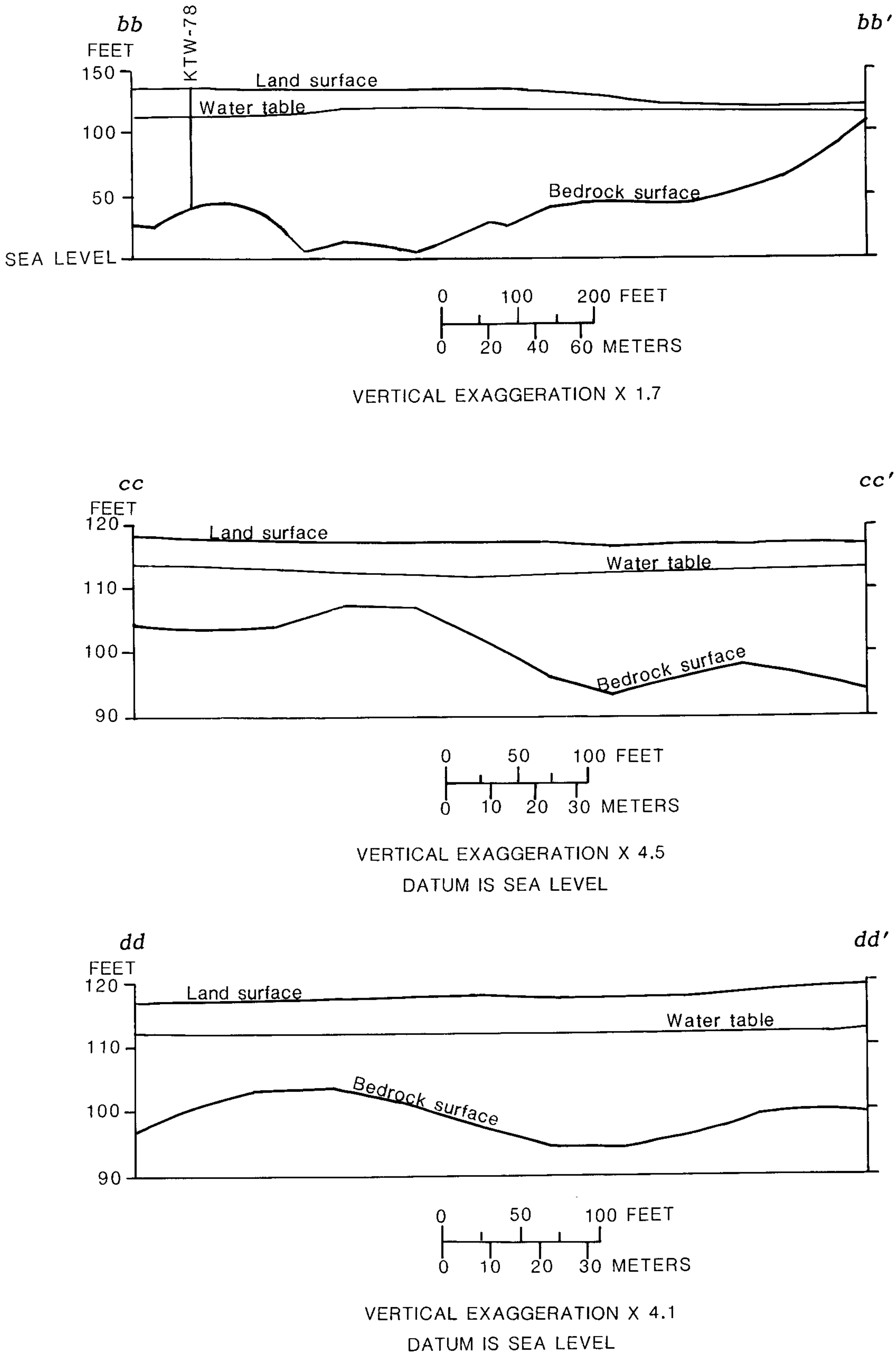

Figure A10.--Geohydrologic sections based on seismic-refraction data for Kingston bb-bb′, cc-cc′, and dd-dd′. Lines of section are shown on plate 2.

