CHAPTER SEVEN

A PROPOSED GROUNDWATER MONITORING NETWORK FOR THE MOIRA RIVER DRAINAGE BASIN

By

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7.1 LOCATION

The Moira River drainage basin is located in eastern Ontario between latitudes 44^0 57' and $44^0$09' N and longitudes $76^0$58' and 77^0 40' W. Elevations in the basin vary between about 80 m (a.s.l.) in the south and about 400 m (a.s.l.) in the extreme north, but most of the land is in the range of 150 to 300 m (a.s.l.). Local relief rarely exceeds 50 m.

The headwaters of the Moira River rise in the rocky highlands of the Counties of Hastings, and Lennox and Addington about 88 k m north from Lake Ontario. The river and its major tributaries, Skootamatta, Black, and Clare Rivers, and the Parks Creek, drain about 2,745 km^2. The Skootamatta and Black Rivers combined drain about 40 per cent of the basin; Clare River and the Parks Creek drain another 20 per cent, and the remaining 40 per cent is drained by the Moira River and its smaller tributaries. Many lakes occur within the upper parts of the basin; the largest being Skootamatta, Lingham, Moira and Stoco Lakes.

NOTE: A Key Map was included as part of the figures for this chapter. Those who wish to make a hard copy of the chapter can also make a transparency of the Key Map and use it for orientation purposes with the other figures.

7.2 LAND USE

Industry and agriculture form the economic base in the southern third of the basin, while tourism, recreation, and logging are the major activities in the north where 80 per cent of the area is woodland. The area south of Thomasburg and the area bounded by Queensborough, Madoc, Malone and Kellers Bridge are the only areas in the basin where the soils are suitable for general agricultural use. Approximately 40 per cent of this area is cultivated, and dairying, beef production, and mixed farming account for more than 90 per cent of the agricultural operations.

Public recreation facilities in the basin are provided in conservation areas and municipal parks. The Moira River Conservation Authority operates seven park areas in the basin. Several tourist camps, used primarily for fishing, are located on Moira, Stoco, and

Skootamatta Lakes. Also, several stream sections are used for boating, canoeing, and fishing.

The major population centres within the basin are Belleville, which is located at the mouth of the Moira River, and the villages of Tweed, Madoc and Deloro.

7.3 GROUNDWATER USE

Groundwater is used in the basin for rural domestic purposes, and to meet municipal, industrial, agricultural, and recreational water supply needs. Most of the rural population lives in the southern parts of the basin and most of their water needs is obtained from groundwater sources, with only a small percentage being obtained from surface water sources. Water use in the northern parts of the basin is small because rural settlement is sparse and generally restricted to hamlets along main highways. Most domestic water supplies are obtained from rock wells that supply adequate amounts of water for domestic use.

The total number of water wells within the Moira River drainage basin that have geographic coordinates on file with the Ministry of the Environment is 3,549. Of these wells, 430 (12.1 %) are overburden wells, 2,921 (82.3 %) are bedrock wells, and the rest are of unknown type. All the overburden wells are located within the lower parts of the basin.

Four municipalities have communal water-supply systems: Belleville, Tweed, Madoc and Deloro. Belleville's water supply is obtained from the Bay of Quinte. Two municipal wells provide water supply to Tweed, another two wells provide water supply to Madoc, and one well provides water supply to Deloro. Most industries in the basin are not served by municipal water supply systems, but obtain their supplies from individual wells.

The most common water-related problem in the Moira River basin is inadequate water supply. Inadequate ground-water supplies for domestic wells are frequent in the limestone areas of the basin, and the quantities of water obtainable in the Precambrian rock areas are unpredictable. The inadequacy of water supplies is sometimes compounded by well interference, poor natural groundwater quality, and pollution of existing supplies.

4.4 PHYSIOGRAPHY

The northern two-thirds of the basin is characterized by Precambrian bedrock topography of the Canadian Shield, while the southern one-third of the basin is characterized by thin overburden on Palaeozoic limestones. The overburden on Precambrian bedrock is thin or absent, and for the most part, the land terrain has rock-and-knob topography. Overburden land forms are limited to occasional kame mounds, esker ridges, and sand plains formed by sediment accumulation in bedrock depressions. Swamp and bog deposits fill numerous bedrock lows and surround many lakes (Sibul et al.1974).

Chapman and Putnam (1984) identified three physiographic regions within the souther one-third portion of the basin, the Napanee Plain, the Peterborough Drumlin Field, and the Dummer Moraines.

The Napanee Plain physiographic region within the lower portion of the basin is part of a larger region extending along the northen shores of the Bay of Quinte between Belleville and Kingston. It is a flat to undulating plain of limestone from which the glaciers stripped most of the overburden.

The Peterborough Drumlin Field physiographic region within the basin is part of a larger region extending from Hastings County in the east to Simcoe County in the west. Within the basin, this physiographic region contains numerous drumlins. The drumlins are composed of calcareous till and the general orientation of the drumlin axes is from northeast to southwest. A few eskers are also found in the region.

The Dummer Moraines physiographic region within the basin extends as a belt between the Peterborough Drumlin Field in the south and the Canadian Shield to the north. The underlying bedrock consists of limestones. A discontinuous limestone cuesta, usually less than10 m high, defines the contact between the Precambrian plutonic rocks and the Palaeozoic limestones in areas east, south and west of Stoco Lake.

The moraines within this region are characterized by angular fragments and blocks of limestone with many Precambrian rocks also present. The surface is extremely rough even though most of the morainic ridges are quite low. Several tributaries to the Moira River cross this morainic belt. Most of them follow pre-glacial valleys, entrenched up to 30 m in the bedrock. A number of these valleys are blocked by glacial drift, thus creating long narrow lakes or swamps. The Moira and Stoco Lakes are prominent examples of this type.

7.5 BEDROCK TOPOGRAPHY AND GEOLOGY

Precambrian rocks underlie the whole of the Moira River drainage basin and are in turn overlain in the south by approximately 105 m of Palaeozoic limestone. Thin and discontinuous overburden deposits cover the southern edge of the Precambrian rocks and become thicker and more continuous over the Palaeozoic rocks in the south.

The bedrock elevation within the basin ranges from about 75 m (a.s.l.) in Belleville at the mouth of the Moira River to between 300 to 400 m (a.s.l.) in the headwater areas. The bedrock surface of the Precambrian rocks exhibits a rock-and-knob terrain which is characterized by low relief. The Palaeozoic rocks, on the hand, exhibit a gently sloping relief with elevation ranging between 75 m and 180 m (a.s.l.) and they control to a large extent the configuration of the present land surface topography in the lower one-third of the basin (Figure Mo-1).

A bedrock valley extends from the Clare River Valley through Stoco Lake to the lower reaches of the Moira River. Another bedrock valley can be traced along the Parks Creek Valley. The Clare River Syncline is a pronounced bedrock feature in the east-central portion of the basin where differential erosion of metamorphic rocks has produced a parallel drainage system (Sibul et al.1974).

The Precambrian rocks consist of plutonic, metasedimentary, and metavolcanic rocks. These rocks outcrop in the northern two-third of the basin and are part of the Canadian Shield. The plutonic rocks consist of granite, syenite, diorite, gabbro, anorthosite, and amphibolite; the metasedimentary rocks consist of paragneiss, pellitic schists and gneisses, marble, and para-amphibolite; and the metavolcanic rocks consist of basic volcanics, greenstone, and pillow lava.

The Palaeozoic rocks in the southern part of the basin are of Middle Ordovician age. These rocks belong to the Shadow Lake Formation of the Basal Group and the Gull River, Bobcaygeon, Verulam and Lindsay Formations of the Simcoe Group. The Shadow Lake Formation separates the Palaeozoic rocks from the older Precambrian rocks. Outcrops of this formation have been found at a number of locations along the eastern boundaries of the basin at McGuire Settlement. The outcrops consist of red and green shale, sandstone, and arkose. Overlying the Shadow Lake Formation is a series of limestones and shales of the Simcoe Group (Figure Mo-2).

7.6 OVERBURDEN THICKNESS AND GEOLOGY

The overburden within the Moira River drainage basin consists of glacial, glaciofluvial, and glaciolacustrine sediments of Pleistocene age with alluvial and swamp deposits of Recent age. The overburden is missing over most of the northern tow-third of the basin. In most of the other areas the thickness of the overburden is less than10 m. Only in the kame moraine along the southwestern boundary of the basin does the thickness of the overburden increase to reach over 70 m. The moraine is approximately 25 km long and attains a relief of 60 to 90 m above the surrounding land surface (Figure Mo-3).

According to Barnett (1992), the glacial deposits in the basin consist of two tills, Map Unit 19 and Map Unit 20. These tills were deposited by minor oscillations of the ice margin of the Ontario lobe during the Two Creeks Interstadial.

The undifferentiated till of Map 19 is found in the lower parts of the basin extending from the City of Belleville to the vicinity of Roslin and Thresher Corners. The till, which forms a drumlinized till plain, has a sandy silt matrix which is high in carbonate content.

The undifferentiated till Map Unit 20 extends as a belt between the till of Map unit 19 and the Canadian Shield. The till outcrops within Dummer Moraine physiographic region and forms broad, gently undulating plains. In most areas, the till is thin and the ground surface is littered with large limestone and Precambrian boulders. The till itself is extremely stoney, has a sandy matrix, and is high in total matrix carbonate.

The glaciofluvial deposits in the basin consist of sand and gravel.Two esker ridges are prominent in the basin. One is the sand and gravel ridge that trends southwest from Marlbank to just south of Myrehall and the other, which is locally known as the Tweed Esker, is a narrow ridge of sand and gravel prominently displayed on the till plain between Tweed and Zion Hill. In addition, the kame moraine, which extends along the southwestern topographic boundaries of the basin, consists mainly of glaciofluvial deposits of sand and gravel, although till occurs at the surface in some elevated parts of the moraine.

Glaciolacustrine deposits of sand, silt, and clay form low plains drained by the Chrysal and Palliser Creeks, and an extensive but thin cover of clay is found in the plain north and northeast of Honeywell Corners.

Alluvial, peat and muck deposits of Recent age are found in river valleys and swamps (Figure Mo-4).

7.7 GROUND WATER OCCURRENCE IN THE BEDROCK

As indicated earlier, over 82 per cent of the wells in the Moira River drainage basin are bedrock wells and about half of these wells have been drilled in the Precambrian rocks. According to Sibul et al.(1974), most of the Precambrian wells obtain suitable supplies within the upper 15 m of the rock, although deeper wells do occur. The well water yield is a function of the number and size of fractures and joints encountered by a well. Since these openings may begin and end abruptly, follow complex trends, and possess strong directional orientation, well yields do vary considerably from place to place.

Some wells drilled in the Precambrian rocks have reportedly failed to obtain sufficient water for domestic uses, many domestic wells have yields less than 5 liters per minute, and some municipal wells at Deloro, Madoc and Tweed yields in excess of 900 liters per minute. The municipal wells are considerably deeper than most other wells constructed in the Precambrian bedrock. Sibul et al.(1974) indicate that the deep municipal wells are located in areas of relatively complex geology and it is likely that folding and faulting associated with metamorphism have resulted in the development of rechargeable fractures and joints at depth.

Singer et al.(1997) calculated the transmissivity values for a sample of 7,875 wells constructed within the Precambrian rocks in southern Ontario. The geometric mean of the sample's transmissivity values was estimated to be 4.2 m^2/day and the water-yielding capability of these rocks was assessed to be poor.

