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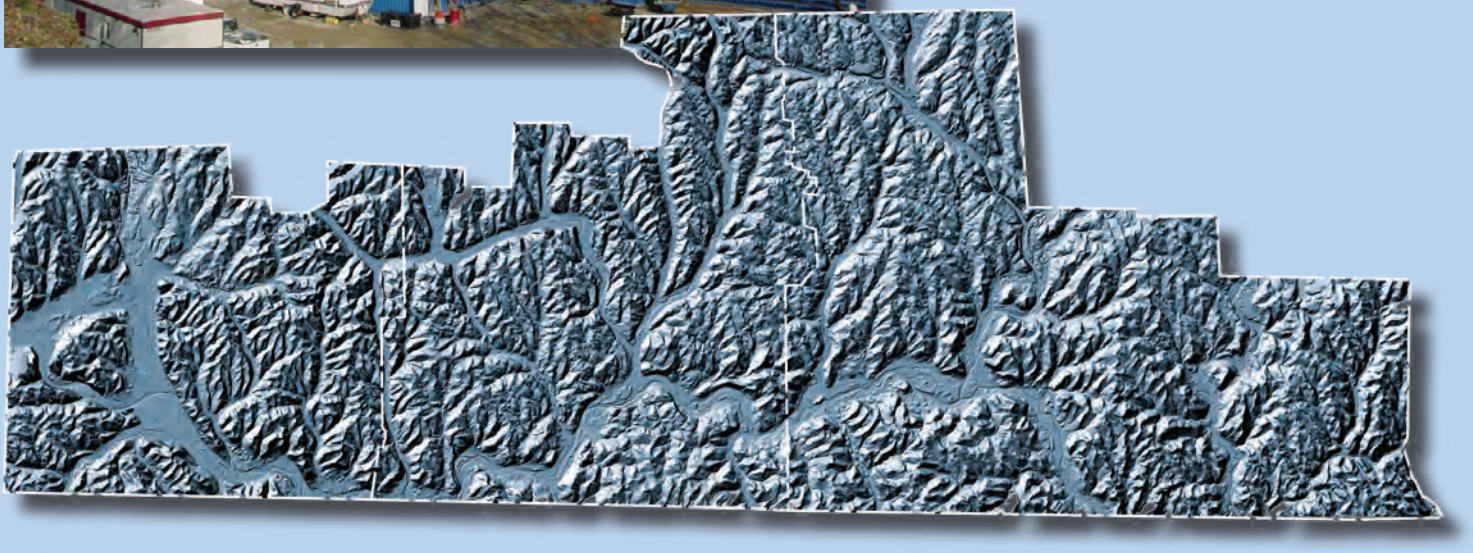
Evaluation of Well Logs for Determining the Presence of Freshwater, Saltwater, and Gas above the Marcellus Shale in Chemung, Tioga, and Broome Counties, New York



Scientific Investigations Report 2010–5224

U.S. Department of the Interior
U.S. Geological Survey

Cover. Gas-well drilling rig, Broome County, New York. Photograph by New York State Department of Environmental Conservation, 2005.

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By John H. Williams

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KEN SALAZAR, Secretary

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Conversion Factors, Datums, and Abbreviations

Inch/Pound to SI

Multiply	By	To obtain
	Length	
inch (in.)	2.54	centimeter (cm)
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
	Flow rate	
gallon per minute (gal/min)	0.06309	liter per second (L/s)

Temperature in degrees Fahrenheit (°F) may be converted to degrees Celsius (°C) as follows:

$$°C = (°F–32)/1.8.$$

Vertical coordinate information is referenced to the National Geodetic Vertical Datum of 1929.

Horizontal coordinate information is referenced to the North American Datum of 1983.

Specific conductance of water is given in microsiemens per centimeter (µS/cm).

Concentrations of chemical constituents in water are given in milligrams per liter (mg/L).

Induction conductivity is given in millisiemens per meter (mS/m).

Gamma is given in counts per second (cps).

ABBREVIATIONS USED IN REPORT

ESOGIS	Empire State Oil and Gas Information System
NWIS	National Water Information System
USGS	U.S. Geological Survey
NYSM	New York State Museum
NYSDEC	New York State Department of Environmental Conservation

Evaluation of Well Logs for Determining the Presence of Freshwater, Saltwater, and Gas above the Marcellus Shale in Chemung, Tioga, and Broome Counties, New York

By John H. Williams

Abstract

Recent technological advances in horizontal drilling and high-volume hydraulic fracturing have made the Marcellus Shale the newest gas-development target or play in the northern Appalachian basin. Protection of freshwater aquifers from contamination by saltwater and gas during the development of the Marcellus Shale play is an issue of concern. Chemung, Tioga, and Broome Counties are in the southwestern part of the Marcellus Shale play in New York and likely will be the focus of drilling early in development of the play in the State. As a preliminary step in understanding and protecting the groundwater resource in the three-county area, logs of water wells in the U.S. Geological Survey National Water Information System and gas wells in the New York State Museum Empire State Oil and Gas Information System were evaluated for the determination of the presence of freshwater, saltwater, and gas above the Marcellus Shale.

Results of the evaluation of the water- and gas-well logs indicate that freshwater aquifer zones are log normally distributed with depth in the three-county study area and that freshwater circulates to a greater depth in the uplands than in the valleys. The base of the freshwater aquifer appears to be about 800 feet below land surface in upland settings but only about 200 feet below land surface in valley settings. At depths greater than 200 feet in valley settings, groundwater in the Upper Devonian bedrock, and in a few areas in the glacial drift, is salty. Gas is present locally in the glacial drift, Upper Devonian bedrock, Tully Limestone, and Hamilton Group above the Marcellus Shale. The highest rates of gas flow above the Marcellus Shale may be associated with the Tully Limestone. The frequency of gas zones generally increases with depth in the Upper Devonian bedrock with pockets of gas locally present above the base of the freshwater aquifer.

Consistent and complete reporting of freshwater, saltwater, and gas during the drilling of future Marcellus shale-gas wells would greatly improve existing information. Field measurement of specific conductance of water produced during drilling and specific-conductance and temperature wireline geophysical logging of open boreholes prior to surface-casing installation would enhance the value of the gas-well logs. Compilation and integration of information from water wells that are inventoried and sampled for water quality during gas development with data from ongoing county-wide and regional programs would provide an important database for understanding and protecting the freshwater aquifers.

Introduction

Recent technological advances in horizontal drilling and high-volume hydraulic fracturing have made the Marcellus Shale the newest gas-development target or play in the northern Appalachian basin. Chemung, Tioga, and Broome Counties are in the southwestern part of the Marcellus Shale play in New York and likely will be the focus of drilling early in development of the play in the State (fig. 1). Protection of freshwater aquifers from contamination by saltwater and gas during the development of the Marcellus Shale play is an issue of concern. As a preliminary step in understanding and protecting the groundwater resource, logs of water wells and gas wells in the three-county area were evaluated for the determination of the presence of freshwater, saltwater, and gas above the Marcellus Shale.

This report describes the geologic formations and water- and gas-well completions in Chemung, Tioga, and Broome Counties, New York. A preliminary determination of the presence of freshwater, saltwater, and gas above the Marcellus Shale in the study area based on an evaluation of water- and gas-well logs is presented. Considerations for future water and gas logging during the drilling of Marcellus gas wells also are discussed.

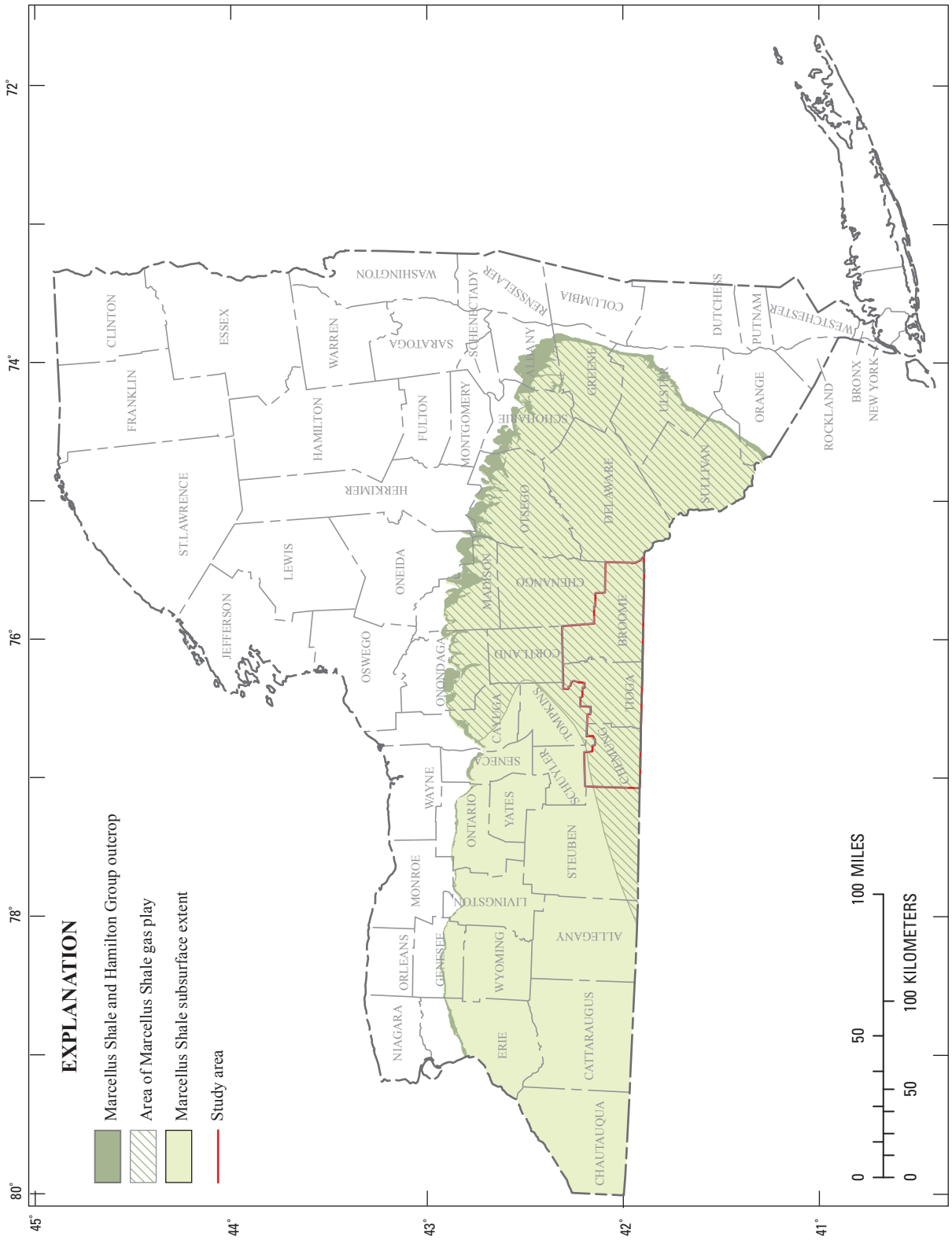

Figure 1. Location of Marcellus Shale gas play in New York State and study area in Chemung, Tioga, and Broome Counties. (Modified from New York State Department of Environmental Conservation, 2009.)

Descriptions of the Well Databases and Methods

Well logs were compiled from two databases, the U.S. Geological Survey (USGS) National Water Information System (NWIS) and the New York State Museum (NYSM) Empire State Oil and Gas Information System (ESOGIS). The NWIS, which is maintained by the USGS New York Water Science Center, stores water-well logs that can be retrieved online from http://waterdata.usgs.gov/nwis/inventory. The ESOGIS, which is maintained by the NYSM Reservoir Characterization Group, stores oil- and gas-well logs that can be retrieved online from http://esogis.nysm.nysed.gov/.

Logs for more than 1,450 water wells stored in the NWIS (fig. 2) and logs for about 350 gas wells stored in the ESOGIS (fig. 3) were reviewed to obtain information on well completions, geologic formations penetrated by the wells, and the presence of freshwater, saltwater, and gas above the Marcellus Shale in the three-county study area. Most of the water wells recorded in the NWIS and almost all of the 55 sites at which saltwater and (or) gas were present in the groundwater (appendix 1) were inventoried by Randall (1972) as part of valley-fill aquifer investigations in the 1960s and 1970s. The presence of saltwater was reported by drillers or well owners based on taste tests or was determined by water-quality analyses that indicated a chloride concentration of greater than 250 mg/L. The presence of gas was reported by drillers or well owners or was observed during field inventory.

The gas-well logs in the ESOGIS are for single- and multiple-well sites, wells whose confidential status had not expired (typically 2 years), and permitted but uncompleted wells. Because the formations above the Marcellus Shale have not been the focus of gas exploration, many of the gas-well logs contain little or no information on this stratigraphic interval. Ninety-three of the gas-well logs report penetration of water and (or) gas zones above the Marcellus Shale (appendix 2). Water flows were reported by gas-well drillers as freshwater or saltwater presumably based on taste tests. Water flows commonly were rated by the gas-well drillers in inches of the stream discharging from an open pipe into a mud pit while drilling with air. Reportedly, a 1-inch stream roughly equates to a flow of 10 to 20 gal/min, and a 2-inch stream roughly equates to a flow of 40 to 50 gal/min. Gas-flow rates generally were not quantified; those that were rated were reported in MCF (1,000 cubic feet), which presumably equates to the flow rate per day.

The spatial and stratigraphic distributions of freshwater, saltwater, and gas above the Marcellus Shale were investigated through an analysis of the water- and gas-well logs. Geographic Information System (GIS) coverages and histograms of the well data were created using ARCGIS software to aid in this preliminary delineation.

Description of the Geologic Formations

South-central New York is underlain by sedimentary bedrock of Cambrian, Ordovician, Silurian, and Devonian age (fig. 4). The sedimentary bedrock gently dips to the south and is underlain by Precambrian crystalline bedrock. A deep exploratory well in Chemung County, purportedly the deepest cable-tool hole in the world at the time (1953), penetrated more than 11,000 ft of sedimentary bedrock, including 600 ft of the basal Cambrian formations.