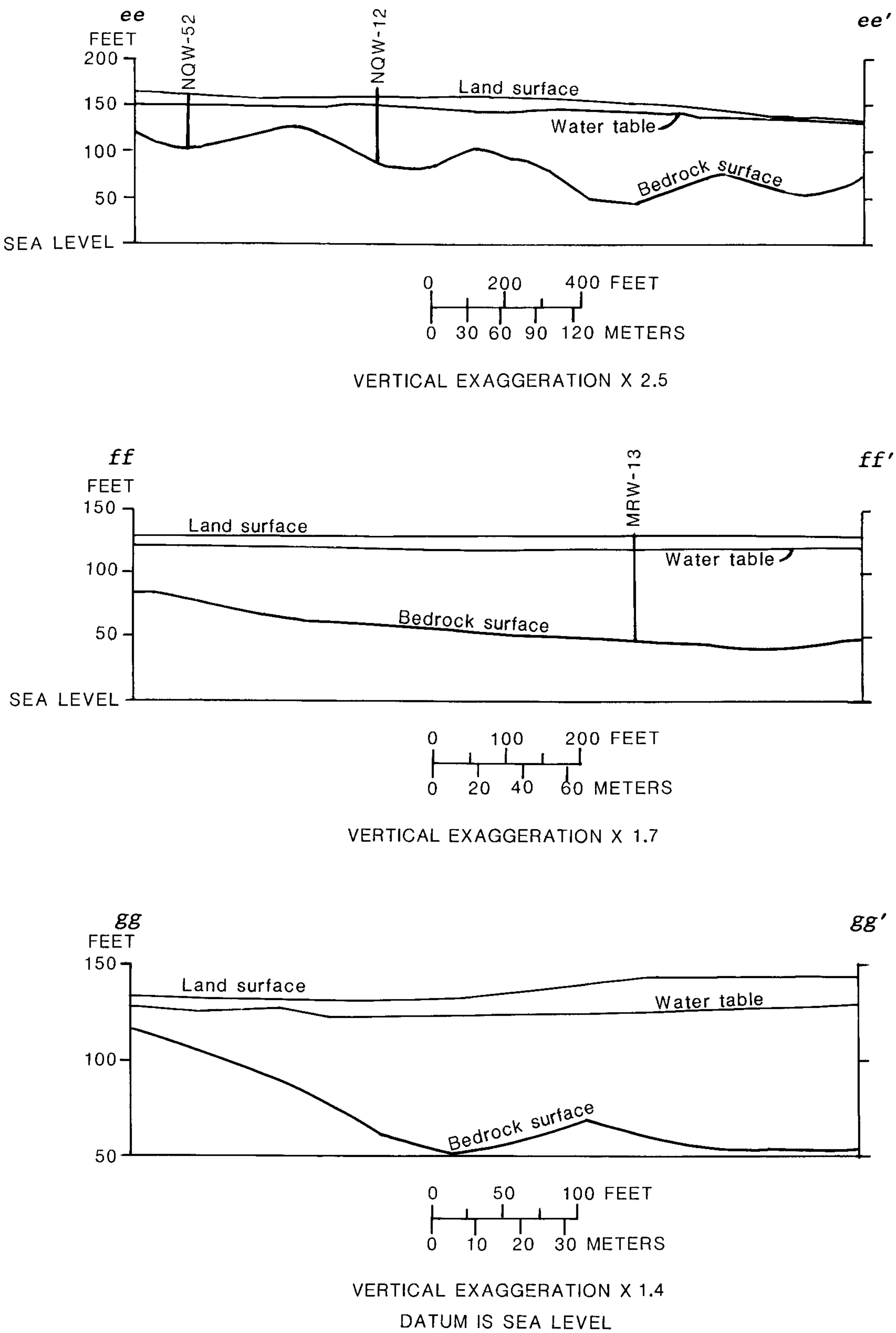

Figure A11.--Geohydrologic sections based on seismic-refraction data for Newton ee-ee', ff-ff', and gg-gg'. Lines of section are shown on plate 2.

