mainly composed of glacially-derived tills, lacustrine clays, and outwash sands and gravels of pre-Wisconsinan to Wisconsinan age. Ground water from bedrock aquifers is primarily found in limestones and dolomites of Ordovician or Silurian age.

The development potential or potential yield of an aquifer depends on aquifer coefficients (transmissivity, hydraulic conductivity, and storage), aquifer thickness, areal extent, water levels, and recharge.

''Safe yield'' is a term frequently used to describe the amount of ground-water which can be withdrawn without exceeding a given criteria. For example, safe yield is often defined as an amount not exceeding average annual natural recharge. However, safe yield estimates based solely on natural recharge are conservative because they ignore the effects that ground-water development may have on the recharge capability of an aquifer. For example, pumping ground-water from an aquifer which is hydraulically connected to a river may induce recharge to the aquifer through the streambed. If the hydraulic connection is good, the pumped water will eventually be derived from stream flow reduction, in which case safe yield is limited by an allowable reduction in stream flow.

Safe yield is also defined in terms of the maximum pumpage which will avoid lowering water levels below some predetermined level. For example, it may be decided that for an unconfined aquifer, the maximum allowable reduction in saturated thickness is 50 percent. Analytical and numerical models can then be used to estimate the amounts of water which can be pumped at given locations without exceeding the 50 percent reduction criterion.

Minimum ground-water levels may be established by the Natural Resources Commission (IC 13-2-6.1). If established, the minimum level criteria may govern the safe yield of a given ground-water withdrawal facility.

Transmissivity Values

Transmissivity is a measure of the water-transmitting capability of an aquifer. Expressed as the rate at which water flows through a unit width of an aquifer, transmissivity is obtained by multiplying the aquifer's hydraulic conductivity by its saturated thickness.

Transmissivity values in this report were obtained by three methods. Aquifer test data yields the best estimates of transmissivity. Fairly good estimates can be obtained from specific capacity data (pumping rate divided by drawdown) which has been adjusted for the effects of dewatering and/or partial penetration of the aquifer. Specific capacity data with unadjusted drawdowns yields the least reliable estimates.

Fig. 37, which shows transmissivity values at various locations in the Whitewater River Basin, is color-coded to show which method was used to estimate each value. The wide range of values is due partly to variations in geologic materials and partly to the different methods used to estimate transmissivity.

For comparative purposes, it is best to examine transmissivity values of the same color category, thus

Table 31. Stream-flow characteristics at wastewater treatment facilities

Site[1]	Location	Stream	Area (sq mi)	1-day, 30-year low-flow		7-day, 10-year low-flow		Average flow	
				cfs	mgd	cfs	mgd	cfs	mgd
27	Brookville	E.F. Whitewater	382	15	9.7	20	12.9	396	256
4	Cambridge City	Whitewater	88.1	5.0	3.2	7.0	4.5	101	65.3
8	Centerville	Nolands Fork	61.7	0.99	0.64	1.7	1.1	70.5	45.6
9	Connersville	Whitewater	443	30	19	38	25	467	302
2	Hagerstown	Whitewater	29.6	1.6	1.0	2.3	1.5	33.8	21.8
12	Laurel	Whitewater	578	43	28	53	34	608	393
23	Liberty	UNT Silver Creek[3]	0.17	0	0	0	0	NA[2]	NA[2]
6	Lynn	Mudd Creek	13.4	0.19	0.12	0.36	0.23	15.3	9.9
14	Oldenburg	Harveys Branch	4.1	0	0	0	0	4.3	2.8
19	Richmond	E.F. Whitewater	121	1.6	1.0	4.2	2.7	115	74

[1]Site locations in figure 33.
[2]NA - not available.
[3]UNT - unnamed tributary.