According to Sibul et al.(1974), the limestones of the Simcoe Group are the most common source of groundwater in the southern third of the basin. Water is obtained from a variety of depths in these rocks but most wells obtain suitable supplies from the upper 10 to 15 m. Yields from wells drilled in the limestones are variable but most are less than 5 liters per minute, which is only marginally adequate for domestic uses. Areas in the basin where well yields are greater than 5 liters per minute usually correspond with bedrock depressions where the overburden is thick and consists of water-bearing sands and/or gravels. Dry wells in the limestone occur randomly in the basin; however, the greatest concentration occurs near Lake Ontario.

Singer et al.(1997) calculated the transmissivity values for a sample of 6,414 wells constructed in the rocks of the Simcoe Group in southern Ontario. The geometric mean of the sample's transmissivity values was estimated to be 5.7 m^2/day and the water-yielding capability of the Simcoe Group was assessed to be fair.

Specific capacity data are available for 1,994 bedrock wells within the Moira River drainage basin. Of these, 835 wells (41.87%) have specific capacities less than 5 l/min/m (Figure Mo-5), 639 wells (32.05%) have specific capacities between 5 and 25 l/min/l (Figure Mo-6), 160 wells (8.02%) have specific capacities between 25 and 50 l/min/m (Figure Mo-7), and 360 wells (18.06%) have specific capacities higher than 50 l/min/m (Figure Mo-8). Based on the distribution of wells on Figure Mo-8, it is possible to conclude that the majority of the high capacity wells in the basin are located either within the Simcoe Group or within the Precambrian rocks.

7.8 GROUNDWATER OCCURRENCE IN THE OVERBURDEN

Sibul et al.(1974) noted that the overburden is a significant source of groundwater supplies only in the southwestern part of the basin. Elsewhere in the south the overburden is relatively thin and consists mainly of glacial till, which is normally a poor source of groundwater. Two main overburden aquifers were identified by Sibul et al.(1974) in the southwestern part of the basin: (1) thick sand and gravel deposits within the kame moraine along the southwestern edge of the basin, and (2) the sand deposits that adjoin this moraine and extend eastward along Chrysal and Palliser Creeks. A third overburden aquifer of sand and gravel is buried directly over the bedrock extending from the southern boundaries of the basin through Honeywell Corners and along Parks Creek.

Specific yields from a number of wells completed in the sands and gravels of the three aquifers exceed 50 l/min/m. However, in spite of these above average values, the specific capacities of most overburden wells are less than 5 l/min/m which indicates that most of the sands and gravels are not extensive and/or are poorly sorted. Water levels in most wells on the moraine are approximately 15 m deep.

Data related to short-term pumping tests are available for 383 overburden wells. The data indicate that 143 wells (37.33%) have specific capacities ranging from 1 to 5 l/min/m (Figure Mo-9), 133 wells (34.73%) have specific capacities between 5 and 25 l/min/m (Figure Mo-10), 42 wells (10.97%) have specific capacities between 25 and 50 l/min/m (Figure Mo-11), and the remaining 65 wells (16.97%) have specific capacities larger than 50 l/min/m (Figure Mo-12).

7.9 SUGGESTED BEDROCK MONITORING AREAS

Figure Mo-13 shows the locations of bedrock wells with specific capacities of over 50 l/min/m and the boundaries of suggested areas for monitoring of groundwater in the bedrock. The susceptibility of groundwater to contamination in the selected areas was determined based on information related to the thickness and type of overburden materials above the bedrock (Figure Mo-14).

Areas where groundwater in the bedrock is highly susceptible to contamination are defined as those areas where the bedrock is either near or at the surface or is covered by highly permeable sand and/or gravel deposits. Areas where the bedrock is moderately susceptible to contamination are those areas where the overburden above the bedrock contains clay or clay till deposits that are less than 3 m in thickness. Areas where the bedrock has a low susceptibility to contamination are those where the overburden contains clay or clay till deposits that are much more than 3 m in thickness. Areas where the bedrock has variable a variable susceptibility to contamination are those where the susceptibility changes within different parts of the area from high to moderate or low.

Based on the above definitions, three areas (A, B, and C) are proposed for groundwater monitoring within the bedrock. Area (A) is underlain by Palaeozoic rocks of the Simcoe Group and areas(B and C) are underlain by Precambrian rocks of the Canadian Shield.

Groundwater susceptibility to contamination within Area (A) is variable ranging from high to low and within areas (B and C) it is high. Area (A) is located in the lower part of the basin extending from Bay of Quinte northward to line that joins Lime Lake in the east to Drag Lake in the west. Area (B) extends from Stoco Lake to the vicinity of Madoc. Area (C) is located in the vicinity of Kaladar.

7.10 SUGGESTED OVERBURDEN MONITORING AREAS

Figure Mo-15 shows the location of overburden wells with specific capacities of over 50 l/min/m, and the boundaries of areas where groundwater within the overburden has a high or a variable susceptibility to contamination. Data related to well yields and the geology of overburden were used to determine the susceptibility of groundwater to contamination in these areas (Figure Mo-16).

Areas where the shallow overburden aquifers are highly susceptible to contamination are defined as those where sand and/or gravel deposits are either near or at the surface. Areas where shallow overburden aquifers are moderately susceptible to contamination are defined as those where the sand and/or gravel deposits are covered by clay or clay till deposits that are less than 3 m in thickness. Areas where the overburden aquifers have low susceptibility to contamination are defined as those where the overburden contains clay or clay till deposits that are more than 3 m in thickness. The term variable susceptibility to contamination is used for areas where the susceptibility of groundwater to contamination area ranges from low to high.

Based on the above definitions, three areas (D, E, and F) are proposed for groundwater monitoring in the overburden. The susceptibility of groundwater to contamination within Area (D) is variable, within Area (E) is mainly high, and within Area (F) is low.

Area (D) covers most of the Palliser Creek watershed and extends through the Moira River Valley to the vicinity of Plainfield. The area is covered with a sandy till and sand and clay deposits of glaciolacustrine origin.

Area (E) extends along the western boundaries of the basin from north of Moira through Halloway and Chatterfon to the headwaters of the Palliser Creek. The area contains a kame moraine which consists mainly of sands and gravels as well as the associated sands that adjoin the moraine along its eastern edge. The thickness of the sands and gravels ranges from 10 to 30 m above the bedrock. However, some well logs within Area (E) indicate the presence of less permeable materials above the sands and gravel.

Area (F) is located to the south of Stoco Lake. The area is underlain by glaciofluvial deposits and sandy till.

7.11 HISTORICAL GROUNDWATER MONITORING NETWORK

Fifteen historical monitoring wells have been identified in the basin. Of these, 12 are in the bedrock and three are in the overburden. The types and locations of these wells are as follows:

Well No. 122	An overburden well, 9.14 m deep, and located in Hasting County, Thurlow Township, Concession 6, Lot 22.
Well No. 123	A bedrock well, 21.95 m deep, and located in Hasting County, Tyendinaga Township, Concession 6, Lot 7.
Well No. 157	An overburden well, 4.27 m deep, and located in Hasting County, Hungerford Township, Concession 3, Lot 5.
Well No. 158	A bedrock well, 18.29 m deep, and located in Hasting County, Hungerford Township, Concession 2, Lot 13.
Well No. 159	A bedrock well, 7.62 m deep, and located in Hasting County,

	Huntingdon Township, Concession 13, Lot 13.
Well No. 161	A bedrock well, 10.97 m deep, and located in Hasting County, Elzevir and Grimsthorpe Township, Concession 4, Lot 3.
Well No. 162	An overburden well, 4.88 m deep, and located in Hasting county, Madoc Township,Concession 3, Lot 6.
Well No. 163	A bedrock well, 12.19 m deep, and located next to Well No. 162.
Well No. 209	A bedrock well, 21.64 m deep, and located in Hasting County, Hungerford Township, Concession 5, Lot 1.
Well No. 210	A bedrock well, 6.71 m deep, and located in Hasting County, Madoc Township, Concession 10, Lot 1.
Well No. 230	A bedrock well, 12.19 m deep, and located in Hasting County, Madoc Township, Concession 5, Lot 28.
Well No. 256	A bedrock well, 57.91 m deep, and located in Hasting County, Thurlow Township, Concession 6, Lot 23.
Well No. 324*	A bedrock well, 59.44 m deep, and located in Hsting County, Hungerford Township, Concession 2, Lot 1. Well contains two piezometers at depths of 17.07 m and 50.90 m.
Well No. 326*	A bedrock well, 13.71 m deep, and located in Hasting County, Hungerford Township, Concession 2, Lot 1.
Well No. 327	A bedrock well, 56.39 m deep, and located in Hasting County, Thurlow Township, Concession 6, Lot 13.
Well No. 554	A bedrock well, 17.68 m deep, and located in Hasting County, Sidney Township, Concession 5, Lot 13.

Figure Mo-17 shows the locations of the historical monitoring wells and Appendix I gives the geographic coordinates of these wells.

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Barnett, P.J. 1992. Quaternary geology of Ontario; Chapter 24 in: Thurston et al., Geology of Ontario, Ontario Geological Survey, Special Volume 4, Part 2. Ontario Geological Survey, Ministry of Northern Development and Mines, Ontario.

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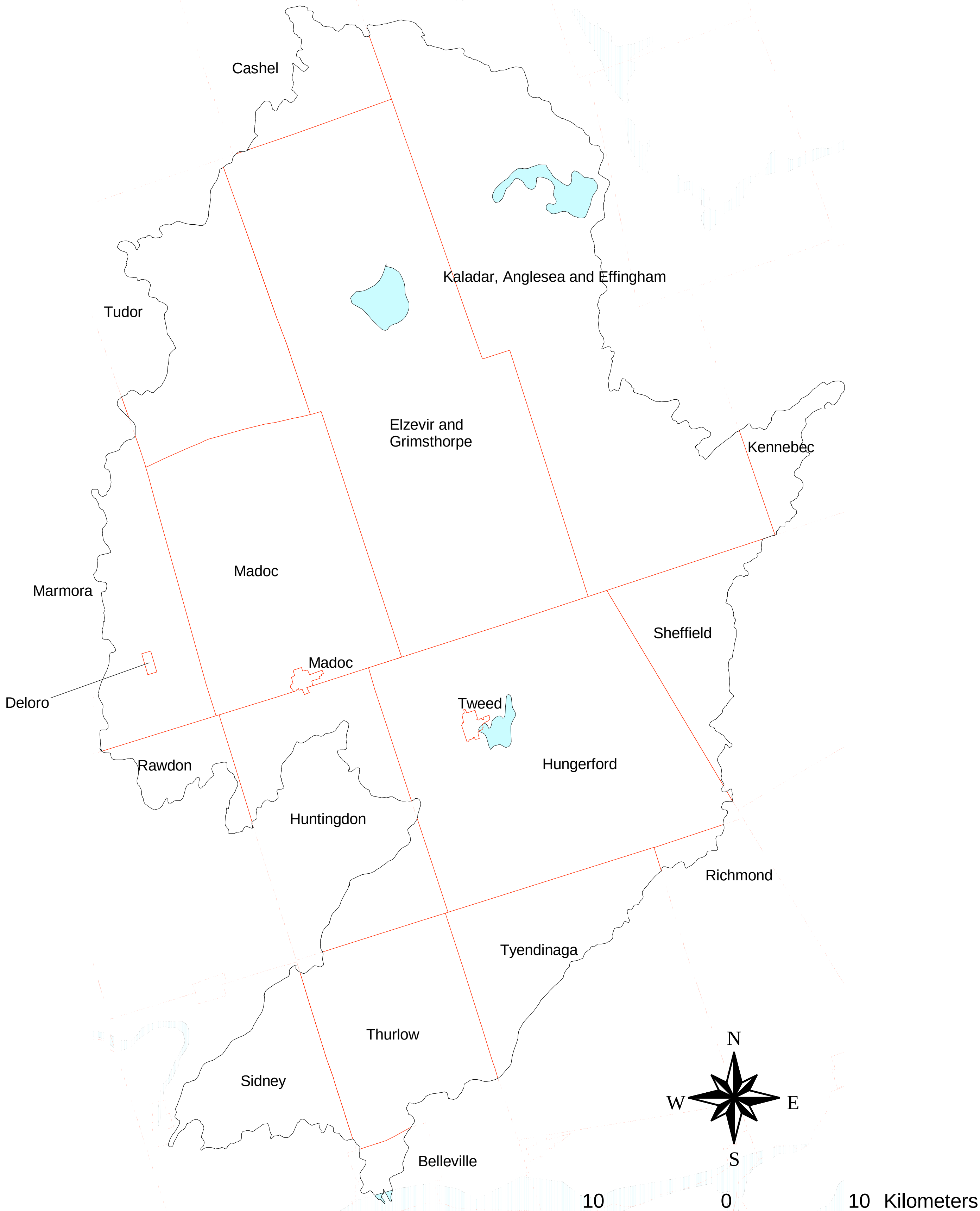
Thurston, P.C., Williams, H.R., Sutcliffe, H.R., and Stott, G.M., 1992. Geology of Ontario, Special Volume 4 Part 2. Ontario Geological Survey, Ministry of Northern Development and Mines, Ontario.