Glacial drift, including till and stratified deposits, discontinuously overlies the sedimentary bedrock in the study area. Till, an unsorted mixture of clay, silt, sand, and boulders, mantles the uplands. Stratified drift of lacustrine silt and clay, outwash sand and gravel, and ice-contact deposits fills the glacially scoured valleys (fig. 5). An extensive and thick deposit of moraine, which consists mostly of till and lacustrine silt and clay with scattered sand and gravel, is present in northwestern Chemung County. Saturated deposits of sand and gravel in the valleys form major aquifers that supply freshwater to small and large communities and base flow to streams. Although the valley fill reaches thicknesses of greater than 500 ft, the total thickness of saturated sand and gravel rarely exceeds 50 ft. More detailed information on the valley-fill aquifers in the study area is presented by Randall (1972), MacNish and Randall (1982), Randall and others (1988), and Miller (1988).

Sedimentary bedrock of Upper Devonian age underlies the study area (fig. 6). Sandstone, siltstone, and shale of the Java Group crop out in the southwestern corner of Chemung County. The shale, siltstone, and sandstone of the West Falls Group crop out in Chemung and Tioga Counties and the southern part of Broome County. Shale and siltstone of the Sonyea and Genesse Groups crop out in the northern part of Broome County and in the northernmost valleys of Tioga and Chemung Counties. Each of these formations generally coarsens upward and to the east. The Upper Devonian formations form a fractured-bedrock aquifer that supplies freshwater to many farms, rural homes, and small communities, as well as base flow to streams. Additional information on the Upper Devonian bedrock aquifers just to the south of the study area in Pennsylvania is presented by Williams and others (1998).

The Tully Limestone (fig. 4), a key stratigraphic marker bed whose top is delineated in almost all of the gas-well logs, underlies the Upper Devonian bedrock. Below the Tully Limestone are shales and calcareous sandstones of the Hamilton Group. At the base of the Hamilton Group is the Marcellus Shale, a black, organic-rich shale. Although gas has been produced from the Marcellus Shale in New York since 1931, the combination of horizontal drilling with high-volume hydraulic fracturing has made this formation the latest “hot” prospect in the State.

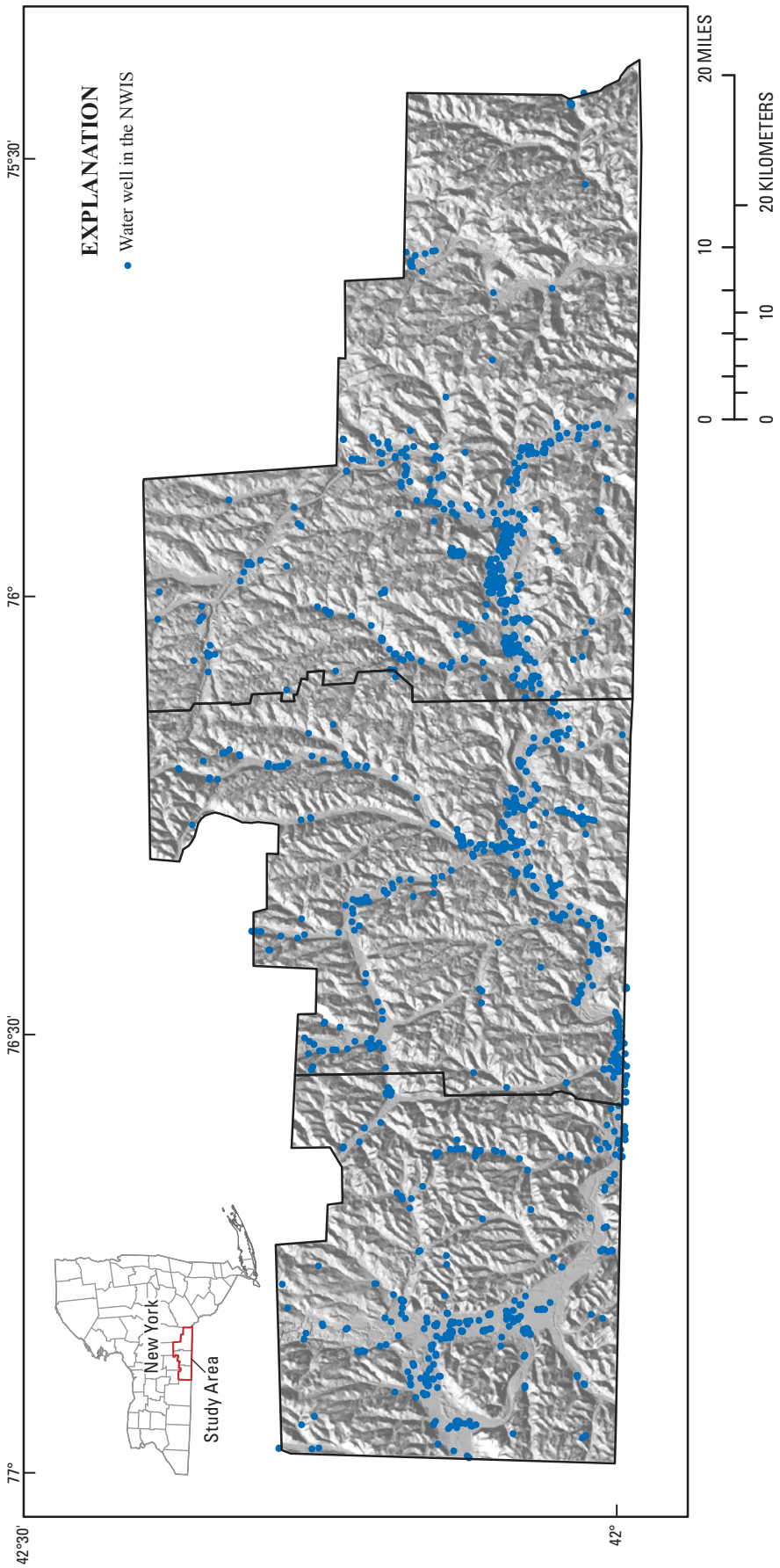

Figure 2. Location of water wells in the U.S. Geological Survey National Water Information System in the study area, 2010.

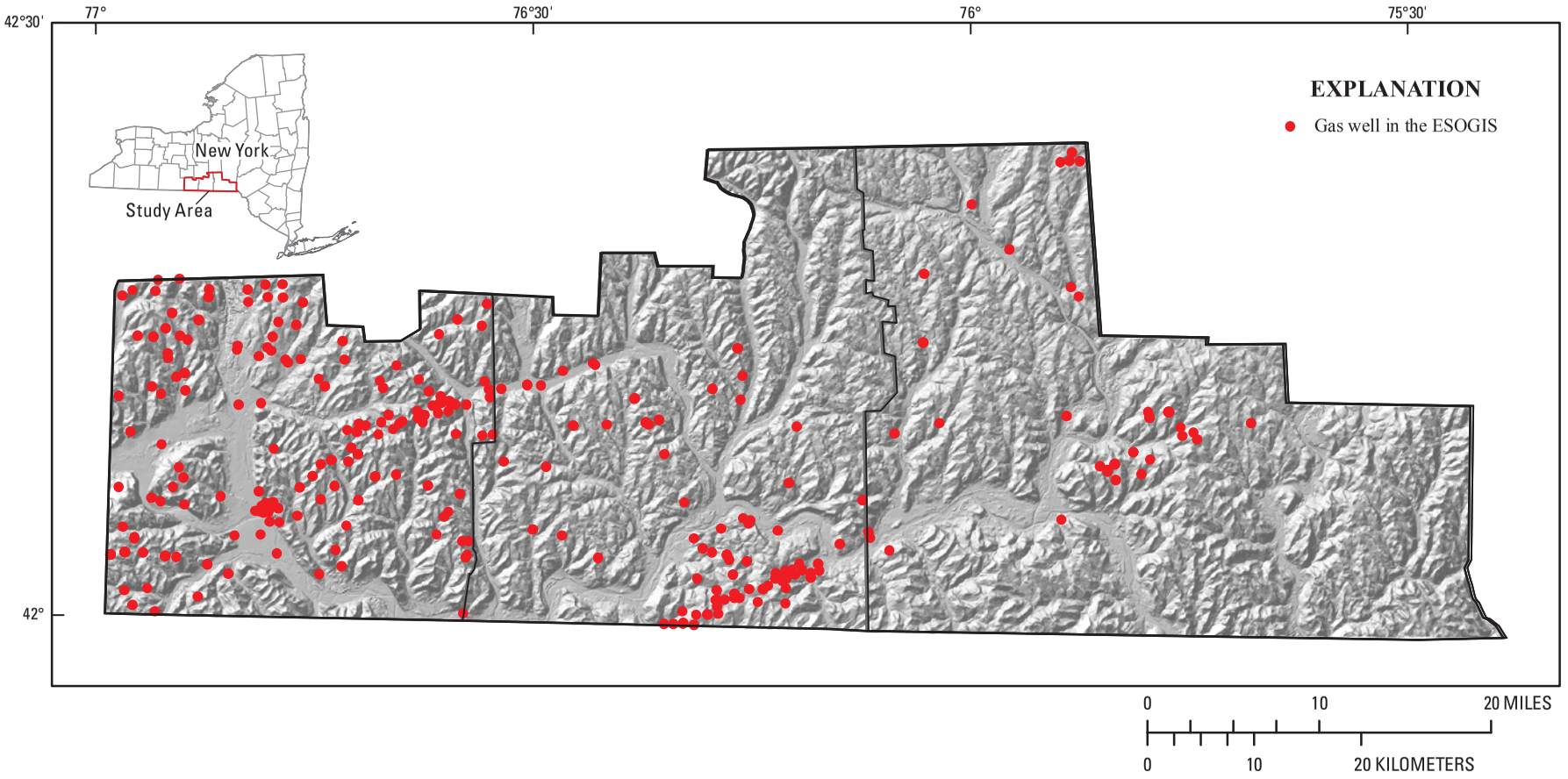

Figure 3. Location of gas wells in the New York State Museum Empire State Oil and Gas Information System (ESOGIS) in the study area, 2010.

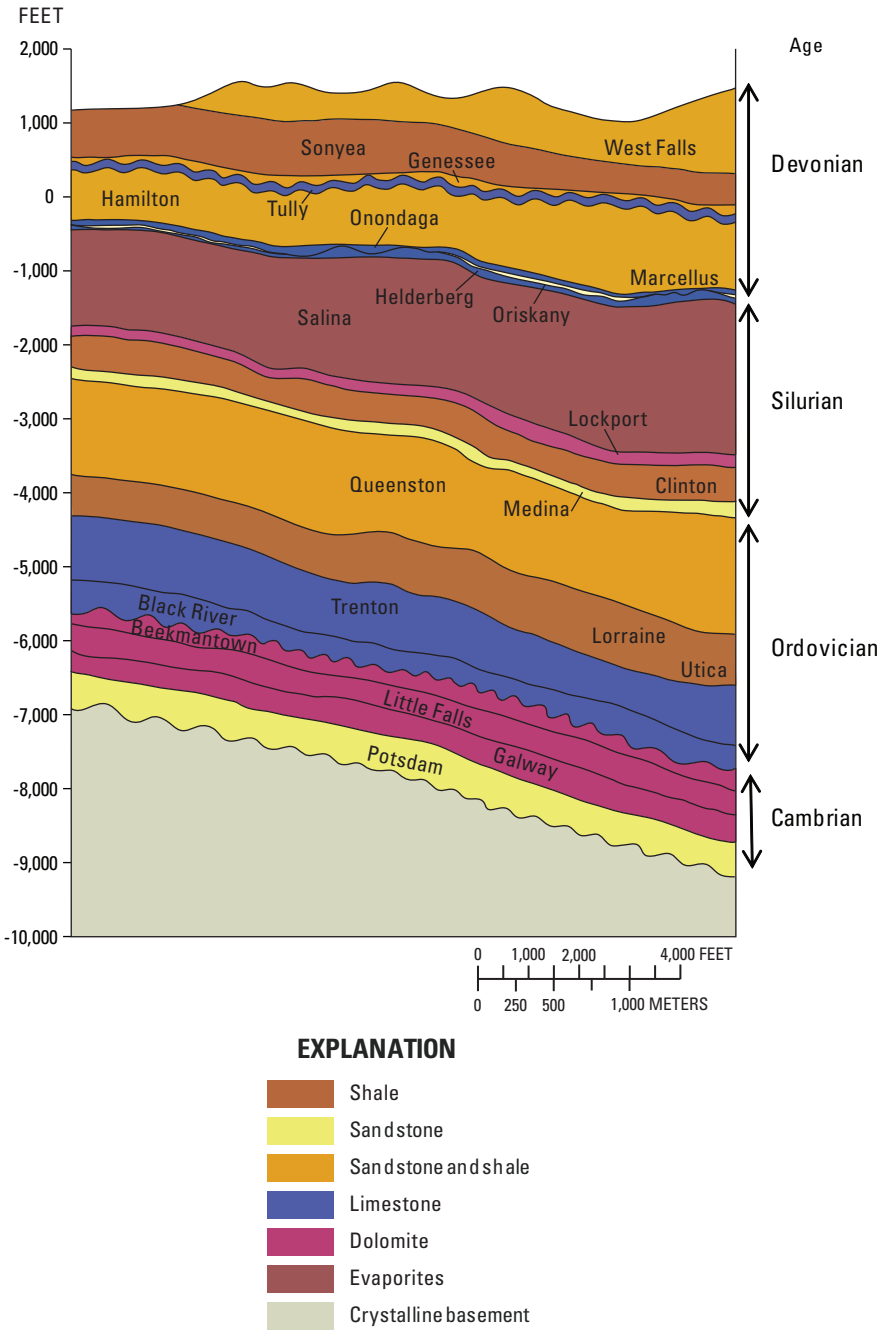

Figure 4. Generalized north-south section with bedrock formations in south-central New York. (Modified from New York State Museum, 2009.)