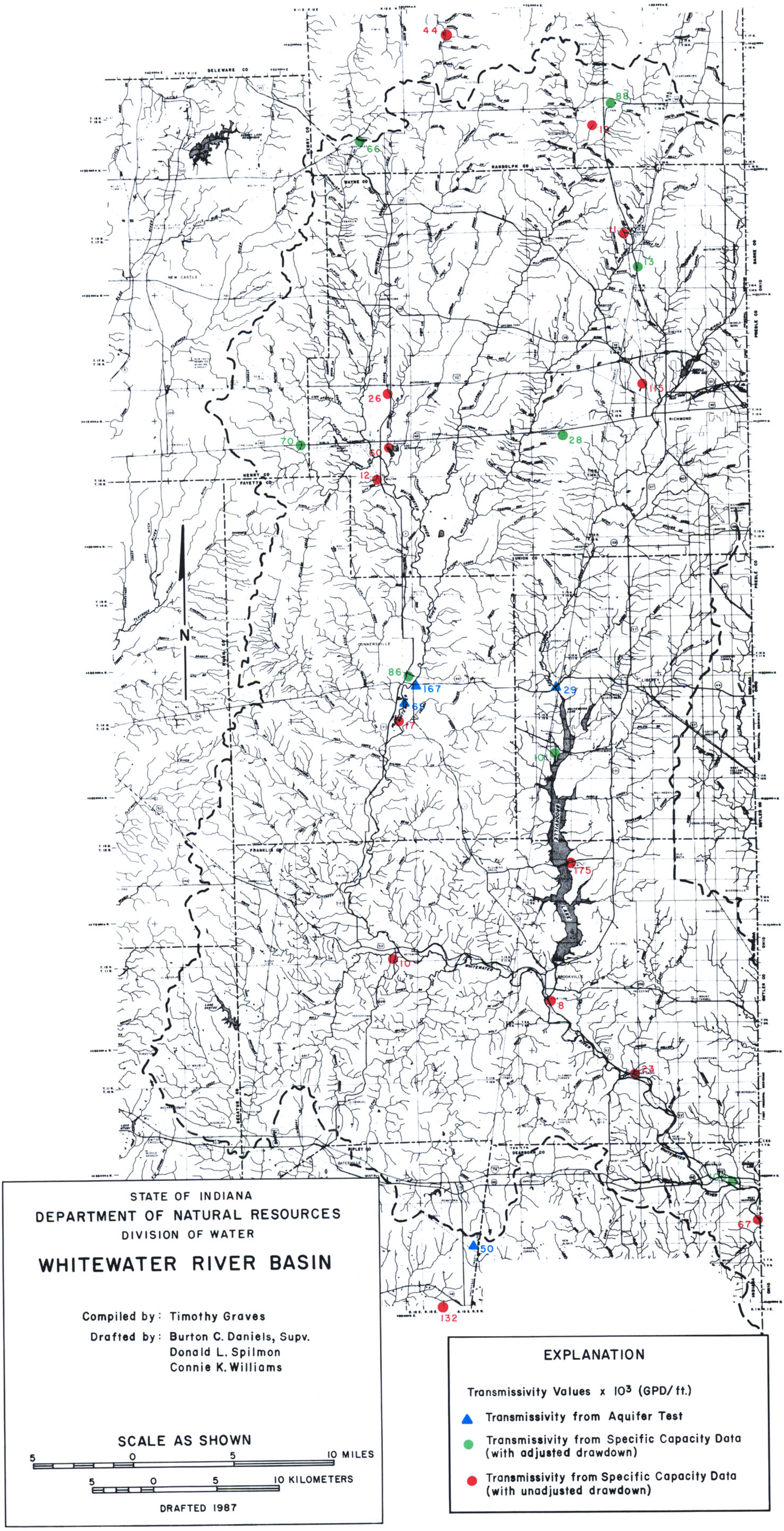

Figure 37. Transmissivity values

eliminating one of the sources of variation. The resulting comparison is based solely on differences in the thickness and permeability of the water-bearing formation.

Interpretation of a given transmissivity value is complicated by the fact that transmissivity is the product of hydraulic conductivity and saturated thickness. Therefore, a given transmissivity value could result from a thick sequence of relatively low-permeability materials or from a thin sequence of relatively high-permeability materials.

Recharge

Natural recharge rates for aquifer systems in the Whitewater Basin have been estimated based on aquifer geometry and hydrogeologic conditions. Applying these rates across an aquifer system yields an estimate of the total system recharge. Summing the totals for each system gives an estimate of the recharge to the entire basin. Using this method, the recharge to the Whitewater Basin is estimated to exceed 178 mgd (table 32).

As table 32 shows, the estimated recharge rate of 500,000 gpd/sq mi for the Whitewater Valley Aquifer System is several times greater than rates for other unconsolidated systems. The presence of well-drained, loamy soils and highly permeable sands and gravels in the major river valleys permits substantial percolation of rainfall-derived recharge. The hydraulic connection between the major rivers and the underlying outwash deposits also can permit temporary recharge from streams during storm events.

The recharge rate for the Wayne-Henry Aquifer System is about one-third that of the Whitewater System due to the lower permeability of till sequences overlying sand and gravel lenses. However, the Wayne-Henry System covers an area four times that of the Whitewater System. When the lower recharge rate is applied across a much larger area, a greater total recharge value is obtained (table 32).

Recharge rates for other unconsolidated systems are estimated to be 100,000 gpd/sq mi for the Fayette-Union System and 50,000 gpd/sq mi for the Dearborn System. Recharge to bedrock will be less than that of the overlying materials.