FIGURES



Key Map - Mo A transparency to be used with other figures for orientation purposes

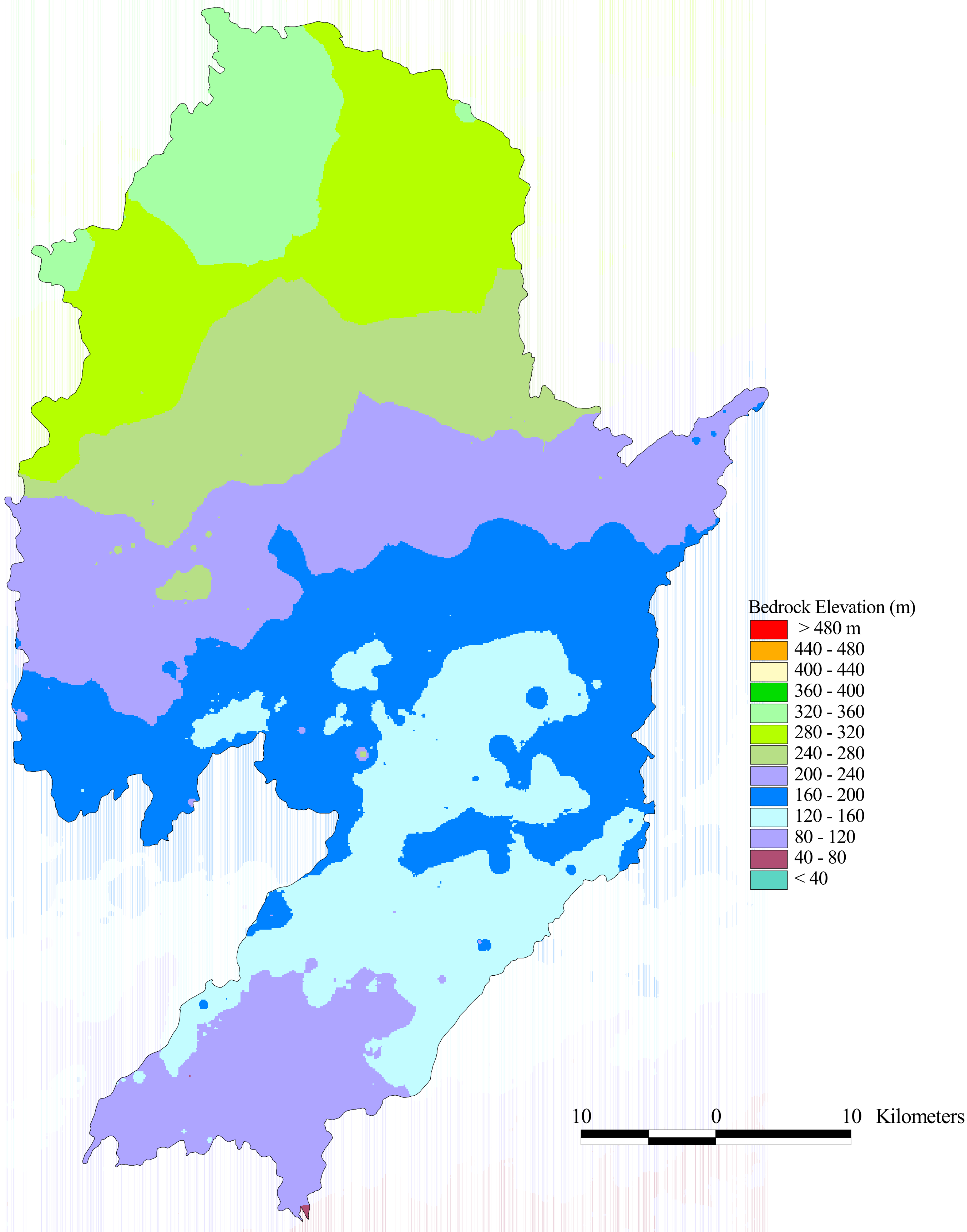


Figure Mo-1. Bedrock topography in the Moira River drainage basin.

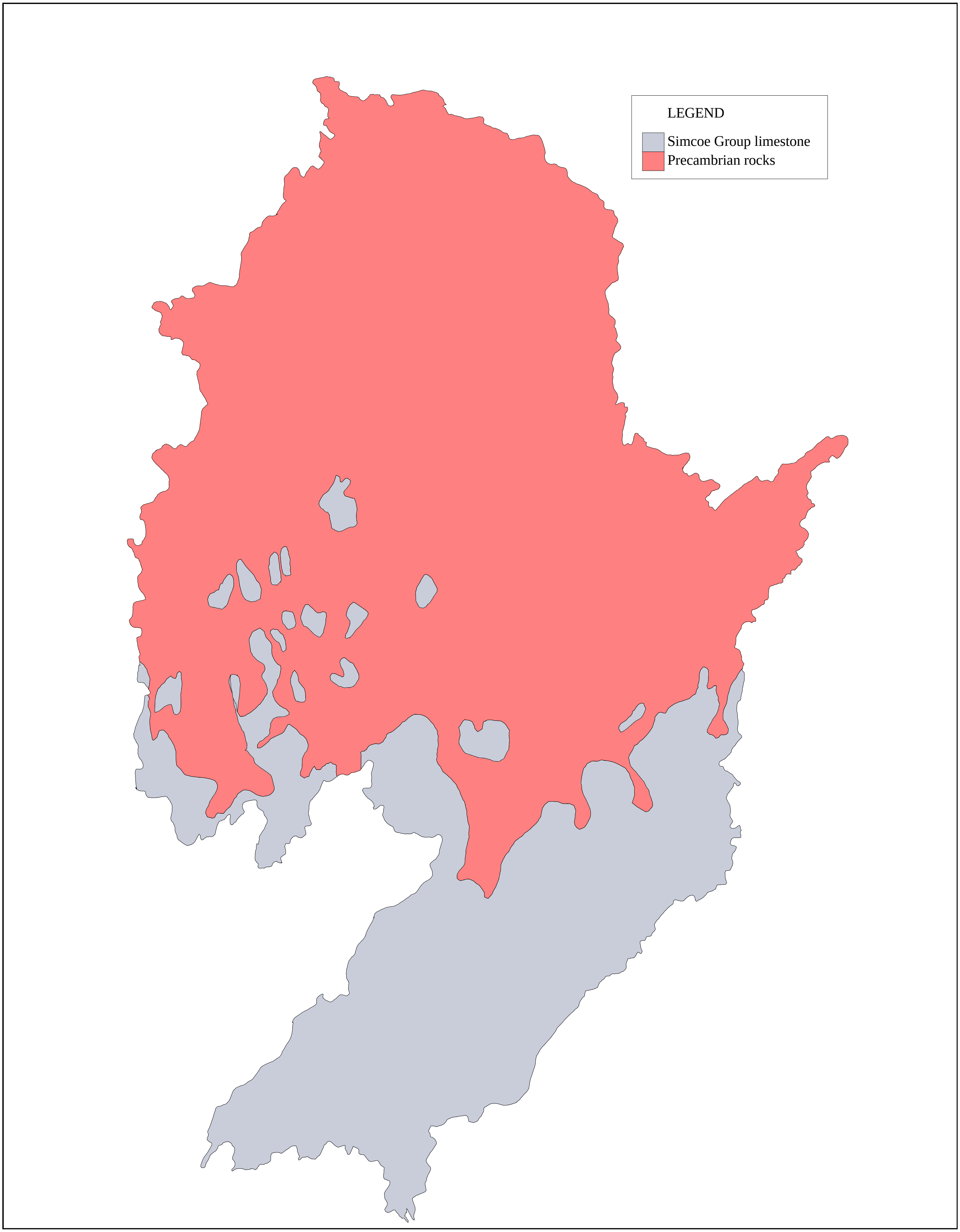


Figure Mo-2. Bedrock geology in the Moira River drainage basin.

