CHAPTER TWO

A PROPOSED GROUNDWATER MONITORING NETWORK FOR THE BIG OTTER CREEK DRAINAGE BASIN

By

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2.1 LOCATION

The Big Otter Creek drainage basin is located in southwestern Ontario between longitudes $80^0$29' and $80^0$57' W and latitudes $42^0$38' and $43^0$03' N. The creek and its tributaries drain an area of about 713 km^2 which comprises parts of the counties of Brant, Elgin, Middlesex, Norfolk, and Oxford.

The Big Otter Creek rises at an elevation of about 260 m above mean sea level (a.s.l.) near New Durham in the relatively flat and swampy northeastern corner of the basin, travels for a distance of about 77 km, and empties into Lake Erie at Port Burwell. The main tributaries to the Big Otter Creek are the Little Otter Creek, an un-named tributary at Bayham, the Stony Creek, the Branch Creek, and the Spittler Creek.

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.

2.2 LAND USE

The Big Otter Creek basin is almost entirely rural and includes only a few small urban settlements such as Tillsonburg, Norwich, Port Burwell and Vienna. The basin is a major producer of tobacco which is being cultivated mainly in the Norfolk Sand Plain. To maintain soil organic content on tobacco lands, rotation crops of rye and wheat are being cultivated. On heavier soils, corn, oats, hay and pasture are being grown and dairy farming is dominant. Also, woodlots are being maintained in poorly-drained areas.

2.3 GROUNDWATER USE

Groundwater is used in the basin to meet commercial, domestic, industrial, irrigation, livestock, and municipal needs. The availability of water and the amount required for a specific purpose dictates the method of groundwater extraction. The main types of extraction in the basin are wells and dugout ponds. The later are common in sandy soils where the water table is close to the ground surface.

The number of water wells within the Big Otter Creek basin is over 2500. Of these, about 85% are constructed in the bedrock and the remaining wells are in the overburden. Approximately, 36% of all the wells are used for rural domestic purposes and livestock watering. Also, the municipal systems for Norwich, Tillsonburg, and Otterville obtain their water supplies from groundwater sources.

Tobacco is planted extensively on the sandy soils in the basin and requires irrigation. Approximately 15% of the water used for Irrigation is from groundwater sources (wells and dugout ponds).

2.4 PHYSIOGRAPHY

The main land forms within the Big Otter Creek basin are the result of sediment deposition, erosion, and modification that occurred during glacial and post-glacial times of the Quaternary Period. These forms are comprised of end moraines, a ground moraine, the Norfolk Sand Plain, kettles, spillways, and abandoned shorelines.

Chapman and Putnam (1984) identified two main physiographic regions within the Big Otter Creek basin. The southeastern half of the basin, along the lowlands adjacent to the Big Otter Creek and the Little Otter Creek, exhibits gentle topography and is part of the extensive Norfolk Sand Plain which is a major physiographic feature of this part of Ontario. The Mount Elgin Ridges, which are located in the northern and northwestern parts of the basin, are characterized by high ridges and knob-and-kettle topography and are part of the Horseshoe Moraines physiographic region. The ridges include the St. Thomas, Norwich, and Tillsonburg end moraines.

The St. Thomas Moraine forms the northwestern boundary of the basin. It extends to the southwest from Mount Elgin as a high, well-developed ridge and to the northwest as a gently rolling feature. Southeast of St. Thomas Moraine, parallel to it, and separated from it by sand and till plains, is the Norwich Moraine. This moraine extends from just north of Norwich to Delmer as a relatively subdued and gently rolling ridge. The Tillsonburg Moraine, which is a well-developed ridge that marks the northeastern boundary of the basin, curves west and crosses the basin just north of Tillsonburg and then curves south and forms part of the western boundary of the basin.

A small ridge, which has in some places a topography characteristic of an end moraine, is located in the lower part of the basin and forms the divide between the Big Otter Creek and its tributary, the Little Otter Creek. The ridge has been mapped by Sibul (1969) as an extension of the Paris Moraine.

2.5 BEDROCK TOPOGRAPHY AND GEOLOGY

There are no bedrock outcrops in the Big Otter Creek basin, as the rock surface is now completely covered by glacial drift. The bedrock elevation ranges from about 250 m (a.s.l.) in the northern part of the basin to about 110 m (a.s.l.) near Port Burwell and appears to have a number of bedrock valleys (Figure Bi-1). The most prominent of these valleys is the one that occurs along the lower part of the Big Otter Creek and extends under most of the Little Otter Creek Valley. The general slope of the bedrock surface is toward the south at an average of 3 meters per kilometer.

Sanford (1958) identified four Palaeozoic formations within the Big Otter Creek basin, the Bass Island Formation of Silurian age, and the Delaware, Detroit River Group, and Bois Blanc Formations of Devonian age. Thurston et al. (1992), however, mapped the Delaware Formation as part of the Detroit River Group.

Figure Bi-2 shows the bedrock geology of the basin. The Bass Island Formation subcrops at the extreme northeastern corner of the basin and consists of grey to brown, fine granular dolomite. The Devonian Bois Blanc Formation subcrops as a band that crosses the northern part of the basin and consists of grey limestone and sandy limestone and dolomite with abundant nodular chert. Most of the basin is underlain by rocks of the Detroit River Group which consist of brown and buff limestone and dolomite that grade upward to finely crystalline limestone, with interbedded black shale.

2.6 OVERBURDEN THICKNESS AND GEOLOGY

The thickness of the overburden varies from about 15 m at the northern end of the basin to about 90 m at its southern end. The thinnest overburden deposits (15-30 m) extend along the valley of the Big Otter Creek from Tillsonburg in the center of the basin to Hatchley at its northeastern end. The thickest deposits (more than 75 m), on the other hand, are found in the lower parts of the basin and along its western boundaries (Figure Bi-3).

The overburden consists of glacial, glaciofluvial, and shallow-water lacustrine and fluvial deposits of Pleistocene age as well as alluvium, beach, muck and swamp deposits of Recent age. Figure Bi-4 shows the overburden geology of the basin and the locations of overburden wells. Figure Bi-4 indicates that the glacial till deposits predominate in the northwestern parts of the basin where a number of morainic ridges occur. The shallow-water lacustrine and fluvial deposits, on the other hand, cover most of the low, flat areas in the southeastern parts of the basin.

According to Sibul (1969), the oldest till exposed in the Big Otter Creek basin is a compact, stony, sand till that contains many large boulders. This till is believed to be of the same age as the Catfish Creek Till. The silty clay to clayey silt till deposits that form the St. Thomas and Norwich moraines are believed to be lower Port Stanley Till. The silt to clay till with moderate amounts of stone and pebbles, which forms the Tillsonburg Moraine, is believed to be upper Port Stanley Till.

Also, the till cap over the extension of the Paris Moraine within the Big Otter Creek basin may have been formed during a pause in the retreat of the Port Stanley ice front or during a subsequent re-advance that deposited Wentworth Till. Finally, a rolling plain, underlain by silt till, lies between the northeastern extent of the St. Thomas and Norwich moraines. The surface of the plain has been reworked by lake waters and consequently the material is difficult to identify as till.

Most of the kame and outwash deposits of glaciofluvial origin within the Big Otter Creek basin are located along the St. Thomas Moraine near Holbrook, Burgessville, and Newark. Some outwash deposits also occur near the Tillsonburg Moraine.

Shallow-water lacustrine and fluvial deposits cover the Norfolk Sand Plain. The deposits consist of fine- to-medium -grained, cross-bedded sand up to 25 m thick. Closely associated with these deposits are the remnants of abandoned shorelines which stand at elevations of 236 to 253 m (a.s.l.) and consist of beach sand and gravel, and sand dunes. These shorelines mark the locations of ancient glacial lakes Arkona, Whittlesey, and Warren.

Alluvial deposits are found along most of the Big Otter Creek. Also, bogs and swamps deposits are found in kettles, abandoned stream channels, and low depressions.

2.7 GROUNDWATER OCCURRENCE IN THE BEDROCK

According to Sibul (1969), water may be obtained anywhere in the basin from wells constructed in the bedrock but only in the northern half of the basin groundwater quality is generally fresh. Even there, the fresh water is restricted to the upper zone of the bedrock and deep wells will encounter mineralized water which is not of economic value at present. Therefore, the poor natural water quality of groundwater within the bedrock rather than the availability of water is the critical factor.

Sibul (1969) notes that the configuration of groundwater levels within the bedrock appears to be a subdued reflection of the surface topography. By and large, groundwater divides and local divides coincide closely with topographic divides. Groundwater flows towards the Big Otter Creek from elevations ranging from 280 to 300 m (a.s.l.) in the northwestern corner of the basin to elevations between 160 to 200 m (a.s.l.) in the lower end of the basin.

Figure Bi-2 shows the locations of all the bedrock wells within the Big Otter Creek basin. The figure indicates that there are no wells constructed within the Bass Island Formation and only 17 wells have been constructed within the Bois Blank Formation. All the remaining bedrock wells have been constructed within the Detroit River Group hydrogeologic unit.

Singer et al. (1997) estimated the geometric mean of the transmissivity distribution for the Bass Island Formation to be about 30 m^2/day based on a sample of 739 water wells in southwestern Ontario. Further, the authors estimated the geometric mean of the tranmissivity distribution for the Bois Blank Formation to be about 40 m^2/day based on a sample size of 1,069 wells, and the geometric mean of transmissivity distribution for the Detroit River Group to be about 31 m^2/day based on a sample size of 6,762 wells. The authors describe the water-yielding capabilities of the three hydrogeologic units as being very good to excellent.

Short-term pumping tests are available for 232 bedrock wells within the basin. Of these, 54 wells (23.3 %) have specific capacities less than 5 l/min/m (Figure Bi-5), 98 wells (42.2 %) have specific capacities between 5 and 25 l/min/l (Figure Bi-6), 20 wells (8.6 %) have specific capacities between 25 and 50 l/min/m (Figure Bi-7), and 60 wells (25.9 %) have specific capacities higher than 50 l/min/m (Figure Bi-8). Based on the spatial distribution of high capacity bedrock wells on Figure Bi-8, it is possible to conclude that the majority of these wells are located within the Detroit River Group.

2.8 GROUNDWATER OCCURRENCE IN THE OVERBURDEN

Compared to the bedrock, the overburden is a significant source of groundwater within the Big Otter Creek basin. The main overburden aquifers are the coarse, sorted sand and gravel deposits that are either exposed at the ground surface or exist at various depths within the overburden.