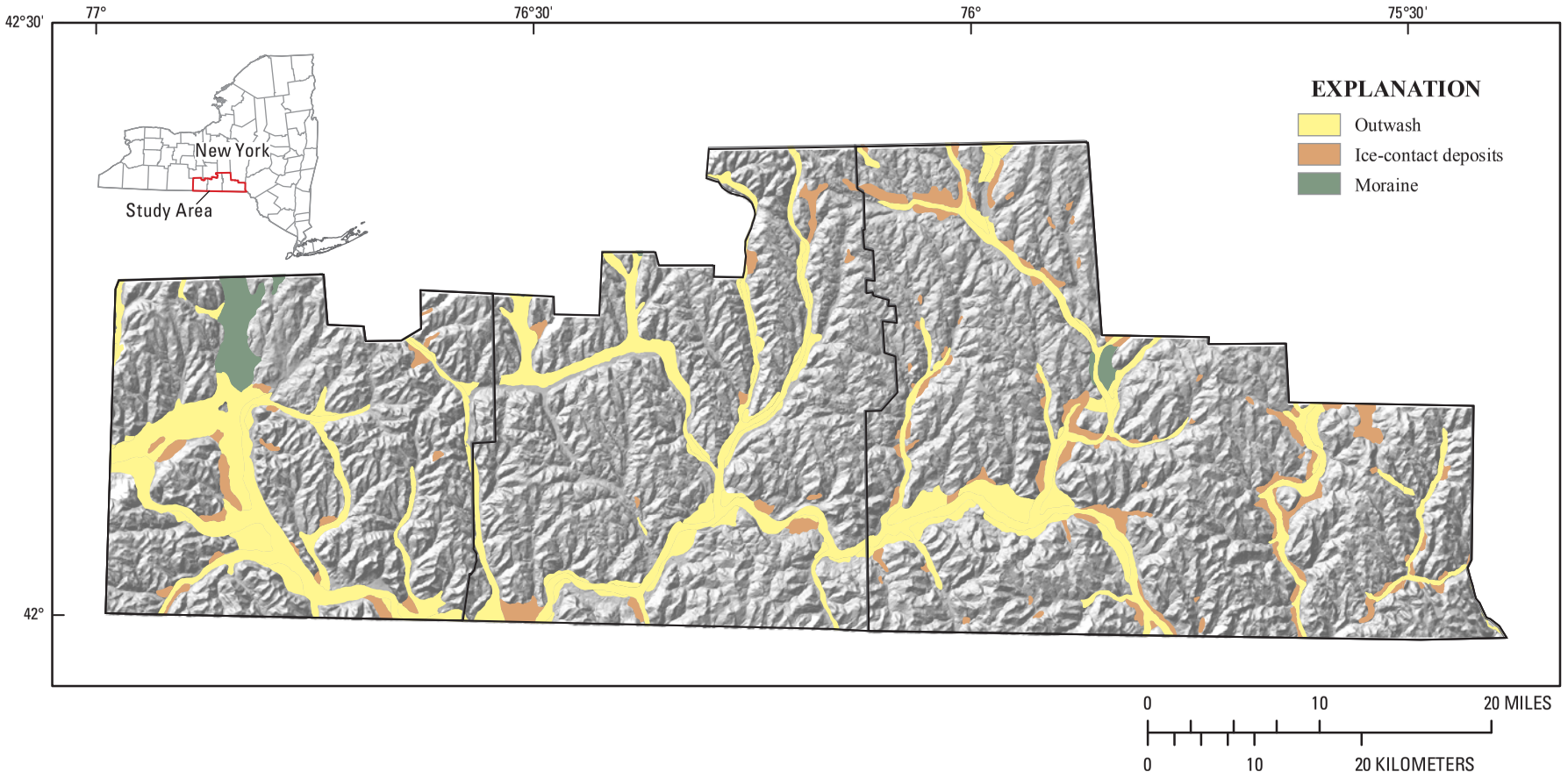

Figure 5. Surficial geology of the study area, Chemung, Tioga, and Broome Counties, New York. (Modified from Cadwell and others, 1986.)

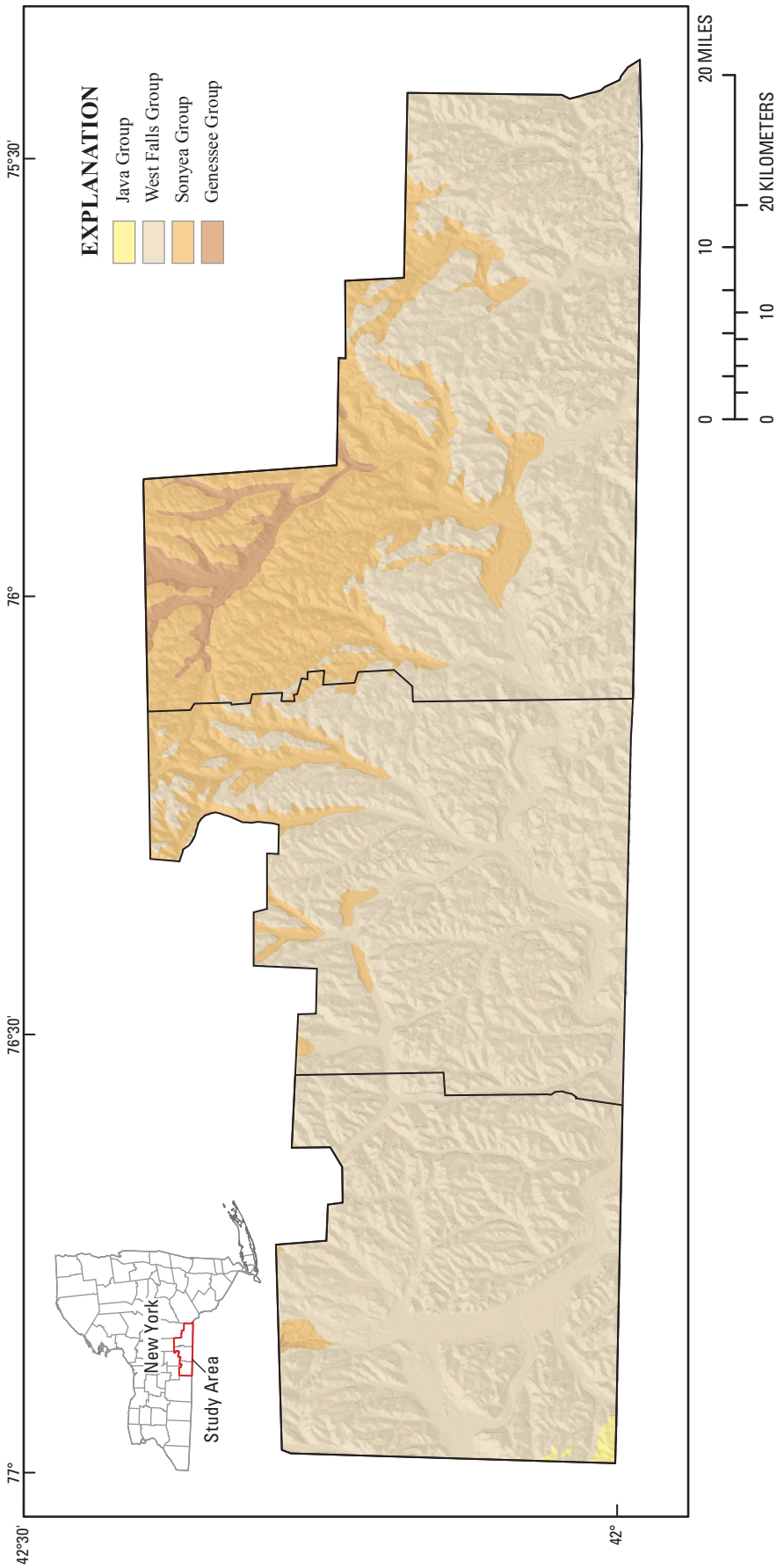

Figure 6. Bedrock geology of the study area, Chemung, Tioga, and Broome Counties, New York. (Modified from Fisher and others, 1970.)

Historically, gas production in the study area mainly has been from three formations that lie below the Marcellus Shale—the Oriskany, Helderberg, and Trenton-Black River. The Oriskany Sandstone of Lower Devonian age is typically a fossiliferous, quartz-rich sandstone cemented with quartz or calcite. The Oriskany, which has intergranular and fracture porosity, has been a widespread gas producer in New York and throughout the Appalachian basin. Many of the exploration wells completed in the Oriskany produced saltwater in addition to, or instead of, gas. The carbonate rocks of the Helderberg Group, also of Lower Devonian age, lies below the Oriskany Sandstone and locally have been an important gas producer. Deep gas reservoirs have been developed in the Upper Ordovician Trenton and Black River Groups in patchy dolomite matrix and brecciated zones along fault-related structural lows. The Utica Shale, which lies above the Trenton and Black River Groups, is a black, organic-rich shale that is receiving considerable interest as a low-permeability unconventional gas play similar to that of the Marcellus Shale.

Description of the Wells

Water wells in the study area are completed in glacial drift or the Upper Devonian bedrock. Municipal-supply and other high-yield wells are screened in glacial sand-and-gravel aquifers commonly present along river and major stream valleys (fig. 7). Farm- and home-use wells tap sand-and-gravel aquifers through open-end casing. Wells that tap bedrock are cased to competent rock and completed as open holes.

Until 2000, gas wells in the study area were drilled as vertical boreholes. Since then, many have been completed as horizontal wells to maximize production from target horizons. Both vertical (fig. 8A) and horizontal (figs. 8B–C) wells have multiple casings. The uppermost casing is called the conductor casing and is set to competent bedrock to provide for stable drilling conditions. The next casing interval is the surface casing, which is set to a prescribed depth below the freshwater aquifer. The wellbore annular spacing is cemented from the base of the surface casing to land surface. If drilling conditions dictate, an intermediate casing may be set inside the surface casing (fig. 8B). Finally, the production casing is set inside the surface casing, and if present, the intermediate casing, to the targeted gas horizon. The wellbore annular spacing of the intermediate and production casings typically has been cemented one to several thousand feet above the base of the casings (figs. 8A–B). As presently drafted, the New York State Department of Environmental Conservation (NYSDEC) regulations for horizontal wells with high-volume hydraulic fracturing in shale will require that the production casing be cemented to land surface (fig. 8C) if no intermediate casing is installed (New York State Department of Environmental Conservation, 2009).

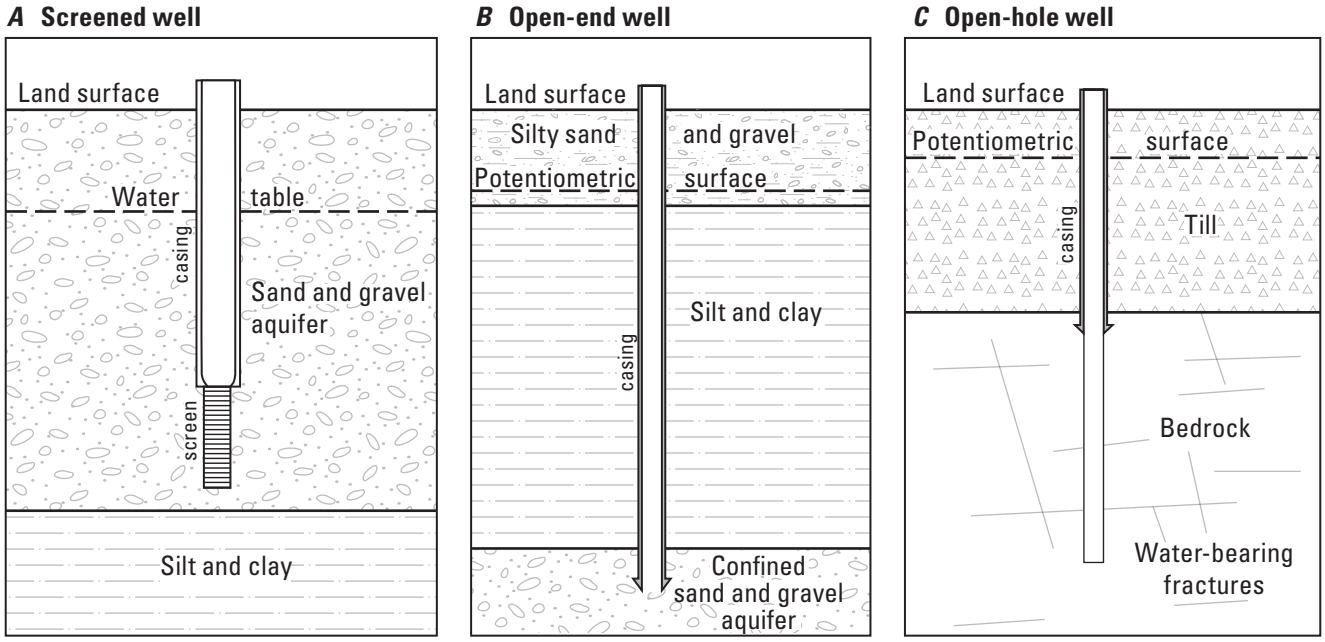

Figure 7. Schematics of water-well completions: *(A)* screened well, *(B)* open-end well, and *(C)* open-hole well (Modified from Williams and others, 1998).

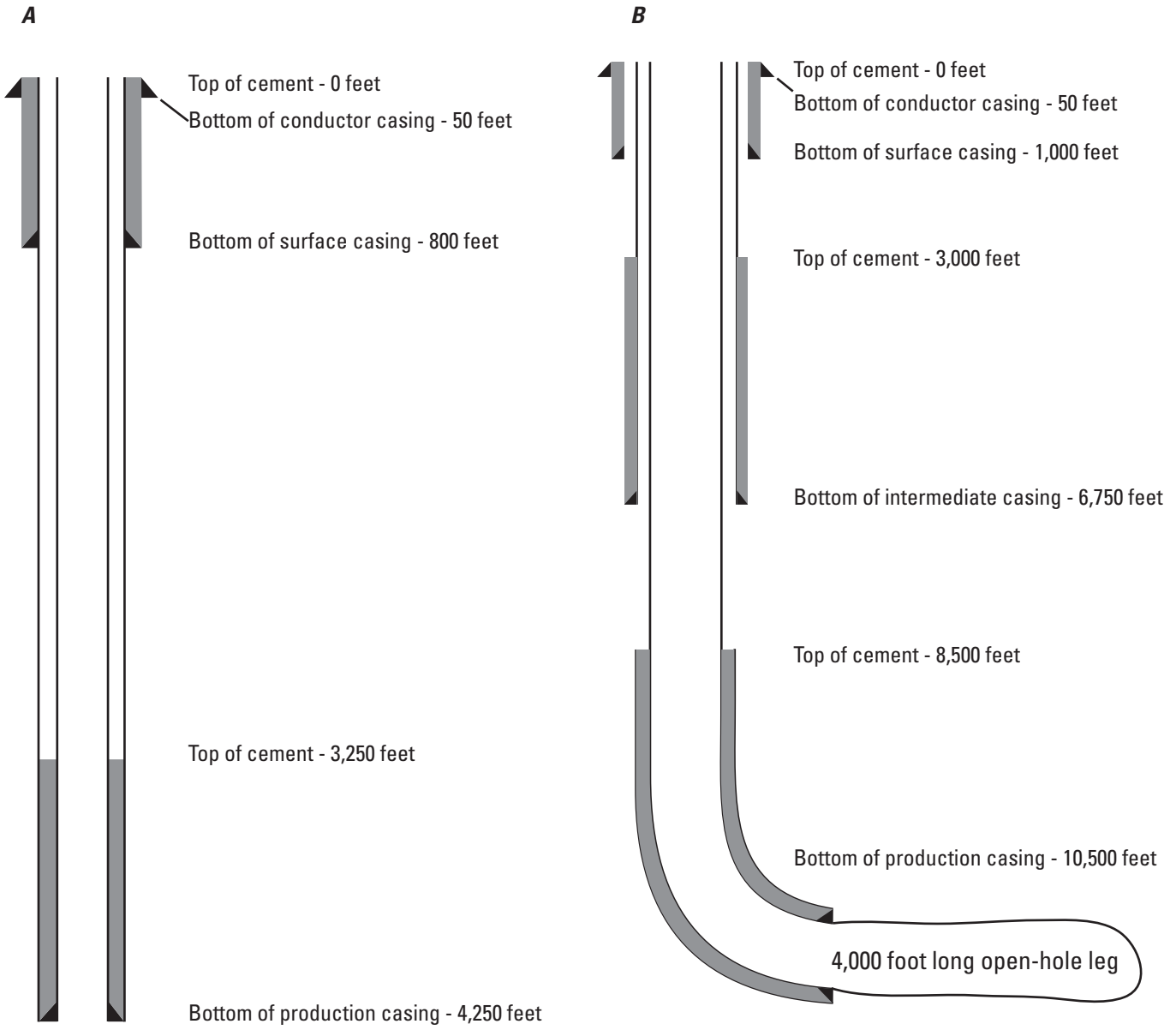

Figure 8. Schematics of gas-well completions: *(A)* vertical well with conductor, surface, and production casings; *(B)* horizontal well with conductor, surface, intermediate, and production casings; and *(C)* horizontal well with conductor, surface, and production casings.