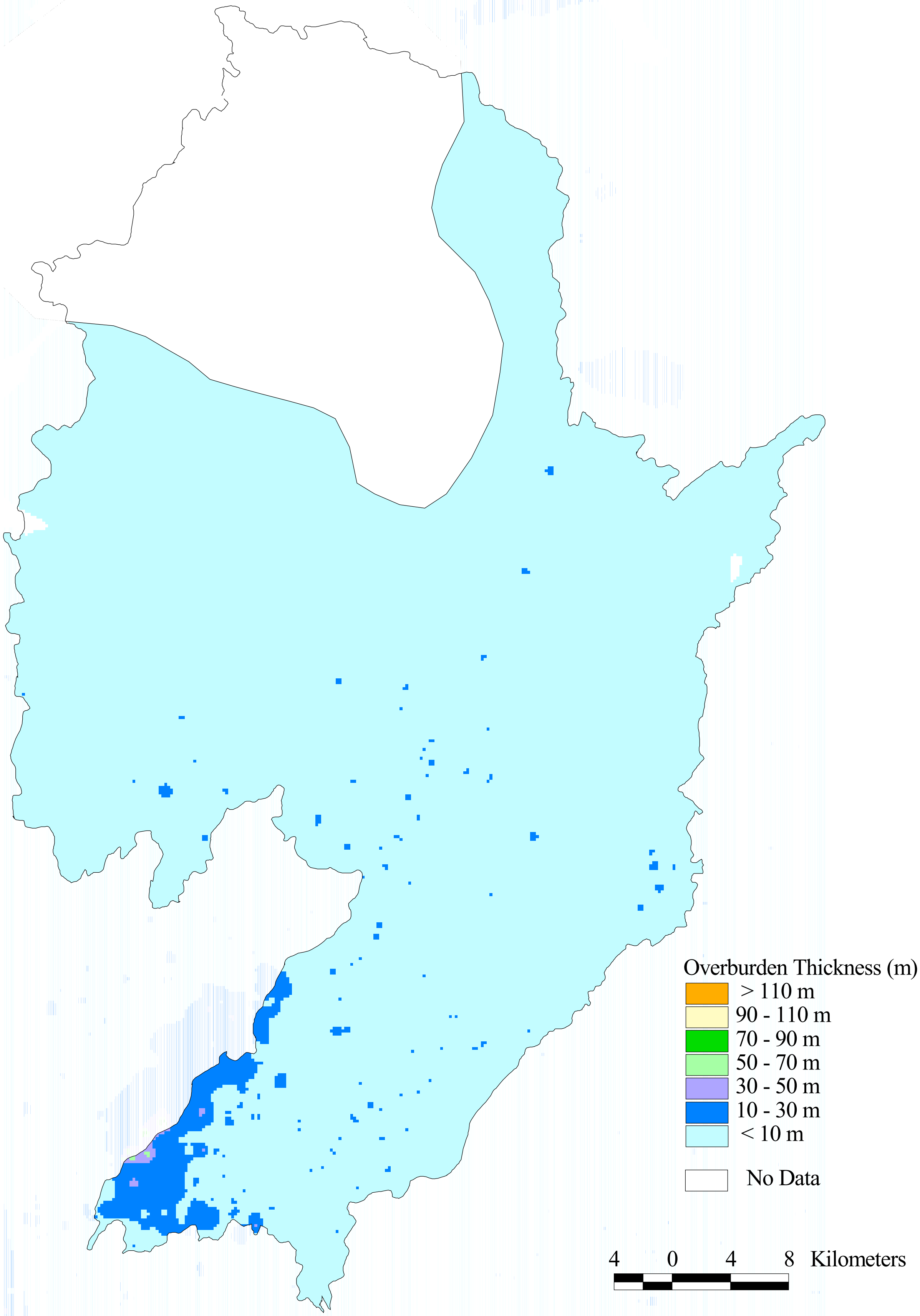


Figure Mo-3. Overburden thickness in the Moira River drainage basin.

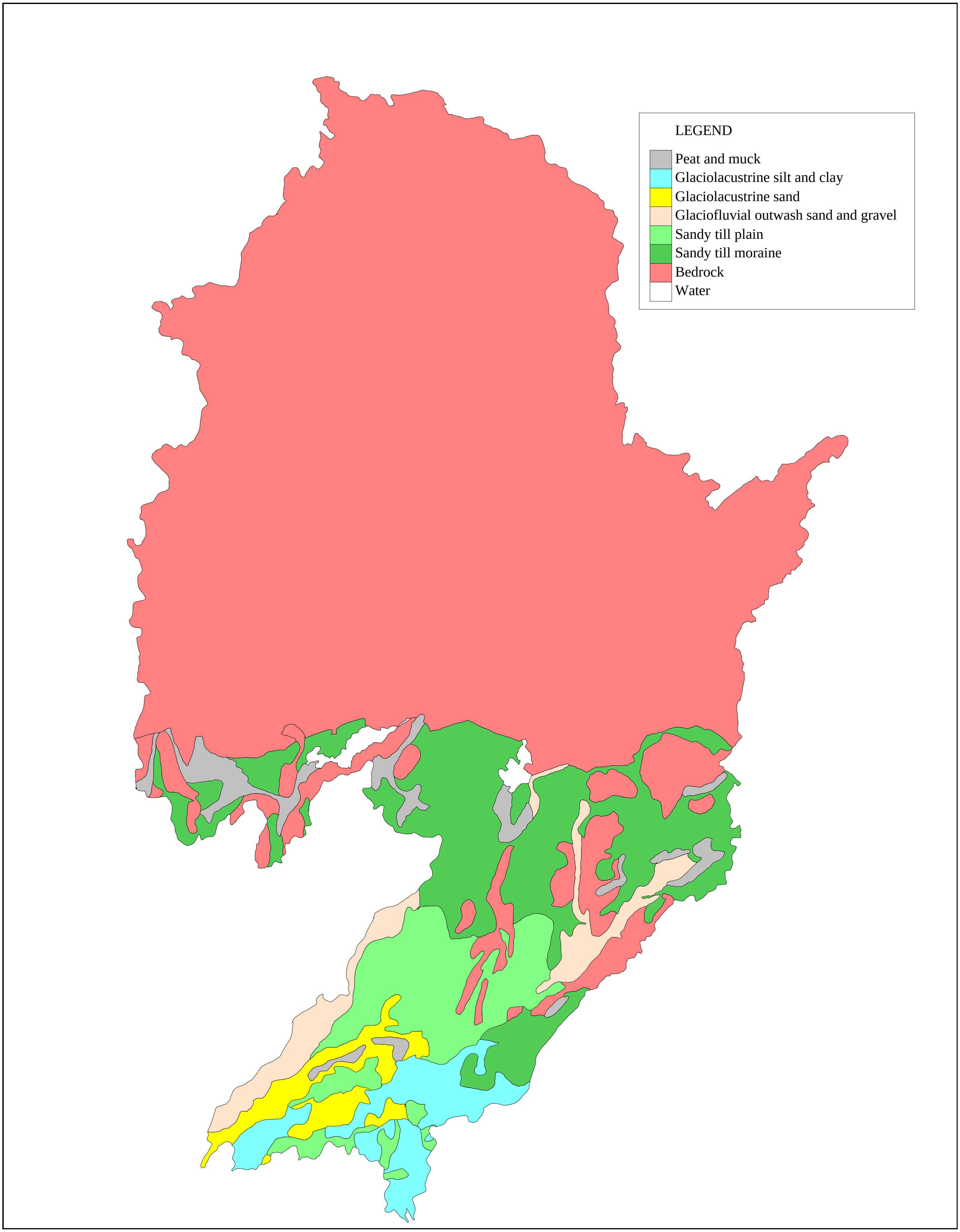


Figure Mo-4. Overburden geology in the Moira River drainage basin.

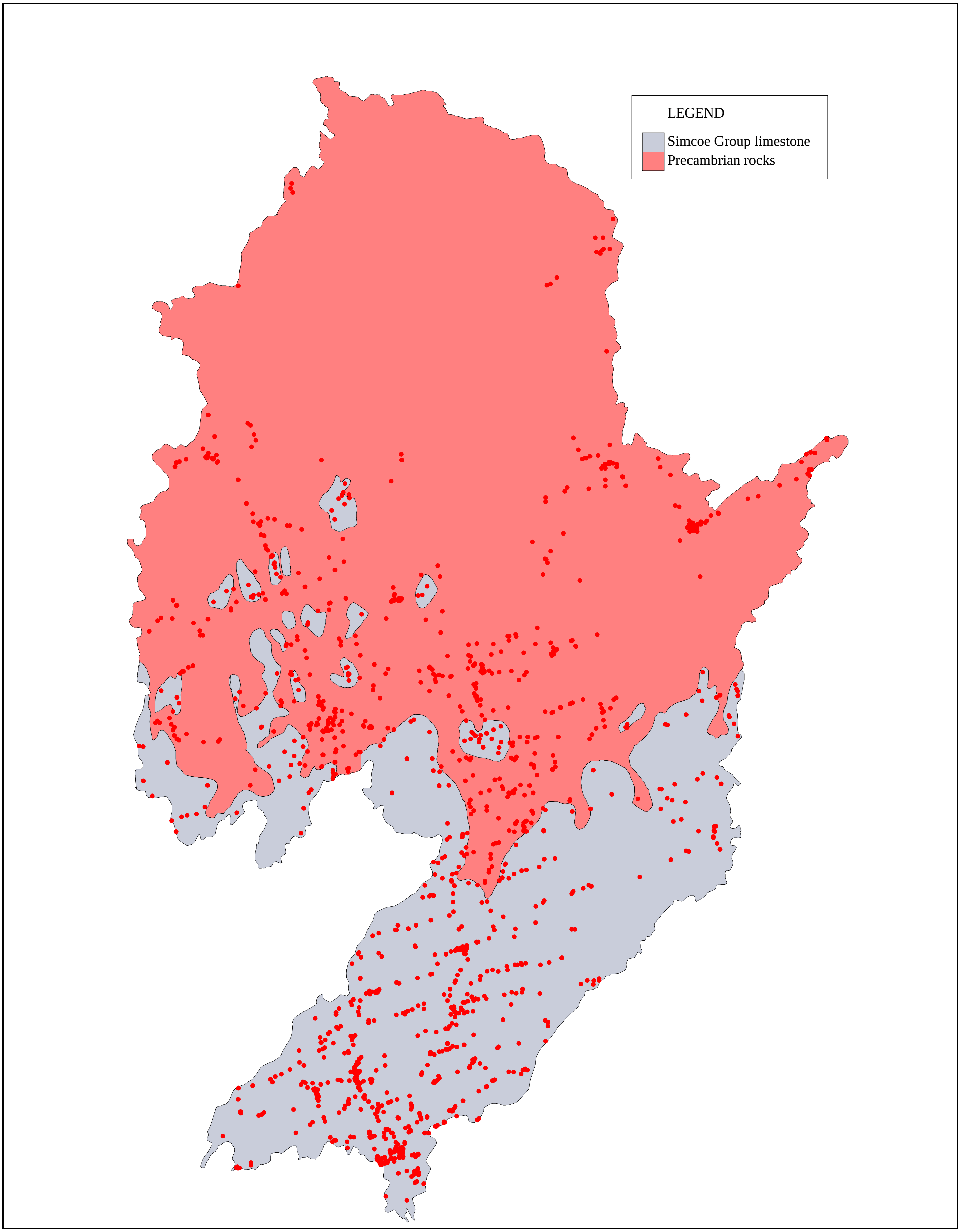


Figure Mo-5. Bedrock wells with specific capacities equal to or less than 5 l/min/m.