Figure Bi-5 shows the locations of the overburden wells within the Big Otter Creek basin. The figure indicates that the wells, with the exception of the lower end of the basin, are equally distributed throughout the basin. Figure Bi-6, however, indicates that most of the low capacity wells with specific capacities of less than 5 l/min/m are associated with the till deposits that extend over the northwestern half of the basin. On the other hand, the majority of the highly productive wells with specific capacities of over 50 l/min/m are associated with the Norfolk Sand Plain. The plain is permeable and thick enough in most places to provide adequate domestic supplies to water wells. Many springs have formed at the contact between the Norfolk Sand Plain and the underlying clay along the Little Otter Creek Valley. The springs have been developed for the Vienna water supply and for many domestic supplies.

The high capacity wells that are located within the morainic ridges and the intervening till plains obtain their water supplies from sand and gravel aquifers that occur at various depths within the overburden. The proportion of sand and gravel strata within the overburden decreases markedly toward the lower end of the basin.

Data related to short-term pumping tests are available for 1,240 wells in the basin. The data indicate that 336 wells (27.1%) have specific capacities ranging from 1 to 5 l/min/m (Figure Bi-9); 502 wells (40.5%) have specific capacities between 5 and 25 l/min/m (Figure Bi-10);125 wells (10.1%) have specific capacities between 25 and 50 l/min/m (Figure Bi-11), and the remaining 277 wells (22.3%) have specific capacities larger than 50 l/min/m (Figure Bi-12).

Figure Bi-12 indicates that the majority of the high-capacity wells within the basin are located in Norfolk Sand Plain. A number of high capacity wells are also found in areas where till deposits outcrop at the surface.

2.9 SUGGESTED BEDROCK MONITORING AREAS

Figure Bi-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 these areas was determined based on information related to the thickness and type of overburden materials above the bedrock (Figure Bi-14).

Areas where groundwater in the bedrock is highly susceptible to contamination are defined as those 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 defined as those 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 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 ranges from low to high.

Based on the above definitions, three areas (A, B, and C) are proposed for groundwater monitoring within the bedrock. Area (A) is located in the lower part of the basin extending from the western topographic boundaries to the vicinity of Bayham, area (B) extends from the northern topographic divide to Eden, and area (C) extends as a narrow band in the northeastern part of the basin.

Areas (A) and (B) are underlain by rocks of the Detroit River Group while area (C) is underlain by the rocks of the Bois Blanc Formation. Groundwater susceptibility to contamination is high within area (C) and variable within areas (A) and (B).

2.10 SUGGESTED OVERBURDEN MONITORING AREAS

Figure Bi-15 shows the location of overburden wells with specific capacities of over 50 l/min/m and the boundaries of suggested areas for groundwater monitoring. The susceptibility of groundwater to contamination in these areas was determined based on information related to the thickness and type of overburden materials (Figure Bi-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 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 high, and within areas (E) and (F) it is low. Area (D) occupies the eastern half of the basin within the Norfolk Sand Plain. Area (E) is underlain mostly by clayey silt to silty clay till and extends from Delmer at the western boundary of the basin to Newark in the north east. Area (F) is located in the north western corner of the basin and is also underlain by clayey silt to silty clay till.

2.11 HISTORICAL MONITORING WELLS

According to Sibul (1969), a number of monitoring wells were used during the study of the groundwater resources of the Big Otter Creek drainage basin. Some of these wells were equipped with automatic recorders and others were measured manually. The types and locations of these wells are as follows:

Well No.1	Well is located in Port Burwell, manual measurements.
Well No.2	Well is located east of Kinglake Station, manual measurements.
Well No.3	Well is located midway on road from Straffordville to Bayham, manual measurements.
Well No.4	Well is located at Corinth, manual measurements.
Well No.5	Well is located north west of Eden, it ends in sand, automatic

	recorder. The well is part of the historical monitoring network and known as well No. 187.
Well No.6	Well is located west of Courtland, manual measurements.
Well No.7	Well is located at Delmer, it ends in silt, automatic recorder.
Well No.8	Well is located on Highway 19, west of Tillsonburg Airfield, manual measurements.
Well No.9	Well is located southwest of Otterville, manual measurements.
Well No.10	Well is located southeast of Norwich, manual measurements.
Well No.11	Well is located midway on road from Newark to Norwich, manual measurements.
Well No.12	Well is located at Holbrook, it ends in till, automatic recorder.
Well No.13	Well is located alongside railroad between Tillsonburg and Sprinford, it ends in bedrock, automatic recorder. The well is part of the historical monitoring network and has two piezometers: one in overburden (piezometer No. 176) and the other in bedrock (piezometer No.177).
Well No.14	Well is located on road between Ranelagh and Hatchley, it ends in bedrock, automatic recorder. The well is part of the historical monitoring network. It has three piezometers, two in the overburden at 9 m and 18 m depths and one in the bedrock at 24 m depth. The piezometers were assigned numbers 173, 174 and 175, respectively.

In addition, three historical monitoring wells were used in the past to monitor groundwater in the basin. The types and locations of these wells are as follows:

Well No. 175	An overburden well, 24.38 m deep, and contains two piezometers; one (Piezometer 173) is at depth of 9.75 m and the other (Piezometer 174) is at depth of 16.76 m. The well is located in Brant County, Burford Township, Concession 13, Lot 19.
Well No. 177	A bedrock well, 37.49 m deep, and contains a piezometer (Piezometer No. 176) within the overburden at depth of 9.75 m. The well is located in Oxford County, South Norwich Township, Concession 9, Lot 27.
Well No. 187	An overburden well, 5.18 m deep, and located in Elgin County, Bayham Township, Concession 10, Lot 22.

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

REFERENCES

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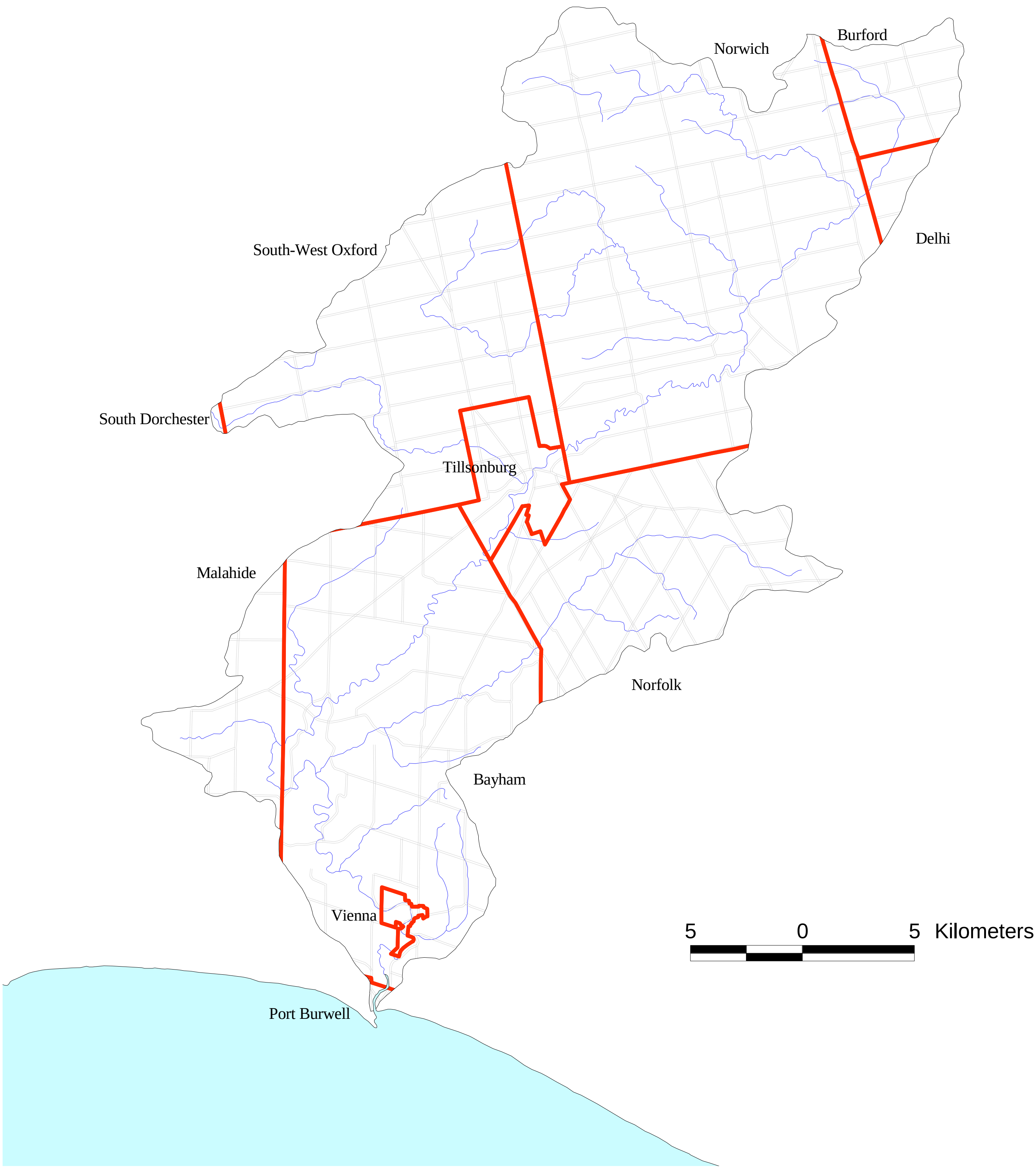
Singer, S.N., Cheng, C. K., and Scafe, M.G. 1997. The hydrogeology of southern Ontario; Volume 1, Hydrogeology of Ontario Series (Report 1), Ministry of the Environment, ISBN 0-7778-6006-6.