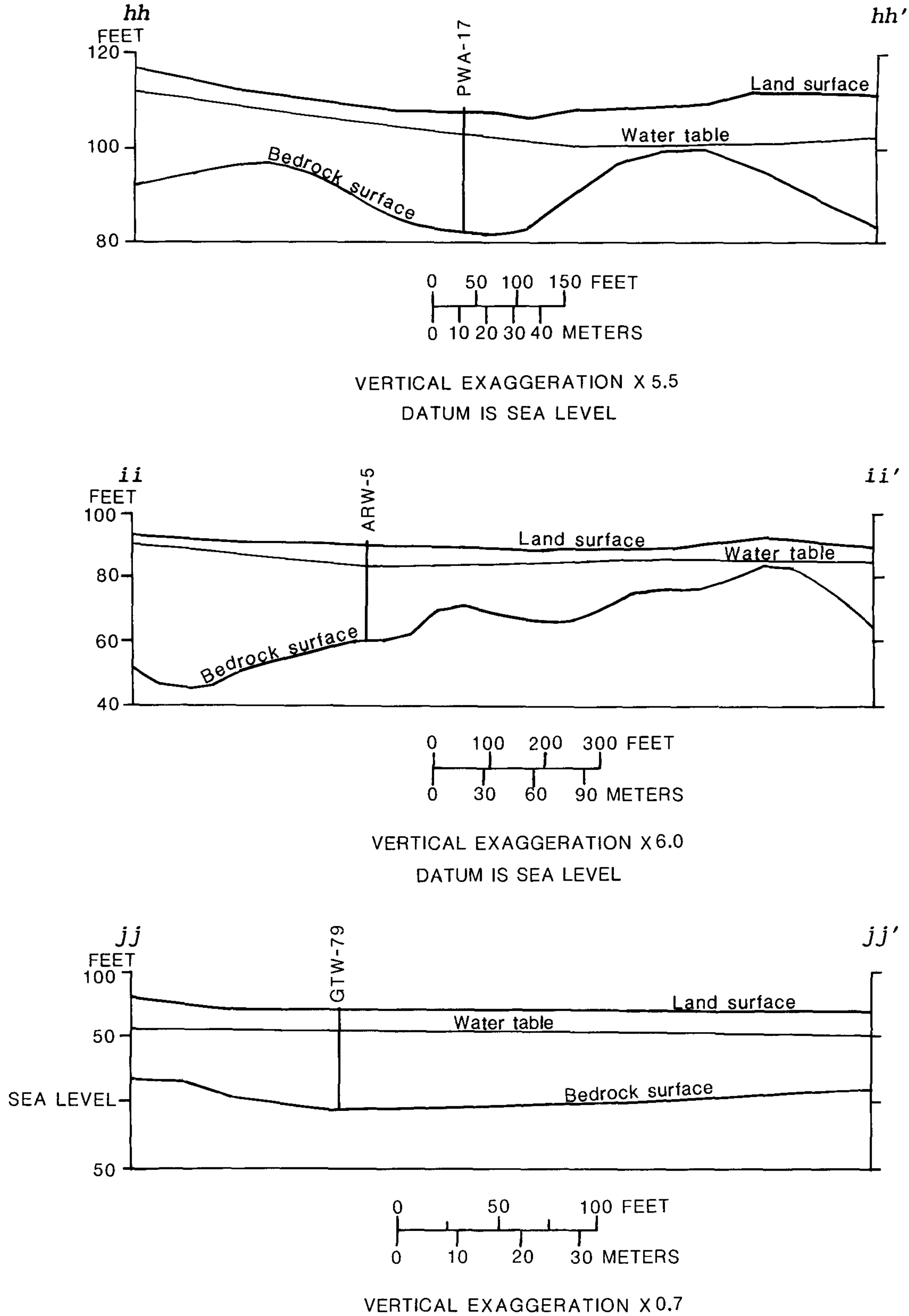

Figure A12.--Geohydrologic sections based on seismic-refraction data for Plaistow hh-hh′ and ii-ii′ and Greenland jj-jj′. Lines of section are shown on plates 2 and 3.

