APPENDIX 1:

NINETY (90) GAUGING STATIONS IN ONTARIO USED IN THE BASEFLOW ANALYSES

Appendix 1: Ninety (90) gauging stations in Ontario used in the baseflow analyses

HYDAT Identification Number		
02AA001	02FD001	02HD006
02AB008	02FE008	02HD007
02AB014	02FE009	02HD008
02AB017	02GA010	02HD009
02AC001	02GA017	02HD013
02AD010	02GA037	02HK007
02BA003	02GB007	02HL004
02BB002	02GB009	02HL005
02BB003	02GC002	02HM004
02BD003	02GC010	02HM005
02BF001	02GC018	02JC008
02BF002	02GD004	02KF011
02CA002	02GD010	02LA007
02CB003	02GD013	02LB007
02CF007	02GD020	02LB008
02CF011	02GD021	02LB012
02CF012	02GE005	02LB018
02DB007	02GE007	02LB020
02DC012	02GG004	02LB022
02DD008	02GG005	02MC001
02DD012	02GH002	04JA002
02DD013	02GH003	04JC002
02DD014	02HA006	04JC003
02DD015	02HA014	04JD005
02EA005	02HC013	04JF001
02EC002	02HC018	04LJ001
02EC009	02HC019	05PC011
02EC011	02HC028	05QA002
02FA002	02HC029	05QA004
02FB007	02HD002	05QC003

APPENDIX 2:

ORDINAL RANKINGS OF LANDCOVER, SOIL, AND QUATERNARY GEOLOGY CHARACTERISTICS BASED ON THEIR INFLUENCE ON BASEFLOW CONTRIBUTIONS

Appendix 2: Ordinal rankings of landcover, soil, and Quaternary geology characteristics based on their influence on baseflow contributions.

i) Potential interception loss by landcover type and their relative rankings with respect to baseflow contribution potential from very high (5) to very low (1)(Dunne and Leopold 1978; Dingman 1994; Viessman and Lewis 1996); P. Lafleur, personal communication, 2001)*.

Land cover classification	Potential interception losses	Potential baseflow contribution
1. Water	NA	NA
2. Marshes	Very low	5
3. Open wetlands	Very low	5
4. Treed wetlands	Very low	5
5. Tundra heath	Very low	5
6. Dense deciduous forest	High	2
7. Dense coniferous forest	Very high	1
8. Mixed forest	Moderate	3
9. Sparse forest	Moderate	3
10. Early successional forest	Moderate	3
11. Successional forest	Moderate	3
12. Mine tailings, quarries, bedrock outcrops, mudflats	Very low	5
13. Settlement and developed land	Very low	5
14. Agriculture	Low	4
15. Unclassified areas	NA	NA

*Note: Relative rankings were developed by the authors and may not be suitable for use in any other application or analysis.

ii) CANSIS drainage class descriptions and their relative rankings with respect to baseflow contribution potential from very high (6) to very low (1) (Expert Committee on Soil Survey 1982; 1987)*.

CANSIS I.D.	Drainage Class	Relative ranking
R	Rapid Water is removed from the soil rapidly in relation to supply; excess water flows downward if underlying material is pervious; subsurface flow may occur on steep gradients during heavy rainfall; source of water is precipitation.	6
W	Well Water is removed from the soil readily but not rapidly; excess water flows downward into underlying pervious material or laterally as subsurface flow. These soils commonly retain optimum amounts of moisture for plant growth after rains or addition of irrigation water.	5
M	Moderately well Water is removed from the soil somewhat slowly in relation to supply due to low perviousness, a shallow water table, lack of gradient, or a combination of these factors; precipitation is the dominant source of water in medium to fine textured soils; precipitation and significant additions by subsurface flow are necessary in coarse-textured soils.	4
I	Imperfect Water is removed from the soil sufficiently slowly in relation to supply leaving the soil wet for a significant part of the growing season; excess water moves slowly downward if precipitation is the major supply; if subsurface water, groundwater, or both are the main source the flow rate may vary.	3
P	Poor Water is removed so slowly in relation to supply that the soil remains wet for a comparatively large part of the time that the soil is not frozen; excess water is evident in the soil for much of the time; subsurface flow, groundwater flow, or both, in addition to precipitation, are the main sources of water; a perched water table may also be present.	2
V	Very poor Water is removed from the soil so slowly that the water table remains at or on the surface for a majority of the time the soil is not frozen; groundwater flow and subsurface flow are the major sources of water; precipitation is less important except where there is a perched water table.	1
#	Non-applicable Hard rock (acidic) and urban areas.	2