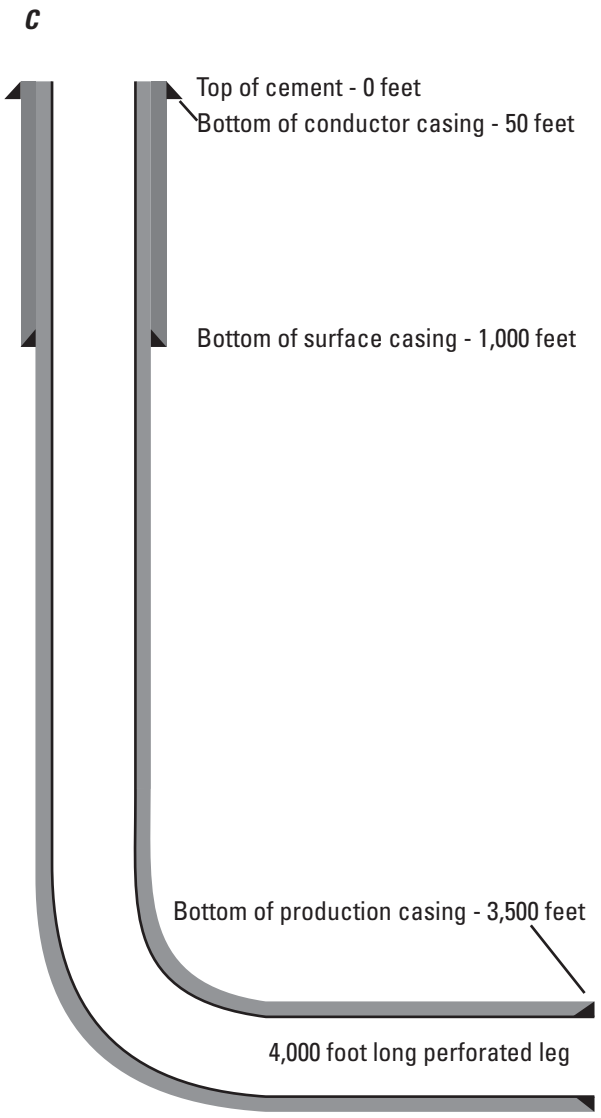

Figure 8. Schematics of gas-well completions: *(A)* vertical well with conductor, surface, and production casings; *(B)* horizontal well with conductor, surface, intermediate, and production casings; and *(C)* horizontal well with conductor, surface, and production casings.—Continued

Freshwater, Saltwater, and Gas above the Marcellus Shale

The presence and distribution of freshwater, saltwater, and gas above the Marcellus Shale were investigated through analysis of the water- and gas-well logs (appendixes 1 and 2). Seventy-four gas wells penetrated 123 freshwater zones in glacial drift and Upper Devonian bedrock at depths of 12 to 784 ft below land surface (fig. 9). About 75 percent of the freshwater zones were penetrated at depths of 150 ft or less below land surface (fig. 10). The distribution of the freshwater-zone depths approached a log-normal distribution. Nine of the 10 gas wells that penetrated freshwater at depths greater than 500 ft below land surface are in upland bedrock settings. The one exception is a gas well that penetrated a highly confined sand-and-gravel aquifer buried beneath 700 ft of morainal deposits, which consist of lacustrine silt and clay with some till near land surface.

Forty-six water wells penetrated saltwater zones at depths of 56 to 520 ft below land surface (fig. 9). Two of these wells penetrated saltwater in glacial drift; the rest penetrated saltwater in Upper Devonian bedrock. Most of the salty water wells penetrated saltwater zones in the Upper Devonian bedrock at depths of 140 to 260 ft below land surface. All the water wells that penetrated saltwater were in river, major stream, or upland-tributary valleys. Sixteen gas wells penetrated saltwater at depths of 500 to 3,400 ft below land surface. Thirteen gas wells penetrated saltwater in Upper Devonian bedrock; most of these saltwater zones are at depths between 1,500 and 2,000 ft below land surface. Three gas wells penetrated saltwater in the Tully Limestone and Hamilton Group above the Marcellus Shale.

Thirty-two gas wells penetrated 49 gas zones above the Marcellus Shale at depths of 263 to 2,281 ft below land surface (figs. 11 and 12). Eighty percent of the gas zones are in the Upper Devonian bedrock, and the rest are in the Tully Limestone and Hamilton Group above the Marcellus Shale. The frequency of gas zones increased with increasing depth to about 1,500 ft. Of the six gas zones that were rated, which likely correspond to higher flow shows, four are in the Tully Limestone. Ten water wells penetrated gas at depths of 49 to 438 ft below land surface. Two of these wells penetrated gas in glacial drift, the rest penetrated gas in Upper Devonian bedrock.

Preliminary Conclusions

Well logs in the ESOGIS and NWIS databases provide a preliminary but incomplete determination of freshwater, saltwater, and gas above the Marcellus Shale in the study area. Results of the evaluation of the well logs indicate that freshwater aquifer zones are log normally distributed with depth and that freshwater circulates to a greater depth in the uplands than in the valleys. The base of the freshwater aquifer appears to be about 800 ft below land surface in upland settings but only about 200 ft below land surface in valley settings. At depths greater than 200 ft in valley settings, groundwater in the Upper Devonian bedrock and in a few areas in the glacial drift is salty. Gas is present locally in the glacial drift, Upper Devonian bedrock, Tully Limestone, and Hamilton Group above the Marcellus Shale. The highest rates of gas flow above the Marcellus Shale may be associated with the Tully Limestone. The frequency of gas shows generally increases with depth in the Upper Devonian bedrock with pockets of gas locally present above the base of the freshwater aquifer.

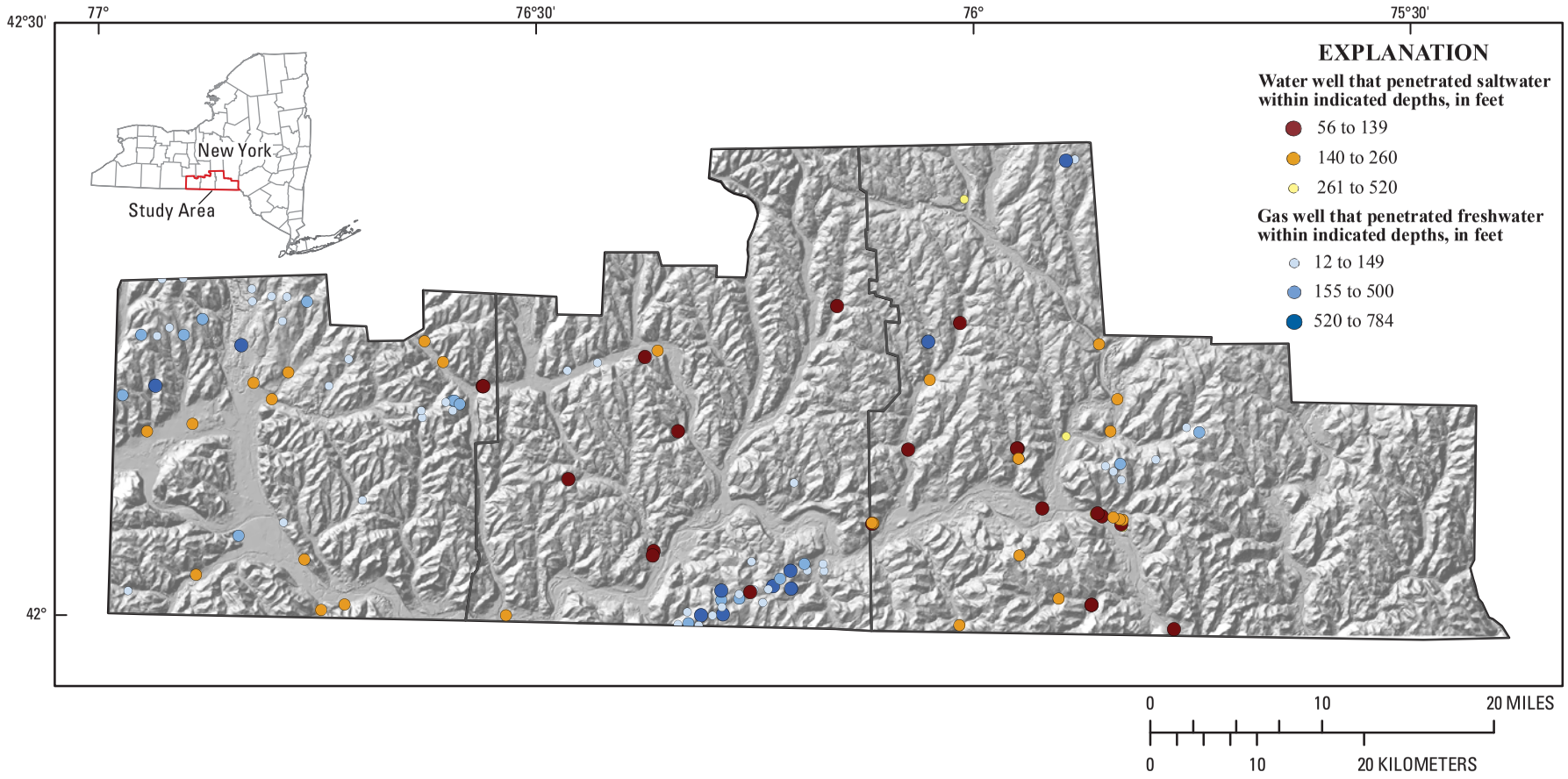

Figure 9. Location of water wells that penetrated saltwater and gas wells that penetrated freshwater in the study area.

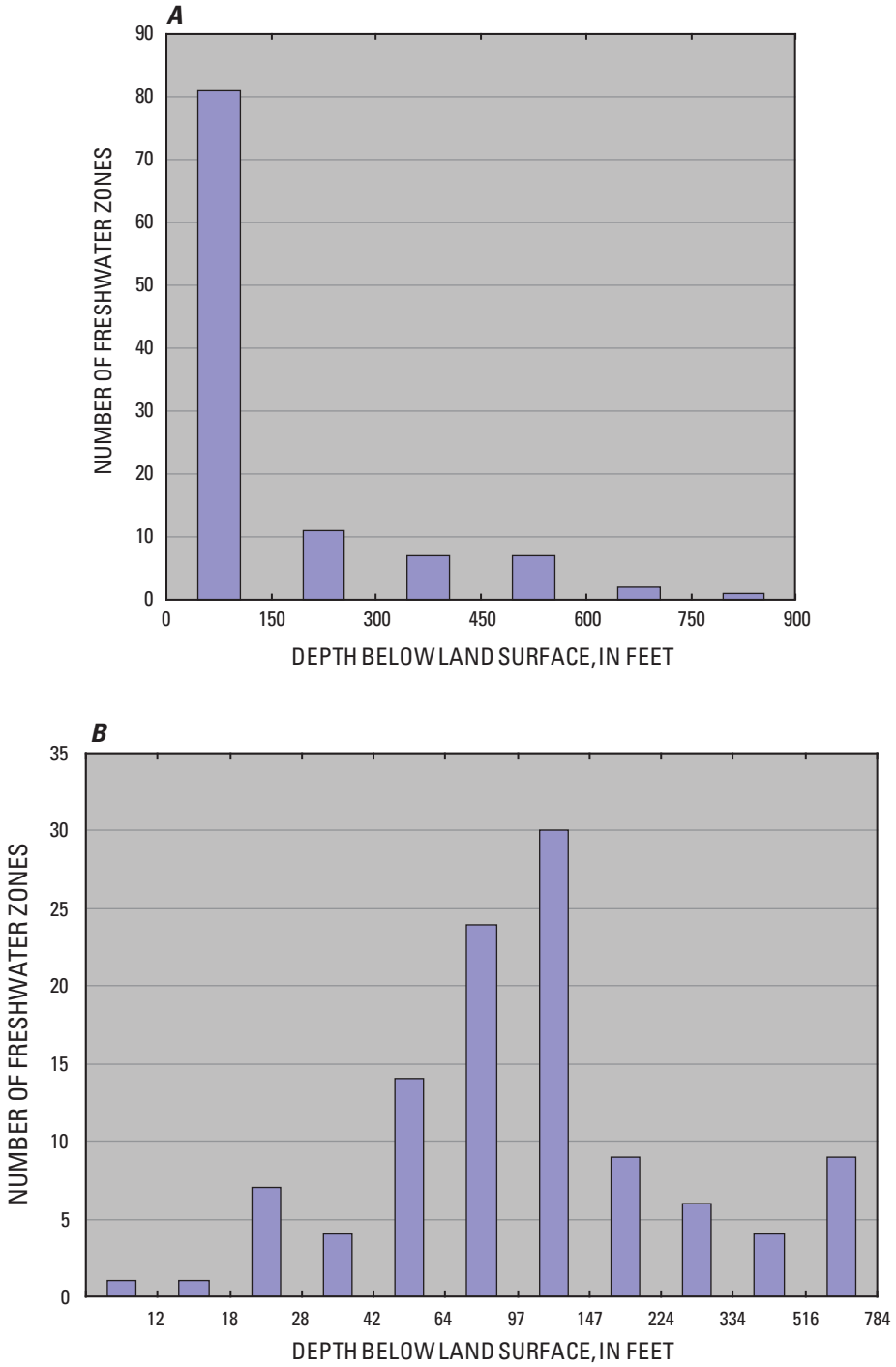

Figure 10. Number and depth of freshwater zones penetrated by gas wells in the study area: *(A)* linear scale and *(B)* log scale.