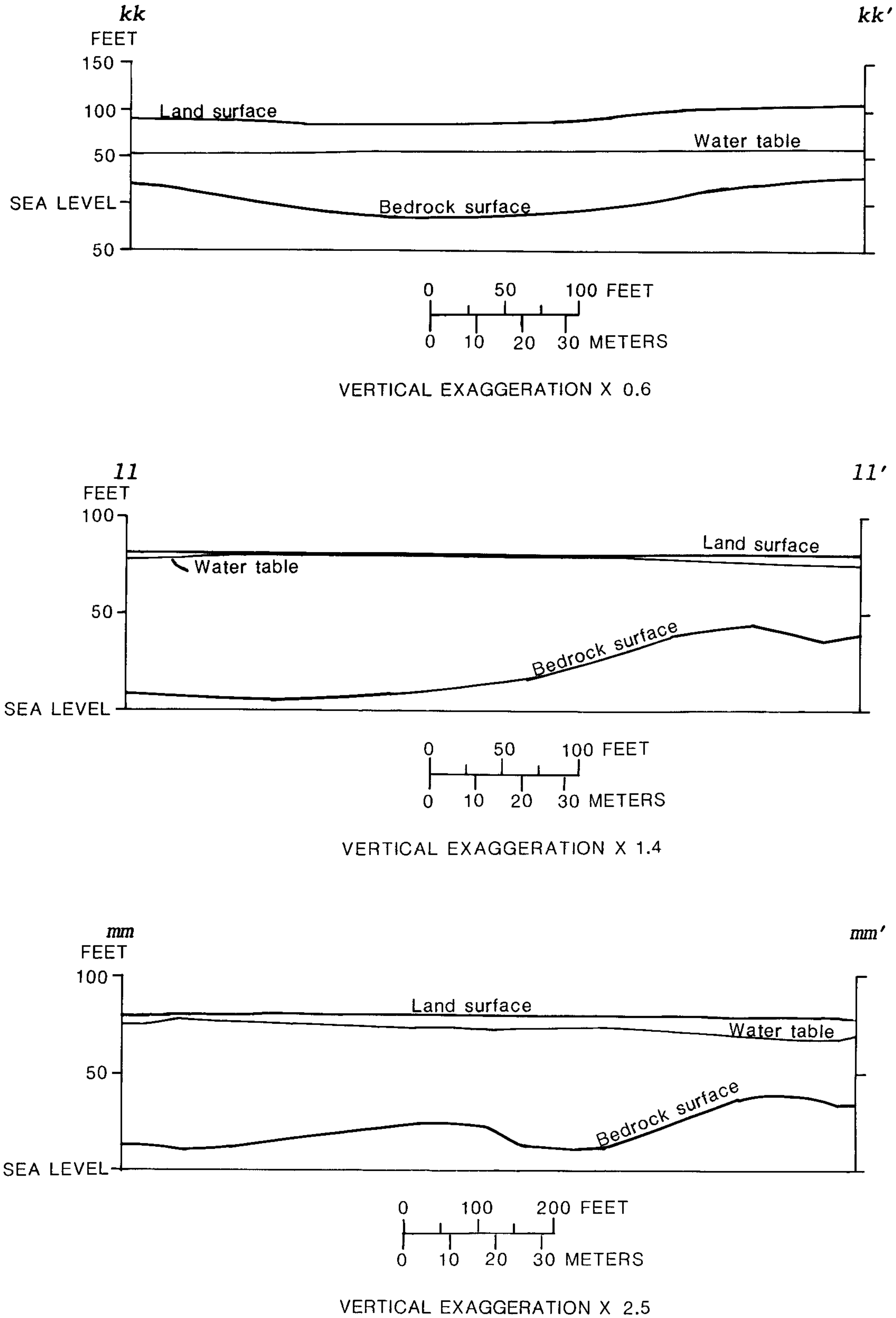

Figure A13.--Geohydrologic sections based on seismic-refraction data for Greenland kk-kk' and Kensington ll-ll' and mm-mm'. Lines of section are shown on plate 3.