*Note: Relative rankings were developed by the authors and may not be suitable for use in any other application or analysis.

iii) Representative values of specific yield (after Todd 1980) and relative rankings used in the multi-criteria evaluation.

Material		Specific yield (S_y) %	Relative Specific yield
Peat		44	Very high
Gravel, coarse	Unconsolidated Material	23	High
Gravel, medium		24	
Gravel, fine		25	
Sand, coarse		27	
Sand, medium		28	
Sand, fine		23	
Till, predominantly sand		16	Moderate
Till, predominantly gravel		16	
Till, predominantly silt		6	Low
Silt		8	
Clay		3	Very low

***Note**: Relative rankings were developed by the authors and may not be suitable for use in any other application or analysis.

iv) Representative values of hydraulic conductivity and relative rankings used in the multi-criteria evaluation (after Todd 1980; Smith and Wheatcroft, 1993; D. Webster, per. comm., 2005)*.

Hydraulic conductivity, meters day^{-1}

10^{4}	10^{3}	10^{2}	10^{1}	1	10^{-1}	10^{-2}	10^{-3}	10^{-4}	10^{-5}

Relative hydraulic conductivity

Very high	High	Moderate	Low	Very low

Unconsolidated deposits

Clean gravel - Clean sand and sand and gravel - Fine sand, peat - Silt, clay, and mixtures of sand, silt, and clay - Silty clay and massive clay

Consolidated rocks

Vesicular and scoriaceous basalt, karstic limestone, cavernous limestone and dolostone. - Clean sandstone and fractured igneous and metamorphic rocks - Laminated sandstone, shale, mudstone - Massive igneous and metamorphic rocks

Depositional environment

Glacio-fluvial (10^{2} to 10^{-2})

Glacio-lacustrine (10^{-4} → 10^{-8})

Supra-glacial till (1 to 10^{-4})

Basal till (10^{-2} → 10^{-6})

*Note: Relative rankings were developed by the authors and may not be suitable for use in any other application or analysis.

v) Relative ranking of specific yield (S_y) and saturated hydraulic conductivity (K_{sat}) for Quaternary geology classes based on potential contributions to baseflow: very high (5), high (4), moderate (3), low (2), very low (1)*.