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 - Bi A transparency to be used with other figures for orientation purposes

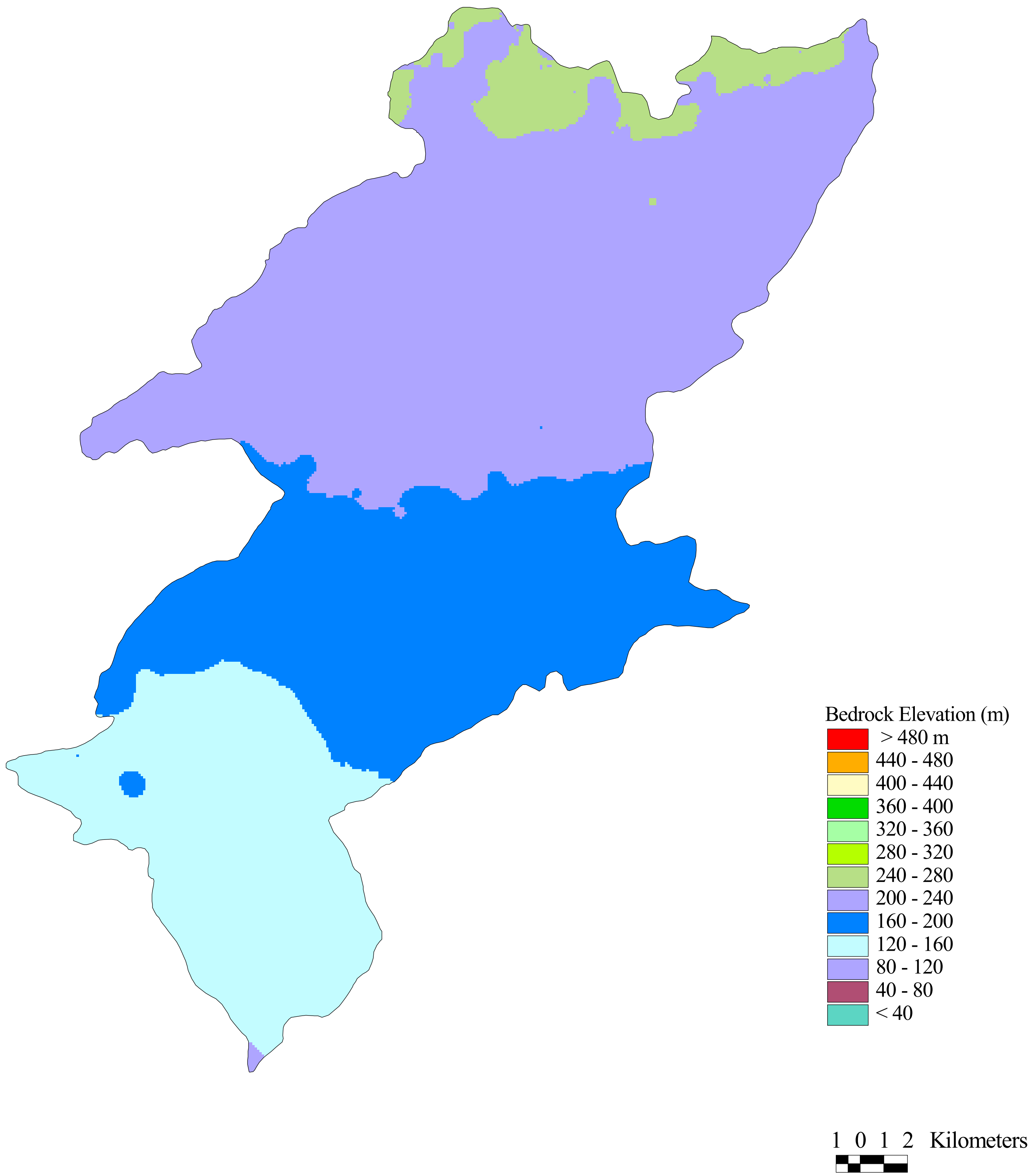


Figure Bi-1. Bedrock topography in the Big Otter Creek drainage basin.

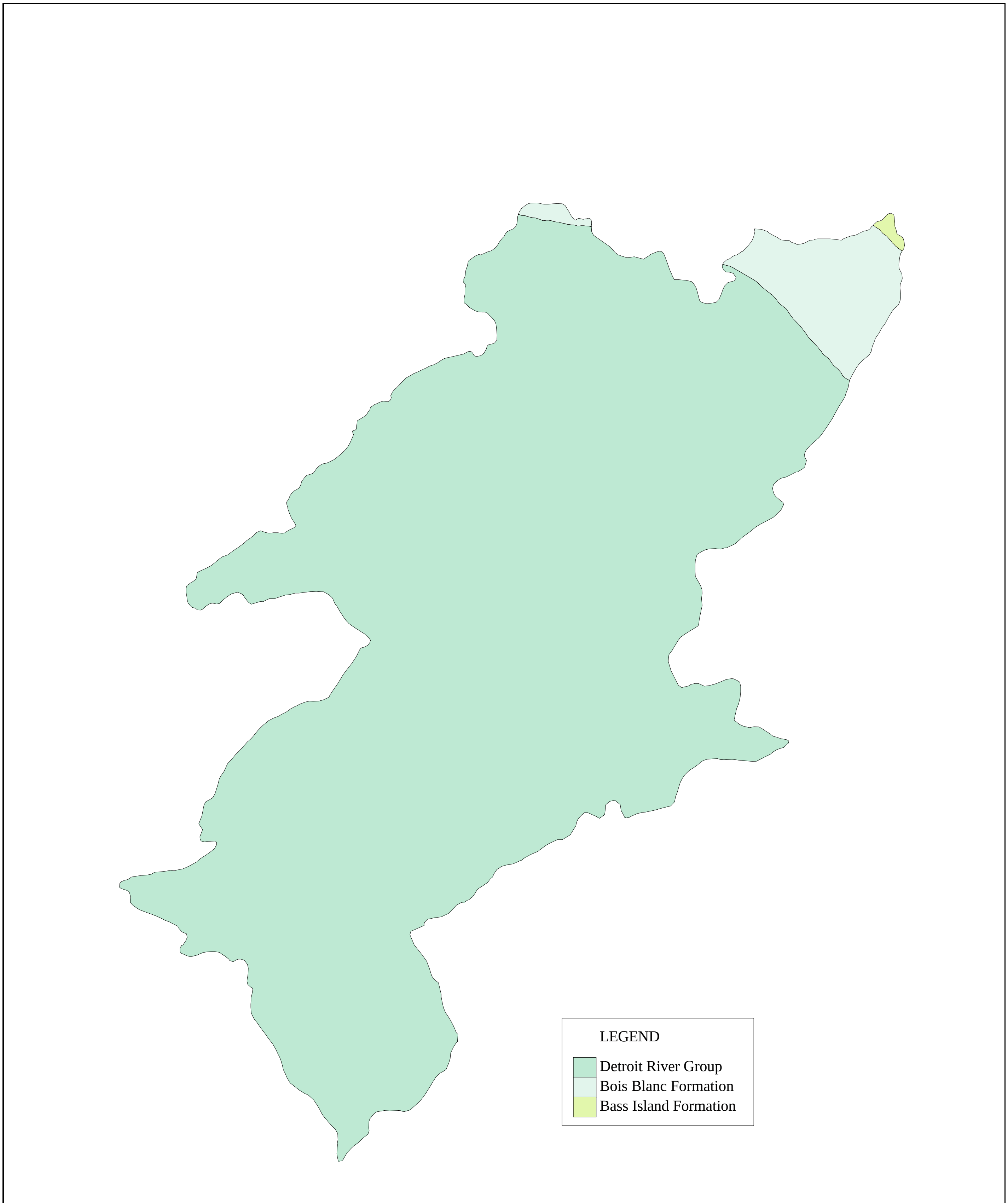


Figure Bi-2. Bedrock geology in the Big Otter Creek drainage basin.

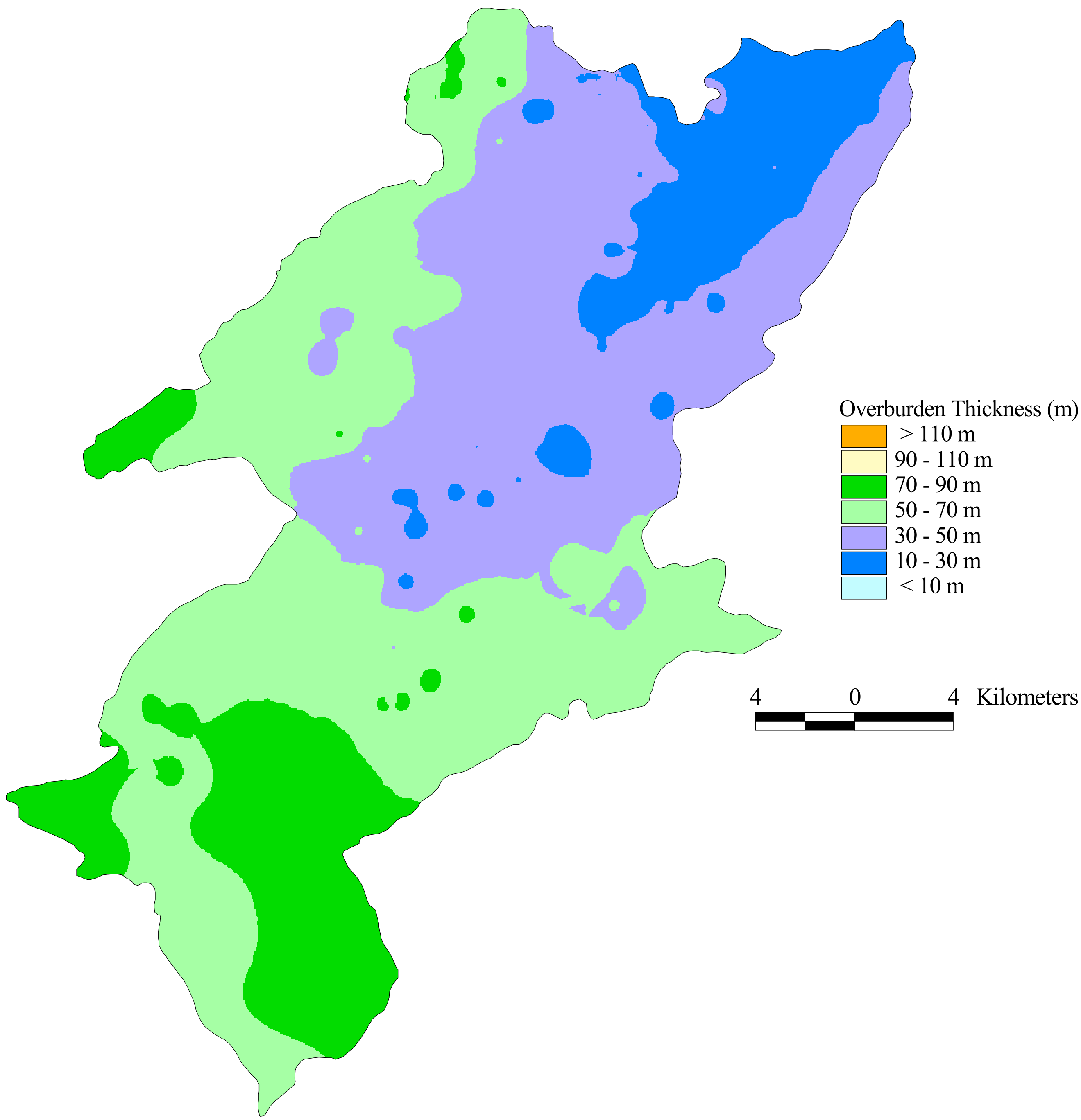


Figure Bi-3. Overburden thickness in the Big Otter Creek drainage basin.