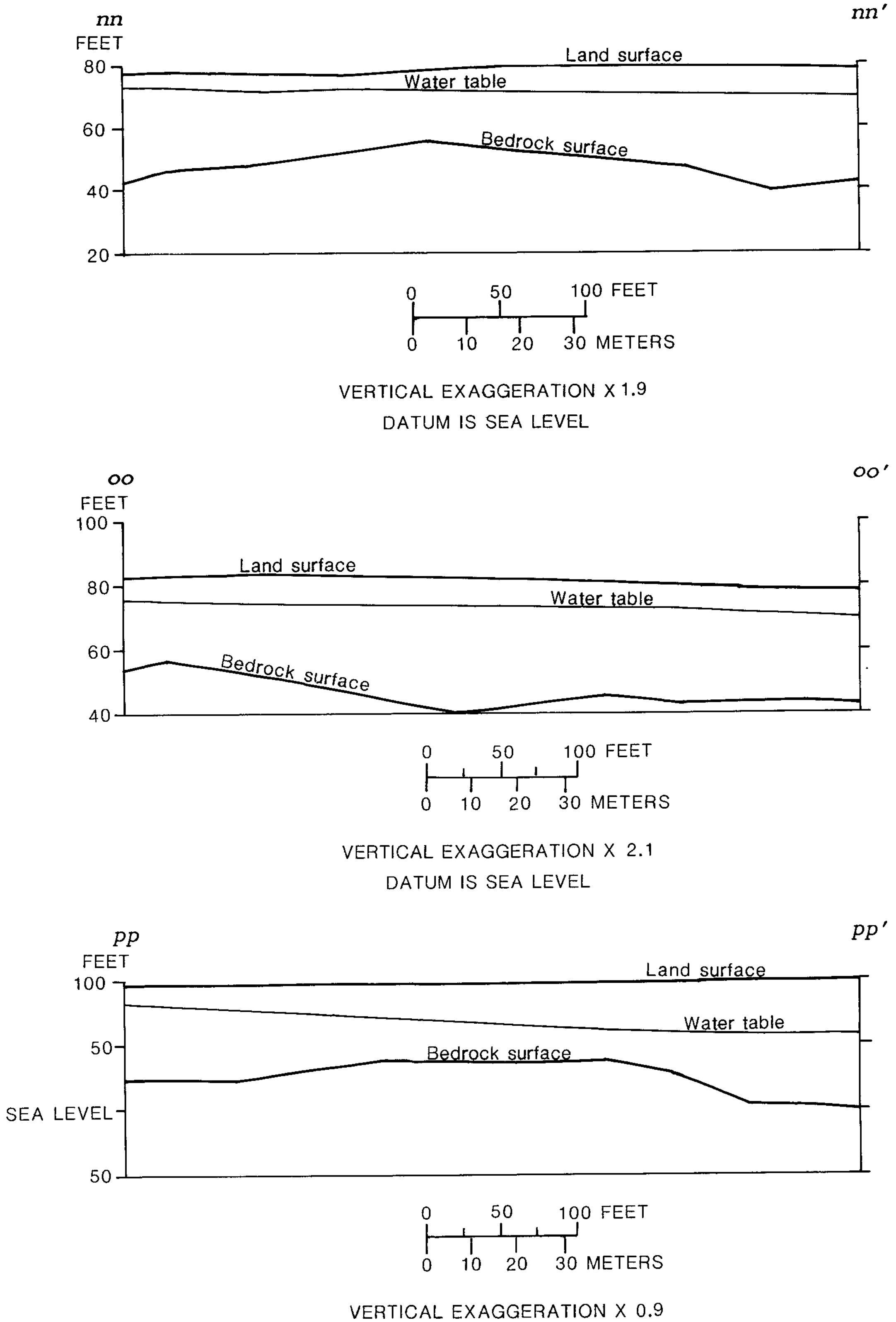

Figure A14.--Geohydrologic sections based on seismic-refraction data for Kensington nn-nn′ and oo-oo′ and Newington pp-pp′. Lines of section are shown on plate 3.