ID	Class description	S_y	K_{sat}
RECENT			
32	Organic deposits: peat, muck and marl	VH (H)[1]	M (H)[1]
31	Fluvial deposits: gravel, sand, silt and clay deposited on modern flood plains	M	M
30	Lacustrine deposits: sand, gravelly sand and gravel nearshore and beach deposits	VH	VH
29	Lacustrine deposits: silt and clay basin or quiet water deposits	VL	VL
PLEISTOCENE			
28	Fluvial deposits: gravel, sand, silt and clay deposited on abandoned flood plains, terrace remnants	M	M
27	Glaciomarine and marine deposits: sand, gravelly sand and gravel nearshore and beach deposits	VH	VH
26	Glaciomarine and marine deposits: silt and clay basin and quiet water deposits	VL	VL
25	Glaciomarine deposits: sand, gravelly sand and gravel nearshore and beach deposits	VH	VH
24	Glaciomarine deposits: silt and clay, minor sand basin and quiet water deposits	VL	VL
23	Glaciofluvial outwash deposits: gravel and sand includes proglacial river and deltaic deposits	VH	VH
22	Glaciofluvial ice-contact deposits: gravel and sand minor till includes esker, kame, end moraine, ice-marginal delta and subaqueous fan deposits	VH	VH
21	Till: undifferentiated, fine grained, predominantly silty clay to silt matrix, commonly clast poor, high matrix carbonate content	VL	VL
20	Till: undifferentiated, predominantly sand matrix, extremely stony, bouldery and high in total matrix carbonate content, often associated with stratified sediments	M	H
19	Till: undifferentiated, predominantly sandy silt to silt matrix, commonly rich in clasts, often high in total matrix carbonate content	L	L
18	Till: undifferentiated, predominantly sand to silty to silt matrix, commonly rich in clasts, often low in matrix carbonate content	L	L
17	Halton Till (Ontario-Erie lobe): predominantly silt to silty clay matrix, high in matrix carbonate content and clast poor	VL	VL
16	Kettleby Till (Simcoe lobe): predominantly silt to silty clay matrix, highly calcareous, clast poor	VL	VL
15	St. Joseph Till (Huron-Georgian Bay lobe): Silt to silty clay matrix, clay content increases southward, clast poor	VL	VL
14	Wentworth Till (Ontario-Erie lobe):sandy silt to silt matrix becoming finer grained to silty clay near Lake Erie, highly calcareous, clast content moderate to low decreasing southward	L	L
13	Newmarket Till (Simcoe lobe): sandy silt to silt matrix, moderate to high in matrix carbonate content, clast content moderate to high	L	L
12	Dunkeld Till (Huron-Georgian Bay lobe): silt matrix, high matrix carbonate content, clast poor	L	L
11	Rannoch Till (Huron-Georgian Bay lobe): silt to clayey silt matrix becoming finer grained southward, highly calcareous, clast poor	L	L
10	Elma Till (Huron-Georgian Bay lobe):sandy silt to silty matrix, clayey silt along southern margin, moderatey stony, strongly calcareous	L	L
9	Port Stanley Till (Ontario-Erie lobe): silt to sandy silt matrix becoming silt to silty clay near Lake Erie, strongly calcareous, moderate to low clast content decreasing southward	L	L

ID	Class description	S_y	K_{sat}
8	Wartburg Till (Huron-Georgian Bay lobe): silty clay matrix, high carbonate content in matrix, clast poor	VL	VL
7	Stratford Till (Huron-Georgian Bay lobe): sandy silt matrix, strongly calcareous, moderately stony	L	L
6	Mornington Till (Huron-Georgian Bay lobe): silty clay matrix, moderate to high matrix carbonate content, clast poor.	VL	VL
5	Tavistock Till (Huron-Georgian Bay lobe): sandy silt to silt matrix, silty clay matrix in south and north, moderate to high carbonate content, clast content decreases from moderate to poor northward	L	L
4	Maryhill Till (Erie lobe): silty clay to clay matrix, moderate to high matrix carbonate content, clast poor	VL	VL
3	Catfish Creek Till: sandy silt to silt matrix, strongly calcareous, moderately stony to stony	L	L
PALEOZOIC			
2	Bedrock: undifferentiated carbonate and clastic sedimentary rock, exposed at surface or covered by a discontinuous, thin layer of drift	L	L
PRECAMBRIAN			
1	Bedrock: undifferentiated igneous and metamorphic rock, exposed at surface or covered by a discontinuous, thin layer of drift	VL	VL

[1] *Adjusted rankings in brackets were used in the multi-criteria evalution.*

*Note: Relative rankings were developed by the authors and may not be suitable for use in any other application or analysis.