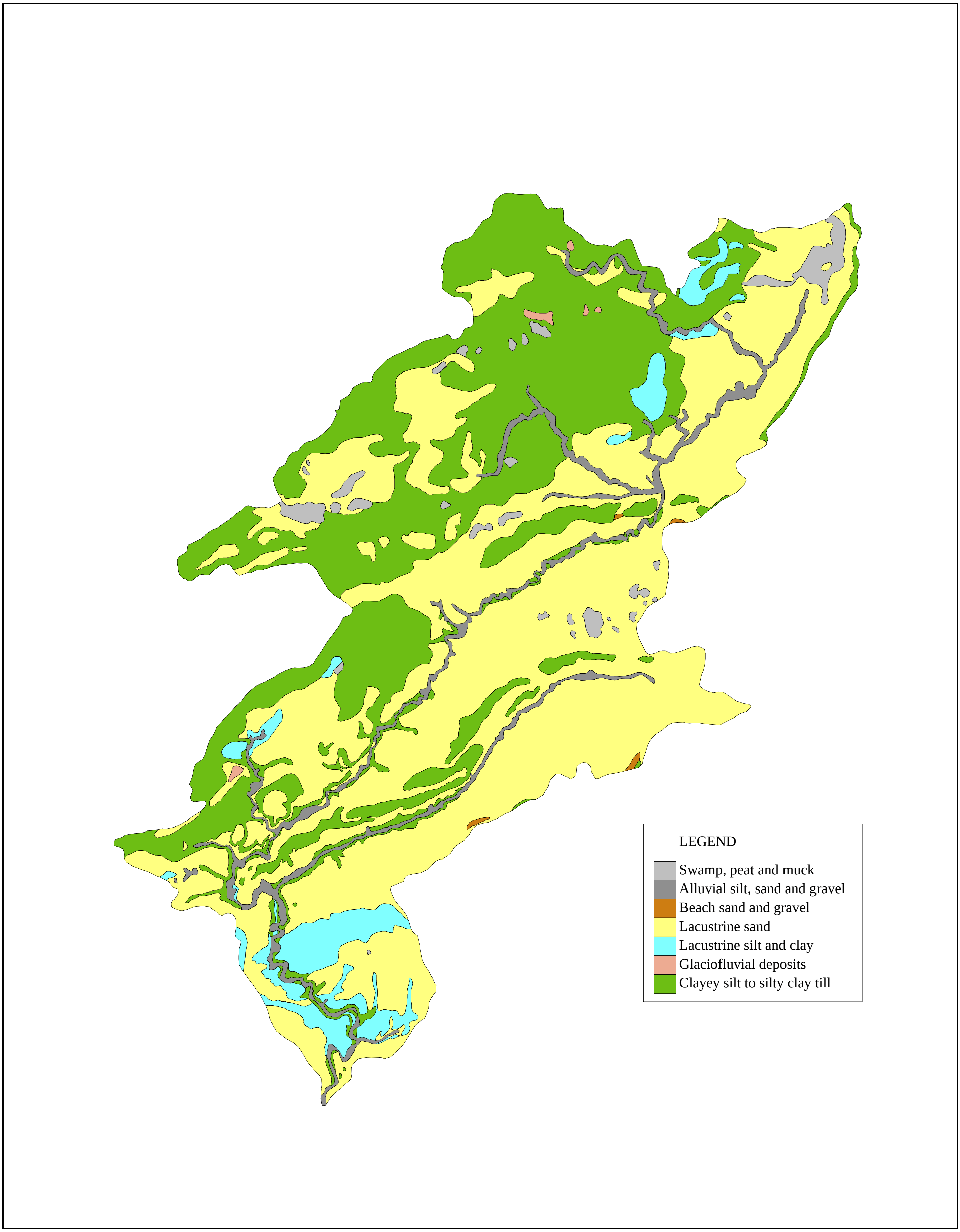


Figure Bi-4. Overburden geology in the Big Otter Creek drainage basin.

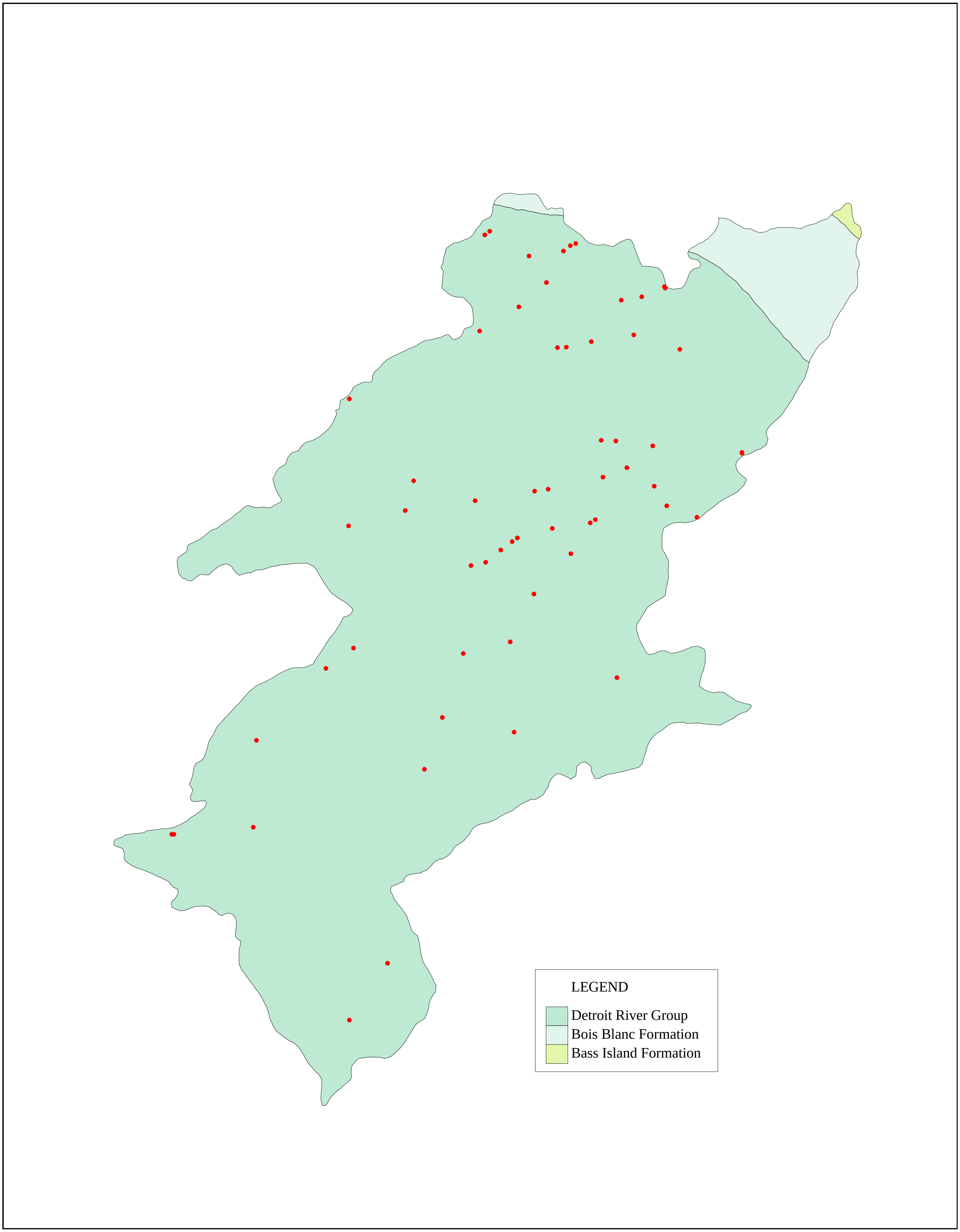


Figure Bi-5. Bedrock wells with specific capacities equal to or less than 5 l/min/m.