Development Potential

Sand and gravel outwash deposits of the Whitewater River valley and its major tributary valleys are the most productive and dependable source of ground-water supply in the Whitewater Basin. These deposits, designated as the Whitewater Valley Aquifer System, (pl. 3), have the highest recharge rate in the basin (table 32). The outwash sands and gravels are typically 25 to 75 feet thick and large-diameter wells can generally yield up to 500 gpm.

Although the Whitewater System underlies less than 8 percent of the basin's total area, about three-fourths of the registered municipal and industrial facilities utilize the system as a ground-water source. Approximately 11 mgd, or more than 90 percent of the ground-water used in the basin, was withdrawn from this system in 1986.

Because of the large amount of storage in and recharge to the Whitewater System, there is a significant potential for further ground-water development from this system. Much of the current ground-water development has occurred in the Richmond and Connersville vicinities. However, the development potential is also high to the south of Brookville, where the outwash is particularly thick.

Where outwash deposits of the Whitewater Valley Aquifer System are not present, intratill sand and gravel lenses are a major ground-water source. These lenses vary widely in depth and lateral extent, and are usually not traceable beyond small areas. However, intratill aquifers in the northern half of the basin are the source of ground-water supply for nearly one quarter of the basin's registered municipal and industrial facilities.

Although well yields up to 150 gpm have been reported in some northern areas of the basin, yields from intratill aquifers typically range from less than 15 gpm in Wayne County to less than 2 gpm in Franklin and Dearborn Counties. This decrease in yields from north to south is primarily due to the thinning and increased age of glacial deposits. Typical aquifer thickness ranges from about 10 feet in northern areas to less than 2 feet in the south.

The water-producing capability of the bedrock aquifer systems generally decreases from the western and northern basin margins, where Silurian bedrock predominates, toward the southern and central areas, where Ordovician bedrock is present (pl. 3). Bedrock of the less productive Ordovician Aquifer System contains more shale and has thinner-bedded strata with multiple shale and limestone layers. Well yields from bedrock also tend to decrease from north to south, probably due primarily to the thinning of unconsolidated materials, which may act as a recharge reservoir for the underlying bedrock.

Table 32. Estimates of aquifer system recharge

County	Randolph	Wayne	Henry	Fayette	Union	Rush	Decatur	Franklin	Ripley	Dearborn	System Totals
UNCONSOLIDATED AQUIFER SYSTEMS											
Wayne-Henry: Recharge rate = 150,000 gpd/ sq mi											
Area (sq mi)	80.0	306.0	42.5	16.5	2.5	—	—	—	—	—	447.5
Recharge (mgd)	12.0	45.9	6.4	2.5	0.4	—	—	—	—	—	67.2
Fayette-Union: Recharge rate = 100,000 gpd/sq mi											
Area (sq mi)	—	48.5	—	129.0	150.5[1]	—	—	34.0[1]	—	—	362.0[1]
Recharge (mgd)	—	4.9	—	12.9	15.1	—	—	3.4	—	—	36.3
Dearborn: Recharge rate = 50,000 gpd/sq mi											
Area (sq mi)	—	—	—	34.0	2.0	14.0	33.0	322.0	21.0	37.5	463.5
Recharge (mgd)	—	—	—	1.7	0.1	0.7	1.7	16.1	1.1	1.9	23.3
Whitewater: Recharge rate = 500,000 gpd/sq mi											
Area (sq mi)	4.0	47.5	—	17.5	7.5	—	—	22.0	—	4.5	103.0
Recharge (mgd)	2.0	23.8	—	8.8	3.8	—	—	11.0	—	2.3	51.7
COUNTY TOTALS											
Area (sq mi)	84	402	42.5	197	162.5[1]	14	33	378[1]	21	42	1376[1]
Recharge (mgd)	14.0	74.6	6.4	25.9	19.4	0.7	1.7	30.5	1.1	4.2	178.5
BEDROCK AQUIFER SYSTEMS[2]											
Silurian:											
Area (sq mi)	81.0	106.2	20.2	52.2	9.2[1]	14	28.8	30.0	0	0	341.6[1]
Recharge Rate (gpd/sq mi)	{ commonly <150,000 }			{ <100,000 }		{ commonly <50,000 }					
Ordovician:											
Area (sq mi)	3.0	295.8	22.3	144.8	153.3[1]	0	4.2	348.0[1]	21.0	42.0	1,034.4[1]
Recharge Rate	{ Ordovician bedrock is only marginally productive }										

[1]Includes area of the county to the Ohio border outside the basin boundary.
[2]Recharge to the bedrock aquifer systems depends upon the recharge rate and water consumption in the overlying unconsolidated aquifer systems. Recharge to bedrock aquifers will generally be a fraction of the overlying unconsolidated system recharge rate.