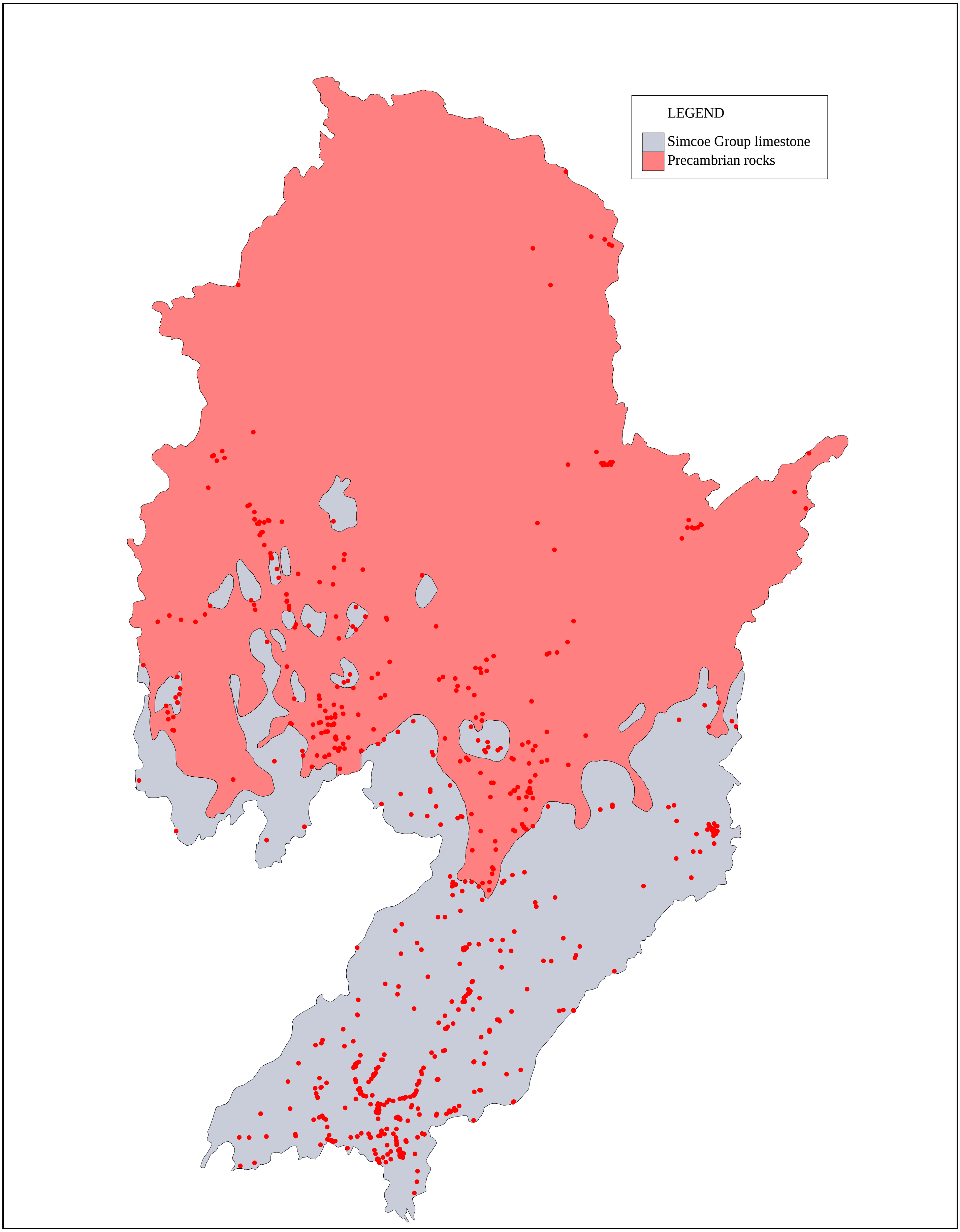


Figure Mo-6. Bedrock wells with specific capacities between 5 and 25 l/min/m.

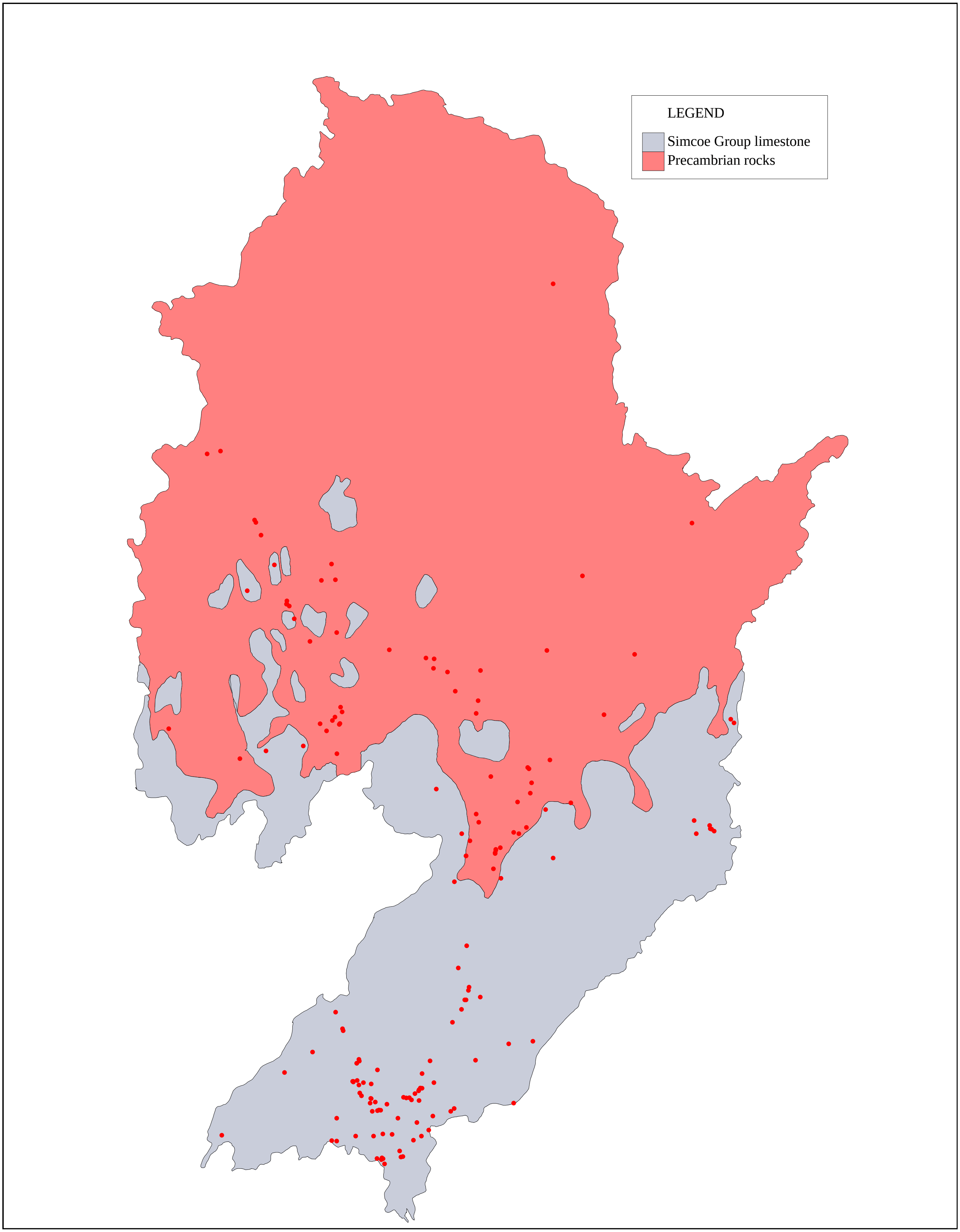


Figure Mo-7. Bedrock wells with specific capacities between 25 and 50 l/min/m.

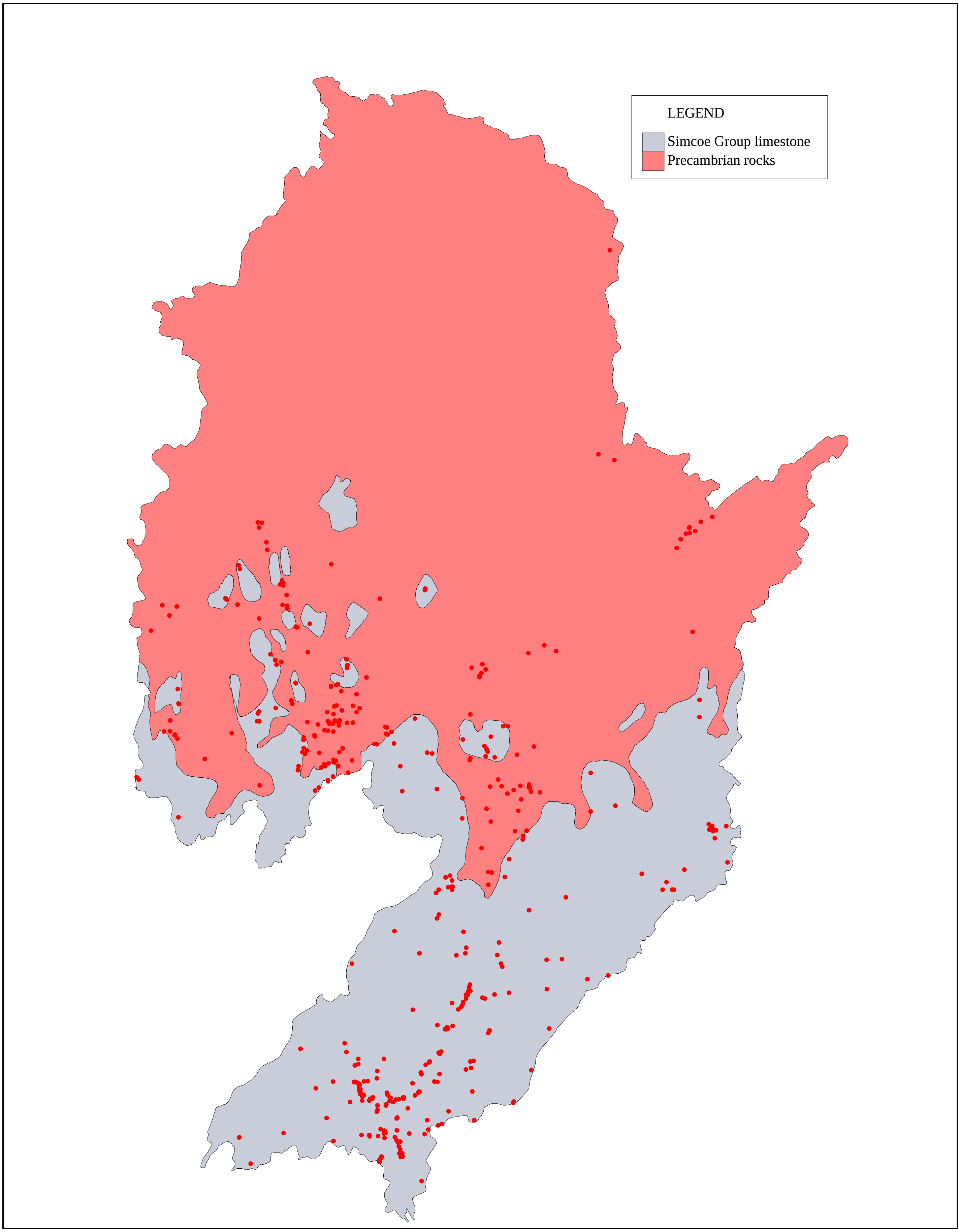


Figure Mo-8. Bedrock wells with specific capacities higher than 50 l/min/m.