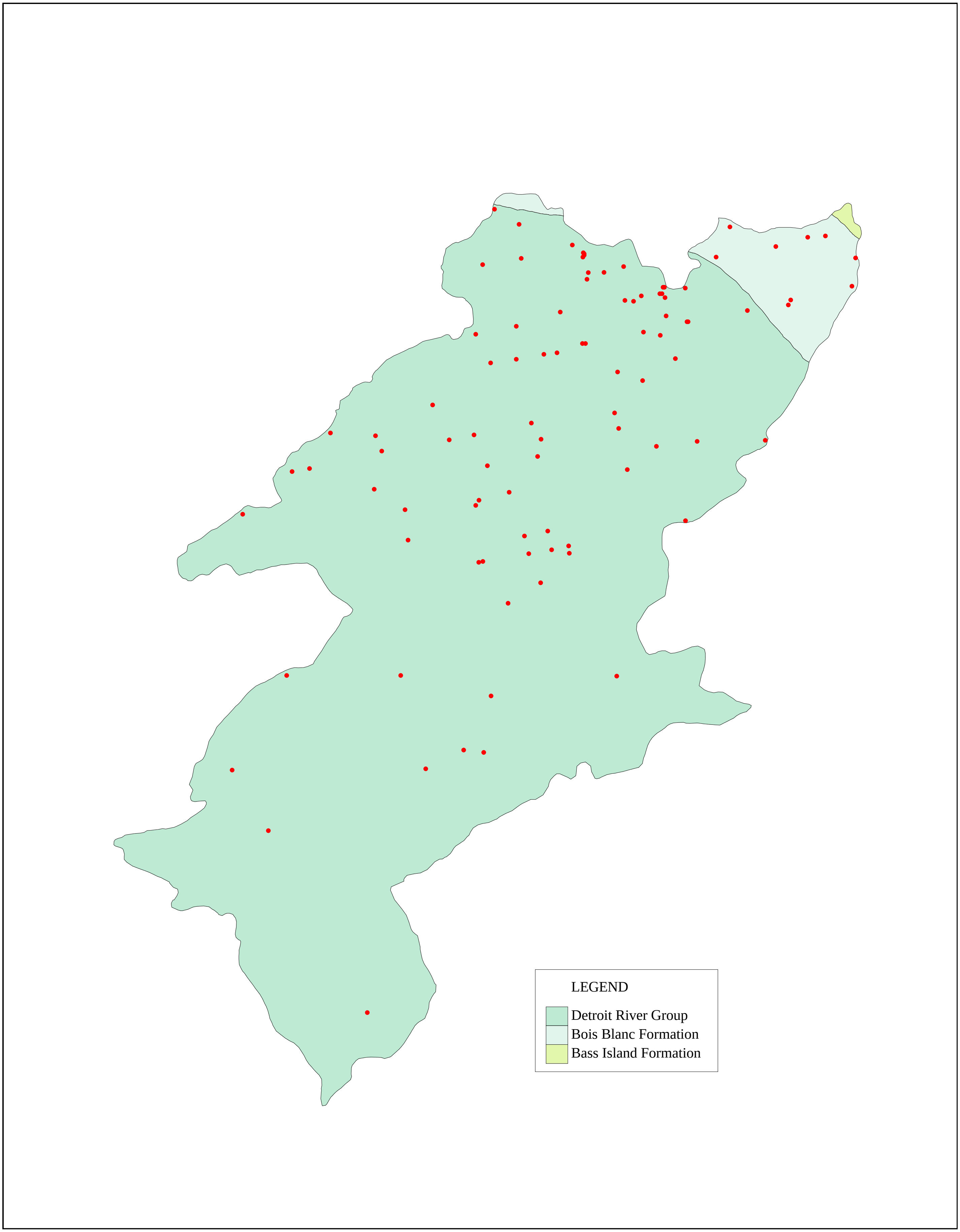


Figure Bi-6. Bedrock wells with specific capacities between 5 and 25 l/min/m.

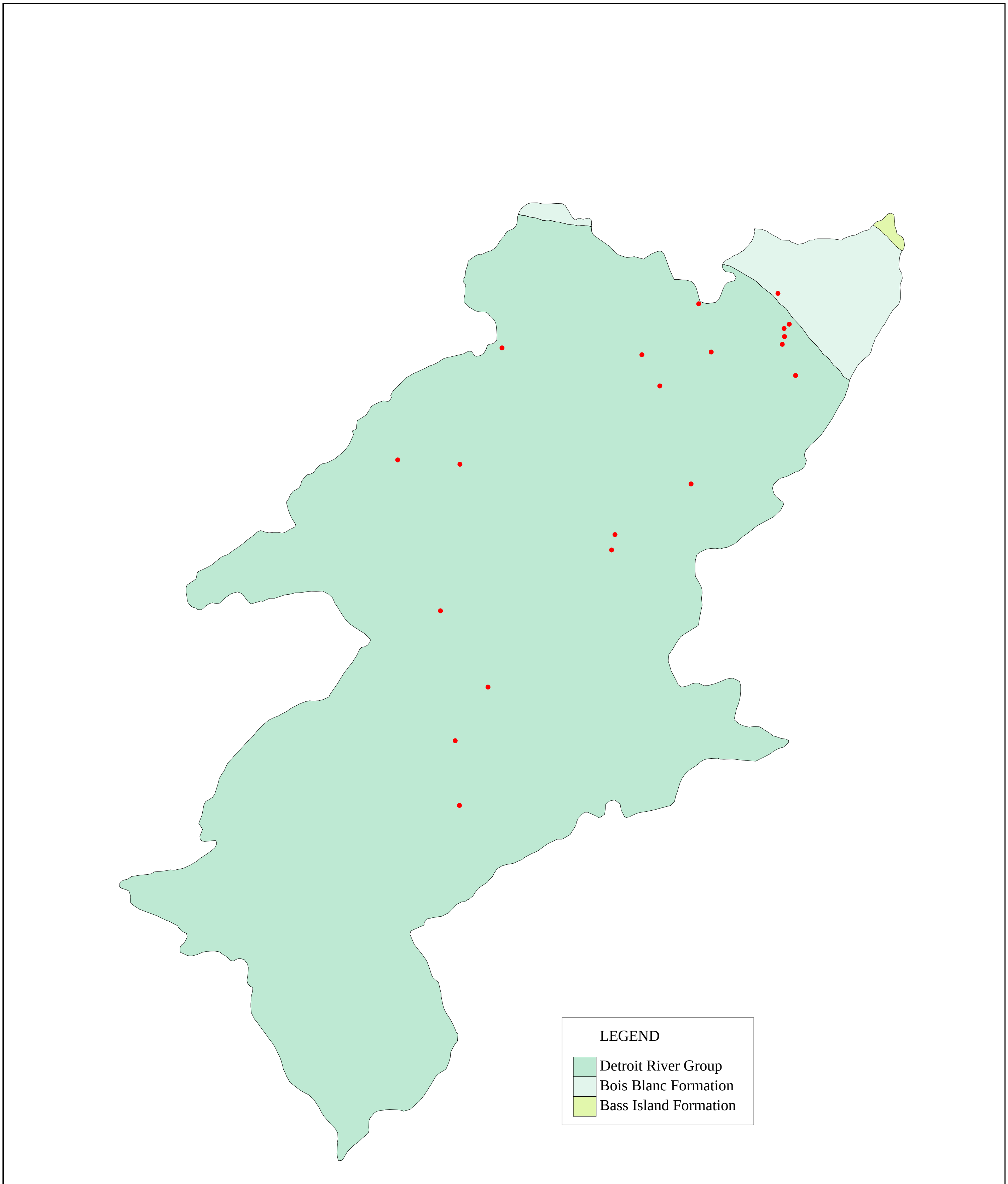


Figure Bi-7. Bedrock wells with specific capacities between 25 and 50 l/min/m.

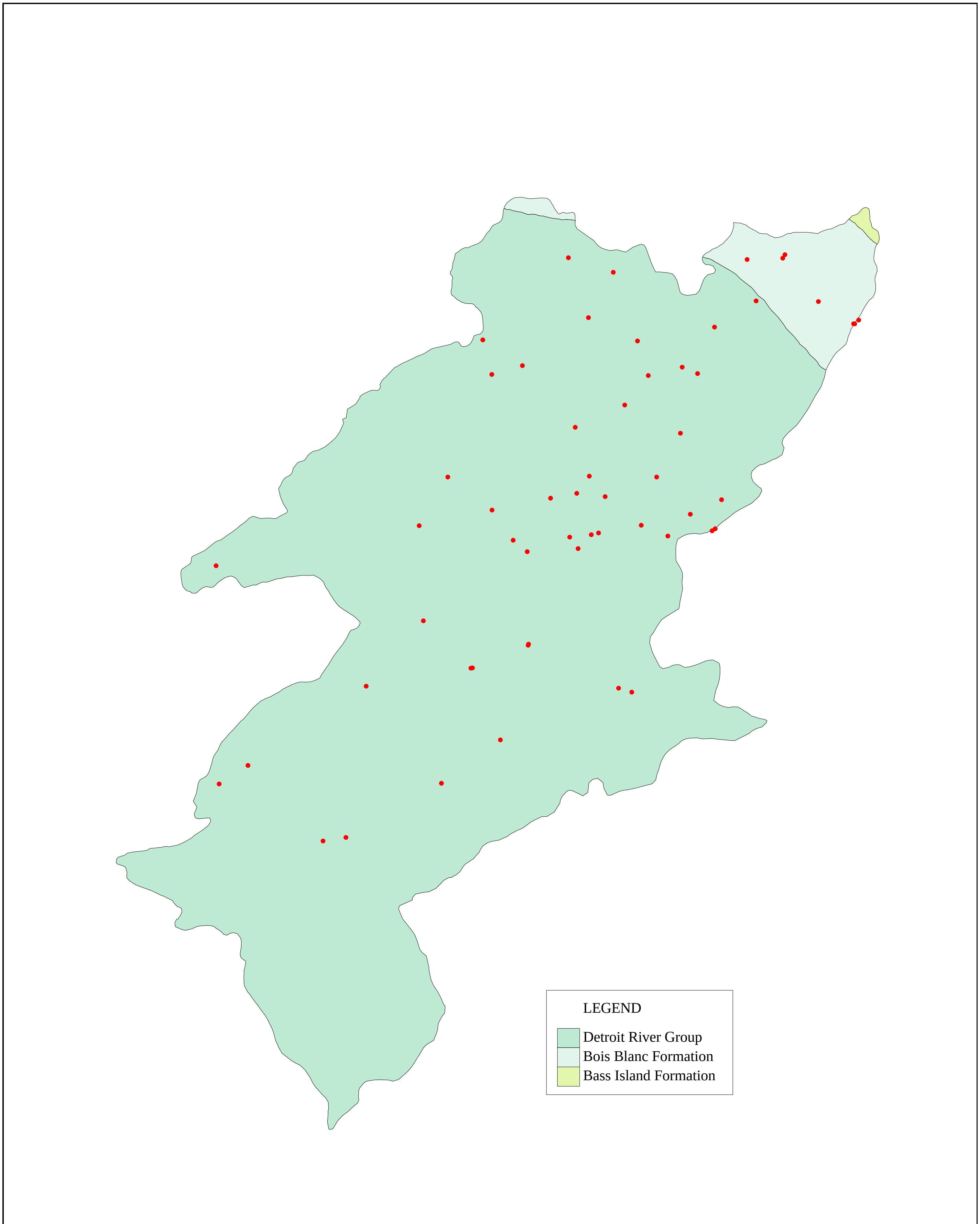


Figure Bi-8. Bedrock wells with specific capacities higher than 50 l/min/m.