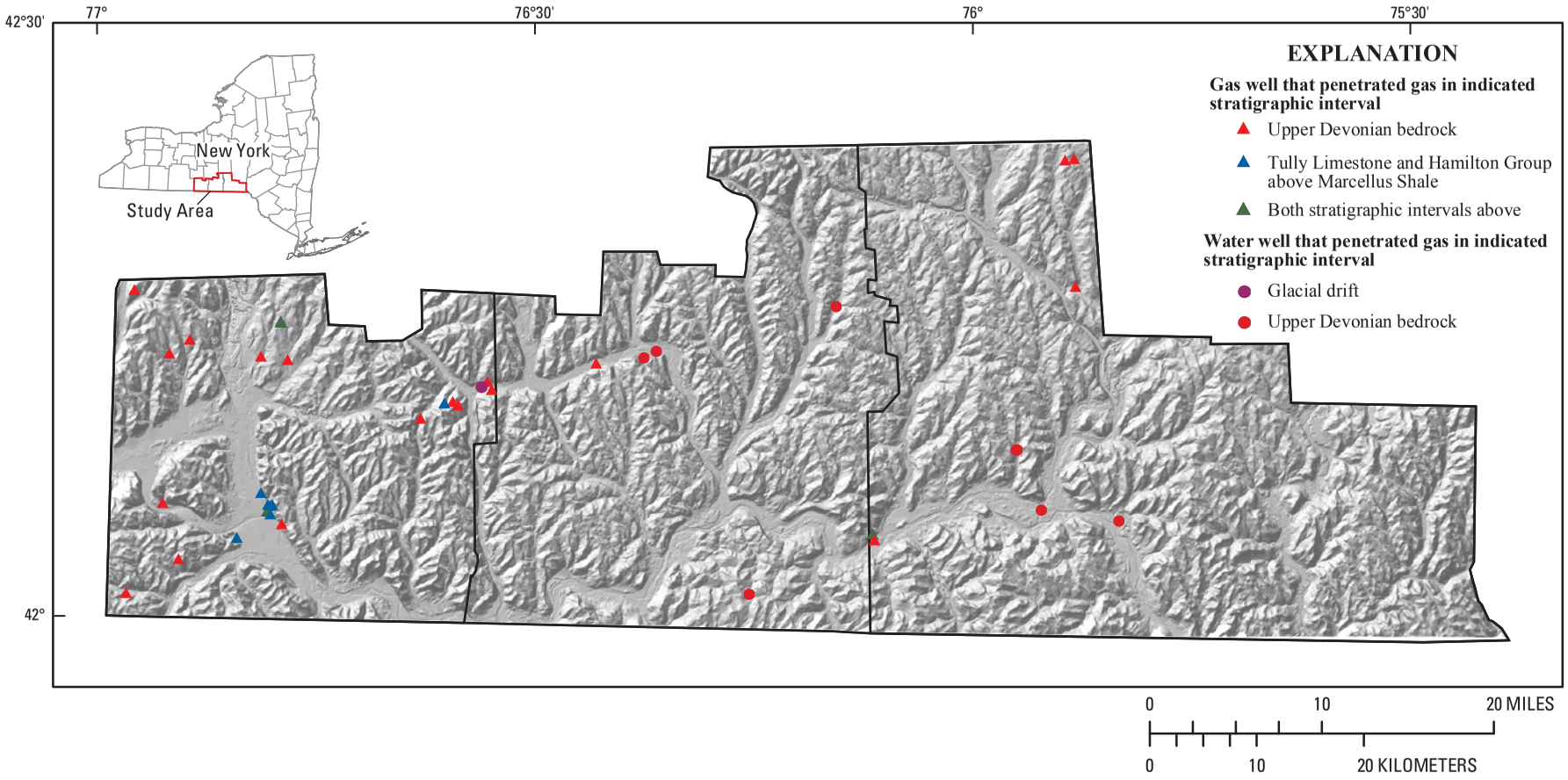

Figure 11. Location of gas and water wells that penetrated gas above the Marcellus Shale in the study area.

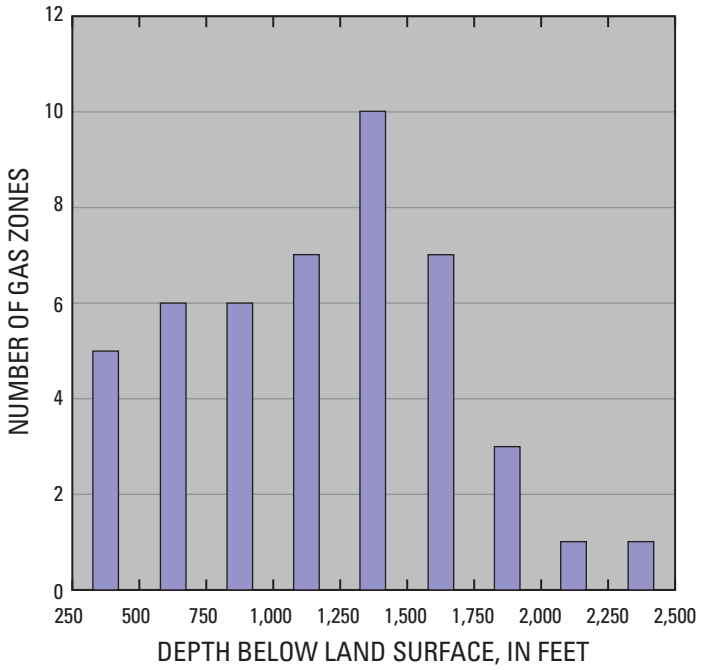

Figure 12. Number and depth of gas zones above the Marcellus Shale penetrated by gas wells in the study area.

Considerations for Future Water and Gas Logging

In the future, extensive drilling likely will occur in the Marcellus Shale play in New York, including areas in the eastern part that have not undergone any substantial gas development to date. Consistent and complete reporting of freshwater, saltwater, and gas during the drilling of Marcellus Shale gas wells would greatly expand the existing databases. Measurement and reporting of field specific conductance of water produced during drilling would enhance the value of the gas-well logs that presently only classify the water as fresh or salty. Specific-conductance and temperature logging of open boreholes prior to surface-casing installation with a portable, wireline geophysical logger commonly used in the groundwater industry (fig. 13) would be an efficient and highly sensitive means to help delineate freshwater, saltwater, and gas shows at Marcellus Shale gas-drilling sites.

As presently drafted (2010), NYSDEC regulations for horizontal gas wells with high-volume hydraulic fracturing in shale require that water wells within 1,000 ft of the gas-drilling sites (or 2,000 if no wells are present within 1,000 ft) be sampled before drilling and at 3-month intervals for a year following fracturing operations (New York State Department of Environmental Conservation, 2009). The presence of nearby water wells is to be determined by review of available water-well logs along with field inventory. In addition to the well data available in the NWIS, the NYSDEC Water Well Program (available online at http://www.dec.ny.gov/lands/33317.html) stores location and construction records for water wells drilled since 2000. The water-quality samples from the selected water wells are to be analyzed for a wide range of constituents, including potential gas-drilling related contaminants such as chloride, barium, gross alpha activity, and methane. Compilation and integration of the water-well records and water-quality analyses related to gas development with other data from county-wide and regional sampling programs, such as the NYSDEC-USGS rotating basin project (Hetcher-Aguila, 2005; Hetcher-Aguila and Eckhardt, 2006; Nystrom, 2007; 2008), would provide an important database for documenting baseline conditions and any potential effects from drilling and hydraulic fracturing. These data could be made available to all agencies, gas producers, and the general public with the ultimate goal of promoting the understanding and protection of the freshwater aquifers in the Marcellus Shale play area.

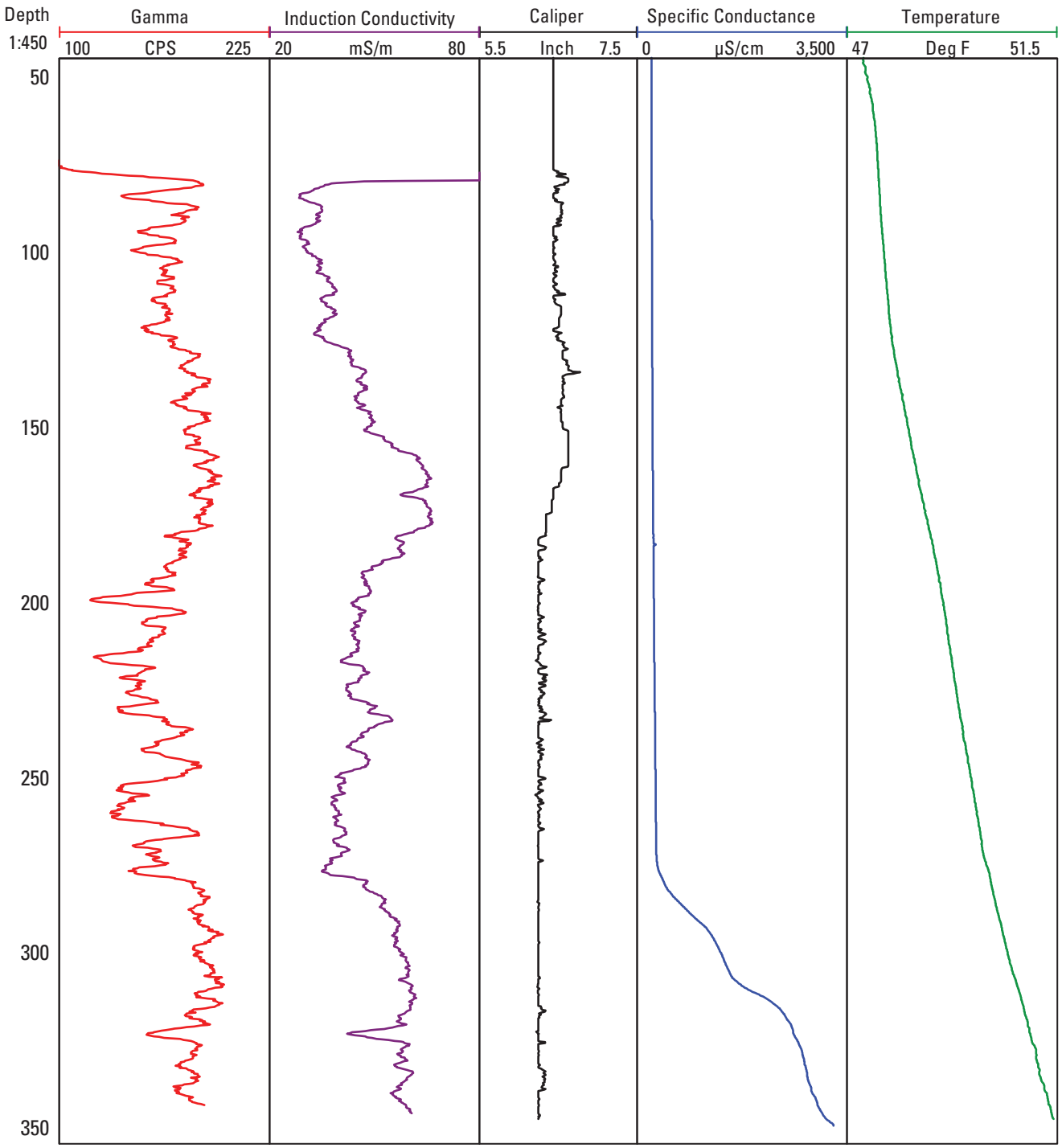

Figure 13. Gamma, induction conductivity, caliper, specific conductance, and temperature logs from a water well that penetrated saltwater below 300 feet in Upper Devonian bedrock, western New York.

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Appendix 1. Log summary for water wells in the National Water Information System that penetrated saltwater and (or) gas in Chemung, Tioga, and Broome Counties, New York, 2010.