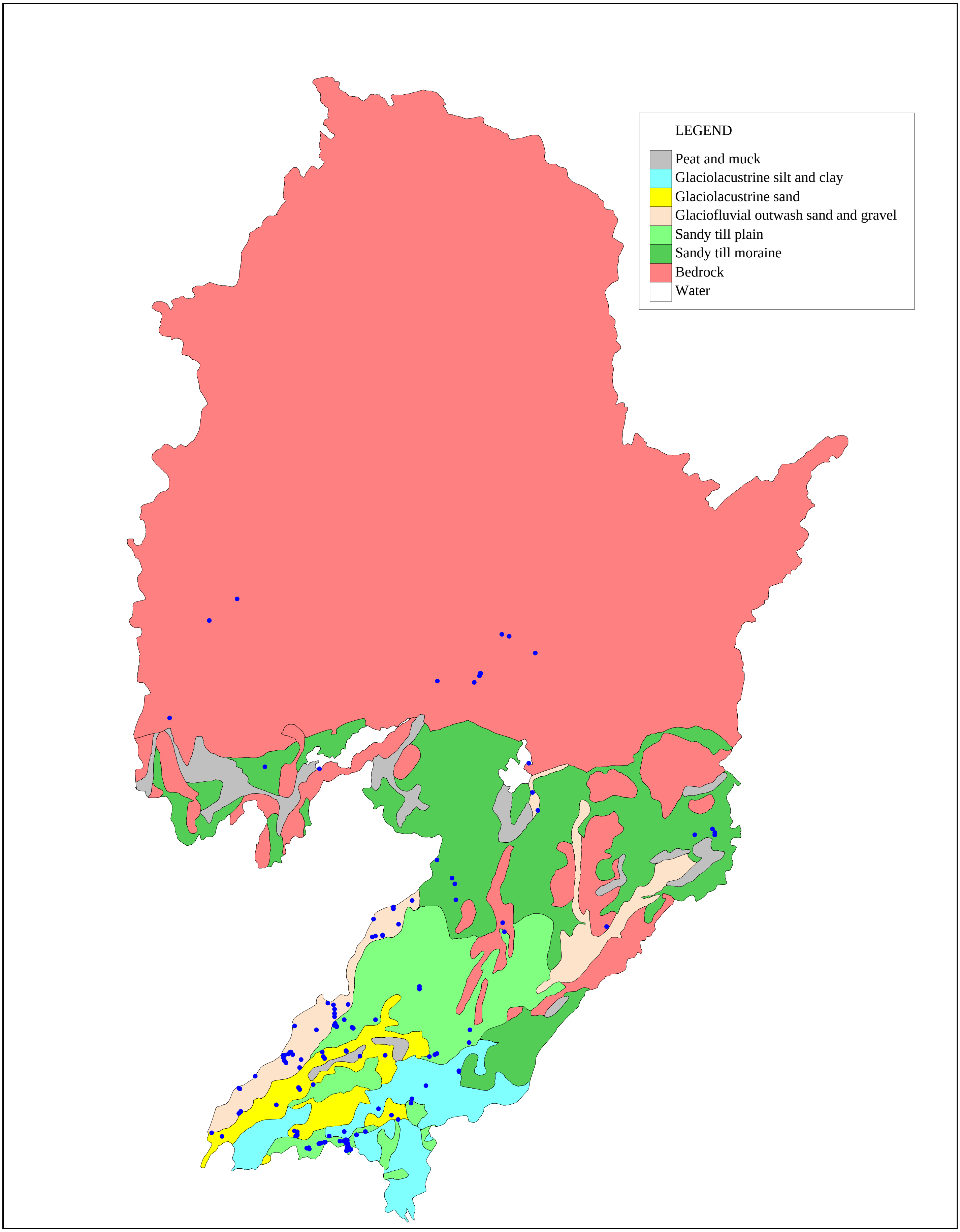


Figure Mo-9. Overburden wells with specific capacities equal to or less than 5 l/min/m.

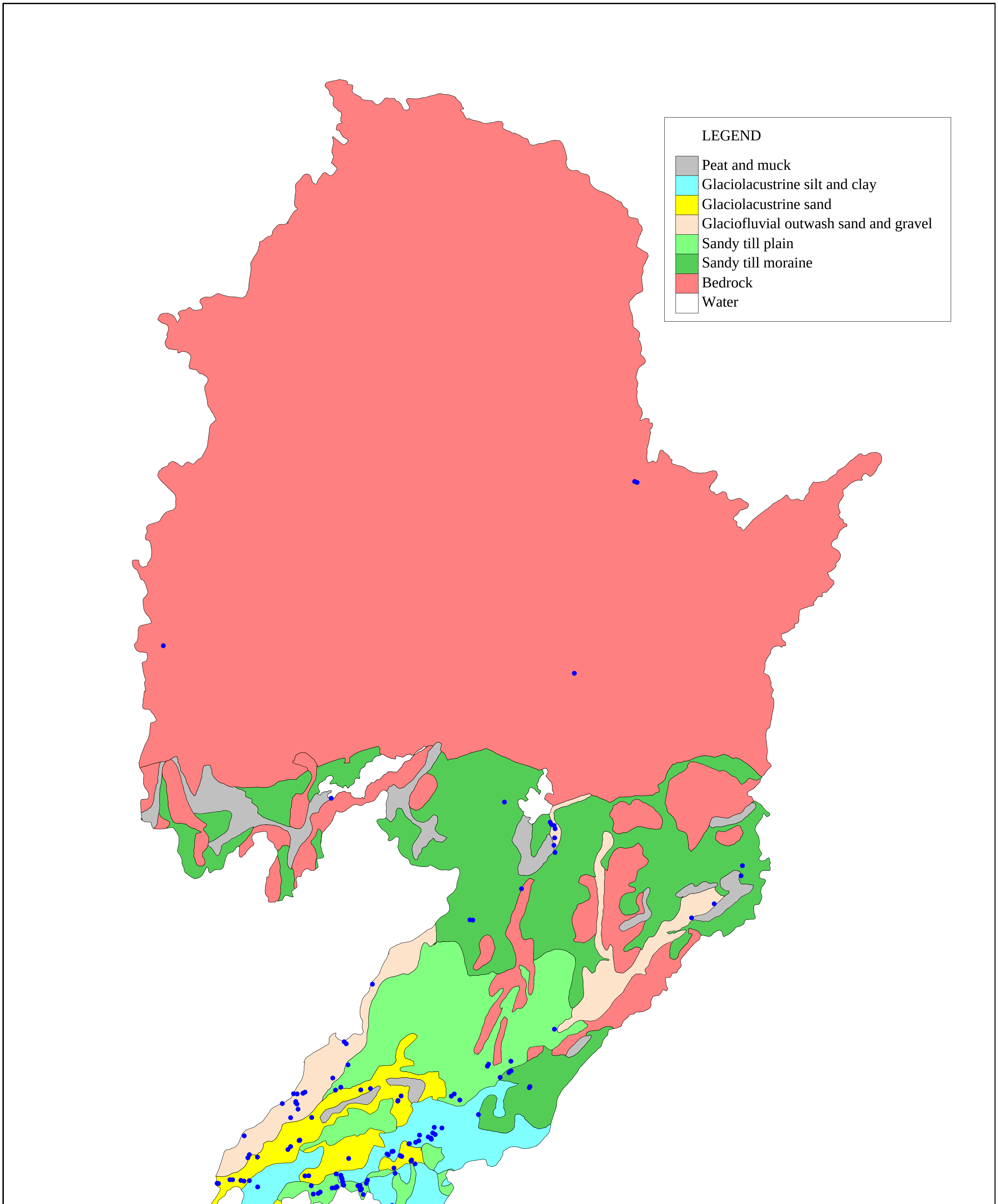


Figure Mo-10. Overburden wells with specific capacities between 5 and 25 l/min/m.

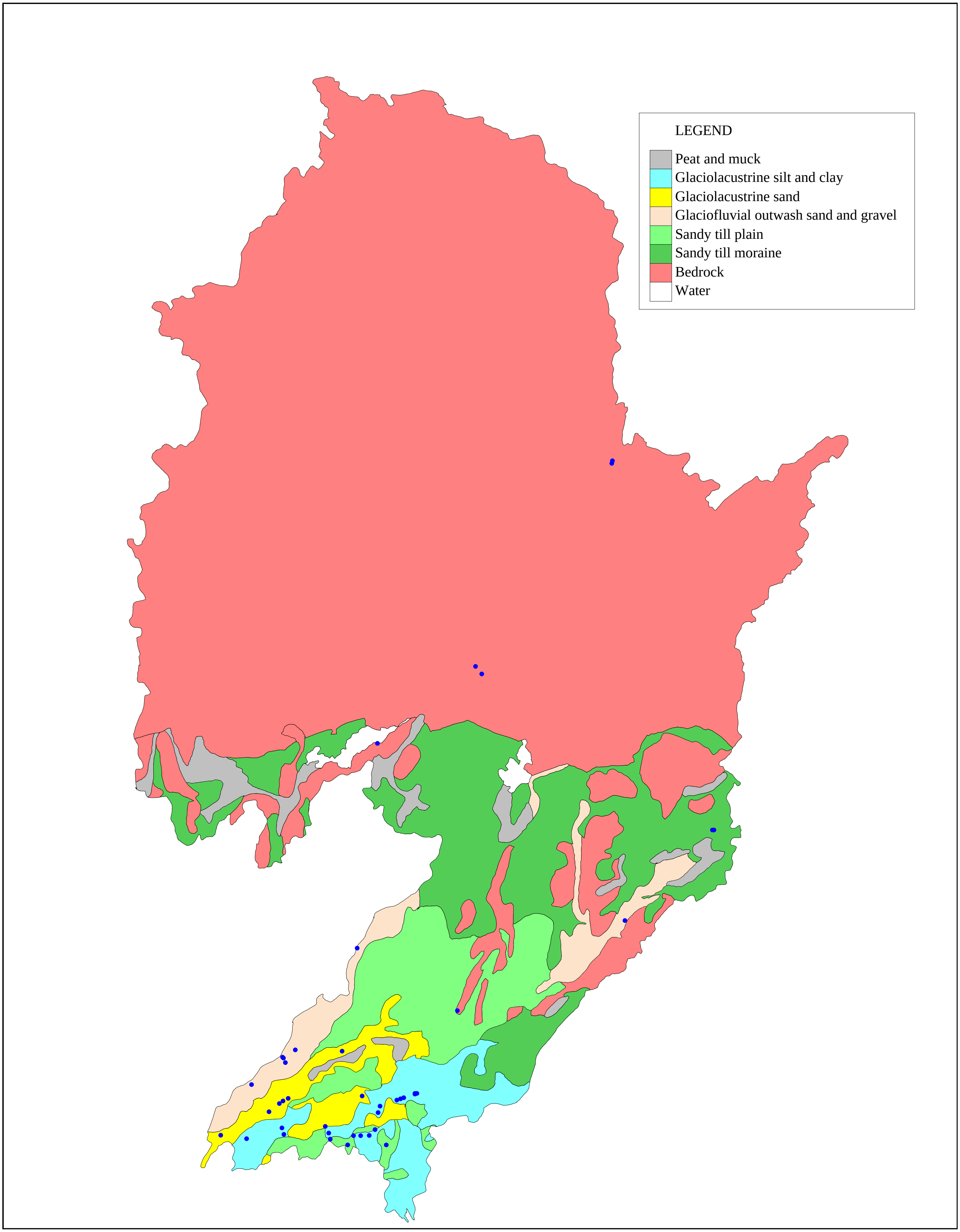


Figure Mo-11. Overburden wells with specific capacities between 25 and 50 l/min/m.