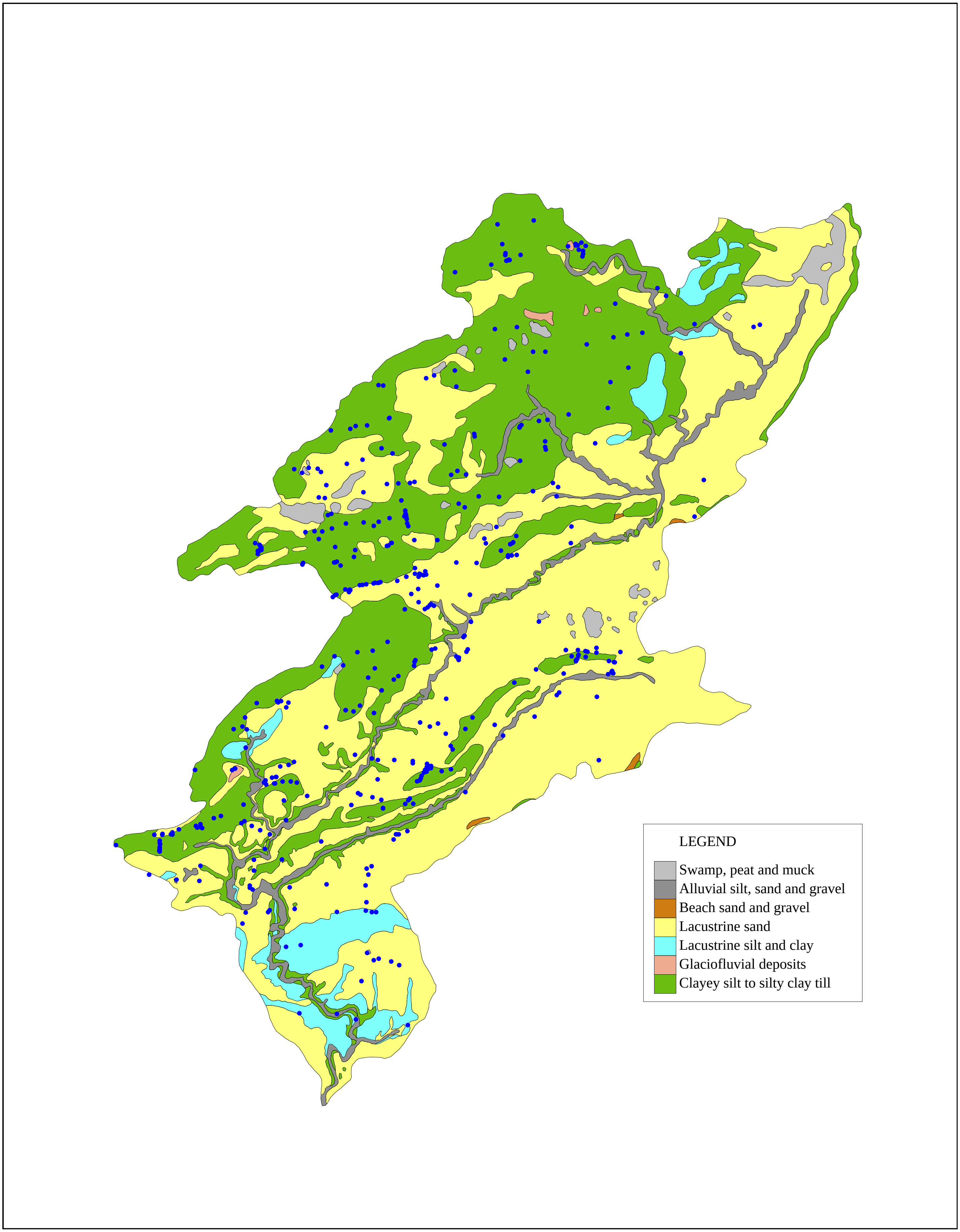


Figure Bi-9. Overburden wells with specific capacities equal to or less than 5 l/min/m.

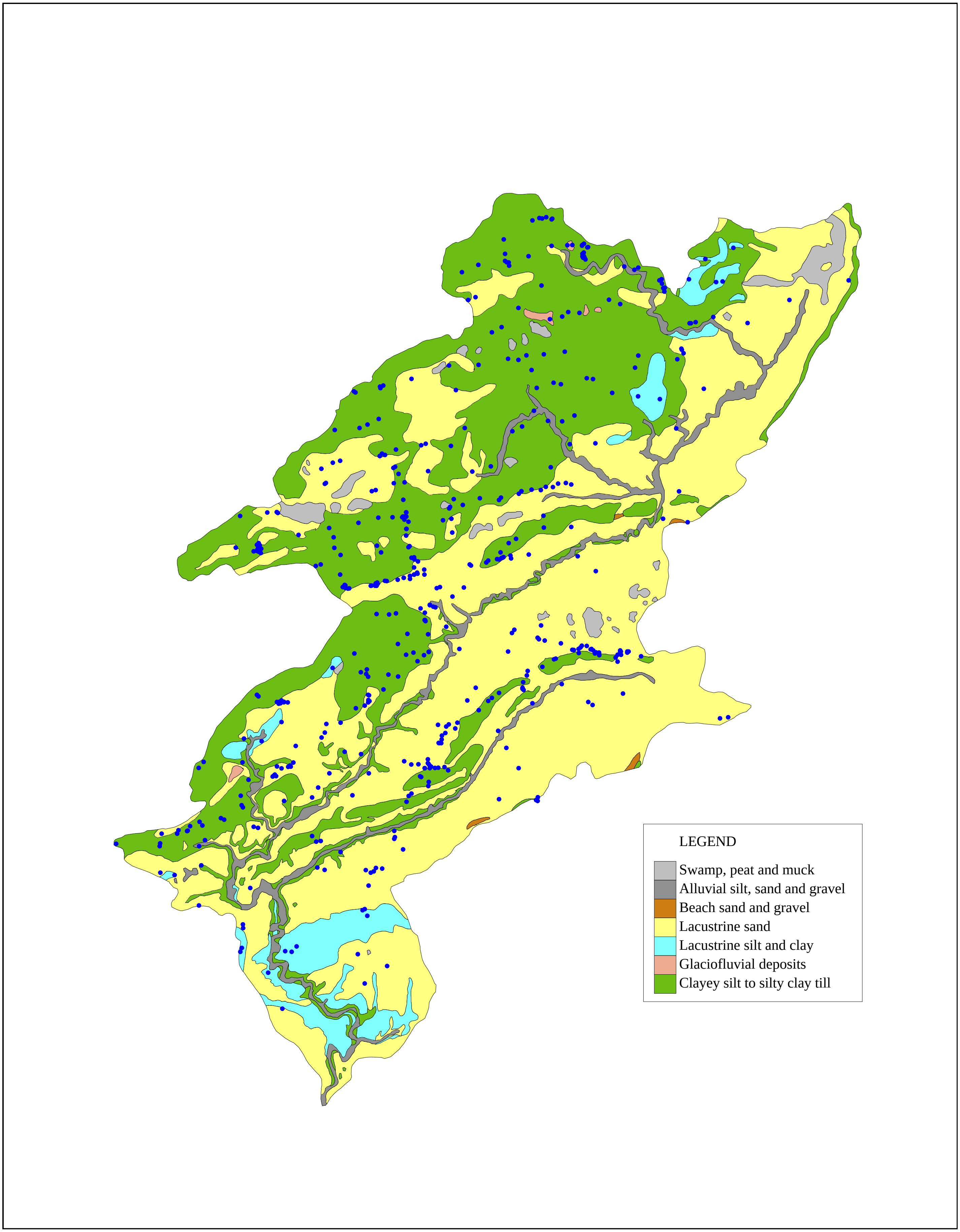


Figure Bi-10. Overburden wells with specific capacities between 5 and 25 l/min/m.

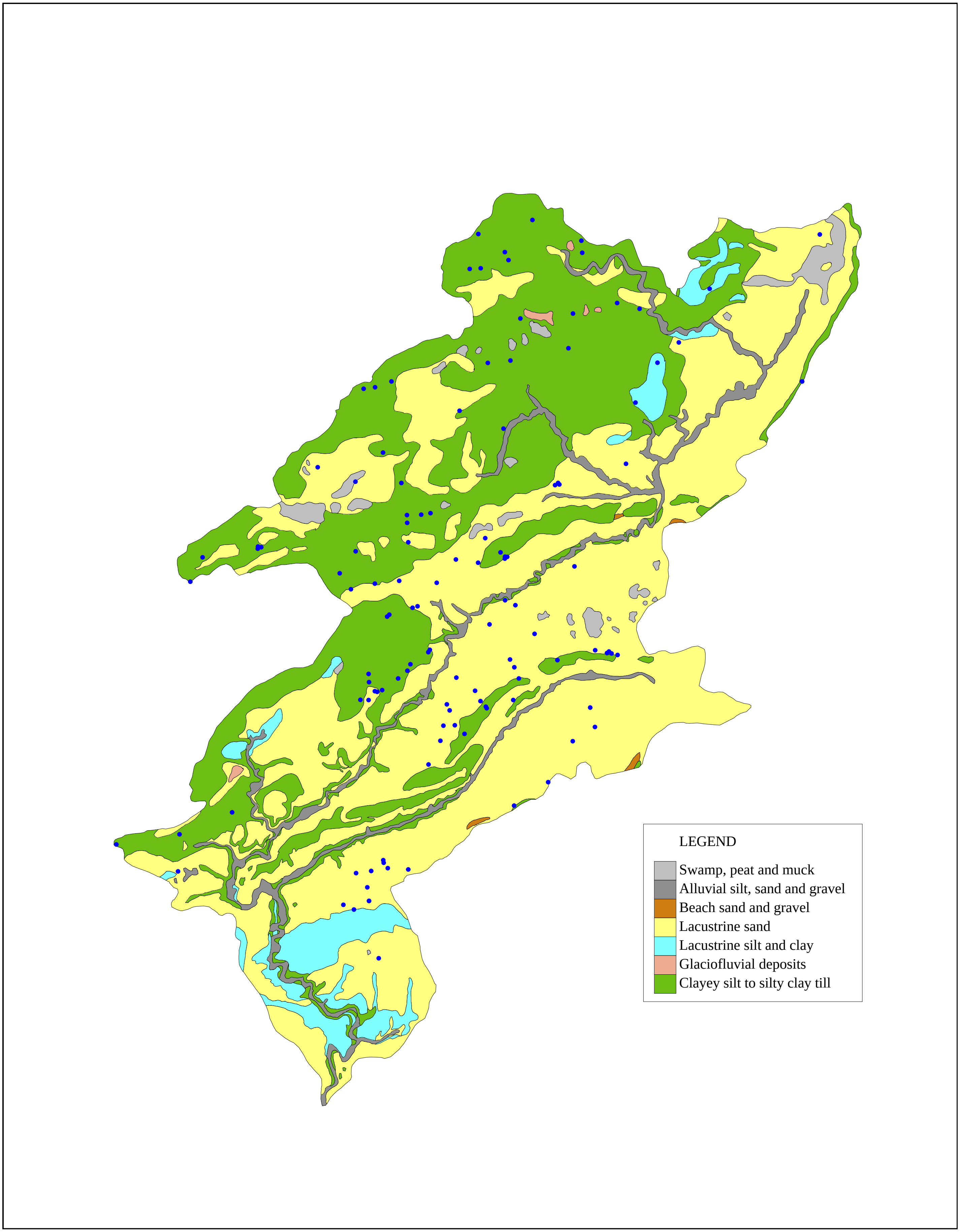


Figure Bi-11. Overburden wells with specific capacities between 25 and 50 l/min/m.