[--, no data; ft, feet; mg/L, milligrams per liter; µS/cm, microsiemens per centimeter; gal/min, gallons per minute; Corp., Corporation]

Well name[1]	Well number[2]	Latitude[3]	Longitude[3]	Altitude[4]	Owner	County	Formation	Completion date	Well depth[5]	Casing depth[6]	Top of bedrock[7]	Freshwater[8]	Saltwater[9]	Gas[10]	Remarks
Bm 1	420014075454501	42.0040	-75.7621	870	Beam	Broome	Glacial drift	1964	37	37	95	37	95	--	Salty water in bedrock 95–100 ft.
Bm 3	420019076002002	42.0054	-76.0052	1,025	Vestal Water District 7	Broome	West Falls	1959	200	90	87	--	200	--	Salty water, 660–1,120 mg/L chloride.
Bm 5	420124075512201	42.0234	-75.8557	1,048	Roser	Broome	West Falls	1958	117	57	--	--	117	--	Salty water, plugged and casing pulled; well 80 ft east supplies house, drilled 1954, reported 101 ft deep and salty.
Bm 6	420124075512202	42.0234	-75.8557	1,048	Roser	Broome	Glacial drift	1960	48	56	--	--	56	--	Field specific conductance 4,700 µS/cm, depth 56 ft when drilled.
Bm 8	420143075533701	42.0287	-75.8932	1,180	Brookside School	Broome	West Falls	1956	242	111	--	--	242	--	Good water when drilled, later became salty and plugged.
Bm 25	420353075561901	42.0648	-75.9383	1,415	Faith Baptist Church	Broome	West Falls	1965	526	90	--	--	250	--	7 gal/min enters above 250 ft; first use 1966: salty, iron, sulfur, hard; 10 days later chloride less than 12 mg/L, iron 0.7 mg/L, hardness 9 mg/L; good 1966–68 except salty when fill pool.
Bm 64	420521075491601	42.0892	-75.8207	900	Wheeler	Broome	Glacial drift	--	90	90	--	90	476	--	Till at land surface; salty water in previous well, reported 476 ft deep, destroyed.
Bm 69	420523076061901	42.0898	-76.1049	1,060	Turecek	Broome	West Falls	1963	203	90	--	--	90	--	Hardpan 0–90 ft; saltwater, plugged; 3 later wells nearby, depths 150–305 ft, saltwater at bottom of each.
Bm 72	420524076061501	42.0901	-76.1038	1,090	Turecek	Broome	West Falls	1963	230	--	--	--	230	--	Saltwater, one of 5 salty wells on this property, see 420523076061901.
Bm 76	420526076062101	42.0906	-76.1055	1,080	Durr	Broome	West Falls	1961	402	113	--	150	225	--	Water hard? and salty; 1.5 gal/min (reported good) enters at about 150 ft, more below 225 ft, tried to plug at 160 ft, failed, well capped.
Bm 80	420530075492501	42.0917	-75.8232	856	Palombo	Broome	Sonyea	1945	424	--	--	31	100	--	Saltwater, worse with depth, first well drilled 1935, salty, no data, destroyed; 3 other wells 1945, all about 100 ft deep, all salty; driven well 31 ft deep, good water.
Bm 93	420544075491801	42.0956	-75.8213	851	Town of Kirkwood	Broome	Sonyea	1962	140	--	--	46	140	--	Saltwater, enters at 140? ft; depth 46 ft, 30 gal/min February 1961; failed 1962, deepened.
Bm 94	420545075493101	42.0959	-75.8249	858	State Hospital	Broome	Sonyea	1910	238	--	--	--	238	238	Flow 0.3 gal/min, salty, field specific conductance 27,500 µS/cm; gas, used for stove and light in cottage until 1925.
Bm 104	420554075504401	42.0984	-75.8452	850	Giles	Broome	Glacial drift	1963	30	30	--	30	75	--	Drilled to 75 ft, 10 gal/min salty water from gravel, plugged back with clay.
Bm 123	420601075510701	42.1004	-75.8516	851	Ensinger	Broome	Glacial drift	1948	35	35	90	148	168	--	Drilled to 168 ft, very mineralized; plugged to 148 ft, taste ok; used 1 year, dynamited at 55 ft (got fine sand) and at 35 ft (got water).
Bm 146	420616075544701	42.1045	-75.9127	845	General Ice Cream	Broome	Sonyea	1950	438	93	--	--	--	438	Yield inadequate, produced gas.
Bm 254	420847075562701	42.1465	-75.9405	995	Roberts	Broome	Glacial drift	--	30	--	--	30	170	--	Strong hydrogen sulfide, also iron turns water orange if add bleach; a 170 ft well on this property, water salty to taste.
Bm 267	420909076035701	42.1526	-76.0655	895	Moyer	Broome	Sonyea	1958	100	--	--	50	110	--	Water enters at about 50 ft, drilled to about 110 ft, water somewhat salty, plugged back.

Appendix 1. Log summary for water wells in the National Water Information System that penetrated saltwater and (or) gas in Chemung, Tioga, and Broome Counties, New York, 2010.—Continued

[--, no data; ft, feet; mg/L, milligrams per liter; µS/cm, microsiemens per centimeter; gal/min, gallons per minute; Corp., Corporation]

Well name[1]	Well number[2]	Latitude[3]	Longitude[3]	Altitude[4]	Owner	County	Formation	Completion date	Well depth[5]	Casing depth[6]	Top of bedrock[7]	Freshwater[8]	Saltwater[9]	Gas[10]	Remarks
Bm 281	420955075531101	42.1654	-75.8860	870	Specialty Foods	Broome	Sonyea	1955	194	130	--	190	300	--	Drilled below 190 ft, obtained saltwater (300 ft?), plugged back, pumped, water did not clear.
Bm 288	421012075501201	42.1701	-75.8363	920	Harris	Broome	Sonyea	1953	139	40	--	139	164	--	Drilled to 164 ft, 30 gal/min, salty; plugged to 139 ft with wood and sand; until plugged, well next door (148 ft deep) turned salty.
Bm 324	421150075494601	42.1973	-75.8291	895	Ramsey	Broome	Sonyea	1963	192	180	--	192	210	--	Drilled 210 ft, 30 gal/min salty water; plugged to 192 ft with cement, no longer salty.
Bm 340	421242076023301	42.2117	-76.0421	935	Richardson	Broome	Sonyea	1964	152	110	100	--	152	--	Partial chemical analyses, salty water; 4,510 mg/L chloride.
Bm 355	421436075510301	42.2434	-75.8505	905	Chenango Forks School	Broome	Genesse	1953	142	32	--	--	142	--	Depth approximated, water reported unpotable; salty, sulfurous, hard.
Bm 364	421535076003001	42.2598	-76.0080	995	Lamb	Broome	Sonyea	1948	140	60	60	33	101	--	Saltwater, reported 5,600 mg/L chloride, enters at 101 ft, well capped and buried.
Bm 387	422150076002101	42.3640	-76.0055	1,125	Hand	Broome	Genesse	1965	521	123	--	--	520	--	Saltwater entered at 520 ft, plugged with concrete and sand; house supplied by spring at base of bluff to the east.
Bm 431	420916075562801	42.1545	-75.9408	1,034	Harendza	Broome	Sonyea	1964	96	60	--	--	--	96	Hard, slight H_2S, gas bubbles when drawn.
Bm 435	420917075563301	42.1548	-75.9421	1,077	Harvilla	Broome	Sonyea	1963	148	50	--	--	--	148	Cloudy most of the time, replace cartridge every 3 weeks, natural gas.
Bm 441	420847075562601	42.1465	-75.9402	990	--	Broome	Sonyea	--	193	--	--	--	193	--	Taste ok, gas, milky but clears fast, drew gallon and froze when partially melted too salty.
Bm 445	420551075495701	42.0976	-75.8321	860	State Hospital	Broome	Sonyea	1925	182	--	115	--	198	--	Hardpan 0–115 ft, drilled to about 198 ft, water salty, 4,150 mg/L chloride, plugged back.
Bm 451	420602075510201	42.1006	-75.8502	851	Seaton	Broome	Sonyea	1960	190	100	100	27	95	--	Saltwater at 190 ft; plugged back to 95 ft, poor water (reported salty) in gravel; use driven well 27 ft deep.
Cm 11	420035076433901	42.0098	-76.7272	852	Village of Wellsburg	Chemung	West Falls	1957	175	99	91	106	175	--	Freshwater at 101 and 106 ft, saltwater at 175 ft, well plugged.
Cm 17	420052076420501	42.0145	-76.7011	900	Tanner	Chemung	West Falls	1961	245	84	--	138	245	--	Salty well at 245 ft, other well 138 ft deep is not salty.
Cm 35	420213076521301	42.0370	-76.8700	1,000	Zepp	Chemung	Glacial drift	1965	105	--	105	105	151	--	Fresh at 105 ft well depth, salty at 151 ft well depth.
Cm 38	420306076445301	42.0517	-76.7477	985	Knapp	Chemung	West Falls	1942	326	--	--	--	250	--	Fresh until 250 ft well depth.
Cm 224	420950076524102	42.1640	-76.8777	983	County Development Corp.	Chemung	West Falls	1961	205	181	--	--	181	--	Saltwater at 181–205 ft.
Cm 265	421159076483501	42.1998	-76.8094	975	Orton	Chemung	West Falls	1967	185	54	--	126	180	--	Saltwater, entered at 180 ft, well filled with concrete; other nearby wells less than 126 ft deep, not salty.
Cm 267	421201076325801	42.2004	-76.5491	1,020	Isberg	Chemung	Glacial drift	1966	59	59	--	--	--	50	Gas reported at about 50 ft.
Cm 268	421202076325701	42.2006	-76.5488	1,020	Asunma	Chemung	Glacial drift	1966	57	57	--	--	--	49	Gas reported at about 49 ft.

Appendix 1. Log summary for water wells in the National Water Information System that penetrated saltwater and (or) gas in Chemung, Tioga, and Broome Counties, New York, 2010.—Continued

[--, no data; ft, feet; mg/L, milligrams per liter; µS/cm, microsiemens per centimeter; gal/min, gallons per minute; Corp., Corporation]

Well name[1]	Well number[2]	Latitude[3]	Longitude[3]	Altitude[4]	Owner	County	Formation	Completion date	Well depth[5]	Casing depth[6]	Top of bedrock[7]	Freshwater[8]	Saltwater[9]	Gas[10]	Remarks
Cm 280	421313076354301	42.2204	-76.5949	1,045	Parke	Chemung	Glacial drift	1964	104	--	--	100	256	--	Fresh at 100 ft, salty at 263 ft well depth.
Cm 286	421415076370101	42.2376	-76.6166	1,075	Louko	Chemung	West Falls	1953	250	--	--	180	250	--	Fresh at 180 ft, salty at 250 ft well depth.
Cm 641	420925076554501	42.1569	-76.9292	950	Riho	Chemung	West Falls	--	210	--	--	--	210	--	Salty at 210 ft.
Cm 642	421110076471801	42.1861	-76.7883	960	Olin	Chemung	West Falls	--	250	--	--	--	250	--	Salty at 250 ft, chloride 1,630 mg/L?.
Cm 643	421233076461401	42.2092	-76.7706	1,070	Russell	Chemung	West Falls	--	140	--	--	--	140	--	Salty at 140 ft.
Ti 258	420724076270401	42.1234	-76.4508	1,185	--	Tioga	West Falls	1964	85	76	--	--	76	--	Original depth 76 ft, water at 76 ft, 6-inch casing to 37 ft, flowed, later found to be salty; cased to 76 ft, deepened, still salty, unused.
Ti 271	420955076193901	42.1654	-76.3272	945	Osovski	Tioga	West Falls	1957	132	21	--	--	132	--	First water at 51 ft, may be some salt and iron in water.
Ti 513	420029076310801	42.0081	-76.5186	822	Geppert	Tioga	West Falls	1962	228	80	80	--	228	--	Salty water, not used for drinking; some nearby wells also have salty water; partial chemical analysis and lithologic log in Randall (1972).
Ti 521	420151076143301	42.0309	-76.2422	1,245	Rogers	Tioga	West Falls	1963	89	52	--	--	--	89	Casing measured, some trash in well, original depth unknown; gas bubbles in water, land surface 3 ft above creek; chemical analysis in Randall (1972); total dissolved solids 456 mg/L, specific conductance 789 µS/cm, chloride 77 mg/L.
Ti 585	420351076211001	42.0642	-76.3524	805	--	Tioga	West Falls	--	--	--	--	--	--	--	Water salty, gas bubbles, flows 6 ft above grade; reportedly drilled for oil; similar well drilled nearby cut off while excavating creek channel.
Ti 586	420337076211301	42.0604	-76.3533	807	Fire District Training Center	Tioga	West Falls	1954	--	77	--	78	122	--	Water enters at 78 ft, salty water at 122 ft, sulfurous water at 190 ft, plugged back.
Ti 703	421359076210601	42.2331	-76.3513	922	Czariecki	Tioga	Sonyea	1963	149	149	--	100	149	149	Cemented gravel 0–30 ft, silt to very fine sand 30 ft to top of rock; water unpotable, strong sulfur odor, gas, maybe slight salt; later well 165 ft east, end in gravel at about 100 ft.
Ti 704	421338076215801	42.2273	-76.3658	968	Goulart	Tioga	Sonyea	1965	170	70	70	--	--	170	Water contains gas.
Ti 731	421622076085501	42.2729	-76.1483	1,062	Jones	Tioga	Sonyea	1960	110	42	--	--	--	85	Flammable gas entered at 85 ft, water mostly at greater depth, has objectionable odor.

[1]County sequential number assigned by the U.S. Geological Survey; prefixes Bm, Cm, and Ti indicate Broome, Chemung, and Tioga Counties, respectively.
[2]Unique site identification number assigned by the U.S. Geological Survey.
[3]Degrees and decimal degrees; North American Datum of 1983.
[4]Altitude of land surface, in feet above sea level; National Geodetic Datum of 1929.
[5]Depth of well, in feet below land surface.
[6]Depth of casing, in feet below land surface.
[7]Depth to the top of bedrock, in feet below land surface.
[8]Depth of freshwater zone, in feet below land surface.
[9]Depth of saltwater zone, in feet below land surface.
[10]Depth of gas zone, in feet below land surface.