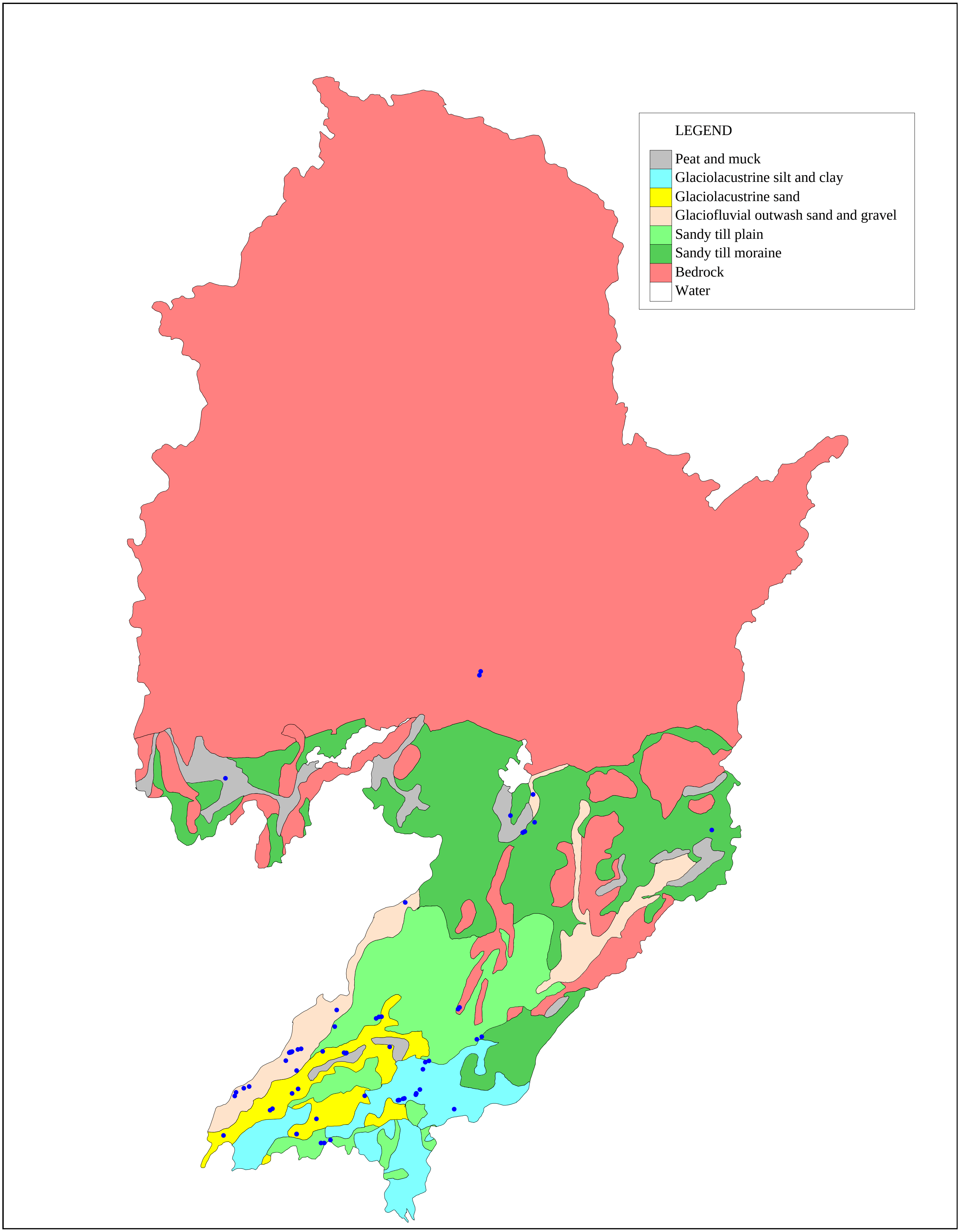


Figure Mo-12. Overburden wells with specific capacities higher than 50 l/min/m.

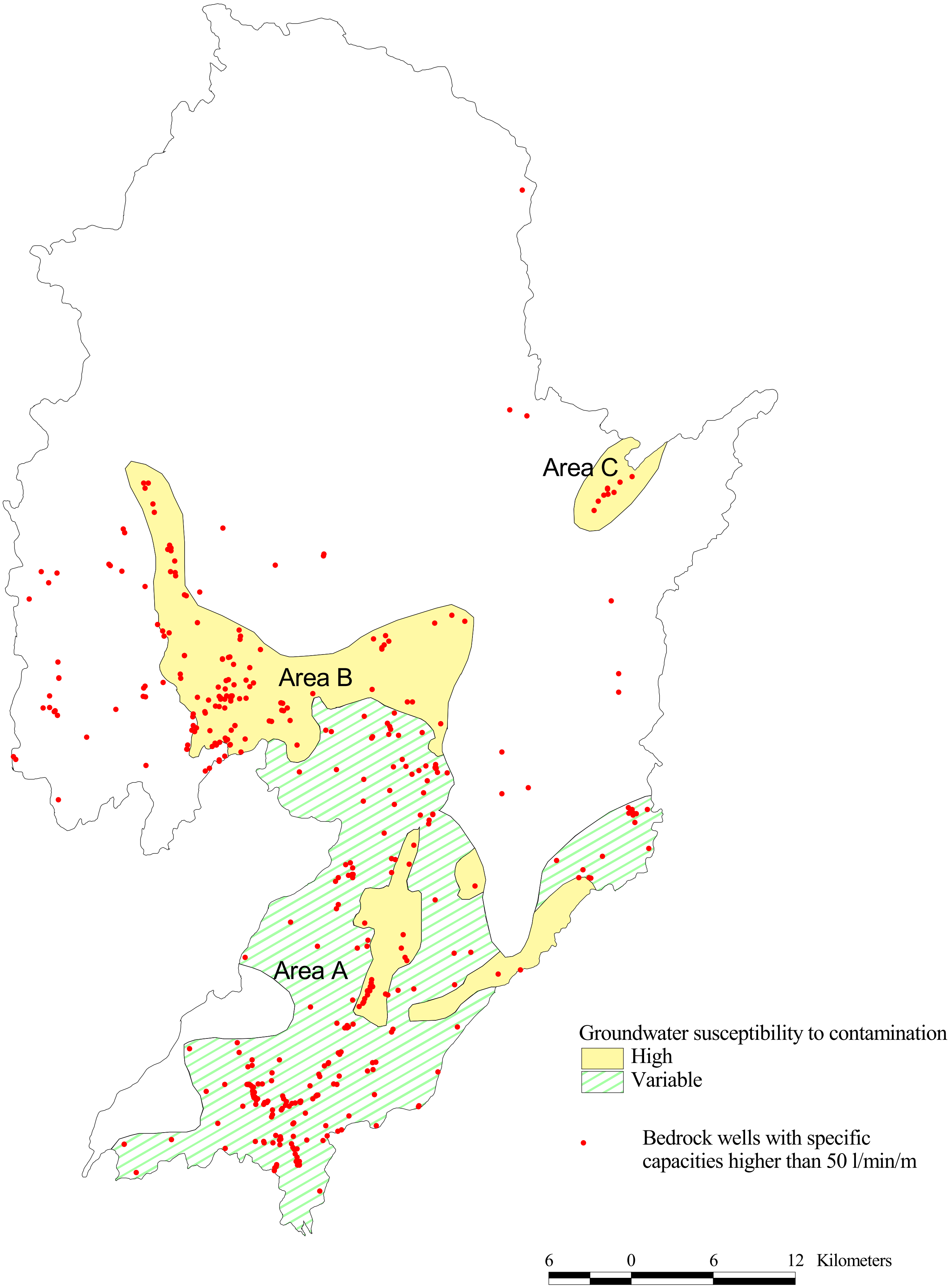


Figure Mo-13. Suggested areas for monitoring groundwater in the bedrock.

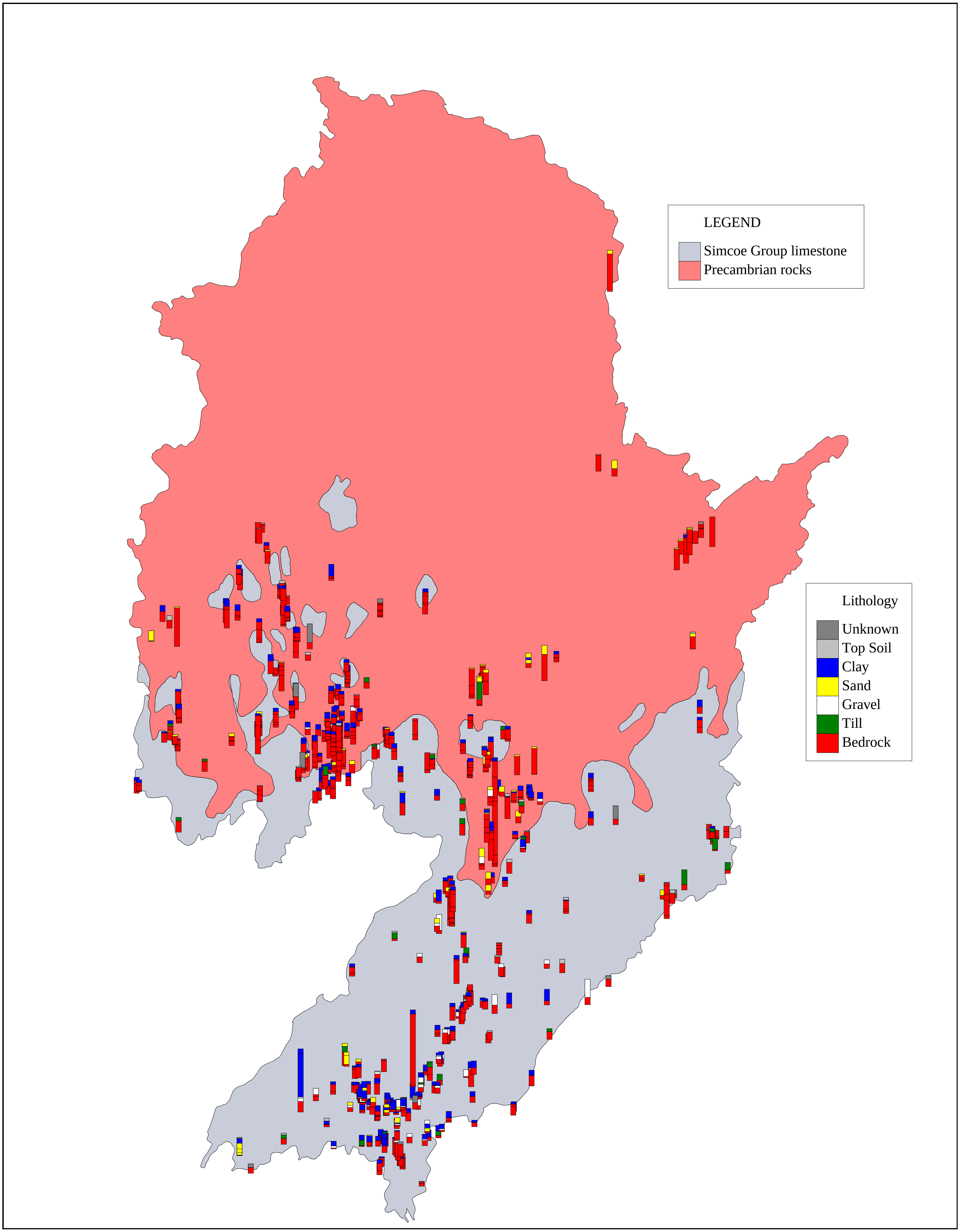


Figure Mo-14. Panel diagram showing the geologic logs of bedrock wells with specific capacities higher than 50 l/min/m.