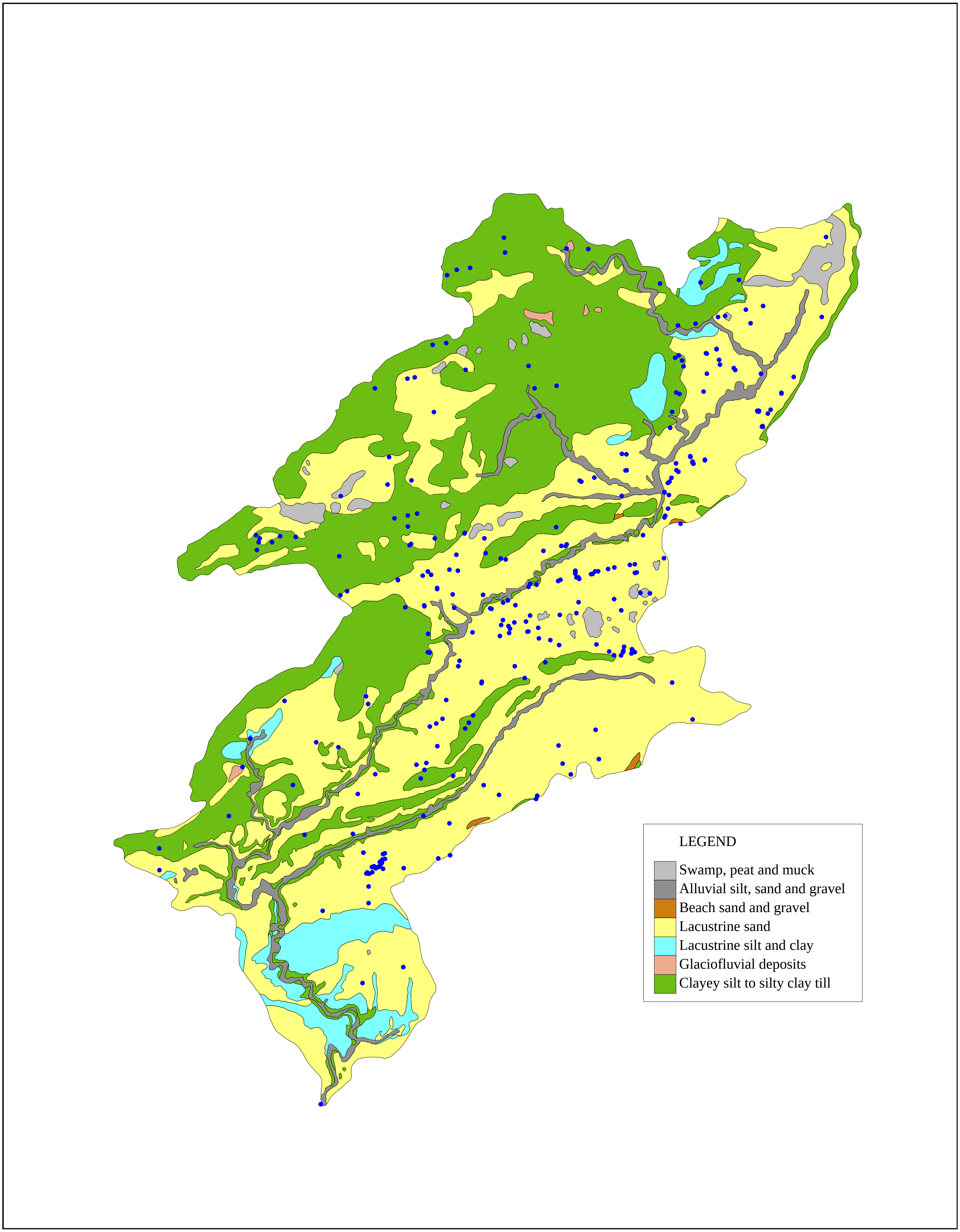


Figure Bi-12. Overburden wells with specific capacities higher than 50 l/min/m.

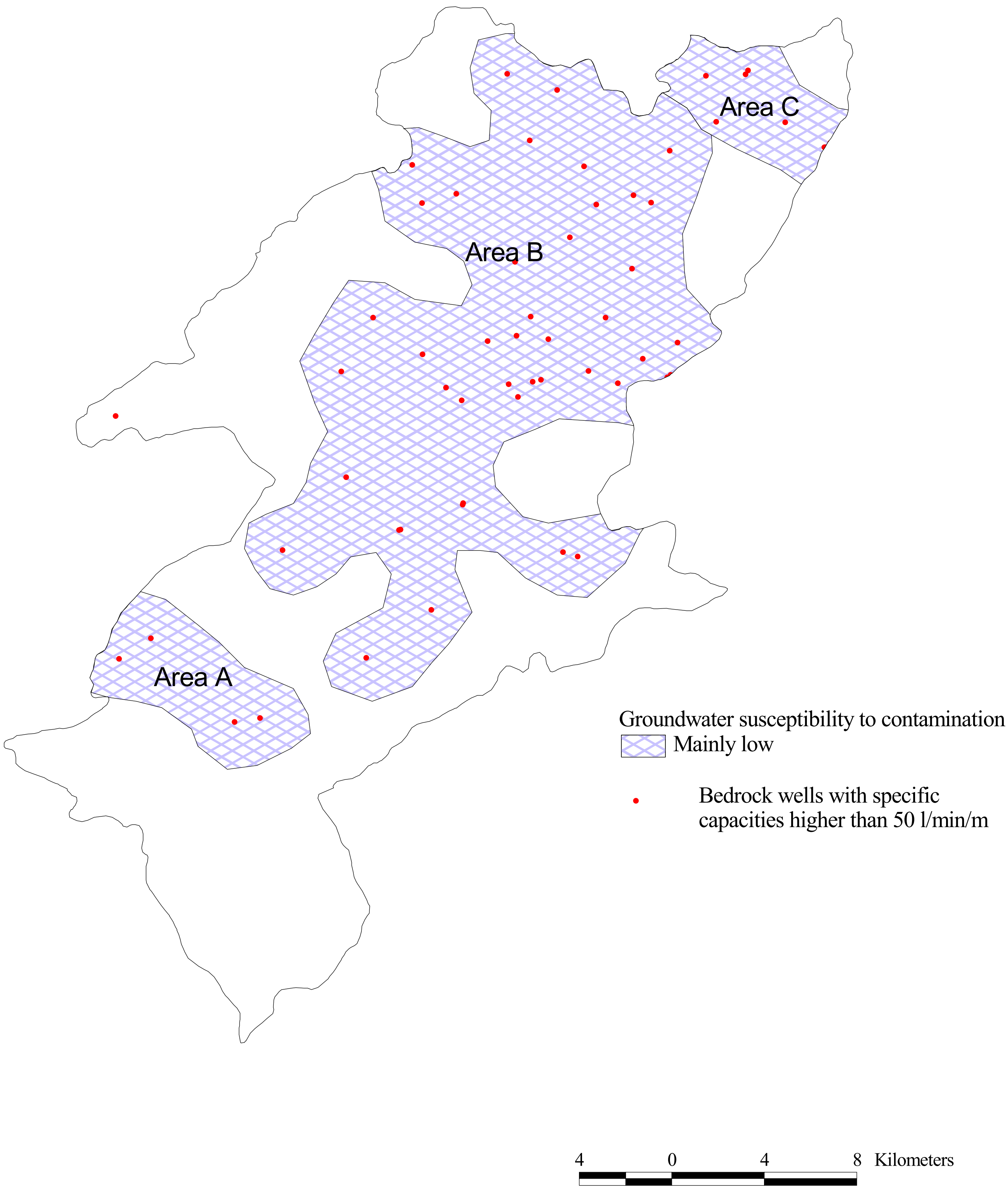


Figure Bi-13. Suggested areas for monitoring groundwater in the bedrock.