APPENDIX 3:

METHODOLOGY FOR DERIVING THE FUNCTIONAL SOURCE AREA INDEX (FSAI)

Appendix 3: Methodology for deriving the Functional Source Area Index (FSAI)

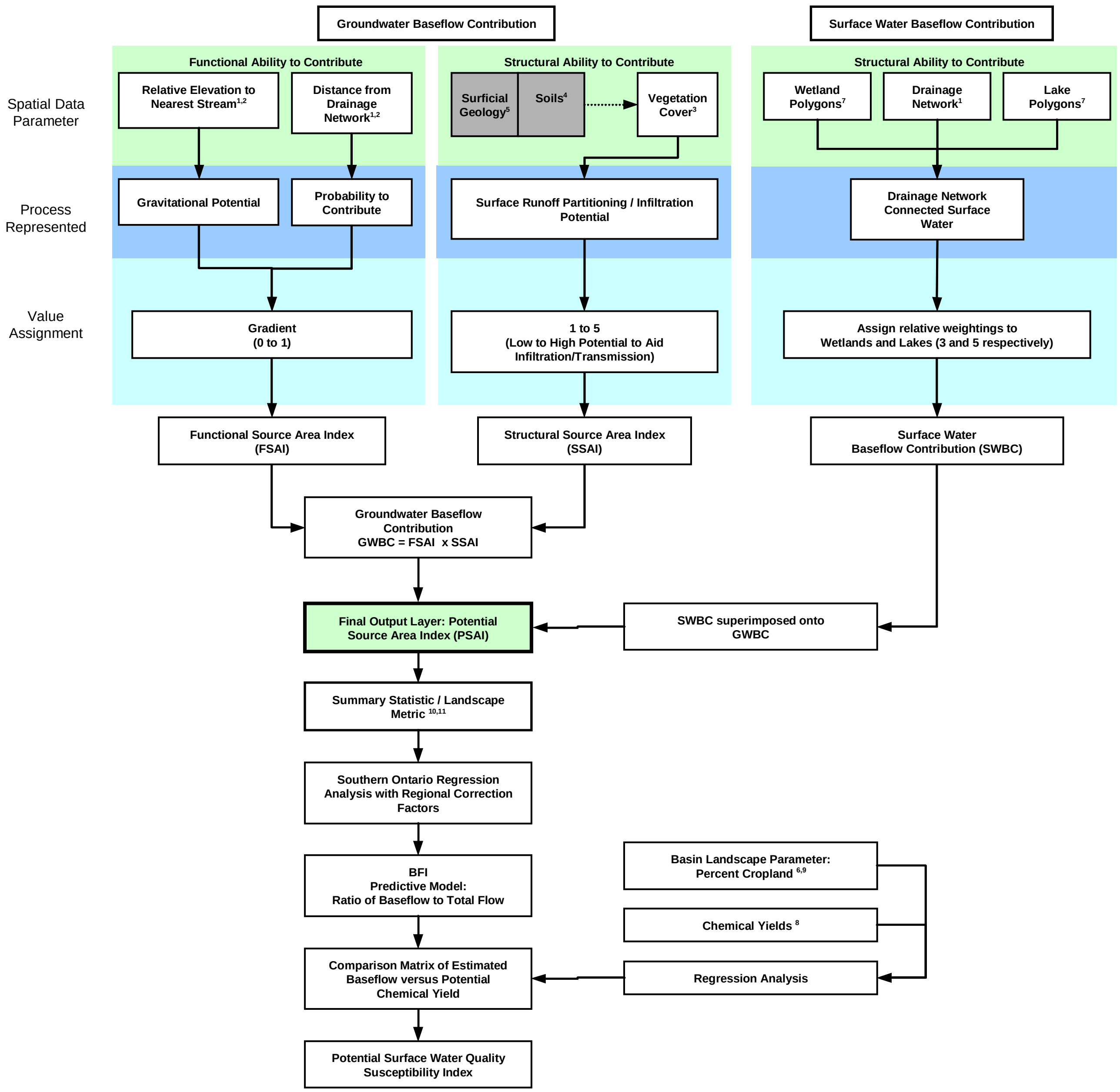
The gradient of a landscape unit was calculated by determining its relative elevation above, and distance from, its hydrologically nearest stream grid cell. The nearest stream was identified by tracing the hydrological flow path from the landscape units (i.e. individual source raster cells). Groundwater flow paths were assumed to be analogous to surface water flow paths as determined using the digital elevation model, flow direction (D8 algorithm), and flow accumulation (FA) grids and the ArcGIS® cost-distance algorithm (CDA). The reciprocal of the square of the flow accumulation was used as the cost surface (squaring the FA values results in a cost surface which simulates downhill flow). Cells with a FA value of zero result in division by zero (i.e. $1 / (0)^2$) and subsequently receive a NoData value, acting as barriers to flow in the CDA and essentially creating drainage divides. The CDA algorithm is applied to each individual cell in the cost surface grid. When the least-cost path from the cell to nearest stream has been identified the value of a specified back-allocation grid at the location at which the flow path meets the stream (*i.e.* the destination cell) is allocated back to the location of the source cell. The application of the cost-distance algorithm in this fashion essentially defines the smallest, non-divisible drainage catchments in the landscape. The NoData cells created in the previous step (*i.e.* the drainage divides) are assigned their appropriate value by an Arc Macro Language (AML) routine that was created specifically for this task. The AML routine seeks out the NoData cells and assigns them the value of their "hydrologic neighbour" as defined by the cells flow direction value. The relative elevation grid was calculated using intermediate grids produced by the CDA described above. The relative elevation grid values were calculated by subtracting a cell's back-allocated nearest stream elevation from its actual elevation. The relative elevation grid contained some erroneous negative values (*i.e.* nearest stream with higher elevation than source cell). In rare instances the CDA calculated a flow path to a stream that was not the nearest stream. The negative relative stream elevation errors were addressed by reclassing them to NoData value cells and then applying a custom AML procedure which seeks out these cells and assigns the correct value. In order to calculate the distance to nearest grid, the euclidean distance between source cell and destination cell was determined using four individual grids with cells containing x and y values. Delta-x and Delta-y were determined by using the x,y-coordinates of source in conjunction with the x,y-coordinates of destination. A gradient is calculated by dividing the relative elevation grid by the distance to nearest stream grid (*i.e.* rise/run). This yields a continuous floating point data range of gradient values between 0 and 1. The value distribution of the gradient in the raster grid is such that there are many cells that have values near zero. A gradient index was created by reclassing values into quantile classes. The resulting gradient index grid still contained values from zero to one but over ten discrete classes.