Appendix 2. Log summary for gas wells in the Empire State Oil and Gas System that penetrated freshwater, saltwater and (or) gas above

[--, no data; ft, feet; Co., Company; Corp., Corporation; °F, degrees Fahrenheit; gal/min, gallons per minute]

Well name	Well number[1]	Latitude[2]	Longitude[2]	Altitude[3]	Owner	County	Formation	Completion date	Well depth[4]	Surface casing[5]
Chase Troy Chem Co. 1	00730	42.17580	-76.02458	830	National Drilling & Development	Broome	--	--	4,412	1,025
Roger 1	01061	42.29185	-75.87700	970	--	Broome	--	--	2,000	--
Quarella 1	04854	42.39907	-75.88001	1,430	Genegantslet Gas & Oil Co.	Broome	Medina	1/20/1968	5,831	598
Gerst 1	08342	42.39776	-75.89021	1,470	James V. Joyce/Dba Pipeline Co.	Broome	Medina	10/2/1972	6,420	638
Harder 1	21457	42.08272	-76.10383	1,150	Kidder Exploration, Inc.	Broome	Helderberg	7/26/1992	4,810	708
V. of Endicott 1	21473	42.07769	-76.10143	821	Kidder Exploration, Inc.	Broome	Helderberg	8/7/1993	4,434	752
Cirba 01	21499	42.14089	-75.84146	1,370	Quaker State Corp.	Broome	Helderberg	10/28/1993	5,230	717
O'Neil 1	21554	42.12948	-75.82361	1,325	Quaker State Corp.	Broome	Helderberg	10/27/1994	5,025	100
Beagell 01	21568	42.13628	-75.83284	1,400	Belden & Blake Corp.	Broome	Helderberg	10/29/1995	5,289	718
Goozovat 1	21713	42.14680	-75.78444	1,485	Belden & Blake Corp.	Broome	Helderberg	11/28/1997	5,004	--
Wicks 2	22855	42.17396	-75.75028	1,105	Cabot Oil & Gas Corp.	Broome	Helderberg	12/17/2000	4,525	706
Logs Unlimited 1	22856	42.16998	-75.73549	1,450	Cabot Oil & Gas Corp.	Broome	Helderberg	3/27/2001	4,952	804
Pond 1	23032	42.24375	-76.04418	1,095	Phillips Production Co.	Broome	Black River	4/23/2004	8,990	519
Butkowsky 1	23056	42.14282	-75.82491	1,470	Belden & Blake Corp.	Broome	Black River	10/11/2003	10,105	1,000
Kesselring 1	00443	42.19864	-76.53773	1,077	Tremblay, Gail R. & Alan B.	Chemung	Oriskany	5/6/1953	11,145	--
Consolidated Brick Co. 1	00474	42.09775	-76.78581	1,002	Belmont Quadrangle Drilling	Chemung	Oriskany	3/22/1940	2,918	--
English 1	00508	42.20536	-76.54253	1,286	NYS Natural Gas Co.	Chemung	Oriskany	4/2/1938	3,362	--
Treat 1	00509	42.23691	-76.70516	1,659	Belmont Quadrangle Drilling	Chemung	Oriskany	12/13/1938	3,447	3,677
Husted	00510	42.22114	-76.70218	1,512	NYS Natural Gas Co.	Chemung	Oriskany	9/12/1939	3,414	511
Bennet 1	00513	42.10282	-76.68367	1,079	NYS Natural Gas Co.	Chemung	Oriskany	12/17/1939	3,463	--
Fasley Lot 2	00554	42.09179	-76.80020	858	Chemung Co.	Chemung	Marcellus	1/5/1944	2,720	--
Beebe 1	00595	42.22757	-76.78626	1,339	Appalachian Development	Chemung	Oriskany	10/30/1943	3,055	--
1_May	00597	42.23128	-76.82434	987	Appalachian Development	Chemung	Oriskany	9/2/1943	2,754	701
Earle	00598	42.22785	-76.82471	989	Appalachian Development	Chemung	--	5/18/1943	1,541	--
Turner 1	00599	42.22263	-76.79994	1,087	Dearth, G. and others	Chemung	--	7/11/1931	3,085	--
Willis 1	00600	42.22347	-76.90397	1,277	Peterman	Chemung	--	4/20/1932	3,135	--
Gregg 1	00601	42.09881	-76.78381	1,173	Belmont Quadrangle Drilling	Chemung	--	5/2/1940	3,129	--
Shay 1	00607	42.09133	-76.79577	855	Rogers and others	Chemung	Oriskany	9/20/1941	2,732	--
Barcus 1	00610	42.09390	-76.78896	850	Kennedy Valve	Chemung	Oriskany	12/10/1940	2,712	1,506
Barcus 2	00611	42.09103	-76.78544	843	Updegraff, C.H. & Nichols, W.M.	Chemung	Oriskany	3/28/1941	3,306	--
Harder 1	00612	42.07076	-76.82307	956	Rogers and others	Chemung	Oriskany	1/27/1941	3,229	--
Fee 1	00613	42.09856	-76.78877	858	Malacoccio	Chemung	Oriskany	10/16/1940	2,772	--
Murphy	01056	42.23553	-76.88105	1,560	Catlin Oil Gas & Mineral	Chemung	--	3/1/1903	2,201	--
Tobey 4	01057	42.09850	-76.90786	1,100	Tobey Oil Gas & Mineral	Chemung	--	1/1/1921	710	291
1_May	03974	42.05185	-76.88830	1,570	Hanley & Bird	Chemung	Oriskany	6/18/1959	4,319	955
City of Elmira 1	04001	42.10855	-76.79688	866	Felmont Oil Corp.	Chemung	--	8/1/1960	2,885	--
Callahan	04026	42.27624	-76.94501	1,637	Felmont Oil Corp.	Chemung	Oriskany	7/19/1960	3,183	--
Coleman 1	04087	42.22016	-76.76962	1,115	Delmont South Penn	Chemung	Oriskany	5/4/1961	2,969	--

the Marcellus Shale in Chemung, Tioga, and Broome Counties, New York, 2010.

Intermediate casing[6]	Top of bed-rock[7]	Top of Tully[8]	Top of Mar-cellus[9]	Fresh water[10]	Salt water Up Dev[11]	Salt water Tully[12]	Gas Up Dev[13]	Gas Tully[14]	Remarks
--	--	2,250	--	--	850	--	--	--	850–1,025 ft sand and much saltwater.
--	--	--	--	--	--	--	2,000	--	Salt spring or 30 ft salt well 1/4 mi away.
--	--	1,440	--	100	--	--	867	--	Freshwater at 100 ft, strong gas show at 867 ft.
--	--	1,487	--	125, 317, 595	920	--	858, 920, 1,250	--	Freshwater at 125, 317, and 595 ft; saltwater at 920 ft; gas at 858, 920, and 1,250 ft.
--	--	2,666	--	--	--	--	--	--	Gas shows in upper Devonian and Hamilton (depths not specified).
--	125	2,336	--	--	--	--	--	--	Gas shows in upper Devonian (depths not specified).
--	--	2,635		78	--	--	--	--	Shale at 0 ft, 1/2 inch stream at 78 ft.
700	30	2,704	--	138	--	3,400	--	--	Shale at 30 ft, 1/4 inch stream at 138 ft, brine at 3,400 ft.
--	--	2,677	--	88	--	--	--	--	1/2 inch stream at 88 ft freshwater.
--	42	2,600	--	50, 100	--	--	--	--	Shale at 42 ft, water 1/4 inch at 50 ft, 1 inch at 100 ft.
--	57	2,228	4,113	57, 85	--	--	--	--	Freshwater 12 gal/min in gravel at 57 ft, shale at 57 ft, damp at 85 ft.
--	69	2,608	4,512	145, 370	--	--	--	--	0–69 ft gravel, sand, and silt; shale at 69 ft, damp in shale at 145 ft, freshwater at 370 ft.
2,509	--	2,348	--	590, 736	--	--	--	--	Show freshwater at 590 and 736 ft.
7,200 (4,500)	--	2,707	--	200	--	--	--	--	Freshwater at 200 ft, conductor casing set to 40 ft, have wrong PDF file (W65 St A).
--	54	1,620	2,770	--	--	--	713, 868, 908	--	Large volume saltwater in Thersea, 5,000 ft saltwater at TD, deepest cable tool hole in the world, bottom hole temp, 245°F.
--	--	1,616	--	--	--	--	--	1,704	
--	0	1,834	3,118	--	1,019	--	1,035	--	
--	--	2,125	--	--	--	--	--	--	Saltwater at 3,444 ft well filled up to 100 ft in 30 hours.
--	27	2,065	3,187	115	--	--	--	--	15 to 20 gal/min at 114–116 ft, 0–27 ft glacial drift.
--	10	2,130	--	55	--	--	--	--	Water at 55 ft in shale.
--	--	1,474	--	--	--	--	--	--	50 MCF shale gas at 2,310–2,525 ft, 260–88 MCF with 6 barrels saltwater in black shale.
--	--	1,773	--	--	1,235	--	--	--	800 ft of saltwater at 1,235 ft.
--	--	1,528	--	700	--	--	--	--	700–701 ft gravel below 640 ft of clay, flowed at 3,580 gal/min for 4 days, spurted up 8 ft in air from 10 inch casing.
--	--	1,518	--	--	--	--	--	--	Well abandoned in Tully limestone, well apparently in path of fault.
--	40	1,560	2,675	--	--	--	1,425, 1,560	--	Fault well? 800 MCF at 1,425–1,560 ft exhausted in 10 days. Sulphur gas 95–115 ft and 340–347 ft.
--	42	1,990	2,980	--	--	--	350–450	--	Small gas flow between 350–450 ft.
--	--	1,845	--	--	--	--	--	1,928	
--	--	1,461	--	--	500	--	--	--	Well on knee of fault, 500 ft saltwater 2 inch stream.
--	--	1,455	--	--	1,434	1,455	1,434	1,455	350 MCF in Tully and hole full of saltwater.
--	--	1,450	--	--	--	--	--	1,450	50 MCF in Tully.
--	70	1,980	--	125, 325	--	--	--	1,980	0–70 ft clay and gravel, little water at 125 ft, lots of water at 325 ft; 75 MCF in Tully.
--	--	1,470	--	--	--	--	--	1,470	75 MCF in Tully.
--	17	1,764	--	--	1,265	--	1,718	--	Saltwater at 1,718 ft, gas at 1,265 ft and some oil at 1,763 ft.
--	--	--	--	--	--	--	610, 645	--	
--	--	3,125	4,110	--	--	--	1,290, 1,334	--	Show of gas at 1,290–1,334 ft.
--	--	1,595	--	--	--	--	--	1,595	3 MCF in Tully.
--	--	1,990	3,002	--	1,780	--	1,205	--	Show of gas at 1,205 ft blew down to nothing by time well got to 1,311 ft, 15 gallons saltwater overnight at 1,780 ft.
--	--	1,552	2,635	--	--	--	1,416	--	Gas pocket 1,416–1,426 ft.

Appendix 2. Log summary for gas wells in the Empire State Oil and Gas System that penetrated freshwater, saltwater and (or) gas above

[--, no data; ft, feet; Co., Company; Corp, Corporation; °F, degrees Fahrenheit; gal/min, gallons per minute]

Well name	Well number[1]	Latitude[2]	Longitude[2]	Altitude[3]	Owner	County	Formation	Completion date	Well depth[4]	Surface casing[5]
Haywood 1	04148	42.18817	-76.58296	1,490	Smith, Albert E.	Chemung	Oriskany	1/5/1962	3,406	1,275
Erickson 1	04174	42.18806	-76.58143	1,229	New York Natural Gas Co.	Chemung	Oriskany	4/27/1962	3,262	236
Baker 1	04179	42.18529	-76.57541	1,520	Fairman Drilling Co.	Chemung	Oriskany	4/25/1962	3,475	727
Rumsey 1	04180	42.17980	-76.58290	1,487	Rumsey, Elizabeth A.	Chemung	Oriskany	4/26/1962	3,479	550
Cotton & Hanlon 1	04191	42.17350	-76.61781	1,276	Fairman Drilling Co.	Chemung	Oriskany	7/24/1962	3,273	424
Phytilia 1	04350	42.18652	-76.59094	1,441	New York Natural Gas Co.	Chemung	Oriskany	3/14/1963	3,409	496
Boor 1	04863	42.25236	-76.77832	1,526	Rio Oil, Inc.	Chemung	Oriskany	7/21/1966	3,310	350
Richards 1	04923	42.02254	-76.94674	1,240	Rio Oil, Inc.	Chemung	Oriskany	10/29/1966	4,149	380
Held 1	06781	42.17925	-76.61866	1,325	Potter-Mckean Resources, Inc.	Chemung	Oriskany	5/19/1969	3,311	348
Hulsebosch 1	17318	42.08289	-76.77229	1,068	Hulsebosch, Adrian & Jessica	Chemung	Marcellus	8/23/1982	3,030	518
Broz Unit 1	22826	42.27282	-76.77380	1,717	Fortuna Energy, Inc.	Chemung	Black River	3/19/2000	9,362	596
Lovell 1323	22831	42.18682	-76.95820	1,490	Fortuna Energy, Inc.	Chemung	Black River	7/8/2000	9,386	944
Whiteman 1	22839	42.28528	-76.91613	1,633	Fortuna Energy, Inc.	Chemung	Black River	7/8/2000	9,372	617
Rhodes 1322	22853	42.19534	-76.92088	1,390	Fortuna Energy, Inc.	Chemung	Black River	2/8/2001	9,682	1,000
Kimball 1	22857	42.27274	-76.79134	1,525	Fortuna Energy, Inc.	Chemung	Black River	10/11/2000	9,166	620
Lant 1	22862	42.26828	-76.81321	1,116	Fortuna Energy, Inc.	Chemung	Black River	2/9/2001	9,330	634
Kienzle 1	22880	42.27898	-76.81384	1,261	Fortuna Energy, Inc.	Chemung	Black River	8/7/2001	9,107	640
Peterson 1	22890	42.28652	-76.89200	1,158	Fortuna Energy, Inc.	Chemung	Black River	10/2/2001	9,387	647
Parker 1401	22891	42.23797	-76.93854	1,805	Fortuna Energy, Inc.	Chemung	Black River	7/19/2001	10,323	972
Roy 1	22901	42.27141	-76.95672	1,221	Fortuna Energy, Inc.	Chemung	Black River	9/6/2001	9,487	652
Lederer 1412	22902	42.25255	-76.86908	1,485	Pennsylvania General Energy	Chemung	--	7/19/2001	9,602	1,034
Gregory 1446	22918	42.20731	-76.88438	1,105	Pennsylvania General Energy	Chemung	Black River	12/14/2001	9,402	1,034
Hardy 1447	22919	42.23742	-76.92014	1,730	Pennsylvania General Energy	Chemung	Black River	10/30/2001	9,859	1,005
Johnson 1	22924	42.26898	-76.75087	1,491	Fairman Drilling Co.	Chemung	Black River	8/28/2001	9,803	663
Chemung SRA 1 Parcel A 1459	22960	42.24457	-76.90649	1,570	Fortuna Energy, Inc.	Chemung	Black River	5/1/2002	9,815	1,023
Root 1514	22975	42.23859	-76.88994	1,345	Fortuna Energy, Inc.	Chemung	Black River	8/9/2002	9,608	1,019
Strope 1516	22979	42.19864	-76.72390	1,285	Pennsylvania General Energy	Chemung	Black River	8/23/2002	9,745	1,018
Stevens WE 1	00257	42.22236	-76.41965	965	NYS Natural Gas Corp.	Tioga	Oriskany	5/28/1947	3,150	--
Robinson 1	20425	42.12369	-76.19493	1,340	Quaker State Corp.	Tioga	Silurian	5/14/1987	5,236	417

the Marcellus Shale in Chemung, Tioga, and Broome Counties, New York, 2010.—Continued