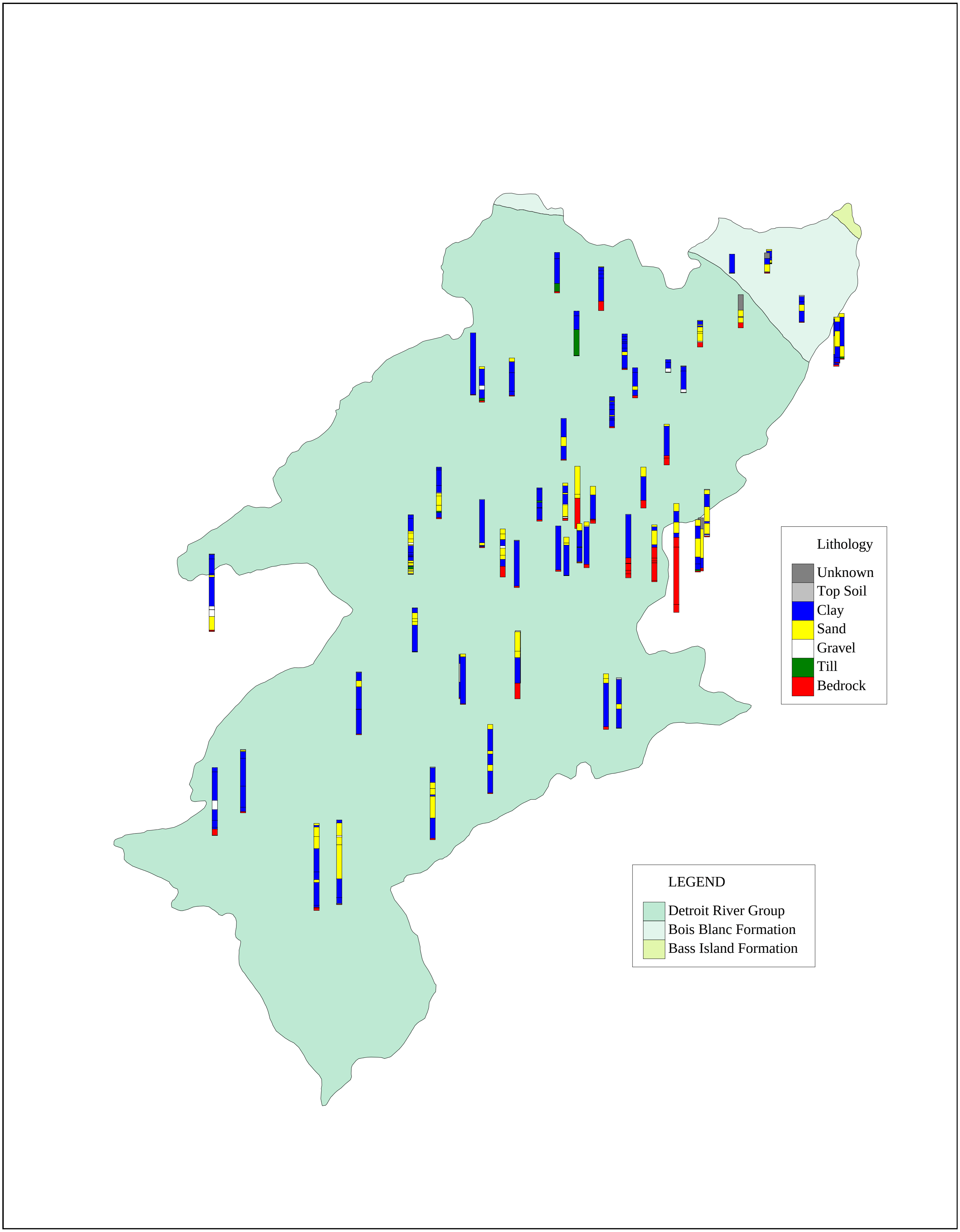


Figure Bi-14. Panel diagram showing the geologic logs of bedrock wells with specific capacities higher than 50 l/min/m.

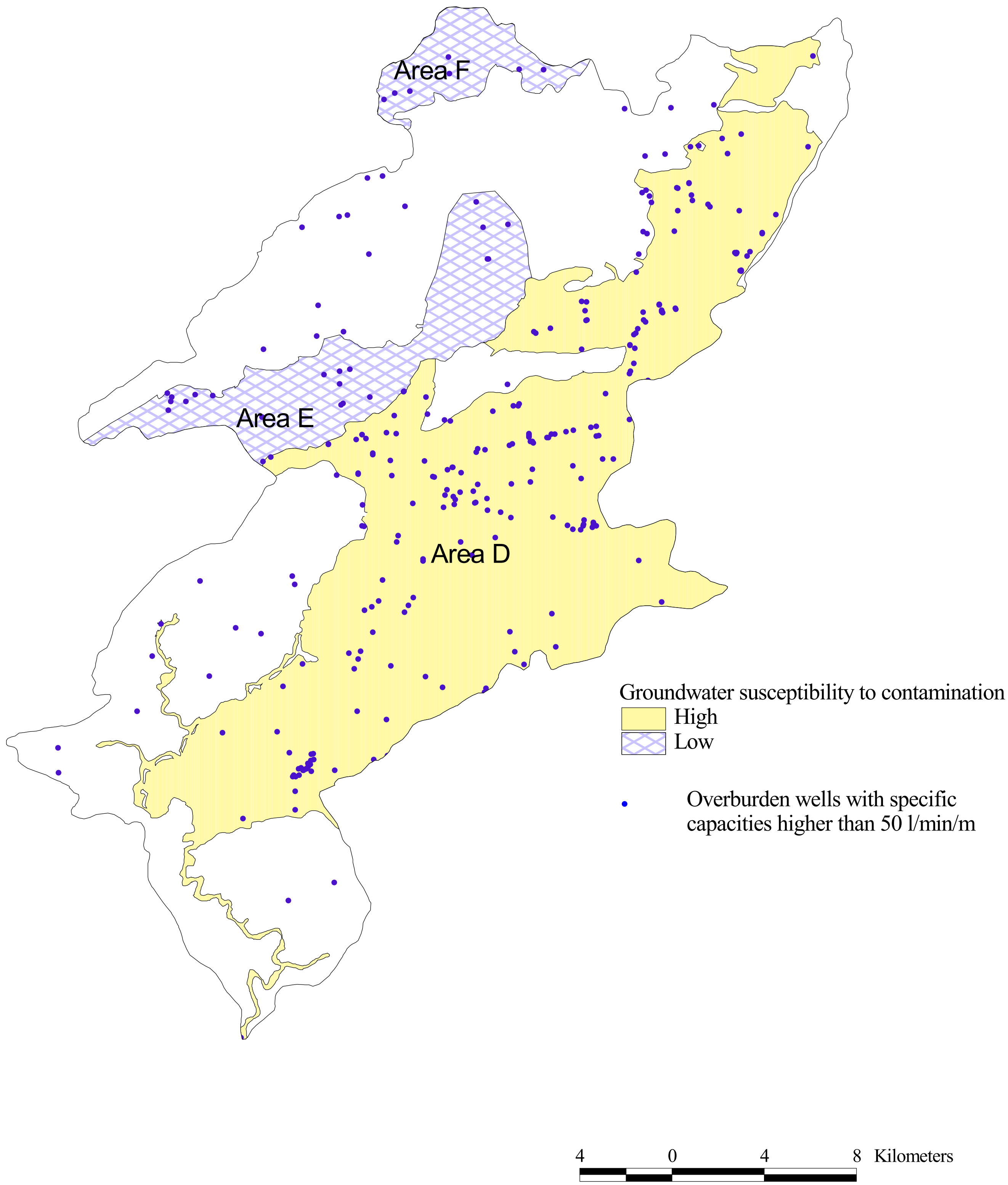


Figure Bi-15. Suggested areas for monitoring groundwater in the overburden.

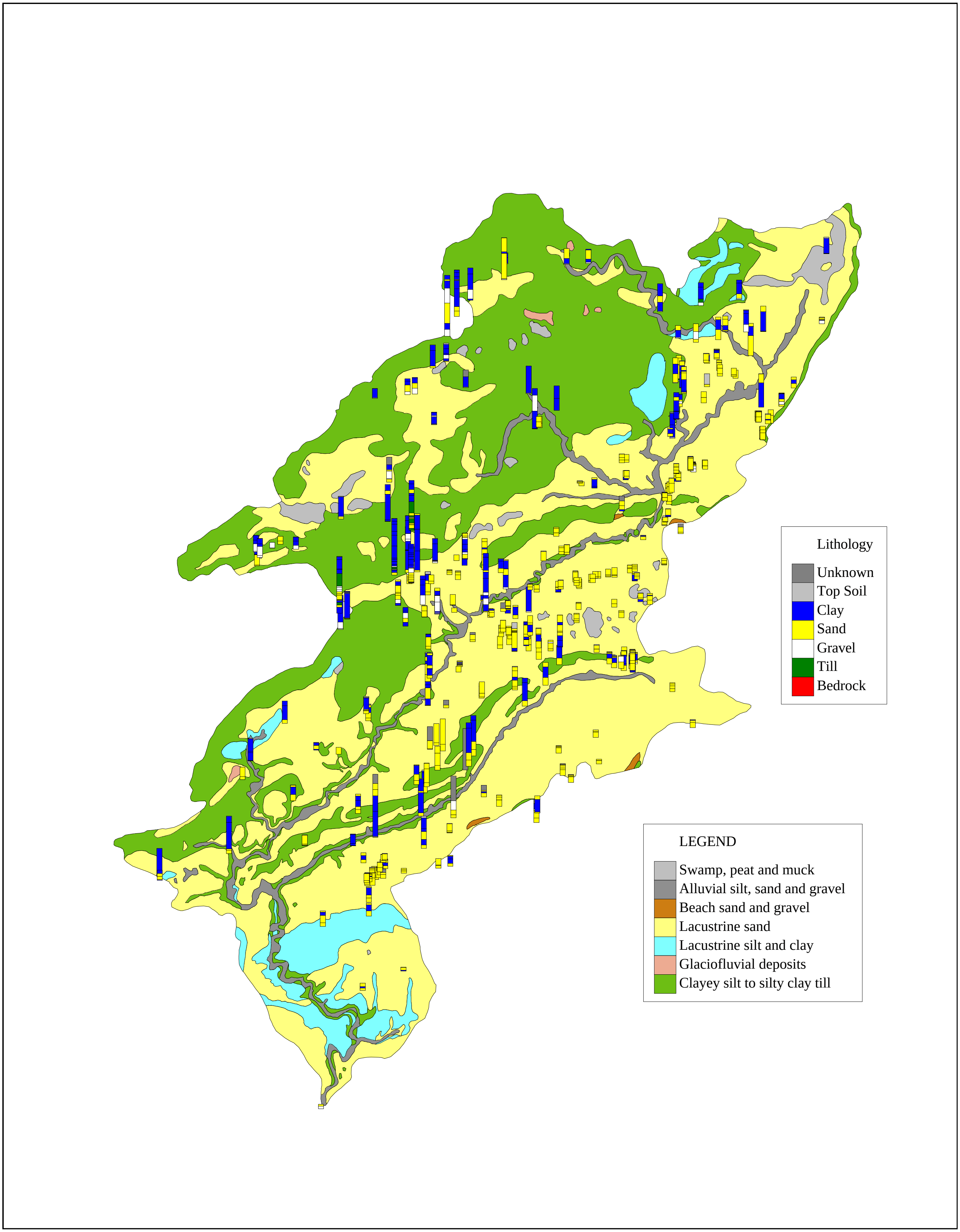


Figure Bi-16. Panel diagram showing the geologic logs of overburden wells with specific capacities higher than 50 l/min/m.

Figure Bi-17. Locations of historical monitoring wells in the Big Otter Creek drainage basin.