APPENDIX 4:

WORKFLOW AND DATA SOURCES USED TO CREATE THE POTENTIAL SURFACE WATER QUALITY SUSCEPTIBILITY INDEX

Appendix 4: (i) Workflow and (ii) Data Sources used to create the Potential Surface Water Quality Susceptibility Index.

(i) Workflow



Note: Superscripts refer to data sources in following table.

(ii) Data Sources

Data	Spatial Scale/ Resolution	Source
[1] Water Virtual Flow Layer	1 : 10,000 1 : 20,000	Natural Resources and Values Information System, Ontario Ministry of Natural Resources
[2] Digital Elevation Model	100 m	Ontario Flow Assessments Techniques, North East Science and Information Section, Ontario Ministry of Natural Resources
[3] Provincial Landcover - 15 Geogratis Classes	100 m	Ontario Ministry of Natural Resources
[4] Soil Landscapes of Canada	1 : 1,000,000	Agriculture and Food Canada, Canadian Soil Information System (CANSIS)
[5] Quaternary Geology of Ontario	1 : 1,000,000	Ministry of Northern Development and Mines, Mines and Minerals Division
[6] Provincial Landcover - 28 Classes	25 m	Ontario Ministry of Natural Resources
[7] Water Polygons Layer	1 : 10,000 1 : 20,000	Natural Resources and Values Information System, Ontario Ministry of Natural Resources
[8] Nitrate/Total Phosphorus Data	NA	Ontario Ministry of the Environment, Environmental Monitoring and Reporting Branch, Provincial Water Quality Monitoring Network
[9] HYDAT Station Basin Boundaries	NA	Ontario Ministry of Natural Resources, Water Resources Information Program
[10] Provincial Water Quality Monitoring Station Basin Boundaries	NA	Ontario Ministry of Natural Resources, Water Resources Information Program
[11] HYDAT Daily Time Series Data	NA	Environment Canada, Water Survey of Canada