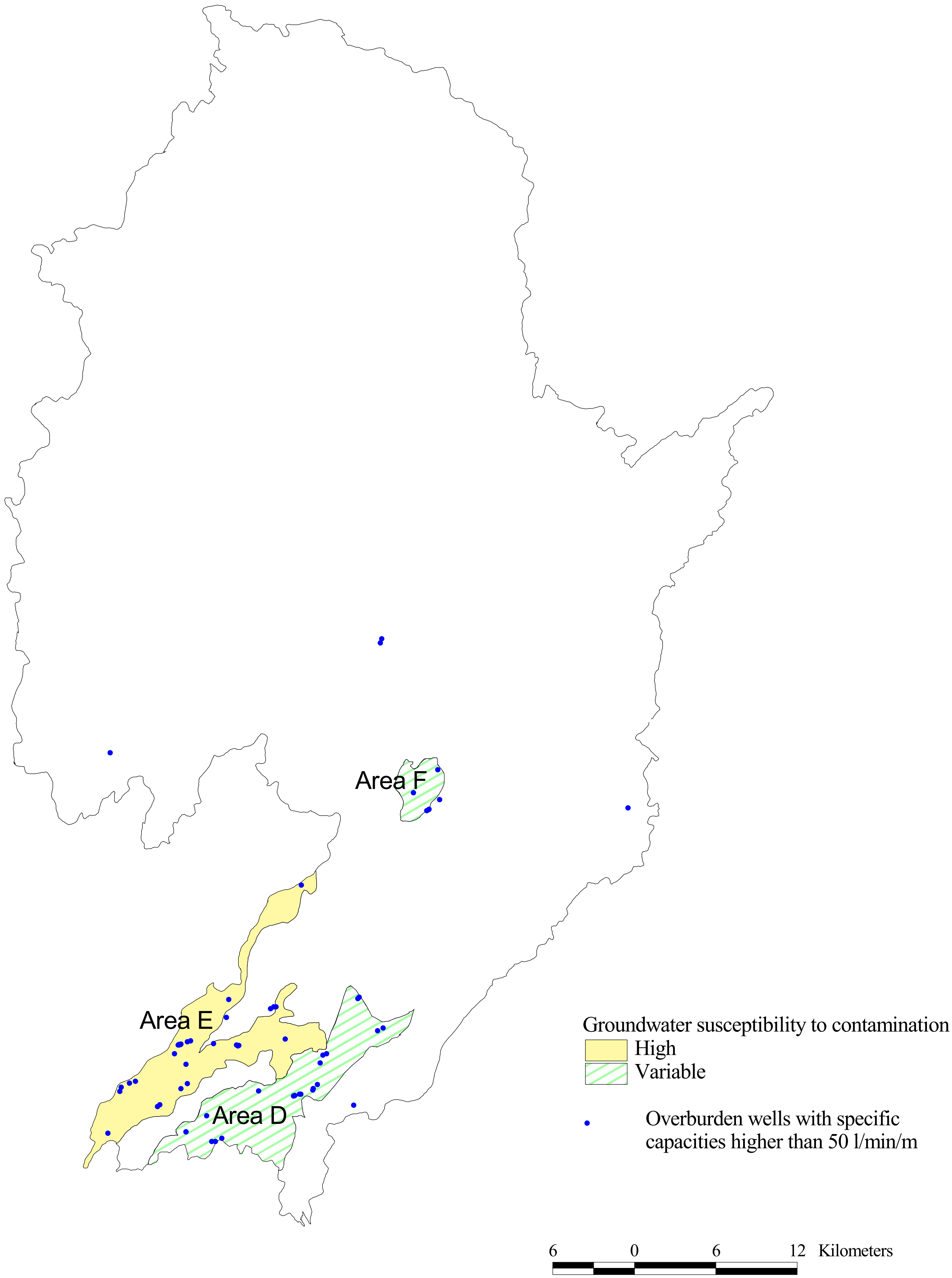


Figure Mo-15. Suggested areas for monitoring groundwater in the overburden.

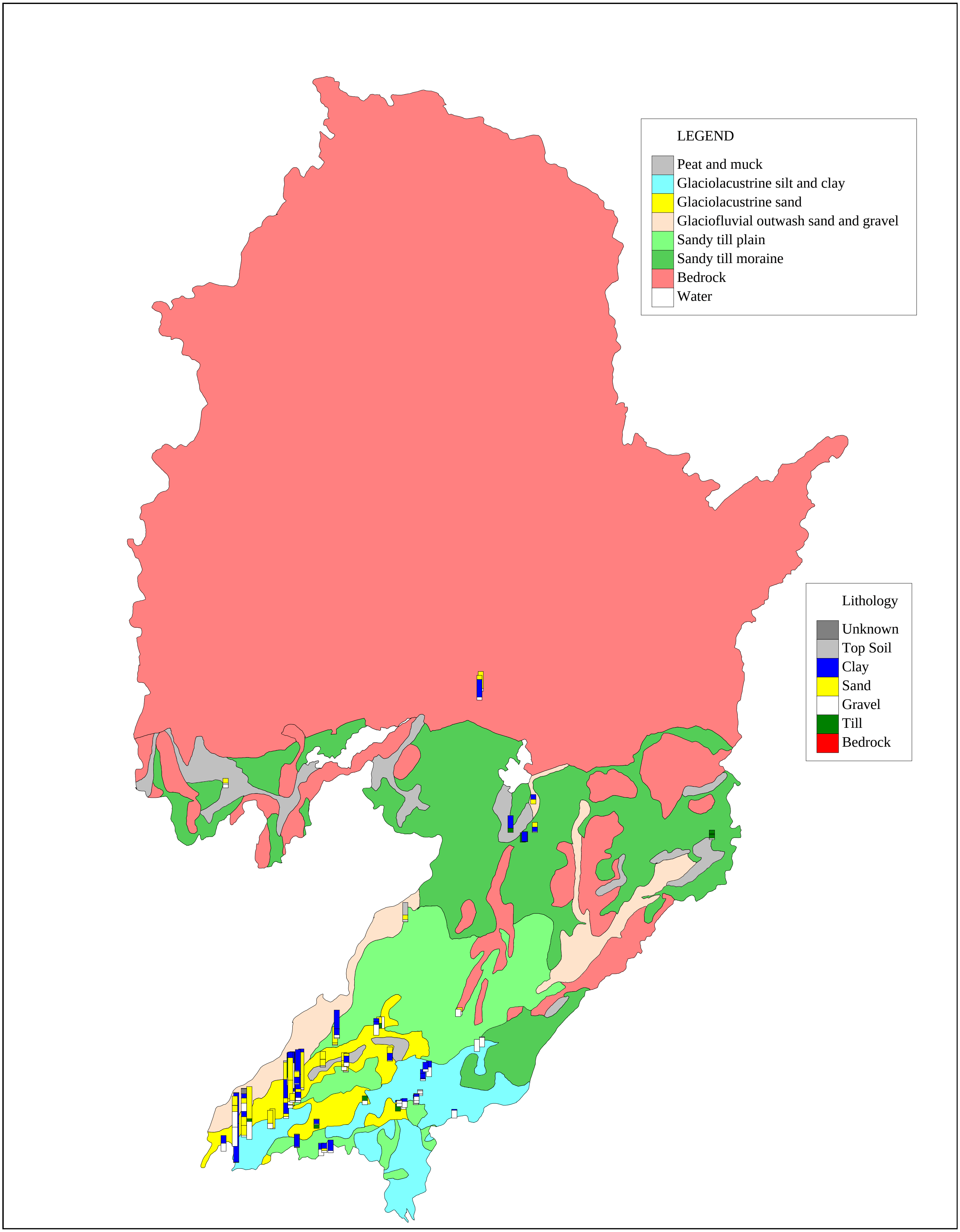


Figure Mo-16. Panel diagram showing the geologic logs of overburden wells with specific capacities higher than 50 l/min/m.

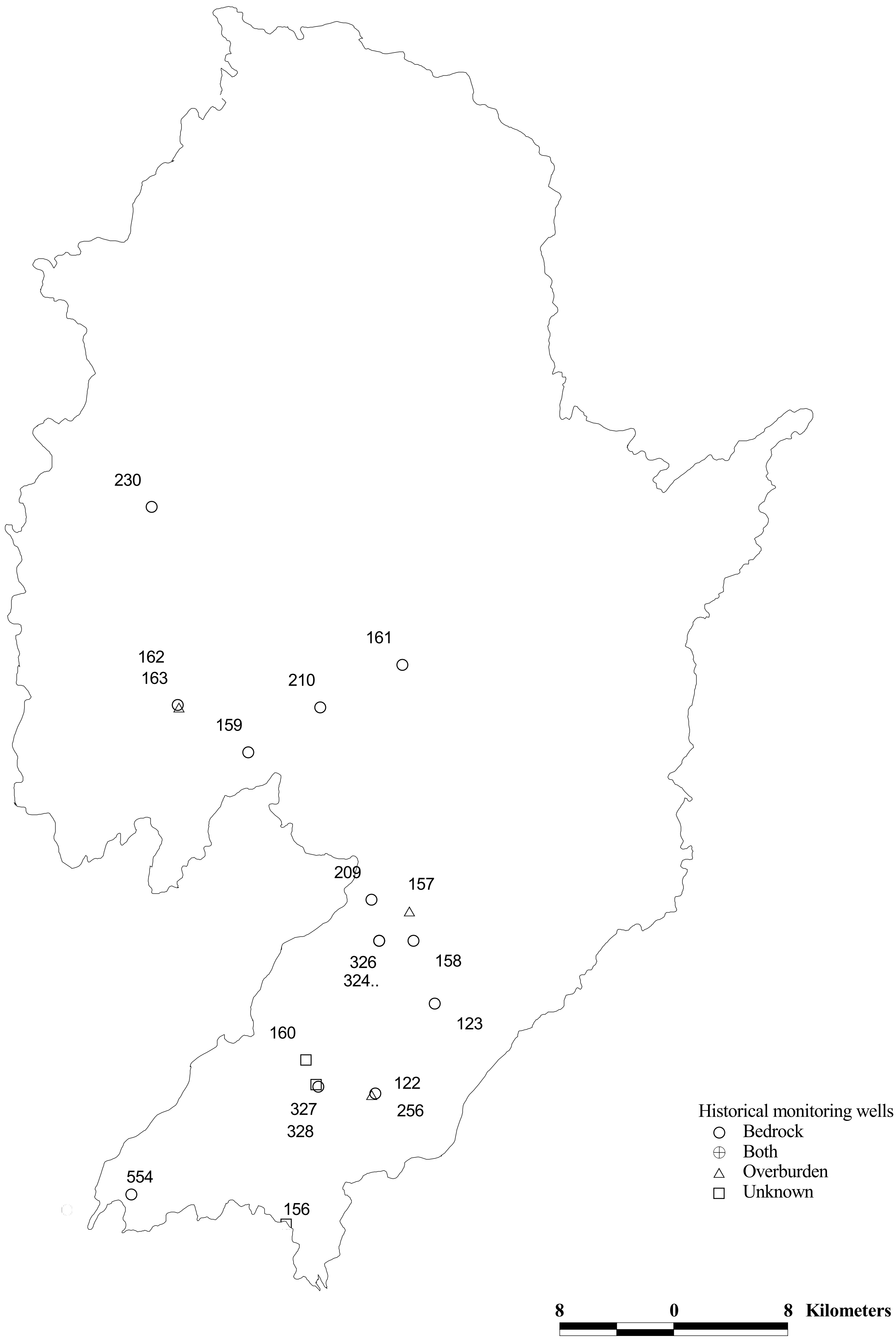


Figure Mo-17. Locations of historical monitoring wells in the Moira River drainage basin.