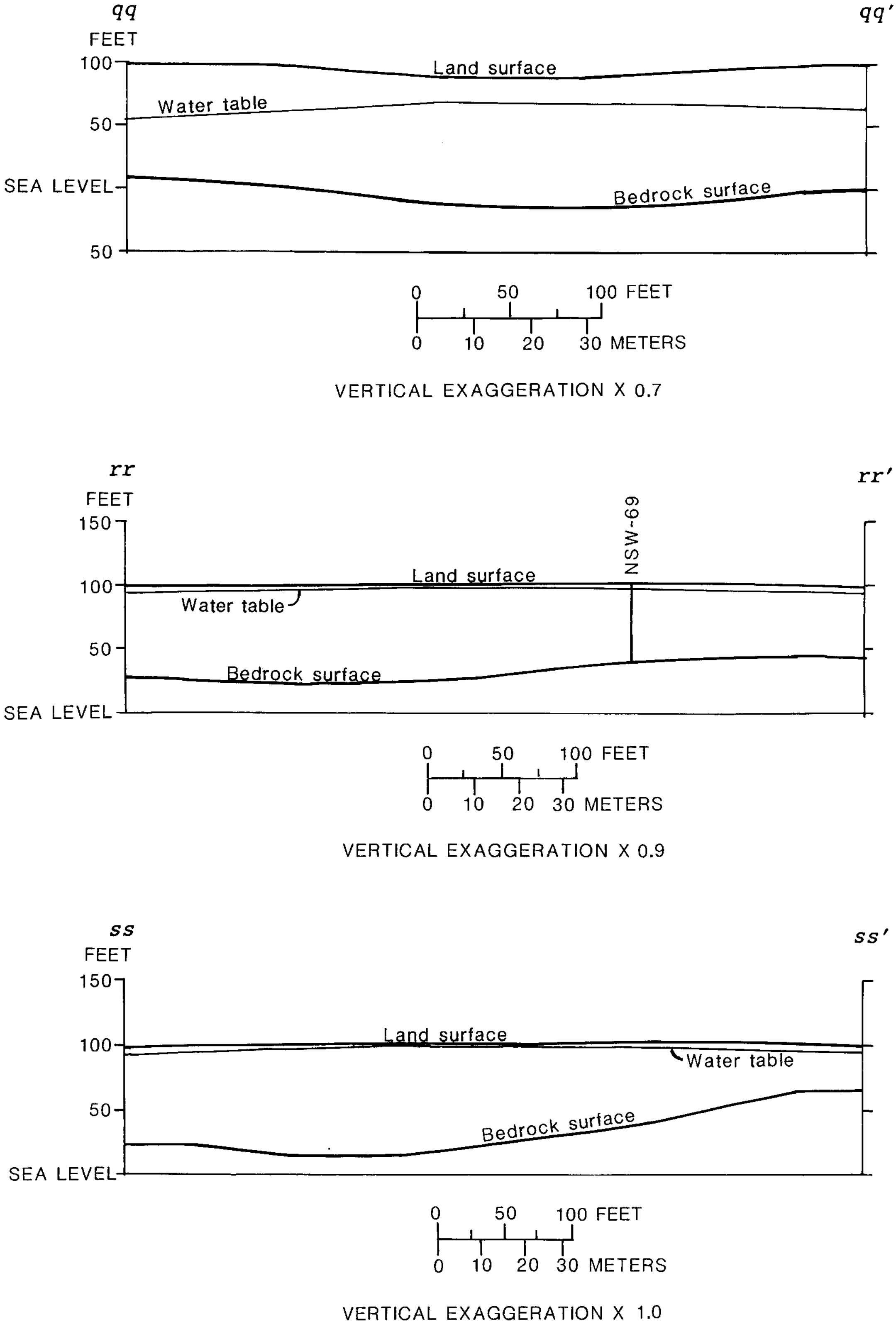

Figure A15.--Geohydrologic sections based on seismic-refraction data for Newington qq-qq' and North Hampton rr-rr' and ss-ss'. Lines of section are shown on plate 3.