Intermediate casing[6]	Top of bed-rock[7]	Top of Tully[8]	Top of Mar-cellus[9]	Fresh water[10]	Salt water Up Dev[11]	Salt water Tully[12]	Gas Up Dev[13]	Gas Tully[14]	Remarks
--	--	2,036	3,134	84, 120, 420	--	--	--	--	Freshwater at 84 ft, not enough to drill with, 120 ft hole full, hole full at 420 ft.
--	--	1,795	--	189	--	--	730	--	No saltwater before Oriskany, gas show at 730 ft.
--	--	2,093	--	75, 155	--	--	1,100	--	Freshwater at 75 and 155 ft in sandstone and shale, gas show 1,100–1,119 ft.
--	--	2,091	--	25, 137	--	--	--	--	Freshwater at 25 ft, hole full of water at 137 ft.
--	40	1,857	--	100	1,178	--	360, 560, 950, 1,178	--	0–40 ft overburden, bailing freshwater at 100 ft, 5 gal/hour saltwater at 1,178 ft, gas shows at 360, 560, 950, and 1,178 ft.
--	--	2,017	3,110	85	--	--	--	2,281	Freshwater at 85 ft, 52 MCF gas at 2,281–2,285 ft.
--	34	2,033	3,060	80	--	--	1,177	2,049	0–34 ft sand, clay, and gravel, good flow freshwater at 80 ft in shale, oil shows 550 and 2,049 ft.
--	75	2,964	3,908	75, 88	549, 956	--	623	--	0–75 ft sand, gravel, and boulders, freshwater in gravel, freshwater at 88 ft in sandstone, saltwater at 549 and 956 ft, gas show less than 20 MCF at 623 ft.
--	75	1,910	3,057	101	--	--	--	--	Overburden 0–75 ft.
--	80	1,770	2,875	77	1,350	--	1,180, 1,285, 1,454, 1,502, 1,563, 1,612	--	Water in gravel at 77 ft, silty shale at 80 ft, perforated 2,900–2,960 ft in Marcellus.
5,680 (4,833)	15	2,391	--	105	--	--	--	--	0–15 ft clay, 2 inch stream freshwater at 105 ft in sandstone and shale.
6,662	89	2,412	--	240	--	--	--	--	15–89 ft clay and gravel, 4 inch stream of freshwater at 240 ft in sandstone and shale.
5,618 (3,352)	26	1,822	2,832	25, 58	--	--	--	--	1/2 inch stream freshwater at 25 ft in unconsolidated, 2 inch stream freshwater at 58 ft in shale, shale 26–405 ft, sandstone and shale 405–620 ft.
5,929 (2,000)	6	2,256	--	328, 784	--	--	--	--	0–6 ft fill, 1 inch stream of freshwater at 328 ft in sandstone, 1 1/2 inchstream of freshwater at 784 ft in shale.
5,570	--	2,153	--	71	--	--	--	--	2 inch stream freshwater at 71 ft in gravel.
5,176 (2,090)	--	1,792	2,855	50	--	--	--	--	Sandstone at 28 ft, 1/2 inch freshwater at 50 ft in sandstone.
5,874 (2,320)	28	1,916	2,973	60	--	--	--	--	0–195 ft shale, 3 ft fresh at 60 ft.
5,142 (2,510)	0	1,487	2,510	22, 74	--	--	--	--	1 inch freshwater stream at 22 ft, 4 inch stream freshwater at 74 ft in gravel, base of gravel at 94 ft.
6,157 (3,400)	4	2,696	--	30, 135, 480	--	--	--	--	Sandstone and shale 4–2,696 ft, 1/4 inch stream freshwater at 30 ft,1 inch stream at 135 ft and 1 inch stream at 480 ft.
5,893 (3,200)	77	1,684	2,659	24, 47, 83, 114, 120, 203	1,190	--	--	--	23–77 ft gravel, 77–1,684 ft shale, damp at 23 ft, 2 inch fresh at 24 ft and 3 inch fresh at 47 ft, 2 inch fresh at 83 ft, 3 inch fresh at 114 ft, 4 inch fresh at 120 ft, 3 inch fresh at 203 ft, damp at 1,190 ft.
5,735	15	2,260	--	114, 203	--	--	--	--	Shale and sandstone at 15 ft, damp at 114 ft and 1 inch stream at 203 ft.
6,360 (2,700)	--	1,802	--	84	--	--	--	--	1/2 inch stream of freshwater at 84 ft.
6,102 (3,500)	95	2,608	--	75	--	--	--	--	20–95 ft sand and gravel, 1/2 ft stream freshwater at 75 ft.
6,130 (3,540)	134	2,082	3,163	28, 133, 195	--	--	--	--	18–134 ft clay and gravel, 1 inch fresh at 28 ft and fresh at 133 ft, shale at 134 ft, 1 inch fresh at 195 ft.
5,935 (3,200)	21	2,412	--	85	--	--	--	--	Shale at 21 ft, 2 inch stream freshwater at 85 ft.
5,700 (3,000)	40	2,125	--	210	--	--	--	--	Shale at 40 ft, 1 1/2 inch stream freshwater at 210 ft.
5,890 (2,875)	98	1,838	--	85	--	--	--	--	2 inch stream in gravel at 85 ft, shale at 98 ft.
--	70	1,542	--	12, 130	--	--	263, 270	--	0–70 ft gravel, freshwater in gravel at 12 ft and in shale at 130 ft, gas shows at 263 and 270 ft.
1,164 (932)	28	2,870	4,461	28, 105	--	--	--	--	Freshwater in gravel at 28 ft (1/4 inch) and in shale at 105 ft (1 inch).

Appendix 2. Log summary for gas wells in the Empire State Oil and Gas System that penetrated freshwater, saltwater and (or) gas above

[--, no data; ft, feet; Co., Company; Corp, Corporation; °F, degrees Fahrenheit; gal/min, gallons per minute]

Well name	Well number[1]	Latitude[2]	Longitude[2]	Altitude[3]	Owner	County	Formation	Completion date	Well depth[4]	Surface casing[5]
Fyock 1	20427	42.03624	-76.21665	1,265	Central New York Oil & Gas Co., LLC	Tioga	Helderberg	2/27/1987	5,534	116
Racht 1	20531	42.03360	-76.22227	1,485	Central New York Oil & Gas Co., LLC	Tioga	Helderberg	10/14/1987	5,410	966
Torbert 1	20532	42.05656	-76.24139	1,260	Quaker State Corp.	Tioga	Helderberg	10/28/1987	5,154	994
Hakes 1	20534	42.02248	-76.22789	1,470	Quaker State Corp.	Tioga	Helderberg	10/20/1987	5,484	1,003
Barnhart 1	20644	42.02530	-76.25499	1,480	Central New York Oil & Gas Co., LLC	Tioga	Helderberg	11/15/1988	5,232	519
Mead 1	20645	42.03417	-76.19666	1,400	Quaker State Corp.	Tioga	Helderberg	12/29/1988	5,225	873
Owen 01	21264	42.02386	-76.27509	1,580	Central New York Oil & Gas Co., LLC	Tioga	Onondaga	8/29/1989	5,375	751
Owen 02	21265	42.03197	-76.27519	1,440	Quaker State Corp.	Tioga	--	9/4/1989	5,295	686
Cook 01	21272	42.01059	-76.29758	1,600	Central New York Oil & Gas Co., LLC	Tioga	Helderberg	12/13/2006	5,455	722
Mead 01	21294	42.01176	-76.27324	1,430	EOG Resources, Inc.	Tioga	Helderberg	9/5/1990	5,268	721
Widell 01	21300	42.04916	-76.19729	1,150	Central New York Oil & Gas Co., LLC	Tioga	Helderberg	6/26/1990	4,720	511
Kittle 1	21375	42.01327	-76.31344	1,185	Quaker State Corp.	Tioga	Silurian	10/31/1990	5,597	532
Spencer 1	21378	42.21514	-76.45367	1,100	Fault Line Oil Corp.	Tioga	Silurian	6/24/1993	3,246	336
Lacher 01	21394	42.00386	-76.31213	1,475	Central New York Oil & Gas Co., LLC	Tioga	Helderberg	12/6/2006	5,293	698
Jones 01	21420	42.05012	-76.17812	1,035	Central New York Oil & Gas Co., LLC	Tioga	Helderberg	8/6/1991	4,634	711
Brenchley 01	21421	42.01080	-76.28504	1,435	Central New York Oil & Gas Co., LLC	Tioga	Helderberg	6/27/2006	5,203	708
Campbell 01	21424	42.04242	-76.20872	1,355	Central New York Oil & Gas Co., LLC	Tioga	Helderberg	5/21/2003	5,031	714
Pierce 01	21451	42.04978	-76.15903	1,140	Central New York Oil & Gas Co., LLC	Tioga	Helderberg	9/2/1992	4,823	709
Bell 01	21452	42.05535	-76.18144	1,180	Quaker State Corp.	Tioga	Helderberg	3/12/1993	4,675	699
Pierce 02	21462	42.05535	-76.16042	975	Quaker State Corp.	Tioga	Oriskany	9/13/1994	4,585	715
Meade 02	21497	42.01795	-76.27435	1,450	Quaker State Corp.	Tioga	Helderberg	9/11/1993	5,338	770
Faber 01	21547	42.02895	-76.25518	1,510	Quaker State Corp.	Tioga	Helderberg	8/27/1994	5,435	713
Wiggins 1	21552	42.03321	-76.23840	1,335	Quaker State Corp.	Tioga	Helderberg	9/20/1994	5,130	738
Waite 1	21708	42.00234	-76.30054	1,400	EOG Resources, Inc.	Tioga	Oriskany	1/22/1998	5,264	776
Nichols-Mead 1	21709	42.00275	-76.32391	1,225	Central New York Oil & Gas Co., LLC	Tioga	Helderberg	12/20/2006	4,928	775

[1]American Petroleum Institute unique well identifier assigned by the New York State Department of Environmental Conservation, Division of Mineral Resources.
[2]Degrees and decimal degrees; North American Datum of 1983.
[3]Altitude of land surface, in feet above sea level.
[4]Depth of well, in feet below land surface.
[5]Depth of surface casing cemented to land surface, in feet below land surface.
[6]Depth of intermediate casing, in feet below land surface; top of intermediate casing cement, in feet below land surface, in parentheses.
[7]Depth to the top of bedrock, in feet below land surface.
[8]Depth to the top of the Tully Limestone, in feet below land surface.
[9]Depth to the top of the Marcellus Shale, in feet below land surface.
[10]Depth of freshwater zone(s), in feet below land surface.
[11]Depth of saltwater zone(s) in Upper Devonian bedrock, in feet below land surface.
[12]Depth of saltwater zone(s) in the Tully Limestone and Hamilton Group above the Marcellus Shale, in feet below land surface.
[13]Depth of gas zone(s) in Upper Devonian bedrock, in feet below land surface.
[14]Depth of gas zone(s) in the Tully Limestone and Hamilton Group above the Marcellus Shale, in feet below land surface.

the Marcellus Shale in Chemung, Tioga, and Broome Counties, New York, 2010.—Continued

Intermediate casing[6]	Top of bed-rock[7]	Top of Tully[8]	Top of Mar-cellus[9]	Fresh water[10]	Salt water Up Dev[11]	Salt water Tully[12]	Gas Up Dev[13]	Gas Tully[14]	Remarks
1,176 (944)	20	2,865	4,548	31, 60, 80, 650	--	--	--	--	Freshwater in shale at 31 ft (1/2 inch), 60 ft (1 inch), and 80 ft (2 inch); 1 inch stream at 650 ft.
--	10	3,100	4,700	22	--	--	--	--	Freshwater at 22 ft in shale.
--	0	2,830	4,410	60	--	--	--	--	Freshwater at 60 ft in shale.
--	10	3,110	4,718	18, 65, 95, 140	--	--	--	--	Freshwater at 18, 65, 95, and 140 ft in shale.
--	--	3,188	4,781	97, 300	--	--	--	--	1/2 inch stream at 97 ft and 2 inch stream at 300 ft.
--	--	2,975	4,625	65, 523	--	2,995	--	--	1/2 inch at 65 ft and 1 1/2 inch at 523 ft, hit water at 2,995 ft (brackish).
--	35	3,376	4,947	32, 95, 180, 323	--	--	--	--	Top of bedrock at 35 ft, freshwater at 32, 95, 180, and 323 ft.
--	35	3,252	4,853	26, 65, 140, 436, 531	--	--	--	--	Bedrock (shale) at 35 ft, freshwater at 26, 65, 140, 436, and 531 ft.
--	63	3,450	4,987	20, 60, 520	--	--	--	--	0–63 ft gravel, freshwater in gravel at 20 and 60 ft and in shale at 520 ft.
--	142	3,230	4,802	82, 142, 520	--	--	--	--	0–142 ft sand and gravel, water 82–142 ft, water in shale at 520 ft.
--	30	2,687	4,338	20, 50, 120, 570	--	--	--	--	Shale at 30 ft, freshwater at 20, 50, 120, and 570 ft.
--	115	3,042	4,575	62, 105	--	--	--	--	Freshwater 4 inch stream from 62–105 ft, shale at 115 ft.
--	4	1,740	2,986	108	--	--	--	--	Shale at 4 ft, no gas, slight water at 108 ft.
--	10	3,270	4,803	62, 173	--	--	--	--	0–10 ft gravel, freshwater in shale 1/2 inch stream at 62 ft and 1/2 stream at 173 ft.
--	45	2,560	4,248	140	--	--	--	--	0–45 ft gravel, 1/2 inch stream freshwater at 140 ft.
--	155	3,280	4,773	90, 115, 145	--	--	--	--	0–155 ft gravel, 3 inch stream at 90 ft, 2 inch stream at 115 ft, and 3 inch stream at 145 ft.
--	10	2,920	4,628	255	--	--	--	--	Shale at 10 ft, 1/4 inch freshwater at 255 ft.
--	35	2,690	4,350	78	--	--	--	--	0–35 ft gravel, freshwater at 78 ft in shale (1/4 inch stream).
--	120	2,705	4,439	65, 120, 200	--	--	--	--	Water from 65–120 ft (1 inch stream), shale at 120 ft, water at 200 ft 1/2 inch stream; directional hole depths not corrected.
--	10	2,484	4,147	60	1,500	--	--	--	Shale at 10 ft, 1/2 inch freshwater at 60 ft, 1/2 inch stream brackish at 1,500 ft.
--	86	3,270	4,880	56	--	--	--	--	0–86 ft gravel and dirt.
--	60	3,286	4,090	40	--	--	--	--	0–60 ft gravel, 1 inch (fresh) at 40 ft in gravel.
--	55	3,030	4,602	112	--	--	--	--	0–55 ft gravel, 1 inch freshwater at 112 ft.
--	78	3,160	4,648	62	--	--	--	--	Water in gravel at 62 ft, shale at 78 ft.
--	100	3,040	4,158	100	--	--	--	--	0–100 ft gravel (water), shale at 100 ft.

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