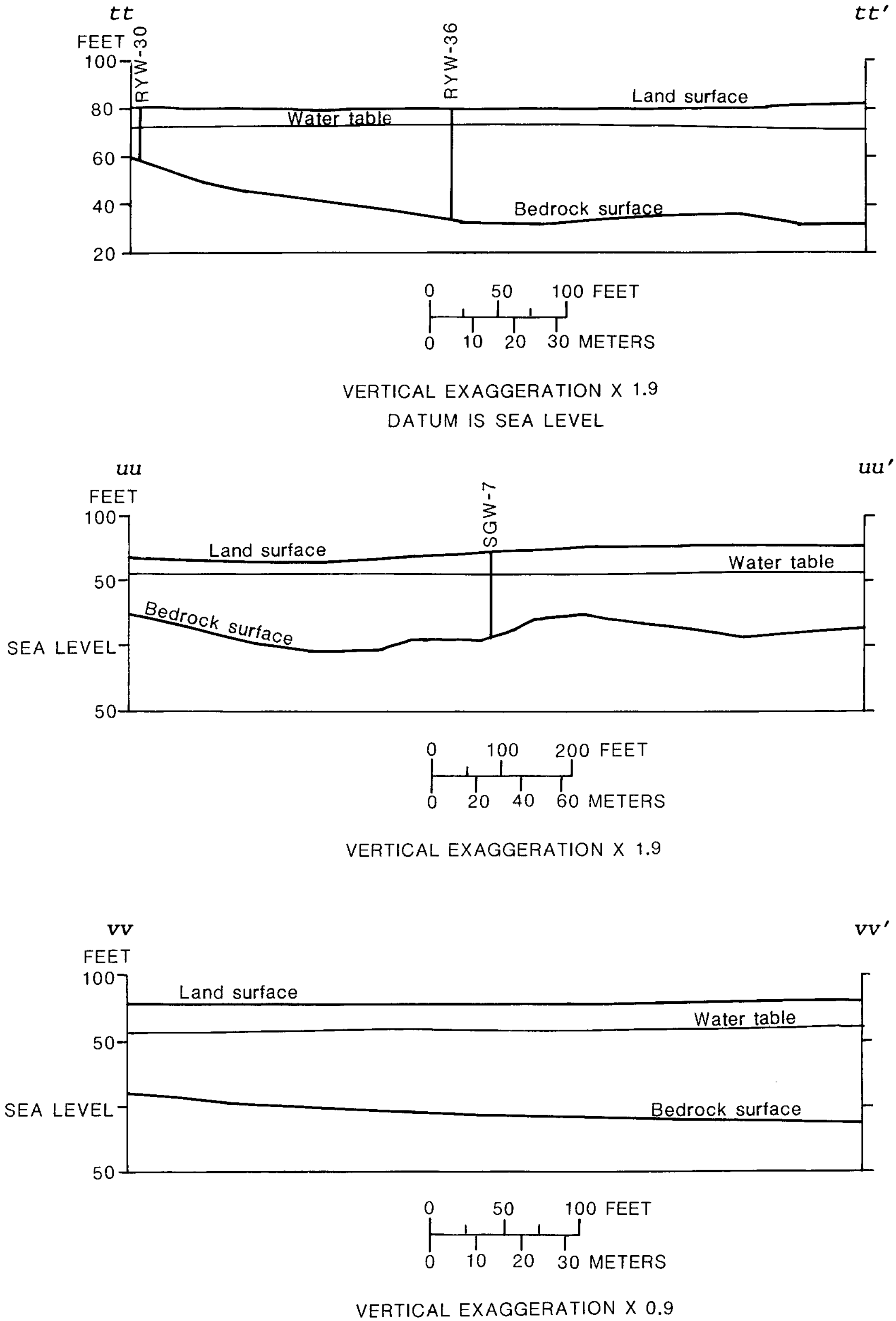

Figure A16.--Geohydrologic sections based on seismic-refraction data for Rye tt-tt′ and Seabrook uu-uu′ and vv-vv′. Lines of section are shown on plate 3.

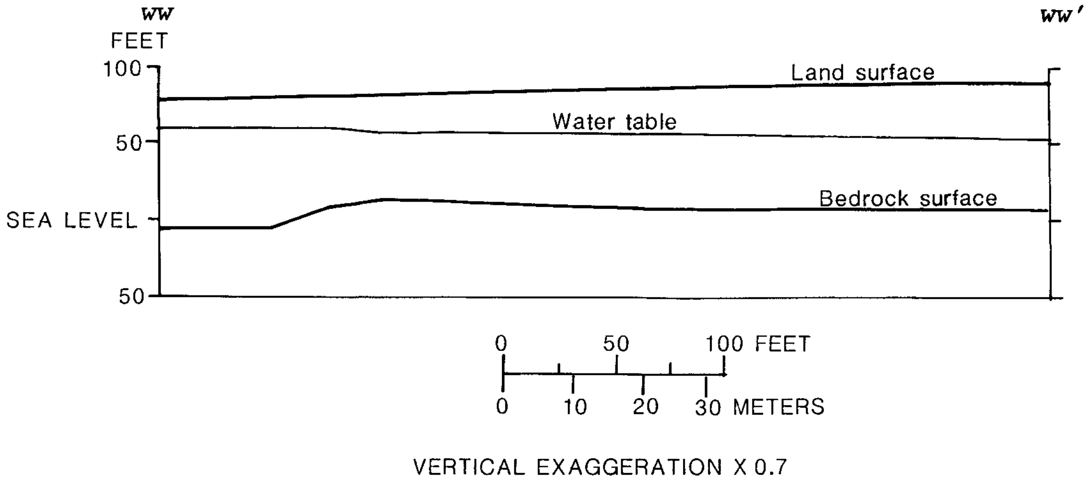

Figure A17.--Geohydrologic sections based on seismic-refraction data for Seabrook ww-ww'. Lines of section are shown on plate 3.